W. Randy Bell has served as Director of the CTBTO’s International Data Centre (IDC) since 28 October 2013. Mr Bell, a national of the United States, was Director of the Office of Nuclear Detonation Detection at the US National Nuclear Security Administration (NNSA) between 2004 and 2013. In this position he led the programme that produces space-based sensor payloads to monitor the globe for nuclear detonations and conducted research to advance space- and terrestrial-based monitoring technologies, such as seismic, infrasound and debris sampling. Prior to that, he held other positions within the US Department of Energy, serving as the Manager of Space and Remote Sensing Systems at the NNSA from 1993 to 2004 and as a nuclear engineer in the Office of Nuclear Energy from 1991 to 1993. Mr Bell began his professional career as an officer in the US Navy’s nuclear submarine service. He obtained a master’s degree in physics from George Mason University in 2010, a master’s degree in computer science from Johns Hopkins University in 1994 and a bachelor’s degree in mathematics from the University of Rochester in 1986.

It is my great pleasure to welcome you to the CTBT: Science and Technology 2015 (SnT2015) conference, which is hosted by the Provisional Technical Secretariat of the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), with generous support from the Federal Ministry for Europe, Integration and Foreign Affairs of Austria. This is the fifth such gathering; all of them have been held in the Hofburg Palace in the centre of Vienna.

The format of these conferences has evolved as the CTBTO itself has matured, but the overall aim remains unchanged. The effective verification of a comprehensive nuclear test ban is founded on the scientific and technical capacity of the world’s experts in nuclear test detection and on the infrastructure that underpins it. This capacity is ever advancing, and we at the CTBTO must remain at the forefront of this advancement if the effectiveness and credibility of our Treaty’s verification regime are to be maintained. Moreover, science and technology are needed to improve the cost effectiveness of our long term operations. We also look forward eagerly to the Treaty’s entry into force, knowing that effective verification is an important consideration as the remaining States Signatories proceed with their individual processes of ratification.

The goals of our conference are straightforward:

- Enlarge the scientific community engaged in test-ban monitoring;
- Promote the wider scientific application of data that are used for test-ban verification;
- Enhance the exchange of knowledge and ideas between the CTBTO and the broader scientific community.

To this end, the scientific programme includes a mix of oral presentations, posters and panel discussions familiar to international scientific meetings. Presentations are arranged under four themes, intended to cover the broad range of research fields directly relevant to CTBT verification. For SnT2015 these include a new theme on performance optimization, to highlight the importance of assessing the quality and efficiency of the work we do and the resources that we use. This theme aims to gain insight from operational analysis to improve our processes.

The opening day offers a programme of keynote addresses and discussions familiar to international scientific meetings. Presentations are arranged under four themes, intended to cover the broad range of research fields directly relevant to CTBT verification. For SnT2015 these include a new theme on performance optimization, to highlight the importance of assessing the quality and efficiency of the work we do and the resources that we use. This theme aims to gain insight from operational analysis to improve our processes.

The opening day offers a programme of keynote addresses and discussions featuring prominent figures whose varied experiences put them in a good position to provide a broader political and diplomatic context to the CTBT. I believe that this will be of interest not only to those in the diplomatic community and elsewhere who are concerned with nuclear-test-ban and non-proliferation issues, but also to those from the academic world who would normally concentrate on the science.
Two discussion panels on the following days address topics of current special interest in the CTBT monitoring community. One alludes to the role of science in on-site inspections (OSIs), which are provided for under the Treaty after it enters into force. This discussion will benefit from the experience of the 2014 Integrated Field Exercise (IFE14) in Jordan. IFE14 was the largest and most comprehensive such exercise so far conducted in the build-up of CTBTO’s OSI capabilities.

The other panel explores the potential role of ‘citizen science’ in the global effort to monitor a nuclear test ban. We know that the CTBTO verification regime is complemented by the national monitoring capabilities of individual States—so-called national technical means. A third component might come from individuals or small groups, contributing to a global body of observational data acquired and analysed independently of the CTBTO and national governments. These panellists have been instrumental in promoting such an initiative, and they will share their ideas at this conference.

SnT2015 will again include a range of presentations describing results from the application of data from the International Monitoring System (IMS) to problems not directly connected to Treaty monitoring. Civil, scientific and even industrial applications of IMS data and International Data Centre (IDC) products pay dividends to the Treaty monitoring mission in a variety of ways. One example is improved methods of understanding and removing what might be considered noise to us but signal to others. Another is the demonstrated near-term value of the system to States Signatories and to the public who have invested so much, and who will continue to invest in order to sustain it. Moreover, the promotion of additional uses of IMS data and IDC products benefits our operational effectiveness in that having more eyes on the data improves quality by detecting and highlighting errors, inconsistencies and other shortcomings in either data acquisition or its subsequent processing. The broader use of IMS data even serves to broaden the pool of experienced candidates from which the CTBTO can hire its specialists.

The CTBTO has long been concerned with training specialists who support its verification regime, from IMS station operators to OSI inspectors. This has been extended to educational events focused on academics and others engaged in, or interested in, broader disarmament or non-proliferation issues. Accordingly, I am pleased that this year’s Academic Forum has been integrated into the SnT2015 programme and will take place on the final day. All participants of SnT2015 are cordially invited to attend.

For those of you not otherwise committed on Friday, we are offering for the first time a number of field trips to organizations with direct relevance to our work. In addition to the CTBTO’s headquarters in the Vienna International Centre, destinations include the Seibersdorf Laboratories, which include Austria’s certified IMS radionuclide laboratory; Austria’s Central Institute for Meteorology and Geodynamics (ZAMG) and the Conrad Observatory, also operated by ZAMG.

Also offered are two evening programmes targeted towards young scientists participating in SnT2015, and those from CTBT National Data Centres. These events will allow members of these groups to make new contacts and to discuss issues of common interest.

Whereas the CTBTO is mandated by the Treaty to explore new potential monitoring technologies, the methods currently used for the IMS, and for an OSI, are governed by Treaty provisions. Although the CTBTO verification system has proven itself capable of performing its task, additional scientific and technological challenges always present themselves. Some pointers to future priorities will be outlined during the concluding session, on Thursday afternoon.

One of the continuing challenges is the improvement of automatic processing of IMS waveform and radionuclide data to produce the IDC’s reviewed products: the Reviewed Event Bulletins (REBs) and Reviewed Radionuclide Reports (RRRs). The review of both IMS data and the output of IDC automatic processing is a major demand on CTBTO resources. In order to acquaint participants with the challenges of preparing these products, the programme will include demonstrations of waveform and radionuclide analysis, where you will have a chance to see IDC analysts in action.

I had the privilege of being a member of the Scientific Programme Committee for SnT2013 and came to realise that it provided a valuable
forum for the exchange of ideas at the forefront of CTBT monitoring. I am confident that SnT2015 will follow this tradition. To me it is clear that we must seek out ideas from fields beyond the traditional participants in nuclear test monitoring, and I believe that our Science and Technology conference series offers an effective way to pursue this goal.

I wish you all a successful and productive experience at SnT2015, as well as a pleasant stay in the beautiful city of Vienna.

W. Randy Bell
Director of the CTBTO International Data Centre Division and SnT2015 Project Executive
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OPENING SESSION:
SPEAKERS AND
MODERATORS
Des Browne
Keynote Speaker

Lord Browne of Ladyton (Des Browne) is Vice Chairman of the Nuclear Threat Initiative (NTI) and a former Cabinet minister in the United Kingdom. Lord Browne is a member of the Group of Eminent Persons (GEM) for the CTBT.

Lord Browne served as Member of Parliament for Kilmarnock and Loudoun from 1997 to 2010. In 2001, he was appointed Parliamentary Under-Secretary of State for Northern Ireland, and in 2003 as Minister of State for Work at the Department for Work and Pensions. In 2004 Lord Browne was appointed Minister for Immigration and Citizenship at the Home Office. Following re-election in 2005, he joined the Cabinet as Chief Secretary to the Treasury and was appointed to the Privy Council.

In 2006 Lord Browne was appointed Secretary of State for Defence, and from 2007 to 2008 he combined this role with the role of Secretary of State for Scotland. In October 2008 he returned to the backbenches and was appointed Prime Minister Gordon Brown’s Special Envoy to Sri Lanka. He also served on the first Joint Committee on the National Security Strategy.

From October 2009 until March 2014, he was Convenor of the Top Level Group of Parliamentarians for Multi-Lateral Nuclear Disarmament and Non-proliferation. He co-founded the European Leadership Network and has been the Chair of its Board of Trustees and Directors since its inception. In July 2010 he was introduced to the House of Lords. Lord Browne was invited by CTBTO Executive Secretary Lassina Zerbo to join the newly established GEM to promote entry into force of the CTBT.

In 2014 the NTI announced Lord Browne’s current role as NTI’s Vice Chairman. In this role, he helps to shape NTI’s strategic direction, including long term planning and international outreach.
Paolo Cotta-Ramusino has been Secretary General of the Pugwash Conferences on Science and World Affairs—winner of the 1995 Nobel Peace Prize—since August 2002. He is also Professor of Mathematical Physics at the University of Milan, and Senior Researcher at the Italian National Institute of Nuclear Physics.

As a mathematical physicist Dr Cotta-Ramusino has concentrated on mathematical aspects of quantum field and string theories. He received his doctorate in physics in 1971 from the Università degli Studi di Milano. He was formerly Director of the Programme on Science, Technology and International Security at the Landau Network Centro Volta in Como. His research and teaching experience have included visiting positions at the University of North Carolina, the European Organization for Nuclear Research (CERN), and Harvard University.

In 1983 he co-founded the Italian Union of Scientists for Disarmament (USPID). He is a member of the International Institute for Strategic Studies and the World Academy of Art and Sciences.

Dr Cotta-Ramusino is an internationally recognized expert on current topics in arms control, disarmament and conflict resolution and regularly lectures at leading academic, research and governmental institutions. This includes recent talks at the Italian Parliament, the Royal Society of London, the Council on Foreign Relations and the Stimson Center in Washington, DC, as well as at the Parliament of the United Kingdom. His works have been published in a wide range of leading journals.
Mark Fitzpatrick

Mark Fitzpatrick is Director of the Non-Proliferation and Disarmament Programme at the International Institute for Strategic Studies (IISS) in London. The programme focuses on proliferation challenges and on nuclear security and nuclear disarmament issues.

Mr Fitzpatrick is the author of *Overcoming Pakistan’s Nuclear Dangers* (2014) and *The Iranian Nuclear Crisis: Avoiding Worst-Case Outcomes* (2008). He is also the editor of six Strategic Dossiers published by the IISS on countries and regions of proliferation concern, most recently on the Democratic People’s Republic of Korea (July 2011) and the Islamic Republic of Iran (February 2011). He has lectured throughout the world and is a frequent media commentator on proliferation topics. He is a founding member of the European Union Non-Proliferation Consortium. He is also a member of the World Economic Forum Global Agenda Council on Nuclear Security and the Policy Advisory Group of the United Nations Association of the United Kingdom.

Mr Fitzpatrick joined IISS in October 2005 after a 26-year career in the US Department of State, including as Deputy Assistant Secretary for Non-Proliferation (acting). His diplomatic postings also included Vienna, where he was in charge of liaison with the International Atomic Energy Agency, as well as postings in Seoul, Tokyo (twice) and Wellington. He earned a Master’s degree in Public Policy from the Kennedy School of Government at Harvard University, and he attended a one-year postgraduate study programme (1990–1991) at the Japanese National Institute of Defence, where his dissertation on Korean unification was published in journals in Japan and the Republic of Korea.
Robin Grimes is currently Professor of Materials Physics at Imperial College London. His research focuses on the use of high performance computing techniques to understand the behaviour of materials for energy applications, including nuclear fission and fusion, fuel cells, batteries and solar cells. He is also Principal Investigator of the nuclear fission consortium project of Research Councils UK.

Professor Grimes has advised the House of Lords Science and Technology Committee’s inquiry into nuclear research requirements and was part of the Scientific Advisory Group for Emergencies (SAGE) that provided official advice on the 2011 Fukushima disaster. He has considerable experience of high level international work with the British Government, including overseas missions to India, Viet Nam, the Republic of Korea, Malaysia and Japan.

Professor Grimes is also the Foreign and Commonwealth Office (FCO) Chief Scientific Adviser (CSA) and is responsible for providing advice to the Foreign Secretary, ministers and officials on science, technology and innovation. His role is to ensure that work on key issues undergoes proper scientific challenge and to strengthen the scientific and engineering capacity within the FCO. The CSA works closely with the cross-government community of Chief Scientific Advisers and the wider British and international academic science community.
Lieutenant General Frank G. Klotz, United States Air Force (Ret.), is the US Department of Energy’s Under Secretary for Nuclear Security and Administrator for the National Nuclear Security Administration (NNSA).

As Under Secretary for Nuclear Security, Lt. Gen. Klotz is responsible for the management and operation of the NNSA as well as policy matters across the Department of Energy and NNSA enterprise in support of President Barack Obama’s nuclear security agenda.

Prior to taking up his current position in 2014, he served in a variety of military and national security positions. As Commander of Air Force Global Strike Command from 2009 to 2011, he established and then led a new 23,000-person organization that merged responsibility for all US nuclear-capable bombers and land-based missiles under a single chain of command. From 2007 to 2009, Lt. Gen. Klotz was the Assistant Vice Chief of Staff and Director of the Air Staff. He served as the Vice Commander of Air Force Space Command from 2005 to 2007 and was the Commander of the Twentieth Air Force from 2003 to 2005.

Lt. Gen. Klotz served at the White House from 2001 to 2003 as the Director for Nuclear Policy and Arms Control on the National Security Council, where he represented the White House in the talks that led to the 2002 Moscow Treaty to reduce strategic nuclear weapons. Earlier in his career, he served as the Defense Attaché at the US Embassy in Moscow during a particularly eventful period in US–Russian relations.

A distinguished graduate of the US Air Force Academy, Lt. Gen. Klotz attended Oxford University as a Rhodes Scholar, where he earned an MPhil in international relations and a DPhil in politics. He is also a graduate of the National War College in Washington, DC. Most recently, Lt. Gen. Klotz was a senior fellow for strategic studies and arms control at the Council on Foreign Relations.
Patricia Lewis
Moderator

Patricia M. Lewis is the Research Director, International Security at the Royal Institute of International Affairs (Chatham House) in London. Her former posts include Deputy Director and Scientist-in-Residence at the Center for Nonproliferation Studies at the Monterey Institute of International Studies, Director of the United Nations Institute for Disarmament Research (UNIDIR); and Director of the Verification Research, Training and Information Centre (VERTIC) in London.


She holds a BSc (Hons) in physics from the University of Manchester, a PhD in nuclear physics from the University of Birmingham and an Honorary Doctor of Laws degree from the University of Warwick. She is a dual national of the United Kingdom and Ireland. Dr Lewis is the recipient of the American Physical Society’s 2009 Joseph A. Burton Forum Award in recognition of “outstanding contributions to the public understanding or resolution of physics”.


She holds a BSc (Hons) in physics from the University of Manchester, a PhD in nuclear physics from the University of Birmingham and an Honorary Doctor of Laws degree from the University of Warwick. She is a dual national of the United Kingdom and Ireland. Dr Lewis is the recipient of the American Physical Society’s 2009 Joseph A. Burton Forum Award in recognition of “outstanding contributions to the public understanding or resolution of physics”.


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Tate Nurkin is the Senior Director, Thought Leadership, with the Aerospace, Defense and Security business line of IHS Inc. In this role he is responsible for producing analysis of emerging and over-the-horizon challenges and competitions affecting the international security environment and global defence industry.

Mr Nurkin is also a member of the IHS Aerospace, Defense and Security Leadership Team, which is responsible for management of the operations of the legacy IHS ‘Jane’s’ brand, and of the IHS Thought Leadership Editorial Council, which shapes content included in IHS’s Thought Leadership Quarterlies. In September 2014 Mr Nurkin began a two year term on the World Economic Forum’s Global Agenda Council on Nuclear Security, and he is also engaged in the Council’s Nuclear Futures exercise workstream.

His current research focuses on the future of military and geopolitical competitions across the Western Pacific, nuclear security issues, emerging disruptive technologies and capabilities, NATO futures, and the future of the global defence industry. He is a frequent speaker and author on geopolitical and security dynamics and military technologies and frequently advises defence and security communities in the United States, Europe, the Middle East, Oceania and East and South East Asia on emerging security opportunities and challenges.

Mr Nurkin also specializes in designing and delivering scenario planning exercises, tabletop games, horizon scanning analyses, ‘blue’ and ‘red’ team panels, net assessments and open source intelligence training for public sector and defence industry clients.

Mr Nurkin joined Jane’s Information Group (Jane’s) in March 2006 and subsequently joined IHS through its acquisition of Jane’s in July 2007. Prior to 2006, he worked for the Modeling, Simulation, Wargaming and Analysis Group of Booz Allen Hamilton, the Strategic Assessment Center of Science Application International Corporation, and with Joint Management Services, a small defence consulting firm based in Atlanta, Georgia, USA. He holds a BA from Duke University and an MSc from the Sam Nunn School of International Affairs at Georgia Tech.
Naledi Pandor is South Africa’s Minister of Science and Technology.

She holds a BA from the University of Botswana and Swaziland and an MA in Education from the University of London. In 1992 she studied for a Diploma in Higher Education, Administration and Leadership at Bryn Mawr College. In 1997 she completed an MA in Linguistics at Stellenbosch University and a Diploma in Leadership in Development at the Kennedy School of Government at Harvard University, while serving as a member of the South African Parliament.

Ms Pandor became a member of Parliament in 1994 and has amassed much experience in positions of public office, including as Deputy Chief Whip of the African National Congress in the National Assembly from 1995 to 1998, Deputy Chairperson of the National Council of Provinces in 1998, and Chairperson of the National Council from 1999 to 2004. Her experience in education policy planning led to her appointment as South Africa’s Minister of Education from 2004 to 2009. She was appointed Minister of Science and Technology in May 2009, and Minister of Home Affairs in October 2012. She was again appointed Minister of Science and Technology in May 2014 following South Africa’s fifth democratic elections. The Cape Peninsula University of Technology and Stellenbosch University have awarded her honorary doctorates.
Laura Rockwood is the Executive Director of the Vienna Center for Disarmament and Non-Proliferation. She recently assumed this position following a year and a half as a resident Senior Research Fellow at Harvard University’s Kennedy School Belfer Center for Science and International Affairs ‘Managing the Atom’ project.

In November 2013 Ms Rockwood retired from the International Atomic Energy Agency (IAEA) as the Section Head for Non-Proliferation and Policy Making in the Office of Legal Affairs, where she had served since 1985. During her employment with the IAEA, she was involved in all aspects of the negotiation, interpretation and implementation of IAEA safeguards and was the principal author of the document that became the Model Additional Protocol. She participated in high level negotiations on the Islamic Republic of Iran, Iraq and the Democratic People’s Republic of Korea and in the negotiations between the IAEA, the United States and the Russian Federation on the Trilateral Initiative and the Plutonium Management and Disposition Agreement. She has also participated in three Non-Proliferation Treaty Review Conferences.

In July 2012 Ms Rockwood was honoured with the Distinguished Service Award from the Institute of Nuclear Materials Management (INMM), which is awarded for long term noteworthy accomplishments in, and service to, the nuclear materials management profession.

Prior to working for the IAEA she was employed by the US Department of Energy as a trial attorney in radiation injury cases and as counsel in general legal matters.

She received a BA from the University of California, Berkeley, and a JD from the University of California’s Hastings College of Law in San Francisco. She is a member of the State Bar of California and of the Bar Association of Washington, DC.
Elena Sokova has been involved in nuclear non-proliferation issues for most of her career. She has been an official of the Soviet/Russian Ministry of Foreign Affairs, Director of the James Martin Center for Non-proliferation Studies (CNS) Newly Independent States Non-proliferation Program, Assistant Director of the CNS, and, until very recently, Executive Director of the Vienna Center for Disarmament and Non-Proliferation. She is also a member of the World Economic Forum Global Agenda Council on Nuclear Security. Ms Sokova is now returning to the CNS as Deputy Director.

Ms Sokova holds a master’s degree in international public administration from the Monterey Institute of International Studies (2000) and a master’s degree in law from Moscow State University (1992). Her areas of research include nuclear non-proliferation issues in Russia and the newly independent states, trafficking in nuclear and radioactive materials, fissile materials security, nuclear fuel cycle developments, and non-proliferation education and training.

Her recent publications include: ‘Nuclear Power Broker’, Bulletin of the Atomic Scientists, September/October 2007 (co-authored with C. Chuen), on Russia’s proposals on multinational nuclear fuel arrangements; chapters in The Search for WMD: Non-Proliferation, Intelligence and Pre-emption in the New Security Environment (Center for Foreign Policy Studies, Dalhousie University, 2006); and chapters in Preventing Nuclear Meltdown: Managing Decentralization of Russia’s Nuclear Complex (Ashgate, 2004).
Ambassador Ahmet Üzümcü is Director-General of the Organisation for the Prohibition of Chemical Weapons (OPCW) and a career diplomat with vast experience in multilateral diplomacy and disarmament and non-proliferation issues. Prior to his appointment as Director-General of the OPCW in December 2009, he was Permanent Representative of Turkey to the United Nations in Geneva, where he chaired the Conference on Disarmament in March 2008.

Ambassador Üzümcü has also served as Deputy Undersecretary of State for Bilateral Political Affairs at the Ministry of Foreign Affairs of Turkey, as Turkey’s Permanent Representative to the North Atlantic Treaty Organization (NATO), and as Ambassador of Turkey to Israel, in addition to earlier postings to NATO, Aleppo and Vienna. He holds a bachelor’s degree in international relations from Ankara University and speaks English and French fluently.

Ambassador Üzümcü received the Nobel Peace Prize on behalf of the OPCW in December 2013.
THEME 1: THE EARTH AS A COMPLEX SYSTEM
1.1: Infrasound and Atmospheric Dynamics

Oral Presentations

T1.1-O1. A Global View on the Coherent Infrasound Field: Reprocessing of the Full International Monitoring System Infrasound Data

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In this study we are going to present preliminary results of global coherent infrasound measured at IMS infrasound stations and its correlation with atmospheric dynamics. A new implementation of the Progressive Multi-Channel Correlation (PMCC) algorithm enables characterization, with a single processing run, of coherent noise in log-spaced frequency bands from ~0.01 to 5 Hz. Such a new array processing algorithm enables a better characterization of all received signals in their wave parameter space (e.g. frequency-azimuth space, frequency-trace-velocity space). This, in turn, enables more accurate signal discrimination, and source and propagation studies. For instance, we are using the processing in microbarom source and propagation studies, in global studies related to the occurrence of sudden stratospheric warming events, and in volcanic explosion detection. We are currently performing re-processing of the entire previous IMS infrasound database covering the time period from April 2005 to February 2015; whereas the number of stations has increased from 30 to 48. Results so far indicate a continuous spectrum of coherent signals at IMS stations within the 0.02 to 5.0 Hz band. Moreover, these results could be used for estimating network detection capability based on empirical station coherent infrasound noise models.

T1.1-O2. A Study of Atmospheric Gravity Waves Using the USArray Transportable Array

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The USArray Transportable Array (TA) is a network of approximately 400 seismoacoustic stations deployed on a 70 km Cartesian grid covering an area of 2 000 000 km² in the continental United States. The network moves eastward through station redeployments and is now located on the Atlantic coast. This dense network has provided unprecedented opportunities for research in seismology, infrasound and atmospheric science. We have developed a novel technique to investigate gravity wave occurrence and propagation across the network and have applied it to atmospheric pressure data recorded from 1 January 2010 through 2014. We divided the stations in this time range into 3600 non-overlapping triads. Each triad is most sensitive to propagating gravity waves in the 1–6 hour period range. We report several lines of research with this new data set. First, we study individual large events in which atmospheric gravity waves are observed to cross the TA. We also study the long term occurrence statistics of gravity waves and compare them to satellite observations. Thirdly, we analyse recordings of infrasound signals that have propagated through the heterogeneous background that the network has allowed us to characterize. We discuss plans for future work when the network is redeployed in Alaska.
T1.1-O3. Determination of Vertical Profiles of Temperature and Wind in the Atmosphere Using Data from Infrasound Monitoring

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The method to determine the vertical profiles of temperature and wind in the atmosphere using data from infrasound monitoring are proposed. The method to determine the average vertical profiles of temperature and wind are proposed. The method is based on the method NeaIder-MFA (multidimensional unconstrained nonlinear minimization) algorithm for finding the minimum of a function of several variables. The methods for the sounding of the fine-layered structure of the temperature and wind speed in the middle atmosphere (z = 20–120 km) are proposed for the first time. The methods are based on the method of decomposition of infrasonic signals from pulse sources. In this method, the recorded infrasonic signal is modeled by the sequence of single acoustic pulse having the form of a U and N waves. Each pulse U and N wave corresponds to the reflection of sound from atmospheric inhomogeneities at different altitudes in the atmosphere. By determining time intervals between such pulses U and N waves it is possible to determine vertical gradients of the effective sound speed at the different altitudes in the atmosphere. The obtained data are corresponds to the theory of the fine structure in the upper atmosphere.

T1.1-O4. Towards a Volcanic Notification System with Infrasound Data

P. Mialle¹, N. Brachet², E. Marchetti³, M. Rippepe³, P. Gaillard², A. Le Pichon², E. Blanc², P. Husson², L. Ceranna⁵, L. Khemiri⁶
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 Powerful volcanic eruptions, such as those of Mount Kelud in 2014 or Eyjafjallajökull in 2010, may cause disturbances in the different layers of the atmosphere. These fluctuations are measured by infrasound stations and analysed in order to extract parametric data that best characterize the volcanic source. The remote monitoring of volcanic activity with infrasound is of interest to the Volcanic Ash Advisory Centres (VAAC) that are responsible for coordinating and disseminating information on volcanic ash clouds that may endanger aviation. The synergy between the CTBTO and ARISE (Atmospheric dynamics Research Infrastructure in Europe) partners offers a unique opportunity for the establishment of a Volcanic Notification System (VNS) using infrasound data from a global station network. The VNS makes best use of the infrasound component of the IMS together with the operational capabilities of the IDC. ARISE advanced products provides valuable parametric inputs on the atmosphere dynamics that drives the infrasound wave propagation. These results may serve as quality indicators increasing the VAACs confidence when receiving notification messages. The proposed approach is tested with VAAC Toulouse, mandated by the International Civil Aviation Organization, and demonstrates the usefulness of infrasonic data to International Airways Volcano Watch.

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Development of optimal infrasound signal detection procedures needs to consider signal characteristics. We investigate the performance of automated infrasound detectors on impulsive and extended signals. In the first case, waveforms recorded by the Republic of Korea infrasound array CHNAR are analysed using the progressive multi-channel correlation method (Cansis, 1995) and the adaptive F detector (Arrowsmith et al. 2009). The automated techniques are compared to the signals identified by five independent analysts. The effectiveness of the detector is shown to be a function of array aperture, RMS amplitudes (1.2–4.5 mPa), and wind conditions. The detection probabilities (DP) is most strongly influenced by noise level with an average DP of ~40% under low noise condition (1. mPa) and an average of ~23% under high noise level (2.9 mPa). In the second case, we design an automatic infrasound detector using single seismic stations in the western US to analyse the signal characteristics of known impulsive and extended signals. Based on the RMS amplitude measurement of pre-group velocity windows, arrival time, SNR, and the duration of the signal were estimated. We identify key features in establishing infrasound bulletins through detector tuning at a single array as well as the effective use of a network of sensors.

T1.1-P2. A Source Identification in the Coastal and Marine Environment Inferred from Infrasound Array Observations in the Lützow-Holm Bay, East Antarctica

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Characteristic features of infrasound waves observed at Antarctica reveal physical interaction involving surface environments in the continent and Southern Ocean. A single infrasound sensor has been continuously recorded since 2008 at Syowa Station (SYO; 39E, 69S), the Lützow-Holm Bay (LHB), East Antarctica. The recording data clearly represent background oceanic signals (microbaroms) during whole seasons. In austral summer in 2013, several field stations are established along the coast of LHB. Two infrasound arrays with different diameter triangles are installed at both SYO (100 metres spacing) and on continental ice sheet (1000 metres spacing). Besides the arrays, isolated single stations are deployed at two outcrops. The new arrays clearly identified the predominant propagating directions in NWN and their frequency content variations of microbaroms from Southern Ocean. Microbaroms measurement is a useful tool for characterizing ocean wave climate, complementing other oceanographic and geophysical data in the Antarctic. Moreover, characteristic signals are demonstrated, such as regional earthquakes, the airburst shock waves generated from meteoroid injection at the Russian Federation on February 2013. Detail and continuous observations of infrasound waves in Antarctica is a new proxy for monitoring environmental changes such as global warming affecting on polar regions.
T1.1-P3. An Overview of Stochastic Propagation Methods for Infrasound Studies

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Propagation of infrasonic energy through the atmosphere is complicated by the dynamic and poorly resolved nature of the propagation medium. While the influence of spatial variations in the atmosphere is well understood, the presence of temporal variations has proven to be a significant challenge in applications involving propagation of infrasound through the atmosphere. This temporal variability combined with the limited resolution of measurements for atmospheric parameters (particularly above the tropopause) result in a dynamic, poorly constrained propagation medium for infrasound propagation through the atmosphere. A variety of methods have been studied to account for the resulting uncertainty including atmospheric perturbation methods and stochastic propagation models. The construction, utilization, and performance of the latter method will be discussed in detail using infrasonic signals generated by large chemical explosions in the western United States. The stochastic propagation framework will be shown to have applicability in monitoring for infrasonic events, improving infrasonic network deployments, and providing additional data streams for climatology and atmospheric transport modelling.

T1.1-P4. Application of Infrasound Technology in Detection of Volcanic Explosions

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Infrasound technology has been used by various institutions around the world for various applications well before the major undertaking by CTBTO in 1999 for establishment of the International Monitoring System (IMS) network. The IMS network consists of four main types of technology and includes infrasound technology. The main purpose for the IMS network is to enforce the CTBT by detecting nuclear explosions conducted anywhere around the world and bring to notice countries responsible for conducting the explosion(s). Infrasound technology detects airwaves or pressure waves generated by nuclear explosions. The airwave or pressure wave is dominated by low frequency signal and can travel very long distances from the explosion source. Volcanic explosions are synonymous to nuclear explosions and they too generate airwaves or pressure waves as well. Rabaul Volcanological Observatory (RVO) in Papua New Guinea operates a network of 14 short period seismic stations to monitor volcanic activity at Rabaul Caldera. Between 1995 and present Tavurvur volcano produced several short duration very explosive strombolian eruptions full of discrete explosions. Effects of airwaves or pressure waves from some of the very strong explosions have featured very distinctly in rattling windows and doors and even shattered glass windows within several kilometres from the source. Similarly airwaves have featured very prominently on seismograms for stations within one to several kilometres and barely just seen on one of the farthest stations 16 km away. The installation of IMS infrasound station IS40, located 23 km south west from the volcano, in 2013 has clearly increased the detection capability of the explosions at distances where normal short seismometers are unable to detect them. This observation and/or outcome is very useful for underdeveloped and some developing countries who are hosts to an infrasound station and also who are volcanic-prone but are unable to monitor many of their active and potentially active volcanoes due to lack of resources or are in isolated and remote locations. If they have access to the data and have the capability to process the data in-country, then the infrasound station may assist such host countries in detection of early phases of an imminent eruption and alert appropriate authorities to take appropriate measures in anticipation for a possible larger eruption.
T1.1-P5. **Atmospheric Infrasound Propagation Modelling Using the Reflectivity Method**

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We demonstrate that the reflectivity method can be applied to the modelling of infrasound propagation. The reflectivity method is a slowness (or wavenumber) integration method widely applied in the seismological community to generate synthetic seismograms in layered media. Some limitations of conventional ray tracing are circumvented since head waves are represented and shadow zones are more correctly modelled. We apply a 2.5-D ray-tracing engine and a slightly modified version of Müller’s reflectivity code to the atmospheric wind and temperature conditions at the time of the Drevja accidental explosion on 17 December 2013, in Northern Norway. The infrasound modelling results are compared with signals observed at the IS37 array station in Bardufoss, situated around 400 km north-east of the event. An important observation is that an infrasound arrival, clearly observed in the IS37 data approximately 20 minutes after the explosion time, is predicted by the reflectivity method and not by ray-tracing, even for very densely sampled ray emission elevation angles. However at shorter ranges (~300 km), the corresponding phase is predicted by both modelling methods. There, the ray tracing shows this arrival as resulting from a ray turning once in the stratosphere.

T1.1-P6. **Detection of Infrasound from Mount Etna REB Events at the Experimental Array in Meron, Israel**

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A great deal of infrasound observations of Mount Etna appear in the literature, and major eruptions have long appeared in the Reviewed Events Bulletins (REB) of the CTBTO. However, thus far, most of these observations have been made from the immediate vicinity of the volcano and from its west, by the IMS infrasound station in Tunisia. There are limited infrasound observations in winter, when stratospheric wind conditions favor eastward propagation of infrasound. We present here the first extensive observations made from the east, during the winter months, when wind conditions allow for infrasound to be detected more than 2000 km away from Mount Etna at our experimental array in Meron, Israel. Using a basic propagation model, we were able to confirm our detection of the vast majority of REB events that occurred during the periods for which we have data.

T1.1-P7. **Dynamics of the Middle Atmosphere as Observed by the ARISE Project**

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The atmosphere is a complex system submitted to disturbances in a wide range of scales, including high frequency sources as volcanoes, thunderstorms, tornadoes and at larger scales, stratospheric warming events, gravity waves from deep convection or wind over mountains, atmospheric tides and planetary waves. These waves affect the different atmospheric layers submitted to different temperature and wind systems which strongly control the general atmospheric circulation. Variations in the middle atmosphere circulation influence weather and climate throughout the troposphere all the way to the earth’s surface. Limited observation of the middle atmosphere limits the ability to faithfully reproduce the dynamics of the middle atmosphere in numerical weather prediction and climate models. The objective of this paper is to present a review of recent advances, especially obtained in the framework of the ARISE (Atmospheric dynamics Research InfraStructure in Europe) project. ARISE is based on the use of the IMS (Infrasound Monitoring System) developed for the verification of the CTBT completed by complementary stations and infrastructures. The main objective is to provide data in the different layers of the atmosphere for improving weather and climate models and monitoring extreme events for many civil applications.
T1.1-P8. East African Infrasound Station Performance

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Infrasound is one of the four techniques in the verification regime of the CTBT. IMS infrasound network is composed of 60 arrays; each array has 4 to 9 sensors disposed in various geometries and installed in different environment or condition. This network was designed to detect a nuclear explosion at a threshold of 0.5 kt. The purpose of this study is to identify the best infrasound station according to the geometry and the weather condition. Mack and Flinn method combined with temperature and wind speed effects on detection in each station were used. Results will be discussed for pentagon based, enhanced triangle and basic array.

T1.1-P9. Fusion of Infrasound with Hydroacoustic and Seismic Data in NET-VISA

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NET-VISA (Network Processing Vertically Integrated Seismic Analysis) is a probabilistic generative model that describes the geophysics of event formation, the propagation of energy along multiple mediums, the generation of noise, and the performance of detectors. In this work we extend the previous models for seismic and hydroacoustic mediums to include infrasound as well. Unlike other mediums, the travel time prediction in infrasound is a complex issue due to constantly changing weather conditions which lead to large variations in the atmosphere. In fact the travel time uncertainties for a global infrasound network are even larger than the average interval between noise arrivals. Consequently, one of the biggest challenges in infrasound is the discrimination between noise and signal. Along these lines we present various attributes of infrasound signals that help differentiate them from noise. In the long term, we expect that the integration of real time meteorological specifications will help the model accuracy. For the present we will show results demonstrating the extent to which infrasound-only events can be statistically justified with existing parametric data.

T1.1-P10. Global Cataloging of Explosive Volcanism Using the International Monitoring System Infrasound Network

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Explosive volcanic eruptions are among the most powerful sources of infrasound observed on earth, with recordings routinely made at ranges of hundreds to thousands of kilometres. These eruptions can also inject large volumes of ash into heavily travelled aviation corridors, thus posing a significant societal and economic hazard. Detecting and counting the global occurrence of explosive volcanism helps towards several goals in earth sciences and has direct applications in volcanic hazard mitigation. This project aims to build a quantitative catalog of global explosive volcanic activity using the IMS infrasound network. We are developing methodologies to search systematically through IMS infrasound detection bulletins and waveform data archives to identify signals of volcanic origin. We combine infrasound signal association and source location using a brute-force, grid-search, cross-bearings approach. When volcanic signals are identified, we extract metrics such as location, origin time, acoustic intensity, signal duration, and frequency content, compiling the results into a catalog. This work represents a step towards the goal of integrating IMS data products into global volcanic eruption early warning and notification systems. Additionally, a better understanding of volcanic signal detection with the IMS will improve operational event detection, discrimination, and association capabilities.
T1.1-P11. Identification Signals from Atmospheric Storms

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The problem of identification of infrasonic signals from atmospheric storms was studied. Such infrasonic signals have a very low frequency (0.005–0.02 Hz) and amplitudes comparable with a noise. The data obtained from IMS station IS43 were analysed. Two identification methods of infrasonic signals were used, the first based on the Fourier and morphological analysis and the second based on correlation analysis. The direction of arrival obtained for the selected infrasound signals were compared with the direction of propagation of atmospheric fronts. Weather maps of atmospheric fronts were presented as well. A quite good correlation between calculated direction of infrasonic arrivals and those for atmospheric fronts was observed.

T1.1-P12. Infrasound Magnitude Estimation

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The International Data Centre (IDC) of the CTBTO has been routinely processing data from the infrasonic component of the International Monitoring System (IMS) for several years now. One aspect of processing that remains to be completed is an order of magnitude estimate of the source size. In this work we report on the inclusion of an infrasound magnitude estimate into IDC devlan processing. Three magnitude estimates are being determined. The first two are based on amplitude attenuation with distance, and assume either the LANL HE amplitude-range attenuation, or the refinements as determined by LePichon et al. (2012) that include stratospheric ducting and the effects of absorption and geometric spreading. The third magnitude estimate is based on the period of the dominant acoustic return at maximum amplitude as developed by the US Air Force Technical Applications Centre (AFTAC). Results taken from both routine processing and for selected significant events will be presented for the three magnitude types.

T1.1-P13. Infrasound Data Analysis of South American Infrasound Stations Using International Data Centre SEL3 Data

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We present a simple and brief method of determining the sources of noise, their frequency, and recurring events from infrasound stations. This is based on the analysis of a large amount of data provided by the automatic newsletter SEL3 along the years. In order to corroborate the data, we have analysed the South American stations IS02, IS08, IS09, IS14 and IS41. Similarly, we can find out that it allows us to locate events with a very good precision.


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Kazakhstan Data Centre (NDC) has bulletins of infrasound detections constantly calculated with the use of the data of two infrasound stations: IS31 Aktyubinsk since 2001 and Kurchatov since 2011. IS31 Aktyubinsk has been installed to the north-west of Kazakhstan, Kurchatov infrasound array, to the east of Kazakhstan. However, during more than two years the data of Kazakhstan infrasound arrays have been processed independently. At
least two arrays are required for the localization of infrasound event epicentre. In presence of two or more arrays
the location is determined as per cross-bearing. First experiments of application of the cross-bearing with the use
of IS46-Zalesovo and Kurchatov stations bulletins have shown that solving the task of localization of epicentres
is complicated due to greater number of false solutions. These results were presented at the Infrasound
Technology Workshop 2012 in the Republic of Korea. NDC of France has offered assistance in solving the
tasks. At the end of 2013, KNDC received adapted version of “Locinfra” software from NDC of France. The
paper presents technology of source localization implemented in “Locinfra”. Even first results of source
localization show that Kazakhstani infrasound array network has got very promising monitoring capability.

**T1.1-P15. On the Use of the Kalman Filter for Infrasonic Detection**

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Currently, usual detection algorithms are based on a temporal segmentation of the signal into multiple windows
of fixed size in which a test function is applied to test the presence of spatially coherent signal. This temporal
segmentation presents limitations such as the choice of the window size and the time step between windows of
analysis. We therefore introduce an innovative detection algorithm based on the likelihood ratio updated at each
new observation. The signals of interest are considered to be autoregressive random processes buried in white
noise that propagate under the plane wave assumption. With this online approach, the function of test relies on
the entire signal and is thus able to discriminate a signal of interest from the noise, even for low SNR. This
algorithm also allows us to perform a detection with multiple simultaneous sources. Then we propose an
improved method to estimate the frequency content of the signals of interest based on the expectation
maximization algorithm useful for source characterization. The derived algorithms are applied on few months of
IMS data.

**T1.1-P16. Reanalysis of Large Infrasound Data Sets with Stochastic Low-Order Models**

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Since the late 1990s, steady progress has been made in understanding the physics of long-range infrasound
propagation in the atmosphere. However, it appears that the propagation problems are still solved principally by
numerical techniques developed long ago. One of the most frustrating aspects of these techniques is their
inability to predict the waveform sensitivities to atmospheric uncertainties. With recent renewed interest in the
role of gravity waves in infrasound variability, there is a need to develop new algorithms for the prediction of
sensitivities. In the present approach, the gravity waves are represented as a random field that is superimposed on
the average background state, and the wave equation is solved using a reduced-order model, starting from the
classical normal mode technique. The reduced model is obtained by retaining a few propagating modes, with the
aim of simplifying the acoustic model to the point that the predicted statistics/sensitivities of signals are correct.
We focus on the asymptotic behavior of the transmitted waves in the weakly heterogeneous regime, for which
the coupling between the wave and the medium is weak. It is expected that this new approach could help
reducing the number of bogus infrasound events in the IDC automatic system.
T1.1-P17. Stratospheric and Thermospheric Infrasound Signals Recorded at IS37, Norway

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The IMS infrasound array IS37, near Bardufoss in northern Norway, started providing data in October 2013. In August and September 2014, IS37 recorded for the first time infrasound signals from each of 15 ammunition destruction explosions at Hukkakero, a military site in northern Finland at a distance of 320 km. The first 12 of the explosions were large blasts with yields of approximately 20 tons and, for each of these events, an extensive wavetrain is observed. Approximately 18 minutes after the explosion, a long duration signal rich in high frequencies, is observed. Between 3 and 4 minutes later, signals of far shorter duration and lower frequency are observed with higher trace velocities, indicating refraction from greater altitudes. Modelling supports the hypothesis that these distinct parts of the wavetrain are stratospheric and mesospheric/thermospheric phases respectively. We observe that the trace velocity for almost all of the stratospheric part of the wavetrain is essentially constant, whereas the thermospheric phases are associated with quite differing trace velocities: indicative of turning points at different altitudes. The final three explosions at Hukkakero in 2014 were of far lower yield and only generated signal detections at IS37 in the stratospheric part of the wavetrain.

T1.1-P18. Study of the Atmospheric Structure and Dynamics by Infrasound Probing Method

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The results of study of the wind field structure in the upper stratosphere, mesosphere and lower thermosphere obtained by a recently developed infrasound probing method are presented. The method is based on the effect of infrasound scattering from highly anisotropic wind velocity and temperature nonhomogeneities in the atmosphere. The spectral characteristics of the wind velocity vertical variations in the middle atmosphere such as vertical wavenumber spectra and coherences are obtained from the vertical profiles of wind velocity retrieved from the infrasound signals detected in the shadow zones. The infrasound propagation from volcanoes and surface explosions through the atmosphere with the retrieved profiles of the effective sound speed is modeled by using parabolic equation method. The obtained consistency between modeled and recorded infrasound signals at different ranges from the infrasound source shows that real time retrieval of the fine-scale wind velocity structure allows us to better predict infrasound field and localize its source as compared to the case when such structure is not taken into account in the existing atmospheric models. The possibility of using retrieved wind velocity structure for improving the models of pollution transport and long-range infrasound propagation in the atmosphere is discussed.

T1.1-P19. Technique of Joint Processing of Pressure Pulsations and Wind Speed Information at International Monitoring System Infrasound Stations

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This technique enables to obtain more credible detection results as it minimizes probability of false alarm with designated detection probability. The technique is based on the principle of likelihood ratio maximization with joint recording of pressure pulsations and wind speed. As an assessment criterion the technique uses the product of conditional probability ratios for independent functionals: $F_1$, $F_2$ of joint recording of functional $F_{det}$ calculated on the basis of data from pressure pulsation measurement channel. A numerator is composed of probabilities product $P(F_i)$ that is calculated subject to signal $S_k$ availability. A denominator is composed of probabilities product $P(F_i)$ that is calculated subject to the absence of signal. A decision on signal detection is made when $\Lambda$ exceeds the threshold level corresponding to detection probability. Signal parameters $S$ are determined as $\Lambda(S)$ reach maximum value. It is proposed to use dependence of pressure root-mean-square error on mean wind speed as functional $F_1$ and correlation factor $r$ of time derivatives of pressure and wind speed as
functional F2 (acquisition data are passed preliminarily through a low-pass filter). STA/LTA and PMCC (multichannel multiple cross-correlation) methods can be used in determining Fdet.

**T1.1-P20. Using Infrasound and Seismic Networks for Monitoring Ecuadorian Volcanoes: Case Study of Tungurahua and Reventador Volcanoes**

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Infrasound and seismic methods have been used for monitoring eruptive activity at Tungurahua and Reventador volcanoes. Since July 2006, a seismo-infrasonic network recorded 6000 explosions at Tungurahua larger than 45 Pa and 3 explosions larger than 1000 Pa. During major eruptions (14–15 July 2006, 16–17 August 2006, 6–8 February 2008, 28 May 2010, 4 December 2010, 3–4 December 2011, 18 August 2012) occurred seismic and infrasound tremors with complex waveforms. Post-eruption activity is frequently followed by swarms of less vigorous explosions. Explosion events occasionally triggered chugging events. In 2002 Reventador volcano produced the largest eruption in Ecuador in the last century (VEI-4). Since November 2004, periods of extended strombolian activity and short-lived vulcanian explosions are characterized by extrusion of lava domes, explosions, ash columns, lava and pyroclastic flows. A 120-sec seismic sensor and a microbarometer were installed on the south-east border of the caldera amphitheater. Non steady activity with fluctuations between quiescence and frequent explosions, tremor, and chugging events is recorded. Furthermore, the IG installed a regional network of six microbarometers for monitoring volcanoes such as Guagua Pichincha, Chimborazo, Antisana, Sangay, and the Galapagos Islands.


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This study uses acoustic reflectivity modelling to describe the propagation and ducting behaviour of infrasonic waves with the aim of identifying and characterizing events at a single station. Atmospheric background conditions are modified by probabilistic variations of gravity wave profiles to simulate atmospheric dynamics and thus identify infrasonic propagation paths through various atmospheric ducts. Using reflectivity as a method adapted from seismic wave propagation, synthetic barograms are calculated by solving the wave equation instead of using a high frequency approximation as e.g. ray-tracing. A probabilistic approach is performed for the atmospheric background modelling with a high number of different gravity wave perturbations included. The aim is to identify a higher number and variety of infrasonic phases resulting from different and more complex wave propagation (including e.g. elevated, mesospheric and changing ducts) to improve the characterization of events detected at a single infrasound array. Repetitive infrasound sources as e.g. industrial and military activity will be used to standardize the identification and discrimination of events at a single infrasound station.

**T1.1-P22. Volcano Infrasound Monitoring Including Propagation Effects Induced by Topography and Atmosphere**

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Infrasound monitoring of active volcanoes provides direct evidence of the injection of volcanic material into the atmosphere. From local to regional distances, infrasound is now used routinely for volcano monitoring whereas volcanic source parameters are commonly derived from direct observations on the field. In this work we compare field observations, with results of numerical simulations using FDTD modelling including topography and atmosphere to show how both effects have to be accounted to improve real time infrasound volcano monitoring. The topographic effect is more significant in near-source (less than 10 km) while the atmospheric
structure has a strong effect at the regional distances (>100–1000 km). We show data collected at regional scale (145–230 km) produced by a giant landslide in Askja Volcano (Iceland) and at local scale (3–60 km) by vulcanian activity of Sakurajima volcano (Japan) to demonstrate that the atmospheric profile and topography need to be considered to derive reliable infrasonic source parameters.
1.2: Solid Earth Structure

Oral Presentations

T1.2-O1. Developing Path-Dependent Uncertainty Estimates for Use with the Regional Seismic Travel Time Model

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The Regional Seismic Travel Time (RSTT) tomography model has been developed to improve regional phase predictions (Pn, Sn, Pg, Lg) in order to increase seismic location accuracy and precision even when regional and teleseismic data are combined. Travel time uncertainty estimates for RSTT are determined using phase-specific one-dimensional, distance-dependent error models that have the benefit of being very fast to use in standard location algorithms, but do not account for path-dependent variations in uncertainty and structural inadequacy of the RSTT model (e.g. model error). While the RSTT error models provide reasonable estimates of travel time prediction error in regions that were well sampled by the tomography data, they likely severely underestimate the errors in poorly calibrated regions. We are developing and investigating a new covariance matrix for RSTT phase arrivals by mathematically deriving a multivariate error model directly from a unified model of RSTT embedded into a statistical random effects model that captures the residual as distance, path and model error effects. Initial work has been the development of a two-dimensional error model using path-distributed residuals, partitioned by distance/turning depth. The goal for a new RSTT uncertainty method is to be readily usable to the standard user.

T1.2-O2. Earthquakes Relocation by Three-Dimensional P-Wave Velocity Model for Abu Dabbab Area, Red Sea, Egypt

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150 local earthquakes recorded at 10 telemetered stations located around Abu Dabbab area, have been relocated by three-dimensional velocity model using Simul3 software using P-wave arrival time data. Three-dimensional velocity model for earthquake location was computed by inverting the high quality data in the period from June to August 2004, for hypocentre locations and P-wave seismic velocities. Hypocentre depths ranged from approximately 6 to 12 km. The present analysis revealed lateral heterogeneities in the structure of the crust beneath the Abu Dabbab area. It was found that the crustal velocity structure is dominated by a high velocity zone at the centre of the eastern part of the study area and extending down to 12 km, and a low velocity zone at the west of the high velocity zone extending down to 12 km, trending to the south east. No large systematic shifts of the relocated earthquake locations were observed, except a systematic shift of about 5 km to greater depth. In conclusion, the new relocated earthquake locations showed tighter clustering of epicentres and focal depths when compared with original earthquake locations.
T1.2-O3. Geophysical Methods in Tracing Palaeozoic Suture Zones Within the Lithosphere of Uzbekistan

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This paper presents interpretations of deep refraction and wide-angle reflections “deep seismic sounding” (DSS) data and analyses of potential field data. An integrated model of the physical properties and lithosphere structures displays distinct features related to the tectonic history of the study area. Linear positive magnetic anomalies reflect the position of associated deep faults, which define the location of palaeosubduction zones. These zones are recognized on crustal DSS profiles and potential fields, crossing the orogenic part of Southern Tien Shan and partly the Amy Darya basin. We have also analysed travel times of seismic P and S waves from deep-focus Hindu Kush earthquakes recorded at some seismograph stations in Uzbekistan. We adopt the hypocentral location and origin times of these earthquakes as reported by the ISC to obtain the necessary travel times. The epicentres of the Hindu Kush earthquakes whose data are analysed were clustered in an area of 100 km by 50 km. The focal depth of these earthquakes as estimated by the ISC ranged between approximately 102 and 262 km. We have plotted and analysed time series of Vp and Vs at stations located in zones separated by palaeosubduction zones of the Gissar and Turkestan oceans.

T1.2-O4. Imaging Crustal Structure of South East Asia from Seismic Noise

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We image South East Asia and the northern part of Australia by cross-correlating ambient seismic noise recorded at over 500 stations. The group velocities are measured through applying narrow band filters on the retrieved Rayleigh wave Green’s functions and used in a probabilistic tomographic approach to map the velocity structure of the region. The inverted images from 8 seconds to 40 seconds show details of the seismic structure of the region beneath the Indonesian archipelago, South China Sea, and northern shelf of Australia, including the boundaries of the oceanic lithosphere. Transdimensional Bayesian tomography is used to invert the traveltimes of Green’s functions for periods between 8 and 40 seconds. Transdimensional Bayesian tomography does not require an explicit choice of smoothing, damping or grid parameterization; the resolution if the solution instead varies spatially and is determined by the data. By sampling the resulting tomographic images at different spatial points, we construct the group velocity dispersion curves. These curves are later inverted to create the 2D shear wave velocity distribution of the region. Various features are imaged, including low-velocity sedimentary basins at shallow depth and high velocities associated with the ongoing subduction of the Australian lithosphere beneath the Sunda Plate.

T1.2-O5. Improving the Regional Seismic Travel Time Model Through International Outreach

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The Regional Seismic Travel Time (RSTT) model and method have proven to be effective for reducing event location errors. RSTT is openly available and is integrated into the location code used by the International Seismological Centre (ISC). Because the RSTT model is global in extent and travel times can be computed in real time, RSTT is applicable to the whole International Monitoring System (IMS) and any regional networks that might be available. This enables a consistent location to be determined at the International Data Centre and
at national data centres, where additional data may be used. The United States and the CTBTO are teaming to sponsor international cooperation activities that introduce RSTT at regional workshops around the globe. To date, representatives from over 65 countries have participated in RSTT workshops. After a brief introduction to the method, workshop participants are introduced to the software and they are shown how to compute travel times, use RSTT with the ISC locator, visualize the RSTT model, and edit the model. RSTT workshop participants have contributed regional models and ground-truth location data, all of which have improved the global RSTT model.

**T1.2-O6. The Effect of Structure on the Mislocation Vectors of Naqu Array and the Slowness-Azimuth Station Correction for Naqu Array**

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Naqu array in western China were built by CEA, it run in 2002 and then began to supply waveform data. The earthquakes occurred from 2007–2008 were used in this paper, the mislocation vectors show symmetry axes in their slowness and azimuth components. For the slowness the line of separation is at about 180° against north. The azimuth pattern shows a symmetry axis perpendicular to the axis in the slowness pattern. Waves arriving from East have a larger slowness, whereas waves from West have a reduced slowness. Waves arriving from North have an anticlockwise mislocation vectors, whereas waves from South have a clockwise mislocation vectors. This phenomenon could be interpreted as the effect of low-velocity sediments below the array according to Kruger and M. Weber (1992). Previous papers also agree to this result. To approve the mislocation vectors of Naqu array, the paper applied SASC (slowness-azimuth correction) to enhance the location accuracy of this array. After correction, the single array location ability was clearly improved and the standard deviations of back-azimuth and slowness residuals drop from 27.1 to 10.1° and from 8.97 to 0.08 s/° respectively for Naqu. The improvement is 82.2% in back-azimuth and 93.5% in slowness location after SASC.

**T1.2-O7. Using International Monitoring System Seismic Data to Measure Fine Features of PKiKP Waves**

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The PKiKP waves reflected from the inner core boundary (ICB) are of interest for deep earth studies and for monitoring purposes of the CTBTO. The PKiKP reflections evidence clear mosaic pattern of the inner core surface. We present a new study of PKiKP waveforms obtained from the International Data Centre (IDC) and the prototype IDC (data are from a Limited Access Contract with CTBTO using virtual Data Exploitation Centre). Our data set includes more than 500 measurements obtained in 1995–2001 (pIDC) and 2001–2011 (IDC). We study the influence of ICB fine structure on kinematic and dynamic characteristics of PKiKP. To improve PKiKP signal-to-noise ratio on IMS array data we used linear and phase-weighted stacking, which enabled uncomplicated measuring of arrival times, peak amplitudes and periods of the detected PKiKP waveforms. Most of measured PKiKP arrival times fit PREM. The empirical probability distribution function for the measured periods is best approximated by a multimodal function with three peaks at 0.6, 0.85 and 1.2 seconds. Correlation kriging analysis of measured periods shows distinct data clustering on the ICB. This supports the ICB mosaic originating from local variations in the inner-outer core transition.
T1.2-P1. Mantle Discontinuities Beneath the Balkans

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The study of the upper mantle structure is of huge interest for understanding of geodynamics. Its characteristics define the thermal and substance transfer between upper and lower part. Receiver function technique is used to study upper mantle structure and the transition zone in the mantle beneath Bulgaria. It is applied to the data from 11 stations of National Digital Seismological Network, equipped with broad band seismometers. The main discontinuities in the upper mantle are well observed. These are asthenosphere-mantle discontinuity, which has a depth between 190 km and 220 km, and discontinuities at 410 km and 660 km. In North of Bulgaria and close to Sofia these two discontinuities have different depths than in iasp91 velocity model. The 410 km boundary varies between 390 (under VTS) and 430 (northern Bulgaria). The 660 km boundary is observed almost elsewhere under Bulgaria and varies between 660 and 670 km. Partially observed boundaries are 330 and 520 km.

T1.2-P2. A Global 3D Velocity Model for Improved Seismic Event Location in Nuclear Explosion Monitoring

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A global 3D velocity model of the earth’s mantle has been developed to improve the accuracy and precision of seismic travel time predictions for a wide suite of regional and teleseismic phases. Improved travel time predictions lead directly to significant improvements in the accuracy and precision of seismic event locations as compared to locations computed using standard 1D velocity models like ak135, or 2½D models like RSTT. A key feature of the model is that path-specific model uncertainty of travel time predictions are calculated using the full 3D model covariance matrix computed during tomography, which results in more realistic uncertainty ellipses that directly reflect tomographic data coverage. Recent improvements in the model include the generation of an S velocity model to compliment the P velocity model and development of capability to compute travel times for core phases, reflections off the core-mantle boundary, and underside reflections off the Moho and the surface of the earth. For use in routine operations, travel time predictions and prediction uncertainties are precomputed and stored in station-phase-specific 3D lookup tables, which allows fast, reliable retrieval of information needed by locators. The lookup capabilities are based on the open-source GeoTess software package available at http://www.sandia.gov/geotess.

T1.2-P3. Crustal Heterogeneity Beneath North-Eastern Japanese Trench Arc System Inferred by Stress and Strain Numerical Modelling and Seismic Coupling Models: Step to Predict Earthquakes

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Development of stress and strain fields is the cause of deformations during a process of subduction. Outer rise earthquakes both tensional and compressional (Christensen and Ruff, 1988) as well as shallow inland earthquakes caused by intersesimic coupling leads to accumulation of strain. These earthquakes occurring in the subduction zones deform the crust permanently which ultimately changes the crustal heterogeneity. Numerical models on stress and strain in the subduction zone will provide an idea about effects of outer rise earthquakes. Further using intersesimic coupling models the behavior of the crust can be understood, since intersesimic coupling is affected by the heterogeneity of structures of the forearc (Mishra et al. 2003). Interseismic coupling is also inferred by the inland deformations, therefore it is also convenient to look in-to inland heterogeneity as
well. Since the 2011 Tohoku Oki earthquake (Mw 9.0), large earthquakes are expected to occur in inland. It is important to know how crustal heterogeneity inferred by seismological and electromagnetic methods affect the inland earthquakes. Therefore numerical modelling on stress–strain and seismic coupling models are essential to better understand the deformations occurring in the subduction zone which will ultimately make a huge contribution in prediction of earthquakes.

T1.2-P4. Crustal Thickness Estimation Beneath the Northern Andes Using the Receiver Function Method

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We calculated receiver functions under the north-western Andes and adjacent areas, to deduce crustal thickness. We use data from the broadband network of Colombia, which has been working since 2008; presently the network consists of 29 stations, 10 of which have been installed between 2012 and 2014, and are operated by the Colombian Geological Survey. With the receiver function calculation, we were able to map crustal thickness and Vp/Vs ratio in regions of the north-western Andean system where there were no previous estimations. We also collected information of Moho depth from previous studies and neighboring regions to present a new map of interpolated crustal thickness of the Northern Andes. Our results included a wide range of crustal thicknesses, with values of around 14 km beneath the Malpelo Island on the Pacific ocean, 20 to 30 km at the coastal Pacific and Caribbean plains of Colombia, 25 to 35 km beneath the eastern plains and foothills, 34 to 40 km beneath the Western Cordillera, 40 to 45 km at the Magdalena River intermountain valley, 53 to 58 km in the northern Central Cordillera, and reaching almost 60 km beneath some of the volcanoes of the southern cordilleran system of Colombia.

T1.2-P5. Determination of the Regional Principal Stress Directions along the Gulf of Suez, Egypt

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Seismicity along the Gulf of Suez was studied, using an earthquake from Egyptian National Seismic Network (ENSN) catalog from 7079 events that occurred between January 1997 and May 2010. The earthquakes are mainly concentrated in four zones; the first zone is located between latitude 27–27.5 and longitude 34–34.5 degrees in the southern entrance of the Gulf. The second zone is located between 27.5–28 and longitude 33.5–34 degrees; the third zone is located between latitude 28–28.5 and longitude 33–33.5 degrees, the fourth zone is located in the end of the Gulf between latitude 29–29.9 and longitude 32.3–32.8 degrees. The orientations of fault planes and slip directions indicated by a population of earthquake focal mechanisms used to determine best fit regional principal stress directions and R = (S2 – S1) / (S3 – S1), a measure of relative magnitudes. The technique has been applied to 20 events from the Gulf of Suez earthquake sequence for which we have found best fit stresses (plunge and azimuth): S1 = 03, 337 S2 = 0, 67 S3 = 87, 159 and R = 0.9. The average misfit between the stress model and all the data is about 7.6°.

T1.2-P6. Development of a Seismic Velocity Model of West Africa Using International Monitoring System Data and International Data Centre Products

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To predict and mitigate the effects of future earthquakes in the West Africa, more information is needed regarding local earthquake sources and how seismic waves travel through the region. A velocity model allows the study of ground shear properties, which is useful to characterize seismic hazard. The velocity model is also important for earthquake location and discrimination between natural and artificial events. Elastic deformation of
ground motion does not only propagate body waves. Much of the energy generated by seismic source propagates surface waves. In fact, surface wave inversion provides vertical distribution of the S wave velocity structure; that is particularly true in West Africa where the density of seismic stations is extremely weak, and there are fewer seismological investigations. From one-dimensional dispersion curves of surface wave, an inversion process is used, with an initial velocity model to generate a new velocity model for shear waves as a function of depth. With this representation, once the source depth is specified, it is straightforward to find the traveltime explicitly for a given epicentral distance.

T1.2-P7. Evaluating the Regional Seismic Travel Time Model

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The Regional Seismic Travel Time (RSTT) model was developed to account for the effects of crust and upper-mantle structure on regional seismic phase travel-times. RSTT was designed with real time monitoring in mind and travel times can be computed on the fly in ~1 ms. Originally the RSTT model only covered the Eurasia region. This was followed by numerous upgraded models that initially incorporated North America before the most recent model (rstt.3.0.4) was developed which has global coverage. In this study we undertake an analysis of the current RSTT model released in October 2014. We focus on how the velocity structure and travel-time errors for each of the phases have evolved. We examine travel time differences for events at a variety of depths at each of the IMS stations and link this to crustal thickness. Existing IDC Source Specific Station Corrections (SSSC) (available at only 44 IMS stations) were compared with RSTT derived SSSC. The RSTT model extends to a distance of 1500 km compared with IDC regional phase observations at distances of ~2000 km. If the RSTT model is to be implemented at the IDC in their routine production of seismic event bulletins, it needs to be decided how to incorporate phase observations and errors between 1500 km and 2000 km.

T1.2-P8. Global 3D Tomographic Imaging of the Crust and Mantle for Enhanced Seismic Monitoring

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Global-scale tomographic images of the earth’s seismic velocity structure provide key insights into the state and evolution of our planet, and thus the development of such models has been a mainstay in solid earth geophysics research for more than three decades. Because of their predictive abilities, global-scale 3D images are also capable of enhancing monitoring applications including accurate seismic event locations based on 3D travel time predictions. We have constructed new images of the crust and mantle using novel data processing and imaging techniques developed over the past several years. The new techniques include 3D ray-tracing with multipath considerations, global multiple event location algorithms, and multi-resolution imaging within a spherical tessellation model framework. The most recent model is a jointly derived model of shear and compressional wave speeds based on a large suite of P- and S-wave phases. The images reveal new details and more focused structures within the earth, providing clear evidence that these new global-scale models and techniques represent advancements in global seismic tomography. Validation tests demonstrate that these global-scale models reduce the median event location error by 40–70% (relative to a 1-D model) for a suite of 116 validation events with well-constrained true locations.

T1.2-P9. Ground-Truth Events from Mining Blasting

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In Brazil mining blast are systematically made in different locations with sufficient energy to be detected at distances up to 1000 km. However, the origin time is not accurately measured; because it is not of a mining
interest to determine this information. Particularly in the Carajás mine, located in the State of Pará, in northern Brazil at least one big blast is made by month, which could be transformed in a GT0 event if origin time was controlled. This work aims to create conditions to bring these explosions to attend GT0 events requirements by measuring the origin time with the accuracy required by a GT0 event and installing new stations to improve the azimuthal coverage of the Brazilian Seismographic Network in the Amazon region. In this way, we intend to contribute with CTBTO to increase the number of Ground-Truth events in Brazil and help in the development of a three dimensional velocity model for South America. Consequently, improving the CTBTO seismic events association and location capability of the IMS seismic network in the South American continent.

T1.2-P10. Heterogeneities of Short-Period Shear Wave Attenuation Field and Geodynamic Processes at Semipalatinsk Test Site Region

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The records of calibration chemical explosions from Semipalatinsk Test Site region recorded by near temporary stations allowed investigating the structure of attenuation field in the earth crust and upper mantle at the region of Degelen and Balapan sites. The characteristics of short-period S-coda envelopes were analysed. It was determined that Balapan region having two large fault zones experiences abnormally high attenuation of S-waves in the range of 10–120 km depth. Degelen region has much lower attenuation at the same depths. However, at more than 200 km depth the Q factor at the region increases sharply. Using the records of more than 260 UNE recorded by TLG station at epicentral distances 730–770 km, and 170 recorded by BRVK station at epicentral distances 610–700 km, the temporal variations of Lg and Pg waves amplitudes ratio were studied. It was determined that this parameter changes in time significantly for sites Murzhik, Degelen, and Balapan. It is assumed that spatial-temporal variations of attenuation field structure are due to uplift of juvenile fluids along large faulting zones stipulated by long and intensive influence of powerful explosions. This mechanism allows explaining also existence of large thermal anomaly at the region of north-east Kazakhstan including STS.

T1.2-P11. Lithosphere-Asthenosphere System in the Balkan Peninsula Region

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Velocity structure of the lithosphere-asthenosphere system, to the depth of 350 km is obtained for the region of the Balkan Peninsula for the cells sized 1 degree by 1 degree. The models are obtained by the following sequence of methods and tools: surface-wave dispersion measurements and collection; 2D tomography of dispersion relations; non-linear inversion of cellular dispersion relations; smoothing optimization method to select a preferred model for each cell. The 3D velocity model, that satisfies Occam razor principle, is obtained as a juxtaposition of selected cellular models. The distribution of seismicity and other geophysical information is used as independent constraints for the definition of the crustal and lithospheric thickness. The obtained picture of the lithosphere-asthenosphere system for the Balkan Peninsula region confirms a strongly heterogeneous structure of the crust and mantle. The moment tensor inversion of few recent damaging earthquakes which occurred in the Balkan Peninsula region is performed through a powerful non-linear technique and obtained solutions are related to the different rheologic-mechanic properties of the earth’s structure.
**T1.2-P12. ONLI: A Code for Optimized Non-Linear Inversion of Surface-Wave Dispersion Data**

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A code for Optimized Non-Linear Inversion (ONLI) of surface-wave dispersion data is developed. It is based on Monte-Carlo numerical search method. The structure is modeled as a stack of horizontal homogeneous layers and S-wave velocity and thickness for some of the layers are parameterized. Velocity of P-wave and density of relevant layers are calculated by empirical or theoretical relationships or fixed by published structural information. ONLI is programmed to explore parameters’ space in two modes: full and selective search. Full search explores each parameter range, changing the value of relevant parameter by a step. Selective search tests only extreme values of each parameter range in several iterations, decreasing the range by a step in following iteration. Earth’s upper velocity structure is retrieved, with relevant errors, for specific depth range, depending on the available dispersion data. The main innovation of the software is the examination of assembled models by number of criteria, including Moho boundary depth range and rules for S- and P-wave velocities and density. Only the models satisfying these conditions are processed furtherly, reducing considerably the computation time. Number of tests explored the impact of parameterization and proved ability of ONLI approach to deal with non-uniqueness of inversion problem.

**T1.2-P13. Seismic Velocity Structure of the Itezhi Tezhi Region in Zambia Developed by Application of the Receiver Function Method**

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Broadband teleseismic P-waveforms recorded on ITZ station have been computed to isolate near-receiver Ps conversions originating from the Moho discontinuity at a depth of approximately 37 km. The strong trough immediately after the apparent direct P-wave on the station seems to indicate that ITZ may be underlain by a low velocity zone. Reasonably large amplitude arrivals exhibiting times and slownesses consistent with the interpretation as Ps conversions from Moho discontinuity were observed at the station. The modelling technique employed involves forward modelling of the radial component of stacked source equalized receiver functions with predicted synthetic seismograms in the time domain. The crust-mantle boundary (Moho) at the station is sharply defined and the resulting velocity structure is presented as P-wave velocity model. The receiver structure at ITZ has been calibrated to have a four layer over a mantle half-space.

**T1.2-P14. Spatio-Temporal Variations of Short-Period S Wave Attenuation Field Structure in the Region of Nevada Nuclear Test Site**

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We have been studying characteristics of short-period shear wave attenuation field in the region of Nevada test site (NTS). We were analysing recordings of underground nuclear explosions (UNEs) and earthquakes, obtained in 1975–2012 by stations ANMO, TUC and TPNV at epicentral distances up to 1000 km. A total number of 240 recordings were processed. Methods, based on an analysis of amplitude ratios of Sn and Pn, Lg and Pg waves at regional distances, and also S coda envelopes for local events were used. It was shown, that essential temporal variations of the attenuation field structure in the earth’s crust and uppermost mantle of the NTS region were observed during a period considered. The strongest variations took place in the area of Pahute Mesa, where about 2/3 of the largest UNEs were conducted. The data obtained allows us to suppose, that the temporal variations of the attenuation field are connected with active deep fluid migration. We compare common characteristics of the attenuation field in the regions of three large nuclear test sites (NTS, Semipalatinsk and Lop Nor).
T1.2-P16. Velocity Structure of the Iran Region Using Seismic and Gravity Observations

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We present a 3D seismic velocity model of the Islamic Republic of Iran generated using a joint inversion of body wave travel times and high wavenumber filtered Bouguer gravity observations. The body wave data set is derived from previous work on location calibration and includes over 1000 events that qualify as GT5. The associated arrival time data set for these events include many direct crustal P and S phase measurements, as well as regional (Pn and Sn) and teleseismic phases. The data set has been carefully groomed to identify and remove outliers, and empirical reading errors are estimated for most arrivals from multiple-event relocation analysis. We use gravity anomalies derived from the global gravity model EGM2008. To avoid mapping broad, possibly dynamic features in the gravity field into density and seismic speed variations, we high-pass wavenumber filter the gravity measurements. We use a simple, approximate relationship between density and velocity so that both data sets may be combined in a single inversion. The final optimized 3D models allow us to explore how multi-parameter tomography addresses crustal heterogeneities and areas of limited coverage, and improves travel time predictions. Final results of the simultaneous inversion will also help us to better understand one of the most prominent examples of continental collision.

T1.2-P17. Vertical and Lateral Variation of Coda Wave Attenuation in Makran Region, South East of Iran

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Makran region, due to the movement of the Arabian plate towards Eurasia, forms a subduction zone in the south-east of the Islamic Republic of Iran. We use data recorded at stations of the International Institute of Earthquake Engineering and Seismology. The “Single Back-Scattering Method” is used to estimate Qc. The relations of frequency dependence of coda wave quality factor for events up to 100 km epicentral distance is determined. Also, the lateral and depth variation of Qc are computed and discussed. In this study, the Qc values are calculated at 12 lapse times (5–60 s with a step of 5 s). The frequency dependent relationships of Qc for the Makran region varies from $Q_c = (12 + 1.1)f^{(1.3 + 0.15)}$ at 5 s to $Q_c = (137 + 1.1)f^{(1.03 + 0.018)}$ at 60 s lapse time windows. The value of Q is less than 200. This implies, besides a highly tectonically and seismically behavior, a highly heterogeneous medium. In Makran region at a depth of ~97 km the variation rate of Q suddenly increases. Oceanic crust has higher velocity, so attenuation is less than for continental crust.
T1.3-O1. A Bayesian Algorithm for Assessing Uncertainty in Radionuclide Source Terms

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Inferring source term parameters for a radionuclide release is difficult, due to the large uncertainties in forward dispersion modelling as a consequence of turbulent diffusion in the earth’s atmosphere. Additional sources of error include the radionuclide measurements obtained from sensors. These measurements may either be subject to random fluctuations or are indications that the true quantity is below a detection limit. Large reconstruction uncertainties can render a “best” estimate meaningless. A Markov Chain Monte Carlo (MCMC) Bayesian Algorithm is presented that attempts to account for uncertainties in atmospheric transport modelling and radionuclide sensor measurements to quantify uncertainties in radionuclide release source term parameters. Prior probability distributions are created for likely release locations at existing nuclear facilities and seismic events. Likelihood models are constructed using CTBTO adjoint modelling output and probability distributions of sensor response. Samples from the resulting multi-isotope posterior probability distribution are generated that can be used to make probabilistic statements about the source term. Examples are given of marginal probability distributions obtained from simulated sensor data. The consequences of errors in numerical weather prediction wind fields are demonstrated with a reconstruction of the Fukushima nuclear reactor accident from International Monitoring System radionuclide particulate sensor data.

T1.3-O2. A Framework for Systematic Testing of an Improved Wet Deposition Scheme for the Lagrangian Dispersion Model FLEXPART

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Lagrangian particle models such as FLEXPART (FLEXible PARTicle dispersion model, http://flexpart.eu) are used for inverse modelling and prediction of transport and dispersion of trace species in the management of different kinds of emergencies, including nuclear accidents and CTBT applications. As the reliability of the model results is important, we deem it important to establish more extensive evaluation by developing a testing environment for FLEXPART. Besides the usual software tests for assessing the functionality, performance and the structure-oriented work flow of the code, the physical results have to be proven realistic. Efficient testing of future code additions and modifications are conducted by regression testing. This means that current and future test cases for all parts of the model are collected to make sure that changes do not negatively affect the behavior of the model. Since particulate or particle-borne trace substances undergo wet as well as dry deposition which determines the atmospheric lifetime of many aerosol and soluble gas species, this process is an important part of atmospheric transport modelling. Therefore, the development of this testing environment is first demonstrated for the implementation of an improved wet deposition scheme in the latest FLEXPART version.


**T1.3-O3. Application of Atmospheric Dispersion Modelling to On-Site Inspection**

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Local-to-global scale meteorological and dispersion modelling can contribute to CTBTO missions, including on-site inspection (OSI) operational capabilities and exercises such as the recent Integrated Field Exercise (IFE). Modelling can be used to predict optimal locations for detecting atmospheric signatures resulting from underground venting following a nuclear explosion. In order to account for the high degree of uncertainty involved in likely OSI release scenarios, such predictions must incorporate meteorological, release time, and other source term variability. Meteorological and source term ensemble predictions may be constructed using high fidelity atmospheric models that provide realistic concentration estimates for hazardous atmospheric releases (e.g. see the capabilities used by the US Department of Energy’s National Atmospheric Release Advisory Center in responding to the Fukushima Daiichi nuclear power accident as discussed in Sugiyama et al. 2011: Health Physics 102(5), 493–508). These ensembles then may be combined to produce probabilistic estimates of the areas where different atmospheric signatures exceed threshold air concentration or deposition values that are detectable using available instrumentation. As field data becomes available, operational approaches currently used in emergency response modelling that use measurements to refine model predictions and guide further sample collection can be extended to support OSI applications.

**T1.3-O4. Argon-37 in Atmospheric and Sub-Soil Gases**

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For on-site inspection the radioactive noble gas isotope Ar-37 is a definitive and unambiguous indicator of an underground nuclear explosion. In order to distinguish between natural and artificially elevated Ar-37 the location-specific activity range in soils, rocks and the atmosphere were identified. Periodic atmospheric air measurements collected worldwide revealed a background level in the order of 1–5 mBq/m³ air in agreement with former findings and theoretical calculations. Those calculations also indicated that the intrusion of stratospheric air masses may lead to elevated tropospheric Ar-37 concentrations up to 8–10 mBq/m³ air. From CARIBIC flights, a passenger aircraft with a special air freight container filled with scientific equipment in the cargo compartment, tropospheric air samples were analysed for Ar-37 and Kr-85. Selected samples taken up to now in the vicinity of nuclear power plants revealed no significant deviation from the natural background. The natural Ar-37 production in soils and the rock basement underlying the alluvium is investigated by means of insitu measurements of different isotopes, theoretical calculations and irradiation experiments on selected rock samples. This will help to resolve the temporal evolution and/or constancy of the natural Ar-37 background and allow for an interpretation in terms of the identification of clandestine nuclear explosions.

**T1.3-O5. Constructing a Na-22 Radionuclide Tracer Data Set and a Semi-Empirical Production Model**

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Cosmogenic radionuclides are often used as tracers for environmental processes, for example the three dimensional circulation of the atmosphere. The stratosphere-troposphere exchange (STE) mechanism is one important mechanism that is difficult to model and not well understood, partly due to a lack of available data of suitable tracers. The worldwide network created by the International Monitoring System (IMS) of the CTBT is an excellent and unique tool to study atmospheric dynamics of cosmogenic radionuclides on a global scale. Na-22 has several important properties (2.6 year half-life, unique production mechanism) that make it ideal as an atmospheric tracer. However, even with high volume aerosol samplers, it is seldom detected due to a low production rate. Employing a newly developed spectral summation technique and taking advantage of the stable
energy calibration of the radionuclide detectors in the IMS network, it is possible to recover Na-22 signal and report activity concentrations. These concentrations are examined using a semi-empirical production and transport model. The resulting validated data set can then be used as input into atmospheric models to study the movement of air masses particularly when paired with a shorter-lived radioisotope such as Be-7 to function as a radiochronometer.

**T1.3-O6. Noble Gas Migration Experiment to Support CTBT Verification**

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A Noble Gas Migration Experiment (NGME) conducted at the Nevada National Security Site (NNSS) studied the detection of an underground nuclear explosion (UNE) event using noble gas signatures, as might occur in a CTBT on-site inspection (OSI). The NGME project injected 2.49 curie of Xe-127, 1.21 curie of Ar-37, and 121 kg of sulfur hexafluoride (SF6), diluted in air, into a former UNE shot cavity. These tracer gases were allowed to migrate from the cavity to near-surface and surface sampling locations and were detected in soil gas samples collected using various OSI sampling approaches. Based on the detection of SF6, Ar-37, and Xe-127 in the soil gas samples, the project found the following: (1) the dilution factors calculated for SF6, Ar-37, and Xe-127 demonstrated that SF6 was enriched in all of the samples relative to both Ar-37 and Xe-127; (2) when Xe-127 and Ar-37 were present in soil gas samples there were no significant differences in the Xe-127 to Ar-37 ratio relative to the ratio injected into the cavity; (3) the migratory behavior of the chemical and radioactive tracers did not fit typical diffusion modelling scenarios which predicted different arrival times and dilution factors for the three tracers.

**T1.3-O7. Uncertainty Quantification of Long-Range Atmospheric Transport Models: Case Study**

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Accurate atmospheric transport model forecasts can help detect violations of the CTBT, and are important for decision support in case of nuclear incidents. An as accurate as possible forecast is desired, but unfortunately the forecast is prone to errors that are difficult to quantify. A collaboration between SCK•CEN and the Royal Meteorological Institute of Belgium tries to quantify the uncertainty of long-range radioactive xenon background forecasts in the context of the CTBT. The FLEXPART model is used, with input data from the European Centre for Medium-Range Weather Forecasts (ECMWF). Results from the FLEXPART dispersion model will be presented and validated with xenon measurements from the International Monitoring System for a test case. Sensitivity tests will be performed to assess the model sensitivity to certain parameters. Finally, an overview of future work will be given, which consists of using the ensemble prediction system (EPS) of ECMWF to assess the uncertainty related to meteorological input.

**T1.3-O8. Variability in Subsurface Gas Transport in the Light of Field Experiments and Numerical Modelling**

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Before being detected at the surface during OSI or in the atmosphere by IMS stations, radioactive gases migrate through rocks and soils. The large variability of their hydro-geological parameters added to the changeability of meteorological conditions lead to the variability of gas transport. How much of the source term is emitted to the
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atmosphere? How to develop and validate sampling strategies? Besides contributing to understanding gas migration processes, field experiments offer a test bed for sampling strategy and technology from which existing means get reinforced. Gaseous tracers were injected at near-atmospheric pressure in shallow fractured rocks of the Roselend Natural Laboratory (France). Monitoring of tracer breakthrough and of naturally occurring CO₂ and radon confirmed the large spatial and temporal variability of gas transport. The measured signals depend on the sampling locations and design (boreholes, tarps). Soil water saturation has also a strong effect on gas migration and sampling. Numerical modelling allows to interpret field data and to investigate gas transport mechanisms and sampling strategies. Barometric pumping reveals to be efficient only in a narrow range of parameters outside which diffusion is dominant. Subsurface gas transport models and surface gas fluxes can then be coupled with atmospheric transport models.

Poster Presentations

T1.3-P1. A Comparison Between Different Radionuclide Source Location Techniques Using the Third Announced Nuclear Test in the Democratic People’s Republic of Korea as an Example  

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The problem of locating release sources causing detections in systems monitoring atmospheric radioactivity is of crucial importance in the area of verification of nuclear activities, such as CTBT monitoring. An analysis of radioxenon detections, most likely associated with a release from the third announced nuclear test in the Democratic People’s Republic of Korea, has been performed using several different source location algorithms. The analysis include the standard PSR, as used by CTBTO, a modified PSR technique using overlapping Fields of Regard (FOR), a technique using time-shifted overlaps assuming several releases, and calculation of the Bayesian probability density function. The results are compared and discussed.

T1.3-P2. A Comparison of Traditional and New Inverse Modelling Techniques for Source Term Identification in the Atmosphere  

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Inverse modelling plays an important role in identifying the amount of substances released into atmosphere during power plant accidents, volcano eruptions or CO₂ emissions. The problem leads to minimization of the discrepancy between the measurements in atmosphere during a particular time period and the model predictions. First, we review the standard methods based on Tikhonov regularization and Bayesian modelling. Then, we propose several optimization techniques which can be used to find sparse solutions and discuss their modifications to handle selected constraints such as nonnegativity and simple linear constraints, for example the minimal or maximal amount of total release. These techniques range from successive convex approximations to solution of mixed-integer programming problems. Finally, the new methods are applied on the European Tracer Experiment (ETEX).
Argon-37, with a longer half-life than radioxenons, is an excellent candidate for on-site inspection with a prolonged detection time window. However, the natural background of argon-37 in the subsurface, due to cosmic ray and in situ produced neutron fluxes, can be up to several hundreds of mBq/m³, and varies spatially and temporally due to transport and production changes, especially in fractured rocks. This could mask or feign the detection of an excess of argon-37 produced by an underground nuclear explosion, especially in the first metres of soil. The influence of barometric pumping on argon-37 variability in porous as well as fractured media is investigated using numerical simulations of gas flow and transport with the NUFT code. The sensitivity of argon-37 background to uncertainty in natural production and emanation as well as rock parameters is determined. Not only atmospheric pressure but also other meteorological variables, such as water infiltration, are discussed as controlling factors for argon-37 dynamics in the subsurface.

Air pollutants released into the atmosphere are dispersed by wind and turbulence and deposited on ground. Jordan atomic energy commission developed a Gaussian plume model used for the evaluation of the annual averaged atmospheric dispersion of radioactive materials operation at the Jordan Research and Training Reactor (JRTR). During normal operation of JRTR, radioactive materials are released through a 60 metre tall stack. For elevated releases, concentrations are predicted using the Gaussian plume model. For the calculation of deposition of radioactive materials on ground, only dry deposition is considered. The maximum values of the relative concentration were shown at 900 metres distance in ESE direction of JRTR. Even though the probability of an accident in JRTR is extremely low, it is needed to show that the estimated radiological impact due to an accident is met with the specified criteria. A stochastic approach is used for the calculation of the atmospheric dispersion because the time of an accident is unknown in advance. For the estimation of atmospheric dispersion factor, the computer program PAVAN was used. PAVAN was designed according to the methods described in US NRC regulatory guide 1.145 “Atmospheric Dispersion Models for Potential Accident Consequence Assessments at nuclear Power Plants”. The atmospheric dispersion factors for each hour after the accident were assessed at both the Exclusion Area Boundary (EAB) and the Low Population Zone (LPZ).

Fluctuations in the ambient atmospheric pressure result in motion of air in porous fractured media. This mechanism, known as barometric pumping, transports gaseous species through unsaturated rocks to the atmosphere. A thorough assessment of the efficiency of barometric pumping for any fractured porous medium is lacking. A complete set of equations for the general case is written and solved numerically for realistic 3D geological media and conditions. Fractures modeled as polygonal planes with a given transmissivity are
embedded in a permeable matrix. The fluid obeys Darcy’s law in these two media with exchanges between them. The solute obeys convection-diffusion equations in both media again with exchanges. With limited numerical dispersion, the solute transfer between the fractures and the porous medium is precisely evaluated. This model is applied to the Roselend Natural Laboratory. At a 55 metres depth, a sealed cavity allows for gas release experiments across fractured porous rocks in the unsaturated zone. Precision of the calculations is assessed. The pressure and solute concentration fields as well as the influence of the major parameters (fracture density and aperture, porosity, diffusion coefficients) are discussed. Conclusions are given in terms of amplification of solute transfer to the ground surface by pressure fluctuations.

T1.3-P6. Identifying the Source of Specific Events: A Major Challenge for the French National Data Centre

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Characterization of source from atmospheric radioactivity measurements is an essential task of National Data Centre (NDC). One of the objectives of the atmospheric transport modelling is to locate areas that may contain the source at the origin of a set of measurements at IMS stations. The challenge lies in the wide variety of possible solutions, ranging from a single release to a combination of several sources, local or remote, from industrial or military applications. Based on a Possible Source Region method, retro-plumes are calculated using a Lagrangian particle dispersion model, and added to provide a likely area of release. Considering detections and non-detections, it is possible to limit the spatial extent of the solution. In its initial development, the method provided results integrated in time and as such has not made full use of the temporal information inherent to the knowledge of atmospheric transport. This study presents the recent developments undertaken to investigate the comprehensive potential of the PSR method to locate sources. Applied to Xe-133 measurements at FRX27, in Tahiti—a station usually known to experience only a few detections—it defines a narrow solution area, which includes a major producer of medical isotope in Australia.

T1.3-P7. Impact of Higher Resolution Meteorological Fields on the Results of Atmospheric Transport Modelling

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Numerical modelling aims at providing solutions to mathematical equations describing physical phenomena. Already the mathematical models are approximations of reality. Additional simplifications are introduced while performing calculations using finite, spatial or spectral, discretizations of mathematical equations. Furthermore, non-resolved scales need to be parameterized. In this presentation we will focus on the significance and impact of model resolution in the context of atmospheric dispersion. In particular, we will discuss how this notion differs for Eulerian in nature meteorological fields and Lagrangian atmospheric transport models. We will give an overview of the employed parameterizations of sub-grid scale processes. We will present modelling results obtained using the ECMWF meteorological fields at varying resolutions. The computational domains for these studies were selected in connection with the location of the radiopharmaceutical facilities impacting IMS stations, namely in Western Europe and south-eastern Australia.

T1.3-P8. Influence of Precipitation on Be-7 Concentrations in Air as Measured by the CTBTO Global Monitoring System

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Data collected by the International Monitoring System (IMS) during 2009–2012 were used to study influence of precipitation on changes in Be-7 concentrations in atmosphere. The significant decrease in Be-7 concentrations, corresponding to measurements collected by stations located within Intertropical Convergence Zone (ITCZ) is
demonstrated. This effect can be attributed to the process of enhanced wet deposition within the ITCZ. To quantify this effect data collected by IMS stations within ITCZ were thoroughly analysed. It was found that the atmospheric content of Be-7 strongly decreases under the rain conditions. The rain mediated depletion of Be-7 to half of its before rain value, needs about 62 hours in case of light precipitation, while in the case of moderate precipitation about 38 hours is needed. The apparent residence time of Be-7 aerosols, based on their MDC value, depends on the initial activity concentration and on the precipitation amount, and may vary between 10 and 25 days.

**T1.3-P9. Intercomparison Study Between RODOS and FLEXPART Dry Deposition for I-131**

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FLEXPART is a Lagrangian particle dispersion transport model which is originally designed for calculating the long-range and mesoscale dispersion of air pollutants from point sources. Through the years, these type of models have proven to be a very useful tool in an operational context for the protection of the population in case of accidents in a nuclear power plant. In the meantime, FLEXPART has evolved into a more comprehensive tool for atmospheric transport modelling and analysis. RODOS is also a Lagrangian particle dispersion model which has been specially designed to be used in the emergency planning. The main advantage of the RODOS model is that it can work on a very high resolution. Since the FLEXPART model is designed to be operational for the long-range transport and therefore runs on a resolution of 0.2° × 0.2° in this particular case study, it is not trivial to compare the dry deposition fields obtained by both transport models. This presentation will show results of an intercomparison study between both designs and evaluate how well the dry deposition results match to the observations.

**T1.3-P10. Man-Made Nuclear Fission Iodine-129 and Plutonium Determination and Behaviour in Soil**

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Activity and atomic ratios of long-lived radionuclides such as iodine-129 and plutonium-238, 239, 240 are the useful parameters for identifying above- or underground nuclear events when it is already not possible to detect short-lived radionuclides (the right time to determine was missed) as their values depend on the radionuclide source and the processes of their formation. In order to determine a possible nuclear event and contamination source fifty soil samples were collected in the whole territory of Lithuania; in fifteen of them iodine-129 was assessed. Three different techniques for measurement of samples were used: accelerator mass spectrometry for iodine-129, inductively coupled plasma mass spectrometry for iodine-127, plutonium-239 and plutonium-240, and alpha spectrometry for plutonium-238 and plutonium-239, 240 determination. By I-129/I-127 atomic ratio and Pu-238/Pu-239,240 activity and Pu-240/Pu-239 atomic ratios it was evaluated that global fallout of iodine-129 and plutonium prevails, although it was revealed that I-129/I-127 atomic ratio decreased significantly distancing away from the sea deeper into the country drawing an atomic ratio baseline for assessment of possible nuclear contamination in future; plutonium activity and atomic ratios in the southern part of the territory indicated partial Chernobyl contamination. The peculiarities of different iodine-129 and plutonium migration parameters downwards into the soil are also discussed.
T1.3-P11. Nuclear Test Plutonium and Radiocaesium Dispersion in Lakes Ecosystems: Experimental Data and Novel Modelling Approach

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In the case of accidental appearance of radionuclides in water ecosystems the one-phase model cannot be properly employed to predict radionuclide migration and their accumulation zones. Application of the correct model of radionuclide behaviour in their build-up environment in water saturated soils is of great concern as well. A novel two-phase mathematical model was created that analytically describes the dynamics of radionuclides migration in water ecosystems and lakes bottom sediments. For model verification the cores of sediments in the shallow lake, flooded and upland forest soils were analysed. Radiochemical, alpha spectrometric and mass spectrometric methods were used for the plutonium determination and gamma spectrometry was used for the radiocaesium evaluation. The obtained values of the $\text{Pu-238}/\text{Pu-239,240}$ activity concentration ratio and the $\text{Pu-240}/\text{Pu-239}$ isotopic ratio indicated that the global fallout was a source of plutonium. The contribution of the Chernobyl event deposits amounted to about 2.26%, 6.11% and 20.9% of the total radiocaesium inventory in bottom sediments, the upland soil and flooded soil. Radionuclide migration modelling results reliably resembles experimental data. This model describes radionuclide behaviour dynamics in water ecosystems and especially could help to sustain the verification regime in lake-rich regions and wetlands.

T1.3-P12. Sensitivity Analysis of a Short Distance Atmospheric Dispersion Model Applied to the Fukushima Disaster

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Atmospheric dispersion models are used in case of accidental releases of radionuclides to minimize the population exposure and to assess short and long term environmental and sanitary impact. The present study is a sensitivity analysis of the IRSN’s short distance Gaussian model pX (part of the C3X operational platform), applied on the Fukushima disaster case. Results are compared with those of a long-range Eulerian model obtained in a previous study. The Morris screening method was first used to roughly estimate the sensitivity of a set of outputs and to rank the inputs by their influences. The input ranking is highly dependent on the considered output. This first step revealed that interactions and non-linearity are much more pronounced with the short range model than with the long range one. The Sobol screening method was then used to obtain more quantitative results on the same set of outputs. Contrary to the long-range results dominated by a few inputs, here the influence is shared more evenly between the inputs. Variables such as the emission height and stability become preponderant at local scale. The sensitivity analysis was carried out with several Gaussian parameterizations, and the different results obtained are discussed.

T1.3-P13. The “Smoking Gun” and Its Geological Control

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Following production at depth by nuclear fission reactions or neutron activation, gases escape the nuclear cavity, partly filled with melted rocks. In variable hydrogeological and meteorological conditions, these gases have to migrate through heterogeneous rocks and soils before they could be detected at the surface by OSI operations or IMS stations. All these processes may hamper a “smoking gun” evidence of a violation of the CTBT. This
contribution reviews processes and related models or experiments carried out to develop expertise on migration and detection of radioactive gases. In the near field, xenon isotopes are fractionated from their precursory iodine isotopes due to contrasted solubility and diffusion in melt. In the far field, gases are first transported due to cavity overpressure, then by two-phase thermal convection later overtaken by barometric pumping. Toward the surface, increasing porosity and fracture aperture decrease gas fluxes to the atmosphere, also hampered by water infiltration. Besides dilution by the atmosphere, natural and anthropogenic background in xenon isotopes or argon-37 further conceals the signal. Delay, dispersion, dilution and fractionation of gases and their isotopes must be quantified to determine to what extent the source term can be detected at the surface despite extensive interactions with the geosphere.

**T1.3-P14. The Variability of Ar-37 Concentrations in Soil Air Due to Changing Environmental Conditions**

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Ar-37 as an indicator for underground nuclear explosions in the frame of an on-site-inspection depends on knowledge of the natural background and its variability. The Ar-37 production rate in the soil or rock matrix is proven to be spatially variable e.g. as function of depth (Riedmann 2011, Johnson 2015). However, Ar-37 concentrations over time for the same location also scatter in the order of ~50% around the mean value. These significant variations are mainly related to gas transport processes in the soil or in the rock formation. Only the combination of barometric pressure variations, wind stress and water content changes in the pore volume, which affect the effective gas diffusion coefficient, can explain the observed magnitude of concentration variations. During times of lower monthly precipitation, where the soil matrix of the ‘capping layers’ were less saturated, the effective porosity was at its highest (~0.1 - 0.4) and resulted in the lowest Ar-37. The timescale of the activity recovery after a venting event is closely linked with the half-live of the isotope with a faster recovery of Rn-222 compared to Ar-37. The mechanisms governing gas transport are consistent for both gases even though their production pathways are different.

**T1.3-P15. Topographical Effects on Surface Detection of Underground Nuclear Explosion with Gases**

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Monitoring conducted at the Roselend Natural Laboratory (France) as well as during CTBTO field exercises raised questions about the influence of topographical effects on gas dynamics in the subsurface and at the surface. This would have to be taken into account when designing the sampling strategy to detect radioactive noble gases, and in particular radioxenon, during OSI operations, below a tarp or in a borehole. The possible use of radon as a co-tracer to improve detection of radioactive xenon can also be affected by topographical effects. Numerical simulations of gas flow and transport in fractured porous media are performed using the NUFT code. The effects of a cliff or a gentler slope on radioxenon and radon migration in the subsurface are identified, and the related uncertainties are quantified. Wind pumping has a limited influence on gas migration and possible detection. The most influencing parameters, among topography, sampling depth and location, are identified and discussed.
T1.3-P16. Validation of Global Atmospheric Dispersion Model Using International Monitoring System Data

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Long-rang atmospheric dispersion model named LADAS has been developed to evaluate dispersion patterns of the radionuclides released into the air after a nuclear accident. The model was validated by using measurements of the ETEX experiments, and it was also applied to assess the behavior of radionuclides released into the air from the Fukushima accident. After the Fukushima accident, radionuclides were detected through air monitoring positions of CTBTO around the world. Calculated concentrations were compared with the measurements at IMS of CTBTO. From the comparisons of simulations and measurements, the developed model was successfully validated then it could be used to understand the overall dispersion patterns of radionuclides spreading out in the world after the Fukushima accident. The radioactive plume was transported to the east part off the Fukushima site by the Westerly jet stream. And it was detected in North America during 17–21 March, in European countries during 23–24 March, and in Asia during 24 March to 6 April 2011. This event was well represented in the numerical model and the simulation results showed generally good agreement with the observations at IMS of CTBTO.
1.4:
Exploratory Drilling Techniques for On-Site Inspection

Oral Presentations

T1.4-O1. Drilling to Obtain Radioactive Samples: Concept of Operations and Equipment
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The CTBT allows “Drilling to obtain radioactive samples”. The objective of drilling is to obtain data to help clarify whether a nuclear explosion occurred. At any time during the OSI, the Inspection Team Leader may submit to the Executive Council a proposal to conduct drilling. A successful drilling operation will require careful planning and execution to recover relevant samples efficiently and most importantly safely. A concept of operations should be developed that considers all aspects of the drilling and sampling process including health, safety, and environmental protection. An understanding of underground nuclear test explosion phenomenology and its relationship to radionuclide distribution and migration will be important. The emplacement configuration (vertical or horizontal) will present different challenges that affect equipment and their utilization. Sample handling Procedures will have to be developed based on the equipment and requirements. The OSI process of identifying the drilling location will provide much of the information (geology, terrain, mechanical properties, etc.) needed for designing the drilling plan. Inspector training will have to be coordinated based on the equipment, and the pre-existing arrangements, licenses, permits, etc. The time since the triggering event will also be an important consideration as will the type of sample.

T1.4-O2. Modelling Anisotropic Effects for Reservoir Fracture Characterization of a Naturally Fractured Tight Carbonate Reservoir, Onshore Texas, USA
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Anisotropic modelling was carried out to determine crack orientation and density within a naturally fractured tight carbonate reservoir, located onshore Texas, USA. Acquired 3D-PP full-azimuth full-offset reflection data were inverted to generate anisotropic parameters employed for fracture characterization of an oil field currently experiencing production decline despite studies that suggested un-depleted reserve. Generated model confirmed azimuthal anisotropy as crack induced shear-wave splitting and variation in P-wave velocity with offset and azimuth, where P-wave is fastest (Vp-fast) in direction parallel to the crack and slowest (Vp-slow) along orthogonal direction. Amplitude Variation with Angle (AVA) presented a case I AVO, while AVAZ confirmed multi-crack sets induced anisotropy characteristic of orthorhombic symmetry, evident as multiple bright and dim-amplitude azimuth directions as well as complete reversal of bright-amplitude to dim-amplitude azimuth direction as the angle of incidence increases from near (150) to mid (300) offsets. Fitted P-wave velocity ellipse gave crack intensity, open-crack orientation (N26E) and minimum in-situ stress axis (N116E) within the reservoir. The derived model parameters offer vital information necessary to design open fracture intercepting wells. This technique which has proved quite successful in extractive industry could be extended for OSI, especially to select location to drill for radioactive sample.
T1.4-O3. Selecting Targets for On-Site Inspection Drilling to Obtain Radioactive Samples Based on Test Site Observations

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There have been a number of studies concerning underground migration of radionuclides from nuclear explosion test cavities at the Nevada Test Site (now the Nevada National Security Site) as part of the US Department of Energy’s Hydrology and Radionuclide Migration Program. Radionuclides have been detected outside of the immediate vicinity of nuclear test explosion cavities that are identifiable as the source of the radionuclides, as well as cases where radionuclides might have been expected and were sought but not found. This report examines some of these cases as a guide for identifying underground targets for OSI drilling to obtain radioactive samples. Several underground test locations below the water table were selected where identifiable radionuclide migration was detected, one where migration was purposely induced by pumping, and some where migration might be expected but was not found. Prompt fracture injection into the surrounding rock immediately following the detonation occurred in many cases. In the other cases, the migration mechanism is thought to be groundwater movement. There is somewhat limited data available but inferences can be made regarding the potential post-test location of relevant radionuclides that could guide the selection of drilling and sampling targets for OSI.

T1.4-O4. Understanding the Challenges of On-Site Inspection Drilling to Safely Recover Relevant Radiological Samples from an Underground Nuclear Explosion

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The 2014 Integrated Field Exercise demonstrated advancing maturity for CTBT on-site inspection (OSI) techniques. Drilling to recover relevant radiological samples, arguably the most physically intrusive and demanding of the allowed inspection techniques, was purposefully omitted from the exercise. At entry into force (EIF) the CTBTO must be ready to implement drilling as an OSI inspection technique. For drilling to be safe and capable as an OSI technique there are many physical constraints and components that must be considered. When the dynamic nature of a radiological source term is combined with the challenging industrial work environment of a drill site, drilling will require significant effort to plan and execute. It is instructive to review the challenges of drilling for the recovery of radiological samples by considering the relevant historical experience of personnel who led the last US post shot drilling and radiological sample recovery effort. This includes exploring the physical constraints as well as discussion of the drilling equipment, guidance and detection equipment, required personnel, radiation safety systems, and sample handling. Enhanced understanding of the challenges that must be identified and addressed to implement drilling as an OSI technique could prompt the discussion necessary to prioritize development of OSI drilling.

**Poster Presentations**

T1.4-P1. Drilling to Obtain Radionuclide Samples: A Discussion

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The CTBT on-site inspection (OSI) regimes ultimate technique is drilling to obtain radionuclide samples. This is not a common industrial practice and with the global norm against nuclear testing the skill set and equipment will have atrophied within the former testing community. OSI will therefore need to acquire not only a skilled crew and drill rig used to drilling safely in dangerous environments worldwide; possible hydrogen sulfide gas,
hydrocarbon gases and liquids, over pressure zones in the subsurface but augment that drilling equipment with the ancillary equipment needed to augment any drill rig into one that can drill back into a suspected nuclear explosion safely. This equipment ranges from specialized blow preventer stacks, to radiation monitoring alarms, to sampling equipment for cuttings, gases, and cores. Driving these equipment decisions will be the type of sample evidence necessary to fulfill the OSI mandate. Given the complexity of drilling for a radionuclide sample, the complexity of directional drilling to an unknown target it may be prudent to sample for radionuclide gases from the borehole, and radionuclide particulates from the drill cuttings without trying to enter the postulated location of the nuclear explosion cavity.
T1.5-O1. Comoro Islands: Regional Seismic Sources and Related Effects

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The Comoro Islands are defined through the extension and ascension of magma-activity dating from the oldest Island Mayotte 5.4 Ma, Moheli 2.2 Ma, Anjouan 1.5 Ma, to Grande-Comore. Located in the Indian Ocean, the Islands are exposed to a range of seismic activities: from which magmatic activity can generate earthquakes felt on land; and, seismic events are considerable from regional geological characteristics, expectedly the tectonic earthquake’s case. Assessing Comoro-surrounding seismic events using IDC capabilities has several benefits. Based on seismic event’s statistics of Data recorded within the Local system (volcano observatory) and IDC products (Standard Event List 3) from 2000 to 2014, help to identify shortcomings in the locally acquisition. Consequently, throughout this process, the NDC will be developing important mechanisms, managing seismic events. Subsequently, apart from making an assessment of local/regional seismic events, the case of natural hazards applications is important as well. Those natural hazards might be the consequences triggered from such seismic activities, possibly; from volcanic earthquakes, explosive eruptions which may generate infrasound effects, as well as release of massive ash into the atmosphere; and from oceanic seismic events (Mg 6,7,8, . . .), tsunami (small/big) would likely be generated and affect the Islands. Such geological hazard investigations reinforce the research aspect of Natural Hazards in Comoros.

T1.5-O2. Estimation of Radionuclide Releases from the Fukushima Nuclear Accident Using the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) Model and the International Monitoring System Air Concentration Measurements

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An emission inversion system has been built based on the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model and a cost functional. The release estimates are found by minimizing the cost functional which mainly measures the differences between the model predictions and the actual air concentration measurements. A transfer coefficient matrix (TCM) defining the potential impacts of each release segment on all measurements is created first and then repeatedly used throughout the minimization. Tests using pseudo observations generated with the same model show that computing logarithmic concentration differences between model and observations is better than using the concentration differences in the cost functional. The sensitivities of the inverse system to observational errors and model uncertainties are discussed before the estimates of the caesium-137 and iodine-131 releases from the Fukushima nuclear accident using the International Monitoring System (IMS) air concentration measurements are presented.
Global trends show an increasing damage from natural hazards. One possible reason of this is climate change that indirectly influence also to geological hazard as earthquake. Due to increase number of various natural hazard environment and buildings became more vulnerable and results from the earthquake with the same magnitude are more devastating. The Republic of Georgia, located on the East coast of the Black Sea, is prone to multiple natural hazards. By estimation, economic losses from earthquakes is very significant. The most serious deficiency in natural hazard assessment is the lack of high quality national data. After reviewing hazard methods for various countries, some attempts were made to fill these gaps: (1) A detailed electronic database was created of twelve widespread natural disasters in Georgia. (2) A quantitative investigation of magnitude–frequency and spatiotemporal regularities of twelve types of natural disasters was undertaken. (3) hazard maps were drawn based on an innovative approach of assessing the magnitude and frequency of meteorological hazard types, where the corresponding formalization was not yet satisfying. New seismic hazard maps were calculated based on modern approach of selecting and ranking global and regional ground motion prediction equation for region.

T1.5-O4. Macroseismic Effects of Recently Strong Earthquakes in Uzbekistan

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Tectonic, engineering-geology, and seismological preconditions for strong earthquakes that recently occurred in Uzbekistan (Kan, 19 July 2011, M = 6.3, I = 8 on the MSK-64 scale; Tuyabuguz, 25 May 2013, M = 5.6, I = 7; Marjanbulak, 26 May 2013, M = 6.2, I = 8) were studied. Macroseismic data from the Isfara-Batkent earthquake (31 January 1977, M = 6.3, I = 8) were also included. For research purposes and in order to estimate earthquake damage prior to an event occurring, the challenge is precise mapping of main shocks epicentres and their aftershock zones, frequently in densely populated areas. To achieve this goal, all available seismological data from the International Data Centre and from the Kazakhstan National Data Centre were used. Macroseismic research conducted in the epicentral zones of the Kan, Tuyabuguz, and Marjanbulak strong earthquakes showed that the isoseismals do not always correspond to the main tectonic structures. A comparative analysis of the macroseismic fields and focal mechanisms of the four strong earthquakes shows that all macroseismic isoseismals and azimuths of compression and tension are directed north-northwest, which corresponds to Tien-Shan earth crustal shortening. Modern seismicity reflects the geodynamic regime of the Western Tien-Shan region and is manifested by the Isfara-Batkent, Kan, Tuyabuguz and Marjanbulak strong earthquakes.

T1.5-O5. Recent Developments of the National Seismic and Infrasound Networks to Monitor Natural Hazards in Iceland

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The Icelandic Meteorological Office (IMO) is responsible for monitoring natural hazards in Iceland and operates real time monitoring systems including the SIL seismic network, since 1991 and together with the University of Florence an infrasound network since 2010. IMO is the station operator for one seismic (IDA) station for CTBTO IMS. The SIL network covers the volcanic zones and seismically active transforms with over 70 stations; short-, broadband and accelerometers. Magnitude of completeness for all of Iceland ranges from M0 to M3. As a part of the FUTUREVOLC project, four infrasound arrays, are used to monitor volcanic eruptive activity, but have also proven useful to monitor landslides and rock fall. The arrays include four elements in a triangular geometry, with an aperture of 120 metres where each element has a differential pressure transducer.
with a sensitivity of 25 mV/Pa in the frequency band 0.001–50 Hz and a noise level of $10^{-2}$ Pa. Three arrays are installed in South Iceland and the latest addition is collocated with a seismic station in close proximity to the Bárðarbunga eruption, north of Vatnajökull. These places were chosen with the aim to optimize wind noise reduction (on-site bushes and trees) and close proximity to volcanoes.

**T1.5-O6. Seismic Swarm near the Capital of Mongolia Investigated Using Double-Difference Tomography**

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We focus on the main active seismic zones in the area of Ulaanbaatar which can have the main impact on the seismic risk of the Capital of Mongolia. A seismic activity is taking place near and within Ulaanbaatar area since April of 2005. The seismic swarm observed by local permanent network has reveals the significant increase of seismic activity in the Ulaanbaatar area. For precise study of this seismic activity region, we had installed a number of temporary seismic stations since December of 2008. This study discusses some results of the analysis of this high seismic activity recorded by permanent and temporary networks. We show that relative earthquake location using double-difference methods requires an accurate knowledge of the velocity structure throughout the study region to prevent artifacts in the relative position of hypocentres. The distribution of focal depths indicates that the seismogenic layer in and around Emeelt fault is located in the upper-mid crust with its thickness no deeper than 20 km.

**T1.5-O7. The Deep Ocean Temperature Derived from CTBT Hydroacoustic Recordings of Deterministic Transient Signals and Ambient Acoustic Noise**

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IMS arrays of hydrophones have been placed in the Sound Fixing And Range (SOFAR) channel to detect explosions. Only few stations are necessary, since the SOFAR channel hardly attenuates acoustic energy, i.e. sound waves. As an example, small explosions of tens of kilos of explosive material can be detected over ranges of thousands to ten thousand kilometres. The propagation of sound is dependent on the temperature. In this presentation, it is assessed how IMS hydroacoustic recordings can be used to probe the deep oceans and derive the temperature, i.e. at depths were hardly any in situ observations are possible. This is relevant since it is being debated that the oceans have taken up a large amount of heat under global warming over the last decade. We will show how techniques with deterministic transient signals from earthquakes and ambient acoustic noise can be used to explore the temperature in the deep oceans, which are otherwise difficult to monitor with e.g. in situ means. Temperature changes as a function of time (over ten years for the IMS) will be presented.
T1.5-O8. Tsunami Warning System for the Eastern Mediterranean and Its Connected Seas

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Bogazici University–KOERI (Turkey) is providing a Tsunami Warning System to Eastern Mediterranean, Aegean and Black Seas since 1 July 2012 as a Candidate Tsunami Service Provider within the Intergovernmental Coordination Group for the Tsunami Early Warning and Mitigation System in the North-eastern Atlantic, the Mediterranean and Connected Seas (ICG/NEAMTWS) Framework. KOERI continues to operate 129 BB and 86 strong motion and 6 short period sensors. The regional coverage includes 77 stations from GFZ and additional 16 stations through bilateral agreements. An agreement with CTBTO is in place for the real time data transmission from 6 primary and 10 auxiliary IMS stations. KOERI continued to participate in the NEAMTWS Communication Test Exercises (CTE), and acted as the Message Provider in the second NEAMTWS Tsunami Exercise, NEAMWave14, in November 2014 for a tsunami scenario in Black Sea. This presentation provides a status overview of the operational system together with the challenges associated.

Poster Presentations

T1.5-P1. Seismic Microzonation of the Main Cities in Jordan Using Microtremor Observations

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Microtremor measurements are useful for determining local site effects in seismically active regions (such as Jordan) where ground motions are few, and in urban or industrial areas where the noise level is high. Due to variations in geological and geotechnical characteristics of the subsurface, each site responds differently when subjected to an earthquake (or a tremor). The microtremor method is reliable for dynamic site characterization of sedimentary basins. These studies were performed with a Kinematics SSR-1 recorder. Two kinds of seismometers were used: a three-component Dyneer of natural frequency 2 Hz in accordance with a set of L-4C two horizontals and one vertical, a portable computer and a hand held GPS. Digital recordings with a sampling rate of 100 samples per second were made using a 0.2–25 Hz band pass filter. At the investigated area in each city, two maps were prepared showing the spatial variations of the predominant period and seismic amplification according to Nakamura’s technique. The analysis shows that areas with a thick layer of sediments in these cities have relatively high predominant periods and high seismic amplification compared to areas with thin layer of sediments.

T1.5-P2. A Cluster of Deep Crustal Seismicity in the Northern Alpine Foreland of Austria

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During 2008 a cluster of nine earthquakes was detected in the north-western region of Austria, which until then was unremarkable in terms of naturally occurring seismicity. The events (estimated magnitudes 2.0–3.8) were located at depths of about 10–20 km in the general vicinity of Braunau (13.5°E) between the Bohemian Massif and the Eastern Alps, in an area of elevated geothermal heatflow (80–90 mW/m²) with active geothermal energy
production. A relocation of these events (NonLinLoc & HypoDD) using a 3D-velocity model revealed a very dense clustering, and resulted in anomalously deep foci within 10 km of the Moho. Coherent focal mechanisms with T-axes striking NE-SW were determined for the strongest of the events through both, waveform-inversion (gCAP) and P-wave onset polarities (HASH). The waveforms of all events exhibit high similarity, as is typically observed in densely clustered seismicity. Using a crosscorrelation technique we found previously undetected, weaker events during that timespan associated with the same cluster. Similarly deep, lower crustal seismicity in the northern Alpine foreland has previously been observed and investigated in the Swiss part of the Central Alps west of 10°E, where the deepest events have been found to closely follow the Moho of the subducting European lithosphere.

**T1.5-P3. Assessment of the Radiological Impact in Argentina of the Nuclear Tests After Decades**

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Samples of fresh milk to determine the deposition of radioactive fallout have been taken in the city of Buenos Aires with surroundings since 1960. A statistical procedure is used to analyse the temporary variation of the Sr-90 and Cs-137 concentrations. The results allow assessment of the environmental impact and radiological exposure of the population in South America. The objective of this research is to increase the knowledge of the contamination caused by the past atmospheric nuclear weapon tests in the South Pacific and the radiological detriment in the population through the following decades. The maximum concentrations of Cs-137 and Sr-90 were found in 1964–1966, with a maximum dose from the exposure of Cs-137 calculated to 17 μSv/year. In the case of ingestion of milk, the maximum doses in children from Cs-137 and Sr-90 were 5.9 μSv/year and 5.3 μSv/year, respectively. Up until the present day, the radionuclides Cs-137 and Sr-90 are responsible for 50% of committed doses. Today the doses from the residual fall out, i.e. the studied radionuclides, are below the dose level from the natural background radiation.

**T1.5-P4. Armenian Earthquake Catalogue**

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Armenia is a part of the Caucasus, which is one of the most active segments of Alpine-Himalayan seismic belt. The seismicity of Armenian Upland relates to the Arabian-Eurasian plates’ collision, which is characterized by diffusive distribution of shallow earthquakes of various magnitudes. The strong shallow earthquakes are expressed by well pronounced active surface faulting. Comparison of seismicity of Armenia and the Caucasus with tectonic setting shows that all the strong earthquakes are associated with the active blocks, their edges and junctions. The analysis of the focal mechanisms of earthquakes with various magnitudes shows the presence of all fault types in Armenia: strike-slip, normal, reverse, thrust, oblique, normal faulting with various components, and with prevailing strike-slip faulting. The combinations of exposure depend on the relatively neighboring blocks’ movements. The quality of the Armenian National Catalogue is discussed and the representativeness is described. A unified and homogeneous earthquake catalog is a base for analysis—determination of catalogue completeness, recurrence and activity rates etc., which are the key input parameters for probabilistic seismic hazard assessment.
T1.5-P5. Assessment of Tsunami Hazards from the Manila Trench Source to Viet Nam Using Worst Case Scenarios

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In this study, we create worst-case scenarios of tsunami earthquake excited by Manila Trench megathrust and assess the impact to the Vietnamese coast. The tsunami propagation is numerically computed by using the COMCOT open source code. The simulation results show that the Vietnamese coast can be divided into three parts with different levels of tsunami hazards. According to the worst case scenario (Mw = 9.3), the maximum wave height of 18 metres is observed at Quang Ngai coast. Regarding the tsunami travel time, the most vulnerable cities are Tuy Hoa (2.06 h), Nha Trang (2.28 h), Quy Nhon (2.32 h), and Ninh Thuan (2.35 h). The northern coastal zone of Viet Nam has medium tsunami hazards level. According to the worst case scenario, the maximum amplitude of tsunami wave at Hai Phong and Nam Dinh virtual gauge stations are 3.5 metres and 3.7 metres, respectively, while the travel times to these stations are much longer, reaching 8:35 h and 9:45 h, respectively. The southern coastal zone of Viet Nam has lowest tsunami hazards level. According to the worst case scenario, the maximum amplitude of tsunami wave at Ca Mau virtual gauge station is 0.12 metres, while the travel time is over 10 hours.

T1.5-P6. Backtracking the Holuhraun Exceptional Sulphur Dioxide Event in September 2014

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On 28 August 2014, the effusive “Holuhraun” fissure eruption started near the vent of the Bardarbunga volcano leading to SO2 emissions of up to 35 000 tons per day for several weeks. Whereas concentrations of up to 21 000 micrograms per cubic metre measured in Icelandic towns did not come as a surprise, remarkable concentrations could be found in other parts of Europe. This was especially true for the Alpine area, where health-relevant concentrations well above 200 microgram per cubic metre could be found in south-eastern Austria. In the present work measurements of mountainous low-background stations (e.g. Sonnblick, 3106 m a.s.l.) were used together with backward (srs-)fields from the Lagrangian dispersion model FLEXPART using ECMWF meteorological input data to apply a back-trajectory statistic and to calculate the PSR (Possible Source Region) fields in accordance with the method applied for CTBT verification. For this so-called correlation method, a new approach was tested, namely to correlate logarithmic measurement values. As result, it will be demonstrated whether the Holuhraun eruption can be properly identified as source location for the SO2 measured, and whether realistic estimates of the source strength can be provided.

T1.5-P7. Civil Applications of Infrasound and Seismic Data: Location of the Plane Crash of Air Algeria

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On 24 July 2014, a civilian aircraft AH5017 from airline Air Algeria, took off from the international airport of Ouagadougou at 00:55 GMT with 118 passengers on board. Its destination was Algiers international airport in Algeria. One hour later, the flight AH5017, ceased all communications with the control tower in Ouaga and that of Niger. Niger authorities had just taken over the communications with the aircraft a few minutes earlier after being redirected to avoid a big storm over Mali and Southern Algeria. Multiple press releases report that the AH5017 flight disappeared from the radar after being re-routed. It later appeared that the plane crashed shortly after losing contact (Sources: AFP, BBC, Ouagadougou airport, and others). Our NDC collaborated with IDC staff using IMS infrasound and IDC bulletins on the search for infrasound and seismic signals related to the
crash and to locate the crash site. This study demonstrates that CTBTO data and products are useful for civilian applications.

T1.5-P8. Comparison Between Site Motion Amplification Based on the Impedance Contrast Relative to the H/V Ratio Amplification Along the Eastern Shore of the Dead Sea

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This study is oriented towards the reduction of seismic hazards through studying the dynamic characteristics of surface geology, based on ground ambient vibration. Thirty six direct records of ground ambient vibration along the eastern shore of the Dead Sea were obtained, spectrally analysed and the dominant resonance frequency of each were applied as an input parameter in this study. Amplification factor and acceleration were calculated for each site using an optional impedance contrast equal to 0.2. Maximal period of earthquake maximal amplitude 0.25, 0.30 & 0.35 second were applied in this study. This methodology is applied due to its reliability for all expected earthquake magnitudes and hypocentral distances. Based on the previous study of the Dead Sea seismic regime for the past 100 years of instrumental records, the maximal expected earthquake, with a local magnitude of 5.94 was applied, taking into consideration the real geometrical location of the 11 February 2004 earthquake with an epicentre confined by Lat. = 31.6900N and Lon. = 35.5800E. Dynamic characteristics for each site were calculated. Results obtained revealed that the calculated amplification factor, based on an impedance contrast of 0.2 coincides well with the terrain topography relative to the H/V Nakamura approach.

T1.5-P9. Contribution of CTBTO Seismic Data to Ghana’s Earthquake Monitoring

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The National Data Centre in Ghana five years on has made tremendous progress towards the goals of the CTBTO. The data centre which was established in 2010 with the aim of monitoring compliance of the CTBT has also benefited the country in the monitoring of seismic activity. We are integrating IMS seismic data with our national data in the monitoring. The national earthquake catalogue and events obtained from the IDC products and the IMS data is used for earthquake hazard assessment. Ghana is located in a seismically active region and has been affected by two major earthquakes of magnitude 6.5 on the Richter scale in 1862 and 1939. Twenty seven (27) earthquakes of magnitudes ranging from 1.7 to 4.5 have been recorded since the establishment of the Data Centre. The use of CTBTO data is therefore very crucial in the seismic hazard assessment. This is one of the numerous scientific benefits of the CTBTO to the NDC. The NDC is complementing the efforts of the Geological Survey Department of Ghana in monitoring seismic activity in the country with the data it receives from the IDC. Periodically the Centre organizes training programmes for staff and our stakeholders for capacity building.

T1.5-P11. Design Synchronization Output Monitoring System of Earthquakes on the Input Tsunami Modelling Using MySQL

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Earthquake focal mechanism parameters obtained from earthquake monitoring system are generated automatically in the output. The output contains the data and information required for tsunami modelling. Unified integration is done to create a system of monitoring information on the earthquake and tsunami early warning system that can be run in parallel. To connect the network to the server, it takes an array of database created in a special format. The database is designed to use MySQL.
T1.5-P12. Determination of Local Magnitude Scale for West Java Region, Indonesia

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We determine an empirical formula for a local magnitude scale in West Java region, Indonesia. We used amplitude data from ten stations of the InaTEWS network, including the LEM station from the CTBTO network. 162 local earthquakes occurred during 2010–2014 with a magnitude range from 3.0 to 6.0. We derived \( -\log A_0 \) distance correction function for ML based on its original definition. We obtained the following formula for determining ML in the West Java region: \( ML = \log A - 1.13 \log (r/100) + 0.00067 (r - 100) + 3 \), where \( A \) is the maximum amplitude (mm) observed on the horizontal component and \( r \) is the hypocentral distance (km). We found that the residual of magnitude determined using the above formula does not have a significant epicentral dependence. The magnitudes determined by the above formula are slightly larger (by around 0.18) than the magnitudes of the InaTEWS system.

T1.5-P13. Determination of Local Magnitude Scale for Uganda

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We derived ML scale for Uganda using waveform data from temporary broadband seismic network deployed in Uganda and permanent IMS broadband station, AS103 MBAR. We used 54 earthquakes recorded between July 2007 and November 2008. We first determined hypocentres of these earthquakes using P and S phase arrivals, most of their epicentres associated with the western rift of the EARS. To develop ML, we removed instrument responses in waveforms and applied frequency response of the standard Wood-Anderson torsion seismograph for amplitude measurements. We obtained 529 amplitude data from horizontal components of 52 earthquakes whose focal depths are up to 34 km. We performed simultaneous linear inversion to determine coefficients of distance correction function and local magnitudes to obtain the ML formula. We observed that the obtained coefficients of our formula are smaller than those for Southern California, and closer to those obtained for Tanzania. We also compared hypocentres of 7 earthquakes determined by this study to those reported by NEIC’s PDE catalogs and IDC bulletins, and compared ML magnitudes of 4 earthquakes obtained from this study to the mb magnitudes determined and reported by USGS in NEIC’s PDE catalogs. They do not differ much and roughly consistent with each other.

T1.5-P14. Determination of Slip Distribution of the 11 April 2012 Outer Rise Sumatra Earthquake (Mw = 8.6) Using Tsunami Waveform

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On 11 April 2012 large earthquake with Mw = 8.6 occurred in western part of Sumatra. This earthquake was unique because it did not occur in the subduction zone but in the outer rise of Indo-Australia plate. The 2012 outer rise earthquakes have strike-slip source mechanisms and generate small tsunamis. We estimate the slip distribution of the 2012 outer rise earthquake using inversion of the tsunami waveform. We used three tide gauges and data from five DART buoys from IOC and NOAA respectively to perform the inversion. We assumed that the fault length was 350 km and its width was 150 km. The asperity occurred in the epicentral region with the maximum slip of 53.12 metres. The total seismic moment calculated by the slip distribution was \( 1.13 \times 10^{22} \) Nm (Mw = 8.6).
Theme 1: The Earth as a Complex System

T1.5-P15. Developing an Early Warning System Using First Arrivals of P Wave of Earthquakes Recorded in Iran

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Seismic records of the Islamic Republic of Iran indicate the occurrence of many devastating seismic events, some of which were in densely populated areas in the vicinity of major faults. Iran, as an example, is surrounded by many active faults. Therefore, an earthquake early warning can be a useful short term solution to reduce damages and potential casualties of large earthquakes. In this study one of the necessary factors for early warning is investigated. We need to evaluate the accurate estimation of magnitude using initial 3 seconds of P wave. This goal requires systematic procedure calculating empirical relationship between estimated magnitude and seismic wave arrivals. Generally, calculated magnitude with initial seismic wave arrivals are underestimated and need a regression equation to reach the real magnitude. In this study, using first 3 seconds of initial arrival waves of significant earthquakes located around Iran, local magnitude is calculated and calibrated to real magnitude scale. For this purpose, ground motion data was used from Iran Building and House Research Centre (BHRC). Around 30 big earthquakes with their aftershocks were selected. Processing gives a relation of $M_{\text{real}} = 1.223M_{\text{P Arrival}} - 0.6579$ to estimate rapid magnitude evaluation using p arrival waves.

T1.5-P16. Development and Application of a Web-Based Spatio-Temporal Database Platform for an Early Warning System: From Field Monitoring and Data Storage to Database Management and Local Spatial Analysis to Data Visualization

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The fast growing of web-based development and technology for sharing geodata and dissemination of geospatial information has turn in helping decision making to manage natural hazard. Not only in natural hazard, web-based provide a platform for integrating geography information system with other businesses in the area of location based and traffic optimization. On the other hand, early warning system allow the monitoring of the environment and ultimately form an important basis for the protection of livelihoods, adequate risk management and the reduction of negative consequences related to catastrophic slope failures. However, before a warning can be issued, reliable data acquisition, a profound analysis and an optimized visualization have to be implemented. From this basic principle of early warning, the research work would focus on four methodologies: monitoring, database, analysis and visualization. And the application would be tested for nuclear power station.

T1.5-P17. Development and Application of the Bulgarian Emergency Response System for Modelling of the Atmospheric Transport of Radioactive Substances

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The network for atmospheric radioactivity monitoring has been developing since 1959 by the Bulgarian Hydro-meteorological service. The time and space variations of airborne and deposited beta activity are included in long term data records providing impact assessment of the different radioactive pollution sources. The atmospheric radioactivity monitoring is strongly supported by atmospheric transport modelling represented by the Bulgarian Emergency Response System (BERS) for short term forecast in case of accidental radioactive releases to the atmosphere. BERS comprises of two main parts—operational and accidental—for two regions—“Europe” and “Northern Hemisphere”. The operational part runs automatically (see http://info.meteo.bg/ews/), using 72 hours meteorological forecast, resolution 12 hours in time, 1.5 degree in space. The accidental part is activated in case of radiological emergency, or emergency exercises. It is based on numerical weather forecast information and long-range Eulerian 3D dispersion model accounting for the transport, dispersion, and radioactive
transformations of pollutants. Concentrations, depositions and major prognostic dose fields of 31 important radioactive gaseous and aerosol pollutants are calculated at every 3 hours. BERS was tested in ETEX, RTMOD, ENSEMBLE international exercises. The results from different test cases of NPP’s accidental scenarios and environmental impact assessment are presented and discussed.

T1.5-P18. Development of Web-Application System for Waveform Data Observed by Real-Time Seafloor Seismic Network, DONET

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Mega-thrust earthquakes are anticipated to occur in the Nankai Trough, south-west Japan. In the source areas, we installed seafloor seismic network (DONET) in order to monitor seismicity, crustal deformations and tsunamis. DONET system consists of 20 stations, which is composed of strong-motion and broadband seismometers, quartz and differential pressure gauges, hydrophone, and thermometer. The stations are densely distributed with an average spatial interval of 15–20 km and cover near coastal areas to the trench axis. We have developed two application using web-browser; monitoring waveform and downloading seismic data. Monitoring system can view the strong-motion and pressure gauge in real time to promptly identify earthquake and tsunami for the use of disaster prevention officer of local government. After the 2011 Tohoku earthquake, some local government need to organize regional disaster prevention plan. Obtaining and storing knowledge about seismological phenomenon is essential to provide plan, and getting information immediately is important for executing their scheme. Another system allows researchers to download strong-motion and broadband seismograph data. These event data are produced referring to catalogues from USGS and JMA, >M6 (far-field) and >M4 (local-seismicity), respectively. These applications provide seismological information through the web-browsing technology and allow users to view and use DONET data easily.

T1.5-P19. Earthquake Occurrence Statistics and Delimitation of Seismogenic Source Zones in the Himalayan Belt

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The Himalayan belt bounded by 25–40 deg N and 65–85 deg E were investigated for seismogenic source identification and earthquake hazard assessment. An analysis of the database for the period 1853 to 10 October 2005 indicates that the seismic activity in whole area is linked to the ubiquitous tectonic features of the region. The study confirms that the Hindukush and its surrounding areas are highly active and are responsible for maximum percentage of total activity compared with other regions. About 99% of intermediate earthquakes are confined to the Hindukush region between 35.2–38.8 deg N and 68.2–74.9 deg E. It is observed that the intermediate and shallow focus events contributed equally to the seismicity of Hindukush and its close vicinity. The peaks of annual frequency for shallow and intermediate events correspond to the occurrence of large earthquakes since 1963, which are preceded and followed by low seismicity of varying periods. The seismicity of the Western Syntaxis and the Himalayan Frontal Arc are analogous to each other. The distribution of earthquake foci in the Hindukush and its surrounding areas is located in a vertical column, suggesting a V-shaped structure of the region. Based on other seismological criteria, potential zones have been delineated and earthquake hazard in each zone is forecast.

T1.5-P20. Earthquake Monitoring of the Arabian Peninsula and Adjacent Regions

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The verification of the CTBT will be assured by the global alarm system currently being established for the CTBTO. The International Data Centre (IDC) is a central element of the CTBT verification regime. It collects,
processes and analyses data originating from the 337 facilities of the International Monitoring System (IMS). The objective of this study that covers 1356 seismic events from the Reviewed Event Bulletins (REB) is to have a spot at the monitoring of the Arabian Peninsula by the current state of the IMS stations. Data were gathered during the period from January 2009 to December 2014. The study region has been subdivided into 12 seismic zones: Dead Sea, Jordan-Syria, Iraq, Red Sea, Western Iran, PersIan Gulf, Eastern Gulf of Aden, Socotra, Arabian Sea, Western Gulf of Aden, Western Arabian Peninsula, Eastern Arabian Peninsula. As a part of the IMS, there are four seismic stations located on the Arabian Peninsula. All of these stations (EIL, MMAI, ASF and WSAR) are auxiliary seismic stations. The data from these stations are transmitted to the International Data Centre in Vienna where they participate in performing station and network processing along with other IMS stations.

**T1.5-P21. Earthquake Prediction Model with Source Mechanisms of Earthquake Polarity Identification Through Ball Focal Classification using ANFIS and PCA Technique**

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This research is the study of historical data to predict earthquake return periods using the Adaptive Neural Fuzzy Inference Systems (ANFIS) technique. In this technique the historical data set is compiled into daily average earthquake occurrence intervals per year, and the output comprises modelled values. Source mechanism parameters are described using the focal sphere of the source mechanism beneath the earth’s surface, where the ball is a section shaded according to the polarity; this can illustrate the direction, pressure, strain, collisions and inter-block area of the fault. Return period earthquake occurrence models have been studied with respect to time by ANFIS, then polarity recognition has been performed through image recognition techniques on the focal sphere using principal component analysis (PCA). For each model of the return period, earthquake daily average obtained is related to polarity and fault mechanism. The validity of the accuracy of the return period earthquake prediction model was tested through correlation coefficient and RMSE.

**T1.5-P22. Earthquake Hazard Assessment in Morocco**

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In this paper we present and discuss the probabilistic seismic hazard analysis carried out in Morocco. This region was historically struck by strong earthquakes. It was particularly affected by several important earthquakes distributed in the territory of the country and along off-shore zones. In particular, the northern part has been most affected by earthquakes in the past few decades, the most recent being that of 24 February 2004 of magnitude Mw = 6.3. The probabilistic approach is used in order to take into account uncertainties in seismic hazard assessment. Seismic sources are parameterized using the most recent results obtained from seismotectonic regime, knowledge about past seismicity characteristics, and geologic and geophysical data. Source parameters such as b-values, slip rate, the mean annual activity rate, and maximum magnitude are assessed for each seismic source. The attenuation of the seismic ground motion with distance is estimated using attenuation relationships developed by Ambraseys (1995). Results are presented as maps of hazard for return periods of 50 years, 100 years and 250 years. The main purpose of this work is to provide engineers and decision makers with a basic tool for seismic risk mitigation.
T1.5-P23. Estimation of Local Magnitudes and Station Corrections for Selected Seismic Stations in Slovakia

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The modernization of the Slovak national network of seismic stations was finished in 2005. Since that time there was no effort made to modify original definition of local magnitude ML for region of Slovakia. The purpose of this study is to determine same local magnitude for all stations for one observed event. Peak amplitudes on simulated Wood-Anderson instruments were analysed for set of events recorded on six selected stations. Epicentral distances of analysed set of events were in 500 km radius and magnitudes were larger than 1.5. Station correction term for each selected station, local magnitude of event and distance correction term were determined through linear regression. The resulting local magnitudes were compared with available magnitudes from ISC and other national agencies.

T1.5-P24. Evaluation of Earthquake-Induced Strain in Promoting Mud Eruptions: The Case of Shamakhi-Gobustan-Absheron Area, Azerbaijan

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Manifestations of mud volcanism are widespread in Azerbaijan. The number of mud volcanoes in the country located on land and at sea exceeds 250. Mud volcanism is an interesting natural phenomenon. Many mud volcanoes are active at the present time. In the present study we evaluate both the static and dynamic strains induced by earthquakes in the substratum of mud volcanoes. We studied the effects of two earthquakes with Mw 6.18 and 6.08 occurred in the Caspian Sea on 25 November 2000 close to Baku city, Azerbaijan. A total of 33 eruptions occurred at 24 mud volcanoes within a maximum distance of 108 km from the epicentres in the five years following the earthquakes. The overall eruption rate in the studied area of the 50 years before the 2000 earthquakes was 1.24 that is much smaller than the eruption rate of 6.6 of the 5 years following these earthquakes. The largest number of eruptions occurred within two years from the earthquakes with the highest frequency within six months. Our calculated earthquake-induced static effects show that crustal dilatation might have triggered only 7 eruptions at a maximum distance of about 60 km from the epicentres and within 3 years.

T1.5-P25. Ground Motion Scaling Study in Central Anatolia Region, Turkey

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A regional study of ground motion scaling parameters is presented for the region surrounding the Central Turkey. In order to empirically obtain the scaling relationships for high frequency S-wave motion, regressions are carried out on three component broadband seismograms, all recorded within a hypocentral distance of 250 km. The data set used in this study consists of 120 earthquake events with magnitudes between (ML and Mw) 2.8 and 4.6. All selected events are in the upper crust. The peak ground velocities are measured in selected narrow-frequency bands between 1.0 and 10.0 Hz. Random vibration theory (RVT) is used to test estimates of the peak ground motion in the time domain. Results are presented to define a continuous geometrical spreading function, frequency-dependent crustal shear-wave quality factor Q(f), duration and source excitation. We fit stochastic ground motion model (Boore’s implementation) to parameterize the regression results.
T1.5-P27. Kazakhstan Monitoring System: Merging Opportunities to Solve Global, Regional and Local Tasks

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Geophysical monitoring system has been built in Kazakhstan under the support of CTBTO, AFTAC, and other organizations. Twelve seismic and 2 infrasound stations as well as National Data Centre receive data, which is used to solve global, regional and local tasks. The quality of damaging data preparation on nuclear explosions has been improved for the on-site implementation in support of CTBT, due to scientific innovations in the processing of seismic and infrasound data as well as creation and use of archive records of historical nuclear explosions’ base. The technology of obtaining improved seismic data at regional distances, which are used during the construction of a new map of seismic zoning of Kazakhstan (in cooperation with the Institute of Seismology of Kazakhstan), during the study of characteristics of the earthquakes occurred on the territory of Central Asia and Kazakhstan, for the purposes of assessing seismic conditions in the regions of increased responsibility (Semipalatinsk Test Site), etc., has been modeled. The data is used for studying and monitoring of seismic-tectonic circumstances in the responsible facilities location areas (VVR-K reactor, Ulba Metallurgical Plant, etc.). The monitoring results are used in other contexts as well, for example, for quarry explosions’ control, flares, etc.

T1.5-P28. Modernization of the Eastern Caribbean Earthquake and Volcano Monitoring Network Through Collaboration

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The Seismic Research Centre of the University of the West Indies has operated a medium-sized seismic network to monitor earthquake and volcanic activity in the Commonwealth island territories in the Eastern Caribbean since 1952. Over the past two decades a series of regional and international disasters have illustrated the need to fortify the existing surveillance system capabilities and created the opportunity to extend the network and implement modern standards. With limited funding available to carry out the desired upgrade, regional stakeholders have pooled resources and efforts to secure such resources and implement a programme of modernization. Through the utilization of Satellite and Internet Communication Technologies as well as shared ownership strategy, the operation of Virtual Seismic Networks has been facilitated. The boundary and quality of the network are extended and improved not only to facilitate tsunami surveillance but also to provide a better understanding of the dynamic processes and crustal characteristics that determines the potential of the geologic hazards being monitored. The upgraded system will also enable the development of services that will improve alerting capabilities and reduce warning latencies. This presentation focuses on the collaboration and corporation efforts that have been key to the successes so far.

T1.5-P29. New Evidence on the Tsunami Source of the 11 September 1921 Java Earthquake

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The 1921 earthquake was occurred in the Java trench and located between two tsunami earthquake of 1994 (Banyuwangi) and 2006 (Pangandaran) south of Java. The 1921 earthquake also generate tsunami that recorded in tide gauge of Cilacap with maximum height of tsunami is around 10 cm. From paleo tsunami study we found the tsunami deposit of the 1921 earthquake in around of Cilacap, Yogyakarta, and Banyuwangi beach. We suppose that the 1921 earthquake have strike-slip type for the source mechanism. We perform the numerical tsunami simulation to estimate the source of the 1921 earthquake. We used the tide gauge data from Cilacap and also tsunami deposit data in Cilacap, Yogyakarta, and Banyuwangi to validation the tsunami model. We estimate
the fault length was 275 km and width was 125 km. The total seismic moment by the calculation was $5.7 \times 10^{20} \text{Nm (Mw = 7.6)}$.

**T1.5-P30. Preliminary Study of the Static Coulomb Stress Analysis on Doublet Earthquake in Indian Ocean: Case Study of the West Coast of Sumatra Region Earthquake on 11 April 2012**

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Two shallow great earthquakes with Mw 8.5 and Mw 8.1 (depth < 60 km) occurred in the outer rise of the Indian Ocean Ridge on 11 April 2012 with an elapsed time around two hours. These earthquakes are classified as doublet earthquakes. Referring to the earthquake parameters only (location, depth and magnitude), the first earthquake was estimated to trigger the great tsunami event. These earthquakes were felt and caused exceptional panic for the people in Banda Aceh city and its vicinity (north Sumatra island). Based on the tsunami field observation using a tide gauge in Banda Aceh and its vicinity, the tsunami height is only 20–80 cm. The tsunami height is dependent on the focal mechanism type on the source and the large of the vertical displacement of the sea floor deformation. This study estimates the vertical displacement of the sea floor deformation using coulomb stress analysis and to estimate the tsunami certainty. Using the USGS data, the results of the vertical displacement of the sea floor deformation of around 10 cm and a shear stress change of about 5 bars with a west-southwest direction.

**T1.5-P31. Radioactive Material in Chad**

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There are numerous occurrences of uranium in Chad. Most of these are of the vein type linked with alkaline to syenite granites. This type is found in Tibesti, the Massif Central and the Mayo Kebbi regions, but they are more numerous in Tibesti. Other locations include Yédri, to the north of Aouzou where 14 uranium sites have been identified in the fractured zones of the granite structure (or granite range), and at Enneri Misky to the south east of Zouar. In the Guéra, such an occurrence is found: the one from Bouabouri is steep-sided in strongly radioactive granite located to the south of the range next to lake Iro. In Tibesti there are abundant uranium occurrences in a similar geological environment to the Air Mountains in Niger where large sedimentary deposits of uranium are located. Consequently, the enveloping sediments from Tibesti have a great potential for a uranium deposit of the sedimentary type. The use of geophysical methods in Chad was mainly in relation to oil exploration. Several seismic profiles and exploration wells have been made. Some of those have led to gas and oil discoveries that have actually been exploited.

**T1.5-P32. Seismicity in Bangladesh Using Local Seismic Station**

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The frequency magnitude distribution of earthquake in Bangladesh is measured by the b-values. 116 earthquakes of magnitude 3.1R to 6.2R were recorded in Bangladesh during the period April 1997 to May 2006. To estimate b-value the least square method has been used in Richter Gutenberg frequency magnitude relation as a linear equation, and thus the b-value is obtained 0.71, which is lesser then normal (b = 1.0). Gutenberg–Richter law has been applied in the data set. Using this law, it is found that M = 6 R magnitude earthquake in every 27 years and M = 7 R magnitude earthquake at every 138 years. These results are consistent with the time interval of historical earthquake. Lack of smoothness of cumulative curve of earthquake number suggests that this catalog cannot be accepted as homogeneous. Hence the rates and variability of seismicity over time is analysed using Akaike Information Criterion (AIC). The result of AIC analysis suggests that the rate of seismicity changes with...
time. The researcher also examined tectonic stress field near Bangladesh using Harvard CMT catalog. The direction of P-axis of middle and large earthquakes indicated that the compression tectonic stress is loading from north-east to south-west direction.

**T1.5-P34. Seismic Hazard Analysis and Isoseimal for Java, Bali and West of Nusa Tenggara**

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Java, Bali and West of Nusa Tenggara are earthquake prone areas. One efforts to minimize the disaster impact is carried out through seismic hazard research. This study is to analyse the earthquake hazard and isoseismal for the study area. The research includes collecting and processing seismic data, seismic sources modelling and characterization, earthquake hazard and isoseismal analysis. Seismic hazard analysis for the 10% probability of exceedance in 50 years was carried out using the total probability theory and three dimensional source modelling. This study used BMKG catalog 1903–2010, 0–300 km depth, Mw ≥ 5 and PGA data recorded. The results of shows the PGA values varied from 0.05 to 0.5 g. The acceleration ranges relatively close to the Indonesian Earthquake Map 2010. Seismic hazard curves in some big cities in Java showed that the deep earthquake was very influential in Serang, Jakarta and Surabaya. The fault source dominant influence in Bandung, Yogyakarta and Semarang. Isoseismal analysis of Tasikmalaya earthquakes on 2 September 2009 and 26 June 2010 shows the area in the south western part of Java experience strong shocks around VII–VIII MMI (0.25–0.3 g) which corresponds to the hazard maps result of combine source.

**T1.5-P35. Seismic Monitoring of the Namaqualand-Bushmanland Region: Developments**

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In the late 1970s a programme to find a suitable site for low- and intermediate-level radioactive waste was launched in Namaqualand-Bushmanland region. Vaalputs was identified and has been operational since 1986, and seismicity is one of several key factors monitored as part of on-going disposal operations. The seismic history of the region is evaluated so as to assess its long term stability and geodynamic setting. The two-station network of short-period seismometers installed in 1989 was replaced with a three-station network in 2012, comprising one broadband and two short period seismometers. Data from this network, the South African National Seismological Network, and the International Seismological Centre is used to compile a seismic catalogue. A previously known cluster of earthquakes, with Mmax = 5.8, termed the “Grootvloer cluster”, is found to consist of three distinct seismic source zones, namely: (1) the Springbok area—attributed to mining activities that ended around 2000; (2) the Great Escarpment area—attributed to continental margin instability, and (3) the Bushmanland Plateau area, which is not easily understood. This sub-cluster could reflect the strain in the upper/middle crust in response to a transpressional force known as the Wegener Stress Anomaly.
**T1.5-P36. Seismic Hazard Assessment of the Territory of Kyrgyz Republic**

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Kyrgyzstan, which is located in a zone of collision between the Eurasian and Indo-Australian lithosphere plates, is prone to large earthquakes as shown by its historical seismicity. In particular, between the end of 19th century and the beginning of the 20th one, several destructive earthquakes struck Kyrgyzstan, such as the Belovodskoe earthquake of 3 August 1885 (maximum intensity IX), that struck the city of Kara-Balty, just west of Bishkek (Bishkek developed as a city within the 20th century), and the Ms = 8.3 Kemin earthquake of 3 January 1911. Recently, an earthquake of magnitude Ms = 7.3 struck on 19 August 1992 the western part of the Suusamyr valley, in the north Tien Shan region of Kyrgyzstan. Finally, on 5 October 2008, a magnitude 7.0 occurred along the border triangle between Kyrgyzstan, Tajikistan and China. The occurrence of close and large earthquakes makes the Kyrgyzstan the region with one of the highest seismic hazard in the world. Probabilistic seismic hazard maps at regional scale have been recently computed for Kyrgyzstan, confirming the very high hazard of the region. After this investigation at least three more studies on seismic hazard of named territory were carried out. The comparison between these studies is presented.

**T1.5-P37. Seismological Network of Namibia**

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Over the years, earthquakes have been widely reported in Namibia and the first recorded earthquake occurred in 1910. Since then, there have been more than 150 recorded earthquakes reported by the various regional and international seismic monitoring institutions. Currently, seven seismological stations located across the country form the national Seismological Network of Namibia. Seven stations are operational and are a mix of broadband and single-phase stations and are powered by the national grid and others by solar power. The recorded data are streamed in real time via the GPRS mobile network to the main server located in Windhoek. The Tsumeb station is also part of the Global seismological Network and Incorporated Research Institutions for Seismology (GSN/IRIS) and the station contributes to worldwide earthquake monitoring. It is one of the CTBTO’s IMS AS067 monitoring nuclear explosions worldwide. The seismic data are used to provide a monthly event bulletin, monitors earthquakes countrywide and provides data for the Earthquake Hazard Map of Namibia. This is to characterize the seismic profile of Namibia and isolated non-natural events, such as mining and infrastructure development. In this way local sources are separated from that of nuclear origins.

**T1.5-P38. Some Peculiarities of Stress Field and Active Fault “Behaviour” Derived from Focal Mechanisms on the Territory of Armenia**

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Armenia lies within the complex zone of continental collision between the Arabian and Eurasian plates. The Arabian plate is moving northward at the rate of 20–30 mm/year and collides with the Eurasian plate. The Anatolian and the Iranian blocks are squeezed westward and eastward respectively. In the present work, on the basis of analysis, kinematic and dynamic interpretation of individual focal mechanism solutions, we attempt reveal some features of active fault “behaviour”, and time–space peculiarities of tectonic stress field on the territory of Armenia. Based on the analysis of stress map of Armenia we attempt to differentiate local zones with comparatively homogeneous orientations of tectonic stresses and seismic regimes, thus providing information for seismic hazard re-assessment in future. Based on our study, we show the existence of more than one stress regime in the territory, and we suggest that complex active tectonics, connected not only to the convergent motion between above mentioned plates, but also to the motion of several micro plates, produce a wide range of tectonic regimes.
T1.5-P39. Study of the M 2.7 Merbabu Earthquake on 17 February 2014: Is It a Volcano or Tectonic Activity?
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On 17 February 2014, an earthquake occurred around the mountain of Merbabu in Central Java Indonesia. According to the Meteorological Climatological and Geophysical Agency of Indonesia (BMKG) the earthquake was magnitude M = 2.7 with 10 km depth. However, this small earthquake was strong enough to be felt by people surrounding the source and damaged 46 homes. The question also arose as to whether it was a volcano or a tectonic earthquake. A relocation method and earthquake focal mechanism identification were conducted in this study to review the earthquake source. A tomography method was also implemented to find out the flow of the magma. The result of this study will give an answer whether the earthquake was caused by a volcano or tectonic activity. There are similar conditions in Indonesia where a number of volcanoes are showing seismic activity that may caused by a local seismic fault which had not been identified. The existence of CTBTO’s sensor which is closely located to Tangkuban Prahu Volcano in West Java, can be used for a similar study to investigate a possibility of an existence of an active local seismic fault near to the volcano.

T1.5-P40. Study on the 2004 Sumatra-Andaman Earthquake for Making Tsunami Inundation Maps in North-West Coasts of Peninsular Malaysia
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Many places over north-west Peninsular Malaysia experienced giant waves induced by the large magnitude of earthquake during the 2004 Sumatra-Andaman mega earthquake. A number of scientific studies have been implemented in order to understand the unexpected phenomenon so as to improve the current National Disaster Mitigation Plan. Seventy-five sets of tsunami numerical simulations are conducted to identify tsunami propagation and run-up over the selected areas in the region. The parameters in the heterogeneous slip model are estimated using an inversion method from satellite altimetry data. The Non-Linear Shallow Water Equations (NSWE) by considering the effects of the earth’s curvature are applied in the numerical simulation to evaluate the tsunami propagation and run-up at the target areas. The nesting grid system with five layers is applied in the numerical model. The result shows that the largest tsunami height and run-up of 3.2 metres and 5.43 metres respectively are estimated in Langkawi island. The calculated tsunami waveforms at the tidal gauge system almost agree to the observed waveforms. The comparison of run-up data from calculation and survey show significant trend. It is strongly suggested that this scientific finding be used as part of the current decision making process.

T1.5-P41. Study on Tsunami in Relation to Earthquakes
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Thick sedimentation, high density of sea water, anticlockwise oceanic current, frame-shaped Bay of Bengal, shallow continental shelf, and proximity of tectonic subduction zone, all increase the tsunami vulnerability along the Bangladesh coast. The relation between earthquake magnitude M and tsunami magnitude m is m = 2.30 M – 16.20. For an earthquake magnitude M of 6.3 to 6.8 only a small tsunami with height less than 0.5 m is observed on the coast, with no damage (m = –1). For a magnitude M of nearly 7.0, the tsunami height on the coast would be 0.5 to 1.0 metre, with slight damage (m = 0), while if M is greater than 7.3, the tsunami height on the coast would be 1.0 to 2.0 metre with heavy suffering in some areas (m = 1). When M is nearly 8.0 the coastal tsunami height would be 2.0 to 6.0 metre with severe damage (m = 2) and if M is nearly 8.5 the coastal tsunami height would be 10.0 to 20.0 metre and more than 400 km would be greatly damaged (m = 3). For a tsunami magnitude
m = 4 or earthquake magnitude more than 9.0, the tsunami height would be 30 metre or more along the coastal areas.

**T1.5-P42. The Using of International Monitoring System Data for Early Warning of Geophysical Hazards**

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Using of seismic and infrasound data of IMS stations together with the data from Ukrainian NDC allows to monitor geophysical hazards such as earthquakes, storms, tsunamis, explosions, bolides, etc. A multidisciplinary approach had used for searching anomaly geophysical predictors in the Vrancea region and the Antarctic Peninsula region, as well as for building of model of the early warning system of earthquakes. Additionally, in the Antarctic, at the Vernadsky station, were tested the methods for early warning of tsunamis, that use seismic, infrasound and hydrological equipment. All geophysical fields are interrelated, so registration of abnormal signals in each of them and the detection of spatio-temporal relationships between the signals will help to improve knowledge about the mechanisms of development and the possibility of warning.

**T1.5-P43. The Baleakanta Project, A Database of Hydroacoustic Signatures of Large Cetaceans: A Few Cases of Individual Animal Identification**

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The Baleakanta project was initiated in 2013 with the goal of establishing a database of large cetacean calls recorded at the IMS hydrophones. These calls are recorded on a continual basis at the six hydrophone stations of the network, whose main purpose is to serve the mission of detecting nuclear explosions in the oceans. The calls are scientifically valuable as a means of studying the animal’s migration patterns. Statistical information about the signal characteristics, frequency, seasonality, density of these calls are some of the expected outcome of the project and we are planning to make the information available to the marine mammal community. We will report in particular on observations which led us to distinguish two distinct blue whale individuals with type 9 acoustic signature and open the possibility to search for time-frequency methods of individual classification.

**T1.5-P44. The French Tsunami Warning Centre for the Mediterranean and North-East Atlantic: CENALT**

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The CENALT (CENtre d’ALerte aux Tsunamis) is responsible for the French NTWC (National Tsunami Warning Centre). Since its entry in operation, its objective is to transmit a message in less than fifteen minutes for any earthquake that could trigger a tsunami in the Western Mediterranean Sea and the North-East Atlantic Ocean. The data collected from French installations and from institutions from countries around the monitored basin are processed with software that permit to make an early location of the seismic events and to measure the expected sea level effect on the shore. The on-duty analysts interactively revise all the information produced and use references based on historical tsunami and earthquake databases as well as computed tsunami scenario to be able to send the more comprehensive message possible. Communication tests as well as exercises are performed monthly to test and validate the different transmission mode latencies (Global telecommunication system, email and fax) and the efficiency of the system. Furthermore, large scale exercises are organized like in the last quarter 2014 when CENALT participated to the international NEAMWave14 tsunami exercise organized by the
Intergovernmental Oceanographic Commission (Unesco/IOC). These different tests and exercise permit to insure the operability of the overall warning system.

T1.5-P45. The Magnitude of Completeness in Aswan Seismic Network Earthquakes Catalog, Egypt

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The magnitude of completeness, Mc, mapped for Aswan Seismic network Earthquakes Catalog. Mc was estimated based on the maximum curvature method. It is found to be 2.1 for the entire interface catalog. In all catalogs studied, Mc was strongly heterogeneous. The magnitude of completeness, Mc varies from 1.2 to 2.5. The lowest Mc is observed eastern side of Kalabsha fault and the highest Mc appears near the western side of Kalabsha fault. The magnitude of completeness, Mc is approximately 2.2 ± 0.13 in most parts inside the zone(A) at focal depth ranges between 18 to 30 km, 2.3 ± 0.3 at focal depth ranges between 1 to 18 km, 1.4 ± 0.2 at focal depth ranges between 1 to 9 km, 1.9 ± 0.2 at focal depth ranges between 1 to 18 km, 2.1 ± 0.26 (zone F) which focal depth ranges between 1 to 8 km, 1.8 ± 0.19 (zone G) which focal depth ranges between 1 to 8 km, and 1.8 in most parts (zone H) at focal depths greater than 1 and less than 5 km.

T1.5-P46. The Numerical Tsunami Inundation Modelling in Ujung Kulon, Indonesia, for Potential Earthquake Mw 8.7 South West of Sunda Strait

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Ujung Kulon is located in westernmost Java Island, Indonesia. In this area there is the national park that has an important role in protecting the habitat of the Javan rhinoceros. Based on historical significant earthquakes in the Sunda Trench, there is seismic gap in the south west of Sunda Strait. By scaling law calculation, this seismic gap potentially causes the large earthquakes with moment magnitude (Mw) 8.7 and can generate tsunami. To anticipate the impact of tsunami, we perform a tsunami numerical inundation modelling in Ujung Kulon. We use a modification of TUNAMI-N2 (Tohoku University’s Numerical Analysis Model for Investigation of Near Field Tsunami, No.2) to perform numerical inundation modelling. We apply the nonlinear shallow water theory with bottom friction and four different spatial grid sizes (nested grid system) in a spherical coordinate system for the computation. The results show that the first tsunami wave arrived in Ujung Kulon 13.33 minutes after earthquake with maximum tsunami height of 9.8 metre and tsunami run-up of 11.6 metre. These results prove that Ujung Kulon has a high tsunami risk threat from earthquakes that occur around the Sunda Strait.

T1.5-P47. Transmission of Raw Waveform Data According to the Arrangements Between Tsunami Warning Centres and the CTBTO

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CTBTO builds and maintains the International Monitoring System (IMS) primarily for the use of Treaty-related verification tasks. Of the civil and scientific applications for the data from the IMS, the most widespread and publicized of these is in tsunami warning. Following the 2004 Sumatra earthquake which resulted in a devastating tsunami, a decision was reached by the Preparatory Commission that the forwarding of continuous real time data obtained from the IMS by the International Data Centre (IDC) to existing Tsunami Warning Centres would be of practical benefit. To this end, an agreement between the CTBTO and the United Nations Educational, Scientific and Cultural Organization (UNESCO) was initiated to provide for the supply of such data to recognized Tsunami Warning Centres. The agreement between CTBTO and UNESCO was ultimately signed in 2010. By the end of 2014, fifteen centres in fourteen countries (Australia, France, Greece, Indonesia, Japan, the Republic of Korea, Malaysia, Myanmar, Philippines, Russian Federation, Spain, Thailand, Turkey, USA) had
initiated such data forwarding arrangements with the CTBTO. The overview of the present situation is provided through a selection of maps and data volume graphs indicating the dispersion of tsunami warning countries and the data volumes over the years.

**T1.5-P48. Use of International Monitoring System Stations to Provide a New Representation of Kazakhstan Seismicity**

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Until the end of the 20th century only the south, south-east and part of the east regions of Kazakhstan were considered seismically active. The seismic zoning maps of Kazakhstan were constructed according to this information. With the introduction of new IMS stations on the territory of Kazakhstan and in neighboring countries, the knowledge about the seismicity of Kazakhstan has been changed significantly. The following new seismic arrays of the IMS have been installed in Kazakhstan: Makanchi (PS31), Borovoye (AS057), Kurchatov (AS058), together with the three-component Aktyubinsk (AS059) station. Data from the seismic arrays Zalesovo (Russian Federation) and Alibek (Turkmenistan), and three-component station Ala-Archa (Kyrgyzstan) are also used. AFTAC (USA) has assisted with construction of seismic arrays in Kazakhstan, Karatau and Akbulak. The monitoring results showed seismically active zones in Central, West, North and East parts of Kazakhstan. The earthquake catalogue for these regions was compiled. The source mechanisms and aftershock activity were studied for the largest earthquakes; data on strong motions were collected. All new data are used to construct a new seismic zoning map of Kazakhstan. This work is implemented in cooperation with the Institute of Seismology of Kazakhstan.

**T1.5-P49. Variations in Gravitational Field, Tidal Force and Earthquakes (Sheki-Greater Caucasus)**

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Azerbaijan is caught in the active continent-continent collision of the Arabian plate with Eurasia. These regional tectonic processes give rise to earthquakes that have devastated the Caucasus throughout recorded history. Collision and seismic processes involve changes in the underground mass distribution with consequent modification of the gravity. Gravity measurements are able to detect such changes providing information suitable for understanding the physical sources of such phenomena. The time dynamics of the gravity signal measured in Sheki (Azerbaijan), where mainly crust deformation processes are present, is investigated using the power spectrum method and multifractal detrended fluctuation analysis. Our findings indicate presence of two main periodicities (12 and 24 hours) in gravity signal embedded within an antipersistent structure at any timescale. The analysis of the second order fluctuation function reveals that the signal is antipersistent, with an excess (with respect to the simple linear behaviour) of fluctuation variation between about nine hours and two days. The nature of such excess of fluctuation at these timescales is still not very clear; maybe there is some correlation with the earth’s gravity and the last stage of earthquake preparation that occurred in the region.

**T1.5-P50. Why Did the 8.6 M Aceh Earthquake on 11 April 2012 Not Cause a Significant Tsunami and Casualties?**

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Beyond of a view historical tsunamis in the western part Sumatra as the Aceh tsunami 26 December 2004 and Aceh tsunami 11 April 2012 have given several questions for the majority the common people. This study aims to analyse the shape and location of ocean bottom earthquake source as the cause of the tsunami wave
propagation, by performing a cross section in the study area bathymetry maps. Using the equation by Coppersmith through the equation obtained until the resulting output of the vertical deformation fault, the structure of bathymetry and tsunami run-up. The resulting conclusion, that in the case of the Aceh tsunami in 2012 in the form of bathymetry on western Sumatra trench inhibits propagation of tsunami run-up to the maximum tsunami wave as it passes through the subduction zone is 3.5 metres, and 0.8–1.5 8 metres when it reaches the coast, with zero tsunami victims. While in the case of Aceh earthquake 26 December 2004 tsunami in the subduction zone of 12 metres and 27–33 metres when it reaches the coastline with the dead and missing reached 544 064 inhabitants.
THEME 2:
EVENTS AND THEIR CHARACTERIZATION
2.1: On-Site Inspection: The 2014 Integrated Field Exercise (IFE14)

Oral Presentations

T2.1-O1. Application of Airborne Remote Sensing During the 2014 Integrated Field Exercise

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The value of airborne technologies to an OSI was underscored during the 2014 Integrated Field Exercise in Jordan (IFE) in which flight navigation, gamma spectroscopy and multi-spectral instruments (MSIR) were installed into the airframe of an AS332 Super Puma helicopter. Total airborne operations exceeded 17 flight hours and data acquired by system sensors and subsequently processed successfully identified OSI-relevant observables engineered for the purpose of the exercise. MSIR sensors acquired data over targeted areas of the inspection area and successfully identified freshly exposed surfaces and allochthonous material as well as areas that had been subject to modification through vehicle movements and grading. In contrast, the gamma spectroscopy system was used to map a large portion of the inspection area flying at lower height above ground level. In effect, the identification of relevant observables from these sensors during the IFE enabled the interest level of certain areas to be raised. However, the absence of such observables in other areas was also considered important information, as the interest levels of these areas were either confirmed or reduced.


SAMS Network

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The Seismic Aftershock Monitoring System (SAMS) is an important method during the initial period of an on-site inspection (OSI) to narrow down the search area and identify the location of a possible underground nuclear explosion. A network of tripartite mini-arrays and single three-component seismic stations can be deployed during an OSI to detect and localize small aftershocks in the vicinity of a possible explosion. During the 2014 Integrated Field Exercise a trade-off between fast station deployment, precise site analysis and practicability from local conditions was made. A first rough site characterization was undertaken with information about geology, local facilities and infrastructure e.g. roads to select suitable sites and improve the network detection capability. Significant variations in topography of the inspection area in the mountainous Dead Sea Area of Jordan led to considerable limitations concerning the network design. A comprehensive and analytical method to estimate the SAMS network detection capability will be presented which is based on noise measurements from SAMS stations. Results from this analysis would enable inspectors to adapt the network configuration to the needs by densifying the network or relocating stations. Additionally this systematic quality control enables inspectors to identify system failures and manipulation at the seismic stations.
T2.1-O3. Information Based Search by the Inspection Team During the 2014 Integrated Field Exercise

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Having in mind that the sole purpose of an on-site inspection is to clarify whether a nuclear explosion has been carried out in violation of the CTBT, the inspection team applies an information based search to direct the conduct of inspection activities for the collection of information. Such an approach requires that one or more polygons, i.e. regions of any shape and size that enclose a feature or area of interest within the inspection area, are identified by the inspection team based on a systematic analysis of all information available or absent at that time. This analysis leads to specific proposals of inspection activities with the objective of collecting additional information that will increase or lower the interest in these polygons. The application of an information based search during the 2014 Integrated Field Exercise (IFE) resulted in the search area being narrowed down to two locations where increasingly more intrusive inspection techniques were used. As the scientifically credible and realistic scenario was a priori not known to the inspection team, this presentation summarizes the systematic search as applied during the IFE—with examples of the prioritization and decision-making process when the analysis of information presented options for the use of the available inspection techniques.


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For on-site inspection under the CTBT, measurement of argon-37 is considered an important technique, as it is a definitive and unambiguous indicator of an underground nuclear explosion. A new argon-37 detection system for OSI purposes named MARDS-II was developed by the Institute of Nuclear Physics and Chemistry in 2013, on the basis of the MARDS-IA system and lessons learnt from its field deployment in the IFE08 and NG09. The new system was designed to have the capability of separating argon from 400 liters gas sample at room temperature without liquid nitrogen as coolant. The system uses a new optimized modular and automatic design for simplified field deployment. The system is capable of processing four samples per day. The MARDS-II was deployed in the 2014 Integrated Field Exercise and fully operated by the trained surrogate inspector. During the exercise, about ten samples were processed by the MARDS system and in one sample argon-37 300 mBq/m³ in radioactivity concentration was detected. Meanwhile fruitful lessons were learnt from the exercise, which could take as the input for further development, such as state of health monitoring, argon-37 background investigation, and strategies on the deployment of noble gas system in the OSI.

T2.1-O5. Scenario Planning and Preparation of Ground Based and Remotely Sensed Visual Observables for the 2014 Integrated Field Exercise

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The visual observation (VOB, including MSIR) component of an Integrated Field Exercise (IFE) creates the framework for integrating the physical aspects of the inspection area with the technical activities of the exercise. Thus, the inspection team should demonstrate integration of VOB techniques with all other technologies. An important part of an IFE scenario is to provide a plausible context that the inspection team must try to understand, helping to more fully engage the inspection team in its activities and optimizing the results of efforts made. To do so, the scenario story should have clear links to the physical setting of the area in a kind of “what you see is what you get” functioning philosophy. There are visual features in the IFE inspection area (IA) that the inspection team can document to identify locations of interest and formulate hypotheses (via Inspection
Team Functionality (ITF)) required to apply inspection technologies with scientific credibility. For the 2014 IFE scenario, many visual features were not present in the ‘IA’, and therefore the scenario required engineered construction of additional (and artificial) features at two sites that could be consistent with a possible noncompliant event.

**Poster Presentations**

**T2.1-P1. A Multiple Sample Holder for Ganging Samples During the 2014 Integrated Field Exercise**

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The number of environmental samples collected daily by multiple field teams and to different areas of interest during an OSI could be large (up to 50–100). In order to achieve a good throughput rate of the analyses in order to effectively support the inspection, it would be useful to run a cumulative measurement of a group of samples, ganging them. The rationale used to gang the samples should be related to the sample locations, type of sample or by field mission. The relative gamma spectrometry measurement could give some information on the total activity of the group of samples. If the result is positive, the analyst could go through a sequential de-ganging of the group in order to discriminate the one or more samples with the anomalous activity. ENEA has designed, implemented and tested a plastic sample holder for the gamma spectrometry measurement of multiple samples. The holder has been used during the 2014 Integrated Field Exercise for the ganging measurements. The multiple sample holder has been manufactured from a plastic material in order to have a known composition and be easily cleaned and decontaminated; the characterization of the holder has been run with different geometries and positions of the sample containers in order to have a best estimation of the geometric efficiency.

**T2.1-P2. An Analysis of Radionuclide Laboratory Operations in Future Integrated Field Exercises**

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One major goal of an integrated field exercise (IFE) is to learn technical lessons from the experiences of the participants. The authors of this abstract had the opportunity to spend a number of hours in the Base of Operations (BOO) radionuclide laboratory during the 2014 Integrated Field Exercise (IFE). During this experience, many lessons were learned that will be shared in this poster. While there were many aspects of the laboratory operations that went well, the authors will identify aspects that could be improved. Ultimately, the IFE experience offered an opportunity to reevaluate how laboratory operations should look in future exercises and during an on-site inspection (OSI) itself. This poster will present the analysis of how a future laboratory could operate based on these experiences at the IFE. This includes procedures and equipment needed for the successful operation of a radionuclide laboratory for OSI as well as the type of training needed for the inspectors.
T2.1-P3. Capabilities of an On-Site Inspection

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The authors will sketch the technical capabilities of a 10-person team operating a mobile lab and portable equipment against a nuclear anomaly that could be a contained underground nuclear explosion. Survey, including flight, carborne, and backpack, help locate an area for investigation, then in situ survey and sample collections can find isotopic anomalies in concentration, location, and ratio. Where surface radionuclides are not evident, sub-surface noble gas (Xe and Ar) collection and mobile lab measurement can detect leakage from even well-contained nuclear tests. The authors will discuss the initial expectations vs realities of a 4-week field exercise.

T2.1-P4. Challenge-Type Inspections: Continued Relevance in Multilateral Arms Control Regimes? (Doctoral Dissertation at the University of Vienna, 2014)

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A qualitative analysis of regime members’ positions regarding the role, characteristics and importance of challenge-type inspections in multilateral arms control regimes is undertaken through a comparative case study of challenge (CIs) and on-site (OSIs) inspection mechanisms provided for under the Chemical Weapons Convention (CWC) and the CTBT, respectively. The policies of regime members with respect to challenge-type inspections is examined in light of Regime Theory as well as a research model proposed by Rittberger, Zangl and Kruck to study the political system of international organizations. The main findings clearly highlight that regime members consider challenge-type inspections as integral elements of the CWC and CTBT verification regimes and, although likely to be employed only in exceptional circumstances, represent an adequate and valuable verification mechanism. Moreover, though challenge-type inspections are in essence technical fact finding missions, the overall verification process is inherently political in nature and ultimately depends on the political will and trust exhibited by regime members.

T2.1-P5. Comparing In Situ Gamma Spectroscopy and Laboratory Assay of Environmental Particulate Samples: Lessons That Apply to Their Application in Integrated Field Exercise

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In situ gamma spectroscopy and environmental sampling are two techniques that were applied during the 2014 Integrated Field Exercise (IFE) in Jordan. In situ gamma spectroscopy was used in the IFE as a “gamma survey technique” but actually has comparable detection sensitivity for many radionuclides to the laboratory assay of environmental particulate samples. The IFE illustrated the logistical limitations of sampling. In addition to wide area survey, the in situ technique might now be better utilized for quantitative assay in the field to guide sampling decisions. An experiment was performed to directly compare the achievable detection sensitivities of the two techniques (environmental sampling and field in situ gamma) as performed in the IFE using comparable equipment and methods. The results illustrate that the techniques are quite complementary. Further consideration of their complementary nature will guide refinement of the concept of operations and procedures and data quality targets as would apply to exercises beyond the 2014 IFE.
T2.1-P6. Design and Implementation of Buried Sources for the 2014 Integrated Field Exercise

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The scenario for 2014 Integrated Field Exercise included the use of buried sources to approximate radiological deposition on the ground of sufficient strength to be detectable by radiation survey and in situ measurements. Ten 40-MBq Co-60 sources were used as surrogates for a large radioiodine deposition. The sources were buried and retrieved each day that field missions were in the proximity of their location near surface ground zero. This poster will review the choices made for this scenario implementation in regards to source strength, isotope, and source containers as well as the logistics involved in implementing this part of the scenario. Lessons learned from this implementation and implications for possible future exercises will also be discussed.

T2.1-P7. Design and Operational Experience with an Aerial Gamma Radiation Survey System for On-Site Inspection

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One of the detection modalities available for use in an On-Site-Inspection (OSI) is an aerial radiation survey which could detect the presence of nuclear explosion relevant radioactive material at the surface of the ground. Aerial surveys offer the potential of covering large geographical areas in relatively short amounts of time with a reasonable level of sensitivity; and allow access to terrain that may be difficult to reach with ground based methods. A large volume sodium iodide based scintillator detector was provided in 2013 by Canada to the CTBTO as a contribution in kind to support OSI. This detection system was used during the recent Integrated Field Exercise (IFE2014), to survey the inspection area for the presence of radioactive material. In addition a number of surveys under more controlled conditions were conducted prior to the exercise for training and development purposed. This paper describes the system and provides selected results from its use in actual field conditions.


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The simulation of an event for the 2014 Integrated Field Exercise (IFE) involved many aspects for consideration such as whether the event was CTBT compliant or non-compliant, the nature of the triggering event, as well as issues associated with implementation of the scenario. The IFE Scenario Team designed a scenario that took all of these issues, as well as others, into consideration. One of the important components of the scenario was how to best simulate the debris from a nuclear explosion that would be safe for all personnel involved with the exercise, challenge the Inspection Team, be cost effective, and test the equipment and procedures developed for on-site inspection. While the most realistic scenario might have involved the production of fission and activation...
products in a reactor followed by deposition onto and below the surface, a different but effective method using sealed low- and high activity sources and contained radioactive noble gases was followed that met the goals of the IFE. This presentation will describe the radionuclide scenario and storyline associated with the radionuclide information, how the physical injects were devised, and implementation steps for the exercise.

T2.1-P9. Improving the Realism of Future Exercises and Training of Inspectors

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The 2014 IFE was a challenging test. The scenario included a surface release and deposition of relevant radionuclides. From an overall standpoint, the exercise was a good test. However, it lacked in some key areas because of the inability to realistically produce and distribute short-lived fission products on the ground surface surrounding the suspect site. Radionuclide signatures and samples were grossly approximated using surrogate radioactive point sources and barcodes. Thus, the scenario lacked some of the physical distribution of radionuclides, and the expected energy and decay characteristics. Lawrence Livermore National Laboratory (LLNL) has developed and demonstrated a prototype system that can produce, in real time, highly realistic radionuclide outputs through actual detectors. Elements of training scenarios such as the spatial distribution, mix, and decay are achieved by directly injecting pulses into the circuitry of detectors, mimicking an actual radiation field and pulse-by-pulse generation of high resolution spectra. This prototype includes position-keeping and communications capability to enable situational awareness for exercise management. Near-realistic scenarios can be developed and executed while avoiding the use of actual radioactive sources. Other aspects, such as measurement restrictions and “virtual samples”, could also be evaluated using the same technology.

T2.1-P10. On-Site Inspection Data Flow, Information Handling and Management During the 2014 Integrated Field Exercise

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During a CTBT on-site inspection (OSI) the inspection team collects information and data necessary for the purpose of the inspection in accordance with its mandate. Following the lessons learned from IFE08 processes and systems concerned with data flow, information handling and management were designed, tested and finally utilized during the OSI 2014 Integrated Field Exercise. The inspection data and meta-data collected in the inspection area were stored on electronic recording media, and within inspection equipment and navigation tools. Within the base of operation an ICT infrastructure comprised of two local area networks were installed using two separate pools of servers, disk storage fields and software packages in the joint area and office premises, respectively. These systems hosted the Integrated Information Management System (IIMS) and the Field Information Management System (FIMS). We show examples of data handling for selected inspection techniques and for planning and navigation information in an accountable manner to guarantee their originality and uniqueness, to interact with the Inspected State Party (ISP) as required by the Treaty and to have the data and information available for further processing in a timely manner.

T2.1-P11. Operations Support Centre and International Data Centre Interactions During the 2014 Integrated Field Exercise: Observations and Paths Forward

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Several participants in the 2014 Integrated Field Exercise (IFE), two of whom served as Control Team (CT) members for the Operations Support Centre (OSC) during the exercise, present observations on the following
activities: (1) the communication process between the OSC and International Data Centre (IDC) and the nature of those communications; (2) the interactions among the exercise management, CT, OSC, IDC and inspection team; (3) the technical advantages and challenges of engaging the IDC for this specific exercise, including examples of data sets, and injects provided by the CT and IDC via the OSC to fulfill inspection team requests and promote the objectives of the IFE. We also provide recommendations for more beneficial and comprehensive utilization and integration of IDC data sets into an on-site inspection (OSI) via IDC components including special event analyses, with potential incorporation of publically available data sets such as satellite imagery. Noting that this was the first IFE to involve the OSC and IDC (though there was a precursor in BUE1), we explore ways in which the OSC and its relationship with the IDC can develop and mature to best support field activities during an OSI.

T2.1-P12. Performances and Lessons Learned with a Transportable Radionuclide Laboratory Deployed During the 2014 Integrated Field Exercise

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The radionuclide laboratory is a key component to analyse environmental samples and gamma emission spectra for trace amounts of nuclear explosion relevant nuclides. During 4 weeks operations in Jordan for the 2014 Integrated Field Exercise, more than 150 samples and in-situ spectra were successfully analysed to establish baseline information on the Inspection Area, map the presence and concentration levels of key nuclides, and contribute to narrowing-down the search areas. Key performances are presented and specific operational constraints and challenges during an on-site inspection are discussed. Lessons learned that will be key for the next development cycle are described, including needed developments to allow for a more rapid deployment of the radionuclide laboratory in the field.

T2.1-P13. Possible Challenges for On-Site Inspection Technologies in Tropical Environments

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Technologies, procedures and resources of the on-site inspection exercised through Inspection Team Functionality (ITF) proved to be a fool-proof maneuver considering the final results of the 2014 Integrated Field Exercise. Yet, the same technologies in tropical environments tend to fail, particularly the tunnelling of 1000 km² (IA) prior to applying conclusive techniques such as radionuclide (RN) and geophysics (CPT). Visual Observation (VOB), Initial Overflight, and SAMS lead the way in identifying polygons of interest with non-conclusive evidence of a nuclear explosion allowing the RN and CPT to provide more conclusive evidence. Thorough application of RN and CPT is confined to a fraction of the IA, which requires prior indications from VOB and SAMS. Yet sequences of canopies with limited ground access is prone to negatively affect the VOB performance, further forest die-back deceases/ hides the expected heat-signatures from an explosion. The thick weathered overburden of soft material, which are common geology in tropics, absorbed seismic energy, providing ground conditions which will be non-productive for SAMS monitoring. OSI needs to develop new strategies which are independent of climatic conditions and signatures that are not very time critical as SAMS. Seismomagnetic changes caused by a nuclear explosion needs to be considered thoroughly as an answer for this issue.
T2.1-P14. Power of Imagery

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The 2014 Integrated Field Exercise (UFE) scenario and play provided a tremendous example of the power of imagery when it comes to identifying areas where changes to the surface have occurred. In the run up to the IFE the CTBTO procured high resolution satellite imagery to be used as a possible data inject for both visible and 8-band formats. Our poster shows the “what if” of utilizing the full power of imagery to the IFE scenario. The scenario team controlled the data available to the inspection team and Operations Support Centre from open and provided sources to images to those taken prior to May 2014. This was to prevent the Inspection Team from applying the change detection technique to the Inspection area and reveal the modification constructed for the IFE in the first days of the exercise. If such imagery were allowed it was felt that the exercise would have focused too quickly on these areas and lessened demonstration of integration and the synergy of using all of the techniques in a synergistic way to locate the relevant sites.

T2.1-P15. SAUNA On-Site Inspection Noble Gas Equipment: System Design and Usage During the 2014 Integrated Field Exercise

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A high throughput system for processing and detection of radioxenon for on-site inspection (OSI) purposes has been developed at FOI during the last years and here the system design, performance, and experience from operation during the 2014 Integrated Field Exercise (IFE) will be presented. The prototype was delivered to CTBTO for training of operators and initial testing in the beginning of 2014 and then used during the IFE. An OSI puts a high demand on the performance, level of automatization, user interface, and sample traceability of the system. An OSI also poses many challenges for the processing and analysis of sub-soil noble gas samples; many samples per day that might contain high levels of Rn, CO₂ as well as other gases have to be processed and measured with a high sensitivity. To simplify the use an automatic sample scheduler and an integrated analysis tool for rapid assessment of samples were developed.

T2.1-P16. Smart Tag for the Chain of Custody of On-Site Inspection Samples

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During an OSI, ensuring the chain of custody of the samples collected in the field is of paramount importance. The labelling of the samples should be easy to use, reliable, resistant to hard weather conditions and should be readable in the OSI laboratory. The actual methodology for the chain of custody implies that the labels of the samples are 2D adhesive barcode, attached to the samples packaging. The barcode is an informative system that needs a pre-existent database for the insertion of the metadata. We propose a new approach for the labelling of the samples with smart plastic tags, that contain all the metadata of the sample and could be read by a optical device. They can also provide authentication features as they are tamper-evident.
T2.1-P17. The 2014 Integrated Field Exercise: A Successful Platform to Advance On-Site Inspection Related Technologies under Field Conditions

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Late last year, the CTBTO carried out the largest field activity conducted by the Organization since its inception, in the Hashemite Kingdom of Jordan, the 2014 Integrated Field Exercise (IFE). The IFE required focused, cross-divisional cooperation and effort within the Commission to further develop OSI equipment, techniques and processes towards operational status. The exercise was an important milestone in the continuing build-up of OSI capabilities and clearly demonstrated the considerable progress made by the Commission since the previous IFE in 2008 in Kazakhstan. The success of 2014 IFE has subsequently provided the Commission with renewed vigor and focus in its efforts to finalise the OSI regime in support for the entry into force of the CTBT. The poster provides information on the scope of the IFE and presents key planning and implementation aspects of this four-year project. Furthermore, the poster highlights advances made in OSI sciences and technologies as a result of this project and essential lessons identified.

T2.1-P18. The Seismic Aftershock Monitoring System (SAMS) for On-Site Inspection: Experience from the 2014 Integrated Field Exercise

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The Seismic Aftershock Monitoring System (SAMS) has the aim to detect and localize small aftershocks in the vicinity of a possible explosion within an inspection area (IA) of an OSI. The success of SAMS depends on the main elements, hardware, software, deployment strategy, the search logic and not least the effective use of personnel. All elements of SAMS were tested and improved during the Built-Up Exercises (BUE) which took place in Austria and Hungary. The 2014 Integrated Field Exercise (IFE) provided more realistic climatic and hazardous terrain conditions with limited resources. Significant variations in topography of the IA of the IFE in the mountainous Dead Sea Area of Jordan led to considerable limitations which were not expected from experiences made during BUE. The strategies employed and experience learned in the field as a result of this exercise will be addressed in this presentation. Reliable and precise network metadata were identified as crucial to ensure the necessary accuracy of epicentre locations. Best practice for seismometer installations under different conditions could improve the data quality and facilitate the work of inspectors. Strengths and weaknesses of SAMS elements will be presented and concepts on how to eliminate the most important problems for future OSI exercises will be discussed.

T2.1-P19. Use of Airborne MSIR During the 2014 Integrated Field Exercise: A Resident Observer’s Perspective

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Airborne Multi-spectral and Infra-Red (MSIR) imaging was deployed during the 2014 Integrated Field Exercise (IFE) and data were collected, analysed and used. The author attended the IFE as an observer when the MSIR suite was deployed. Observations and thoughts on the use of MSIR will be presented.
T2.2-O1. Getting Closer to Surface Ground Truth Zero (GT0): Enhanced Geo-Positioning and Geological Site Characterization of Underground Nuclear Test Sites such as in the Democratic People’s Republic of Korea Using Openly Available Geospatial Tools like Google Earth

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This presentation describes a new holistic approach that enhances understanding of underground nuclear test sites, illustrated by the Democratic People’s Republic of Korea exemplar, including the geospatial context of the previously recorded event locations and their geologic setting. The “real world” geo-positional accuracy (beyond that possible using only relative re-location) can be brought to within a few hundred metres of actual locations (particularly in areas of high topographic relief) through combination of the seismic data with openly available geospatial tools like Google Earth, augmented by reasoned analysis of additional commercial satellite imagery (acquired both pre-, and post- test). That improved precision effectively meets the criteria for ground truth zero (GT0) in a way not previously obtainable by other applicable remote methodologies when surface disturbances are lacking for tunnel tests. Moreover, such refined geo-positioning provides a more accurate understanding of the likely host rock through geomorphometric correlation with openly available geologic map data. Finally, the topographic elevation data that is derivable from such geospatial tools also provides an empirical basis for determining the likely overburdens associated with each event (and therefore also the likely vertical depths of burial) for more precise seismic energy release derivations (given the recorded seismic moments of those events).

T2.2-O2. Improving Nuclear Verification Technologies and Regional Cooperation Using a Hypothetical Event: A Common Exercise in the 2014 East Asia Regional National Data Centre Workshop

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The East Asia Regional NDC Workshop (EARNW) has been held every year since 2012 for the purpose of capacity development and cooperation of the NDCs in the East Asian region. Using a hypothetical event of interest, a common exercise on waveform (SHI) and radionuclide data analyses in conjunction with atmospheric transport modelling (ATM) was conducted prior to and results discussed at the workshop. The authors designed and organized the common exercises for the EARNW 2014 held from 29 July to 1 August 2014 in Ulaanbaatar. A real chemical explosion at a mine in the Democratic People’s Republic of Korea in 2011 was used to construct the hypothetical event scenario. The participating NDCs had to identify this explosion by estimating the release time and the possible source region of fictitious radionuclide observations. This was done with isotopic ratios and ATM backward tracking. Real noble gas data observed at the IMS stations and artificially prepared particulate data were combined and distributed as the fictitious radionuclide data for this exercise. Seismological
analysis of the real event was carried out by the SHI experts—either subsequent or in parallel to the radionuclide analysis.

T2.2-O3. Noble Gas Background and Response of the CTBT Radionuclide Monitoring System to Nuclear Accidents

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Nuclear reactors and radiopharmaceutical facilities are responsible for large portions of nuclear signatures. The emissions being substantially dependent on type of production facility is a challenge to CTBT but can be minimized by measuring emissions directly at the facility and problem of source location addressed. Although radionuclide stations detect radionuclides, composition/activity levels may be typical to the stations and demonstrates the importance of understanding the global radiological background. The response to nuclear test/accident by CTBT demonstrates high technical standard. E.g. CTBTO’s radionuclide network made a significant detection of radioactive noble gases attributed to the Democratic People’s Republic of Korea (DPRK) on 12 February 2013. The detection was made in Takasaki, Japan, 1000 km from the DPRK test site. Lower levels were also detected in Ussuriysk, Russian Federation. Xenon-131m, xenon-133 identified, provided reliable information on the nuclear nature of the source. During the Fukushima power plant accident on 11 March 2011, 35 radionuclide stations provided information on the spread of radioactive particles and noble gases from the plant. The CTBT data/tools were useful to predict the global dispersion of radioactive materials. The sharing of CTBT data with international organizations such as UNSCEAR, WHO and IAEA has been beneficial because reported radionuclide ratios were used as an input to assess public exposures.

T2.2-O4. Radiation Situation at the Places of Peaceful Nuclear Explosions in Kazakhstan

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The Republic of Kazakhstan is a unique state combining its modern nuclear-free status with a serious nuclear past. There is a large number of radiation-hazardous objects of various types throughout the territory of Kazakhstan: the sites of nuclear testing, research and energy nuclear plants, organizations and plants of uranium mining and processing industry, oil fields. The particular public attention is directed to the places of nuclear explosions. For several decades, a significant amount of underground nuclear explosions (UNE) have been made on the territory of Kazakhstan. The series of peaceful nuclear explosions was performed for solving the number of national economic problems: Azgir test site, the “Lira”, “Mangystalak”, “Meridian”, “Batholith”, “Region” facilities. The paper presents the main results of the investigations performed at the locations of peaceful nuclear explosions. The areas of anthropogenic radioactive contamination of equipment and soil were identified during the survey at some sites. Currently, the radiation situation in the territories and settlements adjacent to the places of peaceful nuclear explosions is normal. All objects of peaceful nuclear explosions are radiation dangerous and require constant monitoring at the state level. The most probable mechanism of threat is the spreading of radionuclides from groundwater.

T2.2-O5. The 2013 National Data Centre Preparedness Exercise: A Complex Scenario for Multi-Technology Analysis

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National Data Centre Preparedness Exercises (NPE) are regularly performed dealing with fictional cases of potential Treaty violations to practice the combined analysis of all CTBT verification technologies. The discussion of results at NDC Workshops enhances the mutual exchange of information between NDC and also with the CTBTO. The scenario of the 2013 NPE was the most complex so far. A fictitious accusing State
Signatory pointed to a series of (simulated) radionuclide findings at IMS stations in Europe/Asia and postulated a connection with detections of a supposed seismic event which occurred within the territory of the fictitious state of FRISIA in Central Europe on 4 September 2013. The seismic event was not included in the REB. The potential connection between the waveform and simulated radionuclide evidence remained unclear for the participants. The verification task was to identify the waveform event in the given tempo-spatial domain and to investigate potential sources of the simulated radionuclide findings. Finally the potential conjunction between the sources and the CTBT-relevence of the whole picture had to be evaluated. The overall question was whether requesting an On-Site-Inspection in FRISIA would be justified. The disclosure of the 2013 NPE indicated a false-positive scenario with completely unrelated causes of the reported signals.

**T2.2-O6. Towards a Physical Understanding of the mb:Ms Event Screening Criterion**

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mb:Ms is one of the four current experimental provisional event screening criteria applied by the International Data Centre. The use of mb:Ms, either for screening or as a discriminant, has a long history based on the empirical observation that for a given body-wave magnitude, mb, earthquakes tend to have a larger surface-wave magnitude, Ms, than underground explosions. However, the physical basis of the criterion is still not fully understood, as shown by the three North Korea announced nuclear tests, which have Ms values higher than other explosions with similar mb. Here I investigate, using historical explosion magnitudes and International Monitoring System recordings of the Democratic People’s Republic of Korea explosions, some of the possible controls on the explosion mb:Ms population such as explosive yield, source depth, and P wave attenuation, and suggest avenues for future research.

**Poster Presentations**

**T2.2-P1. A Summary Report of Atmospheric Transport Modelling and Radionuclide Analyses of the Common Exercise in the East Asia Regional National Data Centre Workshop 2014**

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A summary of ATM and radionuclide data analysis of the 2014 East Asia Regional NDC Workshop common exercise is presented. The exercise scenario was that CTBT-relevant radionuclides released from a hypothetical target event were detected in particulate and noble gas samples at Takasaki station (RN38), and the target event was inferred using estimated explosion time from La-140/Ba-140 ratio in the particulate samples. The possible source area was determined through ATM backward tracking of Xe-133. Real observation noble gas data by the certified IMS stations and artificially prepared particulate data were used as the fictitious radionuclide data in this exercise. Five NDCs from the Republic of Korea, Mongolia, Philippines, USA and Japan participated in the exercise. The Canadian NDC informally participated after the workshop. The analysis results of the radionuclide data by the participating NDCs were evaluated by comparing with the prepared values for the particulate and IDC/RRR for the noble gas. The results of estimated explosion time were evaluated by comparing to the set value. Released Xe-133 activity from the event and the observable radioactivity concentration of Xe-133 at the IMS station were compared among the reported ATM results.
T2.2-P2. Accuracy Analysis of the CTBTO Nuclear Test Detection Scale and Improvement in the Korean Peninsula

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If the Democratic People’s Republic of Korea (DPRK) is trying to conceal their nuclear development capability, by conducting low-yield nuclear tests, there is the possibility that the CTBT monitoring system will not detect them. A recent example is the event that occurred in 2010. Between 13 and 23 May 2010, four radionuclide surveillance stations, in the Republic of Korea, Japan, and the Russian Federation, detected xenon and xenon daughter radionuclides in concentrations up to 10 and 0.1 mBq/m³ respectively. These radionuclide observations were consistent with a DPRK low-yield nuclear test on May 2010, even though no seismic signals from such a test have been detected. But at that time a few low-magnitude (1.39–1.93 or equivalently low-yield) events occurred around the DPRK’s nuclear test site at that time.

T2.2-P3. An Atmospheric Release of La-140 to Simulate a Small-Scale Vent from an Underground Nuclear Explosion

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Researchers have performed an experiment to simulate the near-field deposition pattern of radionuclides released in a small-scale vent from an underground nuclear explosion. High purity lanthanum oxide powder was activated in the Washington State University research reactor to produce short-lived La-140. The particulate source material was injected into the atmosphere using a CO₂ gerb (“air cannon”) in the Yucca Flats area of the Nevada National Security Site. The experiment successfully produced a narrow ground plume extending ~1.5 km downwind from the release point, with sufficient activity to compare and contrast several techniques of gamma radiation survey, and environmental sampling followed by gamma assay in a field laboratory. The techniques studied are relevant to methods planned for use by an on-site inspection (OSI) team under the verification regime of the CTBT. This work will present details and final results of the experiment, including the source production, transport, release, sampling, and survey, and will present lessons-learned that are relevant to the conduct of an OSI.

T2.2-P4. Application of the Local Seismic Observation Data for the Common Exercise in 2014 East Asia Regional National Data Centre Workshop

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As a part of East Asia Regional NDC Workshop 2014 Mongolia, the common exercise took place in regards to event location and discrimination of the seismic event presumed mining explosion near the China–Democratic People’s Republic of Korea border. This event was so small (ML = 2.0) that only two seismic stations, KSRS and USRK, could detect seismic signals in IMS seismic observation network. Interestingly, one IMS Infrasound station, I45RU, detected infrasonic signal from this small event. On the other hands, non-IMS local seismic network data was available such as NECESSArray (NorthEast China Extended Seismic Array) project, which had deployed seismometers over North-Eastern China as Japan–China–US joint academic project at that time, and Korean local data kindly provided by KIGAM. Some participants of common exercise found that signals from this event were detected at many stations in such non-IMS network, and it indicated that these
local/regional seismic data could contribute largely to determine more reliable event location. IMS seismic network is not designed for detecting small-scale nuclear test far less than 1 kt. Therefore it seems to be effective to use non-IMS observation data near hypocentre for detecting such a small event presumed man-made explosion. In this presentation, we would report on our analysis result.

**T2.2-P5. Atmospheric Transport Modelling Confining Possible Origin of East Asian Radionuclide Detections in May 2010**

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Remarkable activity concentrations of Ba/La-140 occurred at IMS radionuclide stations JPP37 (Okinawa) and RUP58 (Ussuryisk) mid of May 2010. In those days also an elevated Xe-133 level was measured at JPX38 (Takasaki). Additional regional measurements of radioxenon were reported in the press. The radionuclide analysis gives evidence for the presence of a nuclear fission source between 10 and 12 May. Backward atmospheric transport modelling (ATM) with HYSPLIT driven by 0.2° ECMWF meteorological data for the IMS samples indicates that, assuming a single source, a wide range of source regions is possible including the Korean Peninsula, the Sea of Japan (East Sea), and parts of China and the Russia Federation. Forward modelling for various source hypotheses complements this picture. Further confinement of the possible source location can be provided by atmospheric backtracking for the assumed sampling periods of the reported regional xenon measurements. New studies indicate a very weak seismic event at the test site in the Democratic People’s Republic of Korea on early 12 May 2010. Forward ATM for a pulse release caused by this event shows good agreement with the observed radionuclide signature. Nevertheless, the underlying nuclear fission scenario remains quite unclear and speculative even if assuming a connection between the waveform and the radionuclide event.

**T2.2-P6. Dating a Nuclear Event Based on Isotopic Ratios**

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Nuclear event zero time is one of the key topics when detecting radionuclides in a sample. One can calculate the time based on parent-daughter relation, such as La-140/Ba-140, Nb-95/Zr-95, Y-92/Sr-92 ratios. Alternative method comprise understanding the nuclear phenomena and by comparing independent (no parent-daughter relationship) isotopes to each other. Due to fractionation, it would be beneficial to compare independent isotopes that are of sample element. Result of the study would be comparison of dating accuracy by different data source and providing of standard nuclear data tables that would enable quick assessment of zero time for different kind of situations like nuclear test, nuclear reactor release or fissionable target irradiation release. The results could be used directly for example in CTBTO sample dating and sample source characterization.

**T2.2-P7. Detection of the 2006 Explosion in the Democratic People’s Republic of Korea by Small-Aperture Array “Mikhnevo” Using Waveform Cross Correlation**

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Three underground tests conducted by the Democratic People’s Republic of Korea in 2006, 2009 and 2013 were measured by small aperture seismic array “Mikhnevo”, which has been operated by the Institute of Geosphere Dynamics since 2004. This array is designed for the purposes of regional seismic monitoring. It has aperture of approximately 1 km and includes ten vertical and two 3-C stations. Sampling rate is 200 counts per second. Automatic processing includes beamforming (azimuth and slowness values for the preset detection beams cover the range of regional and teleseismic body waves), filtering and detection by standard STA/LTA procedure.
Distinct signals generated by the 2009 and 2013 events were detected. The 2006 event was not detected by standard procedure (detection threshold was STA/LTA = 3.5) and we applied waveform cross correlation (matched filter) in order to improve signal-to-noise ratio (SNR). Multichannel waveforms from the 2009 and 2013 signals filtered in various frequency bands were used as templates. The 2006 signal was detected with the cross correlation technique with SNR>4. Therefore, the matched filter technique improves detection capability of a small-aperture array even for teleseismic waves.

T2.2-P8. Discriminating Travelling Ionospheric Disturbances (TIDs) from Underground Nuclear and Large Chemical Explosions Using Combined GPS and Low-Frequency Radio Interferometry Observations

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Recent studies have demonstrated the utility of GPS data collected by the Global Navigation Satellite System (GNSS) for detecting underground nuclear explosions (UNEs), earthquakes, tsunamis, and other large explosive events. In addition, low-frequency radio interferometry data observed by the Very Large Array (VLA) have been shown to capture the signature of the Hunters Trophy UNE conducted at the Nevada Test Site (NTS) in 1992. Both GPS and VLA data sets detected the ionospheric effects of these explosive events as total electron density disturbances. In this study, we investigated the utility of integrated GPS-VLA observations for discriminating the ionospheric signatures of UNEs and large chemical explosions. Specifically, we found that the signatures may be differentiated in both their spectral and anisotropic propagation attributes, which possibly characterize event depths and yields. Additionally discrimination may result the ionospheric phase correction for radio interferometry in the presence of explosion-induced TIDs. These results from complement efforts of the IMS network of ground-based infrasound arrays that seek to characterize explosions based on established correlations between peak acoustic wave frequency and yield.

T2.2-P9. Discussion of a Claimed Explosion on 12 May 2010 in the Democratic People’s Republic of Korea

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Claimed seismological evidence of an explosion in the Democratic People’s Republic of Korea (DPRK), at about 0009 hours on 12 May 2010 (UTC), has been published by Zhang and Wen in Seismological Research Letters (Jan 2015). This is of great interest to those, who had studied the seismicity of the DPRK test site for days prior to May 12 (which radionuclide studies had identified as the time period of the source of anomalous radionuclide signals), and had not found seismological evidence. The data used by Zhang and Wen are from stations in China about 80 to 200 km from the claimed event. But their data are not currently available for open research. We have found some confirming evidence of an explosive event at the claimed time and place, using openly available data. Signals are hundreds of times smaller than those of the small nuclear explosion of October 2006. The fact that such small candidate explosions can potentially be detected is itself remarkable. Estimates of their yield are surely quite uncertain. This presentation, which is associated with a poster giving additional details (see Koch et al. this meeting), will discuss several issues raised by the capability of various networks to detect such tiny explosions.
T2.2-P10. Improving the Ground Truth Locations of Soviet Peaceful Nuclear Explosions

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From the 1960s through the late 1980s, the Soviet Union conducted 122 Peaceful Nuclear Explosions across its territory. These PNEs are now very important to the seismological community as ground truth (GT) events. The PNE locations are widely distributed, thus GT0-1 locations, meaning that the true location is known to within 1 km or better, are used as calibration events for developing seismic velocity models, model validation, seismic discrimination, etc. The monitoring research community generally utilizes PNE locations from Sultanov et al. (1999) as known or verified GT events, though in reality there are errors and some PNEs are indicated as poorly located. We have determined or validated GT0-1 locations for more than 60 of the Soviet PNEs. Some PNE locations published as GT1 or better are found to have larger errors, the greatest of which exceeds 15 km. Our locations were determined using an integrated approach encompassing published literature, internet searches, analysis of open satellite imagery and regional seismic data. In addition, several PNE sites in Ukraine and Kazakhstan were visited allowing GPS coordinates to be obtained in the field.

T2.2-P11. Inverse Modelling Analysis of Xe-131m Measurements over East Asia in April 2013

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We have already applied a formal inverse modelling method to the Xe-133 observations in April 2013. It is a Bayesian methodology and is thus inherently capable to account for uncertainties of model and measurements which must be provided a priori. A source estimate is obtained by optimizing an objective function in a way that the discrepancy between model simulations and samples is minimized on one hand while keeping the estimate compatible with its a priori value on the other hand. Since the cost function expresses agreement of samples with a release originated from a given source location, it can be used for identification of the most plausible source regions in cases where this is not known or uncertain. Now, the method will be applied to the Xe-131m measurements. In addition to using the detections at Takasaki (and a set of non-detections), we will also try to include elevated concentrations from Ussuriysk, derive a suitable source assumption, and determine how well this scenario would be compatible with the other data.

T2.2-P12. Inverse Modelling Analysis of the Radioxenon Detections in Takasaki in April 2013 as a Step Towards Data Fusion

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Our analysis uses source-receptor sensitivities calculated with FLEXPART and ECMWF data on 0.25 degree resolution and an output grid of 20 km resolution. Xe-133 measurements at Takasaki and four surrounding stations are included, with the three significant detections at Takasaki, plus non-detections / not significant detections before and after. The inversion follows a Bayesian approach and minimizes the weighted deviations model: measurement and the deviation from an a priori source term, plus deviation from smoothness. The source is resolved in time and vertically. We are both investigating the scenario where the source is unknown, and a comparison among the cost function values for all candidate grid cells is used to narrow down the possible source region, and a scenario where the test site in the Democratic People’s Republic of Korea (DPRK) is assumed as the source location. In the first scenario, a step towards data fusion is made by overlaying seismic events from a four week time window, ordering these events with the cost function. The method finds the DPRK test site as being among the top 10 events. We obtain a release of $4 \times 10^{11}$ Bq, attributed to a vertical column of about 1000 metres above model surface, lasting for 12 hours in the first half of April 6.
T2.2-P13. Measurement of Cs-137 and Xe-133 in Soil Samples of Douala

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This paper presents an evaluation of U-238, U-235, Cs-137 and Xe-133 in soil samples taken at two sites located in Douala-Cameroon, using gamma spectroscopy based Broad Energy Germanium Detector (BEGe6530). The traces of Cs-137 and Xe-133 discovered in analysed samples call for further investigations to search for the origin of these radionuclides, noting that fallouts from nuclear tests implemented in 1986 in the Sahara desert had probably reached as far as West and Central Africa regions. It is also known that some nuclear tests were carried out in Northern Africa between 1960 and 1996. So far, no research activities have been carried out in Cameroon to assess the impacts of these events.

T2.2-P14. Open Seismic Data Supporting the Occurrence of an Event on 12 May 2010 in the Democratic People’s Republic of Korea

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From several studies in 2012 and 2013 on detections at IMS and other national radionuclide stations, the occurrence of a low-yield nuclear explosion within the Democratic People’s Republic of Korea (DPRK) in April/May 2010 was inferred. The presumed explosion was assumed small, because no seismological evidence could be found, contrary to the case of the announced nuclear explosions in 2006, 2009 and, subsequently, in 2013. Recent work by Zhang and Wen (Seismological Research Letters, January 2015), however, suggested that seismic stations in China indeed recorded signals consistent with such a small event. Intensive search of openly available data from the IRIS Data Management Centre (DMC) was carried out and ten stations operating at the time were identified within a similar distance range as the stations used by Zhang and Wen. Applying classical seismogram analysis and interpretation techniques we identified seismic signals at three stations that are consistent with regional phases from the suggested event near or at the DPRK test site. The phases fit theoretical arrival time predictions as well as P-wave polarization directions, thus supporting the existence of the postulated event. Our study represents an exemplary case for a suspected Treaty violation which could have the potential for an on-site inspection.

T2.2-P15. Registration of Event in the Democratic People’s Republic of Korea on 12 February 2013 by Facilities of Main Centre of Special Monitoring (UANDC)

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The event in the Democratic People’s Republic of Korea on 12 February 2013 was confidently registered by all station of Main Centre of Special Monitoring including primary IMS station PS45. The information about event was processed very quick and forwarded to superior authorities. The notification of operational duty officer about event on the results of processing of digital waveform was made 3 minutes after the arrival of the signal, on the results of processing of analog waveforms, 15 minutes after the arrival of the signal. The estimated magnitude of the event is 5.2 and the event depth is about 1 km. Explosive power estimated in the range of 20–50 kt. It was promoted by the preliminary work on the analysis of the previous two events in the region. Digital waveforms with the signals from the events were taken as reference. For each station, the characteristic identification features was specify and together help us quickly determine the type of event. In addition, to digital waveforms in real time were implemented correlation and polarization detectors.
Global nuclear test fallout, the large scale nuclear accidents at the Chernobyl nuclear power plant (NPP) in 1986 and at the Fukushima Daiichi NPP in 2011 caused a widespread dispersion of technogenic radionuclides all over the world. These events have proven that radionuclides can reach territories from the source even at a distance of 1000 km under favourable meteorological conditions and can be detected by radionuclides “finger prints” which depend on their source. In this work a rapid comprehensive method considering optimization of man-hours of work, materials and including activities such as radiochemistry, alpha-, mass- and gamma-spectrometry techniques combined together for radionuclide determination and assessment source is demonstrated. Alpha spectrometry was performed with the state-of-the-art “Ortec” alpha spectrometer, gamma spectra were recorded by SILENA gamma-spectrometric system with a HPGe detector and radionuclides atomic ratios were measured by a sector field mass spectrometer combined with a high sensitivity APEX sample introduction system. According to Cs-137/Sr-90, Cs-137/Pu-239,240, Pu-238/Pu-239,240 and Pu-240/Pu-239 activity and atomic ratios the contamination origin was determined. It was assessed that global fallout and Chernobyl accident sources prevail in nowadays collected soil samples while Fukushima Daiichi radionuclide fallout influence is not detected. The scheme of working hours optimization is demonstrated.

The aim of this research is to determine the high precision location of the M5.1 nuclear test earthquake in the Democratic People’s Republic of Korea on 12 February 2013 using relocation algorithm of Modified Joint Hypocentre Determination (MJHD) and Double Difference (DD) using IDC-CTBTO, BMKG and global seismic stations respectively. We simultaneously relocated this event using 3 data sets including 2006 and 2009 nuclear test and the seismicity around these three events. We did the precise repicking of the P-wave arrival time in 7 stations in regional scale (Δ≤15 degree) for the first data set. The others data set are the arrival time data from ISC and BMKG for three nuclear tests and the surrounding seismicity in 2012 to 2013. We successfully relocated the event with 7 scenarios of teleseismic and regional relocation. For example, MJHD teleseismic relocation using BMKG arrival data set and 18 selected IDC-CTBTO stations showed the location of 129.0652±0.0505, 41.1814±0.0249 at zero depth. The relocated positions using MJHD and DD are considered better because the smaller value of residual O-C or RMS residual and sum of squared residuals (SSR) after relocation. The results were compared with the location results of previous researchers and analysed using topographic data satellite imagery. Keywords: nuclear test, relocation, MJHD, double difference
T2.2-P18. Scanning and Digitizing of Historical Analogue Seismograms Recorded by Seismic Stations of Kyrgyzstan

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The archive of the Institute of seismology of the National Academy of sciences of the Kyrgyz Republic (IS NAS KR) in Bishkek contains hundreds of thousands of historical analogue seismograms since 1927 from in total 166 seismic stations (permanent and temporary), which have been operated on Kyrgyz territory. The standard equipment at all these stations was Kirnos SKM-3 and SKD seismometers. In the frame of a joint international project on capacity-building for CTBT verification between the IS NAS KR, the Institute of Geophysical Researches of the Committee of Atomic Energy of Kazakhstan (IGR CAE RK) and NORSAR (Norway) historical analogue seismograms of nuclear explosions conducted at different test sites of the world, are scanned and digitized. The project was initiated in 2013 and started in 2014. Until now more than 20 000 seismograms have been scanned with a resolution of 1200 dpi. In addition, more than 3000 seismograms of nuclear explosions recorded by Kyrgyz stations since 1961 have been digitized by IGR CAE RK staff, and then stored in the CSS 3.0 formatted database. This database is widely used for various studies about nuclear test monitoring.

T2.2-P19. Seismological Investigation of the 2013 National Data Centre Preparedness Exercise

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The NDC Preparedness Exercises (NPE) are regularly performed dealing with fictitious Treaty violations to practice the combined analysis of CTBT verification technologies. These exercises should help to evaluate the effectiveness of analysis procedures applied at NDCs and the quality, completeness and usefulness of IDC products. The exercise trigger of 2013 NPE is a combination of a tempo-spatial indication pointing to a certain waveform event and simulated radionuclide concentrations generated by forward ATM based on a fictitious release. The final question was whether the findings are CTBT relevant and justify a request for On-Site-Inspection. The available detections from the closest seismic IMS stations lead to a epicentre accuracy of about 24 km which is not sufficient to specify the 1000 km$^2$ inspection area in case of an OSI. With use of local stations and adjusted velocity models the epicentre accuracy could be improved to less than 2 km, which demonstrates the crucial role of national technical means for verification tasks. The seismic 2013 NPE event could be identified as induced from natural gas production. Similar waveforms and comparable spectral characteristic as a set of events in the same region are clear indications. The scenario of a possible Treaty violation could be disproved.

T2.2-P20. The Role of Infrasound Technology in Meteorite Detection: A Case Study in Sudan

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During the last century, Sudan witnessed numerous falls of meteorite bodies in different parts of the country. The first fall of a meteorite reported in Sudan dates back to 1932; that was a 3.2 kg body known as the Khor Temiki meteorite. The second meteorite fall was in 1966, referred to as the Umm Ruwaba meteorite with a mass of 1.7 kg. The Kingai meteorite, which is the third one, hit the earth in 1976 and weighs 450 g. The fourth one was the 1983 Kidairat meteorite in northern Kordofan, which weighs 100 kg. In 1994 the fifth meteorite fell in New Halfa; it has a mass of 12 kg. The most famous one is the Almahata Sitta meteorite which fell down in the Nubian Desert on 7 October 2008, forming a large fireball, big enough to be noticed by the locals in the
surroundings. The Infrasound detector in Kenya distinguished a sound wave corresponding to 1.1 to 2.1 kilotons of TNT (~1/10 the size of the Hiroshima atomic bomb). The rich history of meteorites falls in Sudan reveals the necessity to introduce meteorite detection technology in the country through the installation of infrasound station as one of the verification regime of the CTBTO.

T2.2-P21. Waveform Analyses Presented at the “Common Exercise” During the 2014 East Asia Regional National Data Centre Workshop

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Technical representatives from 12 NDCs participated in the third (2014) East Asia Regional NDC Workshop held 29 July to 1 August 2014, at Ulaanbaatar, Mongolia. The CTBTO selected a magnitude 2.8 event near the China–Democratic People’s Republic of Korea border for the workshop’s Common Exercise session. Seven teams presented seismic relocation results utilizing the standard Geiger inversion method. They only differed in the selection of seismic stations. Key observations include: (1) the location accuracy is highly dependent on the configuration of the selected seismic network; (2) very impressive location accuracy can be achieved (to within 1 km) when local/regional data are included; hence sharing non-IMS local/regional data would be very helpful; and (3) the Wadati method gives an earlier origin time. The ROK NDC also attempted a whole-cycle analysis, covering the magnitude calculation and yield estimation steps, as well as location based on solely infrasound data. The selection of magnitude-yield formula for this geographic region is not quite settled yet. The need for validated region-specific magnitude-scaling formulae is recognized, thus opening up opportunities for further cooperation among the NDCs. [Disclaimer: The views presented do not necessarily reflect the position of the Department of State or the whole United States Government.]

T2.2-P22. What Can We Learn About Noble Gas Signatures from Field Experiments and Modelling?

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In the absence of performing on-site measurements of noble gases emanating from an actual underground nuclear explosion (UNE), other approaches must be used to understand the nature of radioxenon and Ar-37 signatures that potentially provide a “smoking gun” indication of the occurrence of a UNE. Surrogate chemical tracers either pumped into old explosion cavities or released during a subsurface chemical explosion can simulate some but not all of the processes and influences of the containment regime that are responsible for creating a signature at the surface. However, the results of such experiments used to define computational simulations of UNE-related gas transport processes and containment properties represent one approach to estimating the spatial, temporal and chemical or isotopic character of a noble gas signature. With a combination of tracer experiments and modelling we have made significant progress in understanding how UNEs, their containment and the effects of gas transport in the subsurface are likely to affect signatures that might be observed. LLNL-ABS-666124.

T2.2-P23. Research of the Main Characteristics for Three Explosion Events Based on Explosion Waves

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Three explosion events recorded by stations MDJ and BJT on 9 October 2006, 25 May 2009 and 12 February 2013 were analysed and researched, respectively. Both stations belong to Global Sesimic Network (GSN). The mean ratios of the maximum amplitudes and the power spectrum densities are about 2.3 and 2.7 respectively for
the 2013 event and the 2009 event. The ratios for 2013 event and 2006 are about 10.1 and 13.5, which indicates that the energy released by the 2013 event is about 11.8 times as much as that released by the 2006 event and 2.5 times as much as that released by the 2009 event. The maximum cross correlations were 0.9 and 0.99 for 2013/2006 events and 2013/2009 events in 2–4 Hz, which mean that the 2013 event is highly correlated to the 2006 and 2009 events in the frequency band which the main energy concentrated; that means the relative distances of three events are not long. Comparison of phases had been done to determine the relative location of these explosion events. The results told us that 2013 event lies to the south east of 2009 events.
T2.3-O1. A New, Improved and Fully Automatic Method for Teleseismic Depth Estimation of Moderate Earthquakes (4.5<M<5.5) and an Application to the Guerrero Subduction Zone, Mexico

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We have developed a new, blind and fully automatic teleseismic depth estimation method, insensitive to epistemic uncertainties due to depth-phase picking and identification. It consists of a modification of the cepstral analysis (Letort et al. 2014), which aims to detect surface reflected (pP, sP) waves at teleseismic distances (30°–90°) through the study of the spectral holes in the shape of the signal spectrum. This new method is adapted for complex sources, emergent P-waves arrivals and for complex P-coda showing several phase’s arrivals. We first validate this method in different tectonic contexts (eg. Nepal, Chili, GT5 catalog, worldwide seismicity), using CTBTO arrays and stations from the IRIS network. The use of CTBTO arrays allows us to deal with lower magnitude earthquakes (around M = 4). We then provide an improved view of the Guerrero (Mexico) subduction geometry, by combining new depth estimations with an analysis of the phases reflected on the subduction interface and recorded on the CTBTO arrays. This study shows no important lateral variations of the geometry, suggesting that the lateral variations of Slow Slip Event properties observed for this area by Cavalié et al. 2013, are related to interface frictional property changes.

T2.3-O2. Estimating Depth and Source Characteristics of Nuclear Tests by the Democratic People’s Republic of Korea in 2006, 2009 and 2013 Using Regional and Teleseismic Networks

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The Democratic People’s Republic of Korea (DPRK) conducted underground nuclear explosions on 9 October 2006 (M 4.2), 25 May 2009 (M4.7) and 12 February 2013 (M 5.1). We determined depths and source characteristics of those nuclear tests. The DPRK nuclear tests were recorded by the ASAR, FINES, NVAR, NOA, PDAR, WRA and YKA arrays as well as regional stations. We selected the pronounced coherent spectral nulls from average spectra of pP+P and sP+P stacking five channels for the 2006, 2009 and 2013 nuclear tests. The burial depths for the 2006, 2009 and 2013 tests were estimated at 2.3–2.4 km via pP-P delay times including fundamental-mode Rayleigh wave spectra. The vertically distributed source for the 2006 generated mostly Rayleigh waves with a reverse fault dipping at about 45 degrees, whereas the horizontally distributed sources for the 2009 and 2013 tests with an oblique-reverse faulting were accompanied by SH and Love waves as well as Rayleigh waves indicating that SH and Love waves were attributed to not only release of tectonic stress but also source configuration and source mechanism. Consequently, 2009 and 2013 tests must have been well contained blocking up nuclear debris through long winding drifts not to release radioisotopes to the atmosphere.
T2.3-O3. Infrasound Observations from a Seismoacoustic Hammer Source at the Nevada National Security Site

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As a part of the Source Physics Experiment (SPE) site characterization, Sandia National Laboratories, in conjunction with HK Exploration, deployed a large (13 metric ton) seismo acoustic hammer source at the Nevada National Security Site (NNSS) in December 2014. During early field testing of the hammer source we found that as the mass hit the ground a significant downward deflection of the surrounding surface imparted an observable infrasound pressure wave into the atmosphere. We present results from the early field testing as well as the results from the small-scale experiment at NNSS. The early field testing was conducted in a crane yard in North Las Vegas, Nevada with asphalt at the surface while the test at NNSS was done on alluvium. The alluvium has a higher flexure rate than the asphalt thus allowing better surface deflection and subsequent atmospheric coupling. For nuclear explosion monitoring with infrasound, the ground surface is the source of the atmospheric pressure perturbations and by understanding the source geology we hope to better describe the small-scale waveform characteristics that could be possible diagnostics for underground nuclear tests.

T2.3-O4. MS VMAX: Implementation and Developments of an Operational Tool for Event Characterization at the French National Data Centre

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The surface wave magnitude (Ms) compared to the body-wave magnitude (mb) constitutes a robust discriminant between tectonic earthquakes and underground explosions. However, the use of this discriminant becomes difficult for relatively small magnitude seismic events that do not generate sufficiently large Rayleigh and Love wave amplitudes at teleseismic distances. The MS VMAX magnitude defined by Russel et al. (2006) appears as a better alternative as it does not require a limited frequency range commonly used for the calculation of Ms. The French National Data Centre (NDC) developed an automated MS VMAX evaluation based on the Russel et al. (2006) approach using regional stations and data filtered between 8 and 40 sec periods. Furthermore, this relatively new magnitude can be calculated using different types of sensors (i.e. broadband and short-period), and allows for a better discrimination factor for small magnitude earthquakes (M3.5+). We present the current implementation and developments of the MS VMAX tool at the French NDC. Using a large seismic data set from the Euro-Mediterranean region we show that the MS VMAX method improves event detectability and characterization. Russel et al. (2006), Bull. Seism. Am. 96,2, pp. 665–677.

T2.3-O5. Seismic Vibrations from Wind Turbines and Their Effects on the International Monitoring System Seismometer Array EKA at Eskdalemuir, Scotland

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The UK/Scottish Governments and wind energy industry commissioned research to determine the seismic vibration generated by modern wind turbines. Seismic measurements were made at three separate wind farms with different turbine types. Wind velocity data from the turbines were kindly made available by the farm operators. Turbines generate seismic energy not only at spectral peaks associated with multiples of the blade-
pass frequency, but also at natural resonance modes of the structure. A scaling law is verified from measurements based on the kinetic wind energy at a given hub-height, and the area swept by the blade. A “worst-case” turbine spectrum is constructed that accounts for seismic vibration from both blade-pass and structural resonances. A “sensitivity curve” dependent on frequency and distance is developed for EKA considering the performance of an optimal detector for seismic signals from small underground explosions. Finally, a model is constructed that predicts the effective cumulative seismic vibration at EKA from wind turbines, given the distance, the hub-height, and blade diameter (all parameters required for planning approval). The cumulative seismic vibration from existing, consented, and future wind farm developments in the vicinity of EKA can be assessed by authorities against an agreed threshold to safeguard the IMS station.

**Poster Presentations**

**T2.3-P1. Simulation of Point Explosion’s Seismic Energy by Means of the Frequency Spectrum of Body Waves**

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We solve the inverse problem, which is aimed at modelling a discrete frequency spectrum of seismic body waves generated by artificially weak point explosion or a natural earthquake (M ≤ 4). We propose a spherical model of the hollow area of the point explosion and used a well-known analytical method for modelling the hydro-mechanical oscillations of a liquid drop. Innovation in the applied work is the use of a complete solution of the radial Euler equation. Such a modification of the classical scheme, which uses only an internal solution, is mathematically quite correct, because it means virtuality of seismic source’s elastic oscillation. As a result, with the help of the discrete spectrum of seismic body waves can be determined the linear parameters and total energy of point explosion (weak earthquake) that is approximated as a hollow body with spherical shape.

**T2.3-P2. A Rupture Process Study of the 28 March 2005 Nias Earthquake Using Joint Inversion Method of Teleseismic, Geodetic and Tsunami Data Set**

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The large 28 March 2005 Nias earthquake (Mw 8.6) occurred on megathrust of the Sumatra subduction zone and generated a small tsunami. We estimated the slip distribution of the 2005 Nias earthquake using joint inversion of teleseismic, geodetic, and tsunami waveforms. We used five tide gauge stations around Indian Ocean, nine GPS stations from Sumatran GPS array (SuGar), and 15 seismic station of IRIS array network to perform the joint inversion. We assumed that the fault length was 300 km and the width was 150 km. The result shows that the maximum slip amount of 12.37 metres was found below Nias Island. The large slip area of the 2005 Nias earthquake did not reach the Sumatra trench. The rupture area of the 2005 Nias earthquake was similar to that of the 1861 earthquake. The total seismic moment was calculated to be $1.08 \times 10^{22}$ Nm (Mw = 8.6) by the slip distribution.
Acoustic Waves from Atmospheric Nuclear Explosions Recorded by Infrasound and Seismic Stations of Kazakhstan

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First infrasound stations in the USSR were installed in 1954. By 1991, the network consisted of 25 infrasound stations, 3 of them were located on the territory of Kazakhstan. These are stations in Kurchatov, in Borovoye Observatory, and in Talgar Observatory. A microbarograph in Talgar Observatory was installed in 1962; it recorded large number of air nuclear explosions conducted at Semipalatinsk Test Site and Novaya Zemlya Test Site. In addition, the archive of CSE IPE RAS contains large amount of records of atmosphere explosions (1961–1962) recorded by seismic stations at distance 330–3600 km away from the Test Sites; these records show acoustic signals. Historic analogue records of microbarograph and seismometers with signals related to acoustic wave were selected. The selected records were digitized, and a database for acoustic signals from nuclear explosions was created. The peculiarities of the wave pattern and spectral content of air wave were investigated as well as regularities of dependence of amplitudes and periods of acoustic wave on explosion yield and distance. The created database can be used for different monitoring tasks, such as calibration of infrasound stations, discrimination of nuclear explosions, precision of nuclear explosions parameters, determination of explosion yield and other.

Analysis of Events Recorded at Seismic and Infrasound Stations in International Data Centre Operations

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A system based on four technologies has been established to monitor compliance with the CTBT. Three of them, so called waveform technologies (seismic, hydroacoustic and infrasound), help to detect and locate events. Infrasound technology, based on detection of low frequency acoustic waves is the most appropriate for detection of atmospheric sources. Routine analysis of infrasound data started in 2010 in International Data Centre (IDC) operations. IDC analysts validate and improve automatic system solutions and identify events missed by the automatic system. Since February 2010 the IDC Reviewed Event Bulletin (REB) included almost 6500 infrasound events, about 50% of all validated infrasound events. Majority of infrasound events published in the REB contain phases observed at seismic stations. Examples of these events are large atmospheric events (e.g. 2013 Chelyabinsk fireball), volcanic eruptions (e.g. Mount Kelud February 2014), mining blasts or earthquakes (e.g. Tohoku 2011). This presentation will provide a summary of events recorded at both seismic and infrasound networks of the International Monitoring System (IMS). Results of this study may help analysts to decide about correct associations of infrasound phases and improve location of small seismic events with infrasound associations.

Broadband Hydro-Pressure Variations Recorded by DONET at Tsunamigenic Earthquakes

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Cabled offshore observatories have been deployed since the 1970s in Japan, which traditionally consist of ocean-bottom seismometers (OBSs) and pressure gauges (PGs) with high sampling data set. This kind of observatory allowed us to examine the mechanism of tsunami generation directly in the tsunami source. In the conventional offshore observatory, however, OBS and PG are located a few kilometres away, and moreover there are some uncertainties with orientation of OBS. These difficulties complicate quantitative analysis of OBS and PG records. Recently developed DONET has superior advantages, in which OBS and PG are deployed at the same location, broadband observation is performed by various geophysical sensors, and vertical component of OBS is mechanically controlled by gimbals after the deployment. This study aims to evaluate the hydro-pressure
variations during the tsunamigenic earthquakes in terms of the in-situ measurements. Our present targets are the 2011 Tohoku earthquake and its related large aftershock, which were approximately 800 km away from the DONET stations. We analysed the hydro-pressure variations recorded by differential pressure gauges (DPGs) and hydrophones in addition to PGs. As a result, OBS records suggested that dominant and long-lasting hydro-pressure fluctuations recorded by DONET were ‘forced oscillations’ rather than ‘hydroacoustic waves’.

**T2.3-P6. Characteristics of the Mw 7.1 Double Subduction Earthquake in Northern Moluccas, Indonesia, 15 November 2014**

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Based on the tectonic setting in northern Moluccas, there is double subduction called Sangihe–Halmahera subduction zone. The historical earthquake data recorded that between the years 1600–2007 have occurred around 2800 earthquakes and 10 tsunamis in this double subduction area. On 15 November 2014 an earthquake occurred with Mw 7.1 (USGS) in this double subduction zone. This earthquake generated small tsunami with maximum height was 9 cm that recorded at Jailolo, Halmahera. To find out more detail about the characteristics of this earthquake we perform the joint inversion using teleseismic and strong motion data. We used the teleseismic data from Indonesia regional network, GFZ network, and CTBTO network. Meanwhile for strong motion data we used accelerometer array network of InaTEWS. By the calculation, we get the results that this earthquake has an oblique type (strike 30°, dip 30°, and rake 120°), the source duration was 18 sec, the fault length was 70 km, and width was 15 km, with seismic moment Mo = 2.78 × 10^{-19} Nm (Mw = 7.0). The maximum slip was 6.3 metres with average of slip was 4.1 metres. This earthquake occurred in the boundary between Sangihe and Halmahera subduction zone.

**T2.3-P7. Earthquake Swarms in Greenland**

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Detecting small earthquakes is a challenge in large, sparsely populated regions such as Greenland, where local seismographs are few and far between. Earthquake swarms consisting of tens to hundreds of shallow earthquakes with magnitudes less than 4 occur in Greenland even though it is a tectonically stable, intraplate environment. The enormous distances between events and detecting stations are a challenge in the analysis. The seismograph coverage of Greenland has vastly improved since the international GLISN-project was initiated in 2008, but still it is a common situation to have less than five seismographs located within 1000 km of an event. Some of the larger earthquakes in the swarms, with a magnitude between 3 and 4 are detected by the IMS on the large seismograph arrays located up to 65 degrees away. The analysis of Greenland earthquake swarms is significantly improved by including IMS waveform data as well as SEB phases. The swarm earthquakes have very similar waveforms, so results obtained for the larger events can be used as a priori knowledge for the rest. One of the major challenges is the lack of local velocity models.

**T2.3-P8. Explosion Source Calibration Using a Large Data Set from Neighbouring Quarries**

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Calibration of explosion sources, via quarry blast monitoring is an important seismological ingredient for establishing a regional seismic nuclear discriminant. To create this calibration we are fortunate to have access to
a sequence of 1790 three component recordings of quarry blasts, shot from March 2002 to January 2015. The centroid of these blasts has an estimated location 36.3E and 29.9N. All data are recorded at the Israeli NDC, HFRI, located at 30.03N and 35.03E. For each component we edit the data set to remove anomalously large amplitudes and then Butterworth bandpass filter all traces from 0.5 to 10 Hz. Initially, we compute a mean trace without any gain correction. This averaging results in very well defined P, S and surface waves. Unsurprisingly, due to large variations in explosion yield and location variation, the computed standard deviation trace is largest in the neighborhood of the P and S arrivals. We have binned the complete set of arrivals and have grouped them according to maximum amplitude. For each bin we perform a singular value decomposition to extract the most common signal and for all components compare these signals to determine the relative scaling of the P, S and surface waves.

T2.3-P9. Growth and Attenuation of Seismic Noise Generated from a 12.0 MW Wind Farm

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Development of renewable wind-generated energy is being pursued by many signatory States of the CTBT as an alternative to traditional energy resources. In Canada, wind power capacity has increased by ~400% in the last 20 years. As wind power generation facilities increase in size and number, encroachment upon International Monitoring System (IMS) stations can occur, wherein vibrational and/or infrasonic emissions of the turbines can become an undesirable source of noise within the monitoring band. In an effort to better understand, identify and characterise the noise of modern megawatt wind turbines, a multifaceted study to monitor the seismic and infrasonic noise of a megawatt-class wind facility was conducted between May 2013 and 2014. Four temporary seismoacoustic monitoring stations were deployed to passively record the noise generated by four Vestas 3.0 MW V90 wind turbines of the Summerside Wind Farm on Prince Edward Island, Canada. Analysis of the data identified several vibrational modes within the 1–10 Hz monitoring band visible up to a 10 km distance. Fitted spectral growth and attenuation curves for the turbines have been computed, providing estimates to the scale of separation required to safeguard a hypothetical monitoring station from observing the facility.

T2.3-P10. Identification and Analysis of Infrasound Signal from Earthquake in Romania Using Ukrainian National Data Centre Seismoacoustic Network on 22 November 2014

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An earthquake M5.5 occurred in the Vrancea region (Romania) on 22 November 2014 and bolide exploded over Romania 7 January 2015. Epicentres of both events were almost in the same area. Two Ukrainian NDC infrasound arrays and IMS seismic array PS45 recorded both signals at distances of 330 km and 570 km. Infrasound array MAAG-2 recorded two classical components of infrasound signal from earthquake: the first one formed by the motion of the ground surface in the placement of the array and the second one formed in the epicentre of the earthquake and came by atmospherics channels. The signal from explosion of bolide made a series reflections in the atmosphere. The use of additional data from the IMS stations (I26DE and I43RU) helped to determine the trajectory of the bolide and the epicentre of the explosion. Estimated equivalent of bolide explosion was about 5–10 tons TNT. For both types of signals obtained spatial, spectral, correlation and power estimations.
T2.3-P11. Induced Seismicity Properties as a Tool to Discriminate Natural Earthquakes from Other Types

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Induced seismicity is earthquake activity resulting from human activity that causes a rate of energy release, or seismicity, which would be expected beyond the normal level of background seismic activity. Although researches are still being carried out on the detailed causes of induced seismicity, there are many different applications associated with induced seismic activity. In addition to the subsurface stresses, fluid pressures play a key role in causing seismicity. The imbalance of natural in situ earth stresses will cause an occasional earthquake. Reservoir induced seismicity, hydro fracturing, gas injections and mining are some most familiar of manmade earthquakes while explosions are another type of these events. Discrimination of natural and induced earthquakes is not so simple. Here some cases of reservoir induced earthquakes are studied based on private networks and properties of them are listed. Occurring under dam lakes, very low depths, close relation and dependence on water level of the lake, happening like as tremors with high rate and small magnitude, oscillating with water level changes and affecting seismicity parameters of the area are some properties which give the ability of discriminating these kinds of events from natural tectonic events.

T2.3-P12. Joint Efforts of the Kazakhstan National Data Centre and Lamont-Doherty Observatory of Columbia University, USA, on Preserving the Archives of Historic Seismograms of Nuclear Explosions

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Scientists in Kazakhstan have worked since 1998 to preserve archives of historic seismograms of nuclear explosions, going back to 1961, recorded by stations located on territory of the USSR. During 1998–2000 the work of data collection, scanning, and digitizing, was done by CSE IPE RAS, in close cooperation with Lamont-Doherty Observatory of Columbia University, USA (LDEO). During 2005–2011 this work, which mostly involved the processing of photographic recordings, moved to IGR RK, and was funded by Kazakhstan. Since 2012 the work has been partially supported by the Norwegian Seismic Centre (NORSAR) and LDEO. LDEO has provided software that enables digitization to be expanded to pen-and-ink recordings, and has worked with IGR to obtain the amplitude-frequency responses of seismometers developed and installed at the USSR seismic stations, and to create a modern database of digital waveforms. Currently, the database of nuclear explosions contains 7000 records at regional and teleseismic distances. More than 10 000 seismograms of nuclear explosions (in the atmosphere, under water, and underground) are kept in different archives in Central Asia and have been scanned with resolution 400–1200 DPI. The KNDC staff has given several training seminars on digitizing of analog historical seismograms for the specialists from Central Asia.

T2.3-P13. Modelling of Earthquake Source Physics as a Tool of Most Real Method for Earthquake Modelling

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Seismic waves can be represented as elastic perturbations propagating within a medium, originated by a transient disequilibrium in the stress field. The properties of seismic waves are ruled by the physics of elastic bodies, and are studied using the formalisms of elastodynamic theory. Solving the equation of motion helps us to reach a system of modelling including the physics of the source where the modelling can be updated with the most real conditions of the faulting. Here some analytical and numerical methods are combined presenting the physics of the source where it is modeled as a double-couple. The modelling is performed in all 1D, 2D and 3D dimensions.
covering all properties of far point source, near extended source and full path effects of the propagating waves from source toward the recording site. Some real cases are simulated and results are presented comparing the synthetic signals with real ones. In this research a hybrid 2D (Modal Summation–Finite Difference) and a hybrid 3D (Modal Summation–Ray tracing–WKBJ approximation) and finally a hybrid modelling combining modal summation–finite difference and Green function are tested and results are presented for Bam 2003 and Tehran 2009 critical earthquakes inside Iran active zone.

**T2.3-P14. Moment-Tensor Calculation for the Vega, Colombia, Mw 7.2 Earthquake**

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On 30 September 2012, an earthquake of magnitude Mw 7.2 occurred at the depth of ~170 km in the south east of Colombia. This seismic event is associated to the Nazca plate subduction converging eastward relative the South America plate. The seismicity distribution recorded by the National Seismological Network of Colombia (RSNC) since 1993 shows a segmented subduction zone with varying dip angles. The earthquake occurred in a seismic gap zone of intermediate depth. We estimated the moment tensor, the centroid position, and the source time function. The parameters were obtained by inverting waveforms recorded by RSNC at distances 100 km to 800 km, and modeled at 0.015–0.035 Hz, using two 1D crustal models, taking advantage of the ISOLA code (Zahradnik and Sokos, 2008 and 2013). The DC-percentage of the earthquake is very high (~95%). The focal mechanism is mostly normal, hence the determination of the fault plane is challenging. An attempt to determine the fault plane was made based on mutual relative position of the centroid and hypocentre (H-C method). Studies in progress are devoted to searching possible complexity of the fault rupture process, quantified by multiple-point source models. We evaluated two sources in the frequency range 0.01–0.09 Hz.

**T2.3-P15. Observation of a Series of Marine Explosions Through Seismic, Hydroacoustic and Infrasound Technologies**

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Reviewed IDC bulletin (International Data Centre / CTBTO) shows a seismic event on 2012, June 17 near Petropavlovsk (Kamchatka, Russian Federation). This event is composed of a series of six events occurring on a 20-minute period. These events associate data observed on IMS stations: infrasound on IS44, seismic on PS36, and hydroacoustic on HA11-Wake hydrophones. Our poster details analyses of this series of events: azimuths and arrival times are measured and interpreted, and a new location is performed and compared to IDC-REB location. A cepstral analysis of hydroacoustic phases demonstrates that these events are due to marine explosions. Fine labelling of cepstral peaks combined to charts available in literature allow us to estimate both yield and depth of the explosions.

**T2.3-P16. Study of Historic Seismograms of Nuclear Explosions from Novaya Zemlya Test Site by Data of the USSR Stations**

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The RSE IGR has created a database of the digitized records (720 seismograms) of nuclear explosions conducted at Novaya Zemlya Test Site and recorded by the USSR stations at epicentral distance from 1270 to 4410 km. The digitized seismograms allowed investigating the parameters of nuclear explosions conducted in different environment (in air, under water and underground); characteristic features of wave pattern of each event class were determined. Temporal variations of S-waves attenuation field structure were investigated for the
Test Site region using records of Borovoye seismic station at epicentral distance ~2100–2400 km. Amplitude ratio of S and P waves (S/P) was considered, amplitude attenuation velocity in P-wave coda was studied for narrowband channel with central frequency of 1.25 Hz. By records of UNE conducted at Novaya Zemlya Test Site it was determined that from 1967 to 1990 the average value of S/P parameter decreased significantly. In addition, for the same period, the slope of P-coda increased. Data on temporal variations of the attenuation field at the Test Site region testify the uplift of deep fluids onto the earth crust and upper mantle as a result of long intensive industrial influence on geological environment.

**T2.3-P17. Seismoacoustic Monitoring of Local Events**

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Since the beginning of its deployment, in 2009, Plastina infrasonic array (IPLOR) has proven effective in detecting acoustic signals produced by impulsive sources such as explosions, quarry blasts, volcanic eruptions, bolides, or thunderstorms. This is explained by the sensors’ characteristics (frequency response, dynamic range) and the large aperture of array. Initially comprising three elements, IPLOR is currently a 6-element array, with 2.5 km aperture, and Chaparral Physics Model 25 instruments. The analysis of the large set of data recorded during over 5 years of operation shows the enhancement of the detection capability at relatively low frequencies (0.5 Hz) with increasing of the number of array elements. A better characterization of the signal, in terms of back-azimuth and horizontal trace velocity, is observed as well, corresponding to the improved array response. We present several seismoacoustic events observed with IPLOR array and Romanian seismic stations: a strong local earthquake (ML = 5.7, h = 39 km) occurred within of 40 km distance of array, a quarry blast in Dobrogea region (200 km from IPLOR) and a bolide explosion, recently produced in the array area. Surface explosions and earthquakes are useful sources for checking detection and location efficiency, when seismoacoustic data are jointly processed.

**T2.3-P18. Source Mechanism Analysis of the Mw 6.2 Earthquake in Central Aceh on 2 July 2013 Using Moment Tensor Inversion with Local Waveform Data**

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The source mechanisms of earthquake on 2 July 2013 was investigated by using moment tensor inversion. The result also compared by the field observation. Five waveform data of local seismic network used to estimate the mechanism of earthquake, namely: KCSI, MLSI, LASI, TPTI and SNSI. Mainshock data taken during 200 seconds and filtered by using Butterworth bandpass method from 0.03 to 0.05 Hz of frequency. Moment tensor inversion method is applied based on the point source assumption. Furthermore, the Green function calculated using the extended reflectivity method which modified by Kohketsu. The inversion result showed a strike-slip faulting, where the nodal plane strike/dip/rake (124/80.6/152.8) and minimum variance value 0.3285 at a depth of 6 km (centroid). It categorized as a shallow earthquake. Field observation indicated that the building orientated to the east. It can be related to the south west of dip direction which has 152 degrees of slip. As conclusion, the Pressure (P) and Tension (T) axis described dominant compression is happen from the south which is caused by pressure of the Indo-Australian plate.

**T2.3-P19. Source-Time Function Scaling of Underground Nuclear Explosions**

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In 1993 Ziolkowski developed an equation for the scaling of source-time functions of explosions. This theory has been applied successfully to the three nuclear tests by the Democratic People’s Republic of Korea of 2006, 2009 and 2013, recorded at the seismic station at Mudanjiang, China. When two underground explosive devices
of different size are detonated at different times but at the same location and recorded at the same seismic station, the paths through the earth are identical. Exploiting this fact, and using the scaling law equation and the two equations for the recorded seismograms, the two source-time functions and the Green’s function may be extracted from the data. Using the same theory, we present results using data from a set of underground nuclear tests conducted at the Degelen Mountain Test Site in Kazakhstan, recorded at the UK arrays at Eskdalemuir, Scotland, and Yellowknife, Canada. The source-time functions and the Green’s function are extracted from the seismograms of two closely located explosions. This theory is put at risk by comparing the measured seismograms from a third near-by event with synthetic seismograms obtained by convolving the Green’s functions with a scaled source-time function. The source-time functions of all three events are those of explosions, not earthquakes.

T2.3-P20. The Variety of Infrasound Sources Recorded by Kazakhstan Stations

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The Institute of Geophysical Researches (IGR) of the Atomic Energy Agency of Kazakhstan Republic possesses records from Kazakhstani seismic and infrasound stations for the period from sixties of the twenty century till present. Digital and analog records from the infrasound and seismic stations and arrays were used for the study purposes. Infrasound signals from natural and industrial sources were extracted. These sources are ocean storms, gas flares at oil fields, quarry blasts, aircrafts, spaceship launches and deorbiting, earthquakes, thunderstorms, meteoroids and even volcano eruptions. Moreover, IGR analog archives contain large amount of historical records with infrasound signals from atmosphere nuclear tests conducted at Semipalatinsk and Novaya Zemlya Test Sites (1961–1962), and large chemical explosion “Massa” (1981) conducted near Almaty city. Waveform analysis for the sources of different nature is presented.
2.4: Atmospheric Background of Radioxenon

Oral Presentations

T2.4-O1. Development of a Xenon Mitigation Prototype

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The aim of the xenon mitigation project is to design a mobile system for the reduction of radioxenon emissions from Radiopharmaceutical Production Facilities (RPF). The reduction of noble gas emissions from large RPF is a key issue in increasing the sensitivity of the international noble gas monitoring system. In a first part of the project, the adsorption properties of different adsorbent materials like Activated Carbons and Silver Zeolites were investigated. In a second phase, a study of specific design characteristics of a xenon abatement system on the operational conditions at the Institute of RadioElements was realized. Based on these investigations, a final prototype will be built and tested at IRE. Resulting from the two first phases of the project, the technical design of the xenon mitigation prototype that will be tested at IRE was developed. The shielding and the dimensions constraints (i.e. available space) of the prototype were elaborated in close collaboration with IRE. Due to the constraints on dimensions, the system is very compact and can be used at various places. The key results of the first two phases of the project will be presented as well as the full description of the technical design and the prototype.

T2.4-O2. Impact of Worldwide Xe-133 Atmospheric Background on International Monitoring System Network Coverage

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Monitoring atmospheric concentration of radioxenon is relevant to provide evidence of atmospheric or underground nuclear weapon tests. However, when the International Monitoring Network (IMS) design was set up, the impact of radiopharmaceutical facilities and Nuclear power plants was not perceived at all. It is now well known that during normal operation, these facilities proceed to daily pulsed or continuous releases of radioxenons into the atmosphere leading to a significant worldwide background. Consequently, the effective IMS network capability to discriminate civil sources from nuclear tests may be degraded compared to the expected one. In this study, the evaluation of the global Xe-133 atmospheric background was updated, taking into account the most comprehensive inventory of facilities and realistic releases as possible. The mean industrial contribution at each IMS station is calculated and compared to measurements. In a second step, the average annual coverage of the IMS network was calculated based on backward atmospheric transport modelling considering realistic nuclear test release scenarios. Calculations were carried out considering the current operational 29 station network and the planned 39 station network. Finally, the global IMS network coverage loss due to industrial background is assessed depending on nuclear test atmospheric source terms.
T2.4-O3. Measuring Radioactive Emissions in Gaseous Effluents at Medical Isotope Production Facilities

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INVAP has experience in the design and supply of Medical Isotope Production Facilities (MIPF). Several MIPFs have already been delivered, are currently under design, or to be commissioned in the near future. As designers of Radiation Monitoring Systems for those facilities, this experience throughout last years showed us the relevant features when measuring gaseous emissions in Isotope Production Facilities. This field of measurements is quite specific, with much different requirements on detection strategies and measurement conditions in comparison with those measurements performed regularly on NPPs or Research Reactors, usually carried out using relatively standard instrumentation. Hence, specific detection tools and custom design devices have to be applied. Moreover, also the corresponding software for the User Interface, has to be adapted to the specific production process carried out according to the particular conditions in a specific plant. In this presentation, considerations on the evolution, design improvements and specific data acquisition strategies, being implemented in the measurement of gaseous effluents along several MIPFs supplied by INVAP in the last years, are presented.

T2.4-O4. Update on the Workshop on Signatures of Medical and Industrial Isotope Production (WOSMIP)

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The fifth Workshop on Signatures of Medical and Industrial Isotope Production (WOSMIP) was held in Brussels in May 2015. This annual workshop focuses on the issue of radioxenon background emissions from fission-based medical isotope production and its influence on the International Monitoring System (IMS). The workshop brings together the medical isotope production and nuclear explosion monitoring communities in an effort to minimize the impact on the verification of the CTBT. The fifth WOSMIP workshop involved discussions of the overall radioxenon issue, updates on isotope production methods, technologies used to measure radioxenon (both at the isotope production facility and at IMS locations), research and development targeted at reducing xenon emissions, and methods for data sharing between the communities. This work will outline the goals and outcomes of the recent WOSMIP as well as lay out recommendations from the confluence of the two communities.

Poster Presentations

T2.4-P1. Production of Molybdenum-99 in Argentina, Past, Present and Future

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Fission molybdenum-99 is being produced in Argentina, at the Ezeiza Atomic Centre, since 1985. The procedure involved the irradiation of HEU targets with an Uranium-Aluminum alloy “meat” cladded with aluminum. At the end of the 1990s, the Atomic Energy National Commission of Argentina (CNEA) started the development of new LEU targets for its Mo-99 production, in order to replace present HEU miniplates and in the year 2002 began to commercialize Mo-99 from LEU targets. The production process was sold by the company INVAP to Australia, Egypt, Algeria and Coqui Pharma (USA). By 2018 Argentina expects to operate a new reactor to
produce radioisotopes (RA-10) and to operate a new radioisotopes production plant from fission. A description of these two facilities will be made. Considering the CTBTO recommended emission levels for xenon-133 of less than 5 GBq per day, engineering resources and devices to reach these standards in the new plant will be proposed.

**T2.4-P2. Radioxenon Background in Africa**

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The International Monitoring System (IMS) radionuclide stations on the African continent have been providing data on xenon isotopes concentrations. This research aims at combining activity concentrations of xenon isotopes observed by the TXL (Temporary Xenon Laboratory) in Ouagadougou, Burkina Faso, with activity levels observed by the IMS station in Cameroun, CMX13, and with ground based observation from FRX29, La Reunion, which may reveal information about Medical Isotope Production Facility (MIPF) releases coming from South Africa. The study work will focus on seasonal periods where trade winds are coming from the South African region. The scope of the research is to provide an initial overview of African xenon background levels and detections that can be related to a known MIPF in the Southern hemisphere.

**T2.4-P3. Capabilities of INVAP in Dose Calculation at Medical Isotope Production Facilities**

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Medical and industrial isotopes are commonly used in science, medicine and industry, and the principal use is for medical diagnostics. One of the most used radionuclides is Technetium-99m (daughter of Molybdenum (Mo-99)). The process for its production includes fission of U-235 and during this process fission gases with xenon (Xe) and krypton (Kr) are released to the atmosphere. For many years INVAP has been acquiring experience in the design and start-up of Medical Isotope Production Facilities (MIPF), including the safety and security protection radiological analysis and gaseous effluent release monitoring. The safety analysis is based on conservative Gaussian Plume models which include the evaluation of atmospheric dispersion and transport of radionuclides, meteorological conditions, emission parameters and site characteristics. Normal operation and accidental scenarios (Design Base Accident and Beyond Design Base Accident) are modeled. Soil and groundwater dispersion calculus for the safety analysis are actually in progress. In this work capabilities of INVAP in dose calculation for emissions in MIPF are presented.

**T2.4-P4. Field Measurement of Xe-133 at the Resolute Bay Station (RN15)**

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The Radiation Protection Bureau (RPB) of Health Canada has operated a SPALAX noble gas sampler analyser since September 2012 at the CTBT radionuclide station located in Resolute Bay, NU. The SPALAX has collected and measured successfully 354 samples, from which the presence of Xe-133 was detected with a range of activity concentrations ranging from no detection to 0.78 mBq/m³, with some of the samples re-measured at the RPB noble gas laboratory for confirmation of the activity concentrations. The presence of Xe-133 confirms that medical isotope production may create interpretation difficulties at very remote monitoring sites. This noble gas system is also used to test modifications to the noble gas sampler analyser, in an effort to improve the mean time between failures and decrease operational costs. As of October 2014, a highly robust compressor combining oil/oil free technology was installed—this increased operational uptime and decreased the electrical operational cost by 20%.
**T2.4-P5. Identification of Fission Products in Air Filter by Using Portable HPGe Spectrometry System for Rapid Prediction of Nuclear Exploration**

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Radionuclide sources in the environment include nuclear explosions, releases from normal or anomalous reactor operations, and releases from other nuclear industry, particularly medical isotope production. The most dominant source of artificially created radionuclides is neutron induced nuclear fission. A variety of systems and processes may introduce artificial radionuclides into the environment. Detection and measurements of fission products are necessary in the field of nuclear safety and radiation protection in order to reduce the expected potential risk associated with the radionuclides of interest. A portable HPGe detector and battery powered multichannel analyser has been used to perform in situ gamma-ray spectroscopy. The objective of this study is to provide a simple analytical technique for detection and analysis of radionuclides due to fission products in air and water samples by using a portable HPGe gamma spectrometry system for rapid detection of nuclear exploration. A shielding system has been developed for reducing background radiation levels in order analyse low energy gamma-ray peak due to fission products, specially noble gas (such Kr-85, Xe-133 etc.) including other fission products (Cs-137, Cs-134 etc.). This technique could be utilized for rapid detection and analysis of fission products in air and water samples due to nuclear explosion source.

**T2.4-P6. Improved Simulations of the Radioxenon Background Through Stack Monitoring Data**

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The IMS noble gas network, consisting of 40 monitoring stations, is affected by the radioxenon background mainly produced by medical isotope production facilities. Monitoring stations that are located downwind from such facilities detect radioxenon on a regular basis. These radioxenon concentrations from legitimate sources can potentially mask signals from nuclear tests. In this work it is examined how the access to stack monitoring data of radioxenon emissions improves the understanding of the background. Atmospheric transport modelling is applied to calculate the dispersion of emissions from the medical isotope production facility ANSTO in Sydney, Australia. Long term stack emission data of different time resolutions are used. The resulting simulated time series of radioxenon concentrations at IMS monitoring stations are compared with experimental data. Suitable statistical parameters are identified and calculated for this analysis.

**T2.4-P7. Incorporating Radionuclide Stack Monitoring Data into the International Data Centre**

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The CTBTO operates a worldwide network of noble gas detection systems as part of the International Monitoring System (IMS). These systems take daily atmospheric measurements of trace quantities of radioxenon, one of the most important signatures expected from a nuclear explosion, and report results to the International Data Centre (IDC) in Vienna, Austria. Recently, the CTBT scientific community has discovered that the fission-based production of the medical isotope molybdenum-99 (Mo-99) produces radioxenon effluents in ratios and quantities similar to those expected from a nuclear explosion. In large enough quantities or close enough proximity, these emissions can pose significant challenges to the CTBTO’s analysis of IMS detections. One way to mitigate some of the challenges presented by xenon emissions is for medical isotope producers to share facility stack monitoring data with the CTBTO, which would help to better identify civil sources of radionuclide detections. This presentation examines the verification benefits to sharing stack monitoring data, as well as some of the barriers that currently exist to incorporating this data into the IDC.
T2.4-P8. Non-Traditional Radioxenon Isotope Measurements

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To ensure compliance with the CTBT, it is crucial to have advanced monitoring technologies for the detection of nuclear testing, but also to ensure that detected signals are well understood. Traditionally, Xe-131m, Xe-133m/g, and Xe-135 originating from the fission of heavy nuclei (e.g. U-235, Pu-239) are analysed in the context of CTBT verification. This project explores non-traditional radioxenon isotopes to provide a better understanding of civilian background sources by looking at radioxenon from neutron activation (e.g. research reactors) rather than just fission. Stable xenon in air will activate to radioxenon isotopes during a nuclear explosion. Xe-125, Xe-127, Xe-129m, and Xe-137 were produced in isotopically pure samples via neutron activation at the University of Texas at Austin Nuclear Engineering Teaching Lab’s TRIGA MARK II Reactor. The samples were measured in an ARSA-style beta–gamma coincidence detector. Isotopically pure beta–gamma spectra of these non-traditional isotopes will be presented and analysed. Xe-127 has also been considered for calibration, QA/QC and tracer for medical isotope production facilities.

T2.4-P9. Radioxenon in Nigerian Research Reactor 1 (NiRR-1)

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Radioxenon isotopes (radioactive xenon) are noble gases mainly produced in nuclear fission e.g. uranium-235, either via neutron-induced or spontaneous fission or via neutron activation of xenon gas and other reactions. Most radioactive isotopes of this element are produced by a nuclear fission reaction of uranium-235, uranium-238, or plutonium-239. Xenon-133 is the most abundant radioxenons observed in environmental samples. The minimum detectable concentration (MDC) for Xe-133 in routine samples is about 1 mBq m$^{-3}$. For distinguishing between nuclear explosions and other man made releases, atmospheric monitoring of radioactive noble gas isotopes, xenon isotopes in particular, is of interest to the non-proliferation community. Radioxenon releases can originate from nuclear weapons tests (atmospheric, underground, and underwater), research and commercial reactors, and medical isotope production facilities. Their impacts on atmospheric sample analysis have to be well understood to distinguish between them. This work will describe the production, applications, occurrence, and measurement of xenon isotopes in NiRR-1.

T2.4-P10. Radioxenon Monitoring in the Canadian Arctic in Resolute Bay, Nunavut, at the Aerosol Monitoring Station RN15

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Since September 2012, Health Canada’s Radiation Protection Bureau has been operating a SPALAX radioxenon analyser at its Resolute Bay CTBT Aerosol monitoring station, RN15 and has collected in excess of 350 measurements of daily xenon concentrations. RN15 is one of only four radionuclide monitoring stations north of the Arctic Circle and it is not named among the first 40 radionuclide stations identified to have noble gas capability. The station has detected radioxenon several times at levels up to 0.64 mBq/m$^3$. The station is generally sensitive to north-western North America and mid to northern latitudes of the Pacific and Asia. For example, the site observed the highest weekly radiiodine and radiocesium concentrations among all of the Canadian monitoring sites in the Canadian Radiological Monitoring Network (CRMN) after the Fukushima accident. Despite this increased sensitivity, it is surmised that the observations are part of general circulation of global atmospheric background of radioxenon in the Northern hemisphere dominated by emissions from such medical isotope production sites as the Chalk River laboratories in Canada. Hence, the remote Resolute Bay site has provided valuable and unique insight into the global radioxenon background.
T2.4-P11. Radioxenon Categorization Schemes Based on Statistical Parameters

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Atmospheric concentrations of radioxenon are constantly monitored at 40 noble gas stations. Such a constant flux of data has to be categorized for better data management and also for an apprehension by non-scientists. Until today several universal categorization schemes, e.g. based on three or five levels, to be applied to the samples from all stations have been suggested. In this work a new basis for categorization of radioxenon samples is examined. Each noble gas monitoring station detects various levels of radioxenon according to meteorological patterns and close-by background sources. Thus, over time the signal at each station shows its own fingerprint. Therefore, the standard deviation of the time series provides an unbiased way to describe the distribution of radioxenon concentrations. The time series for each monitoring station can be based on experimental data and on simulated data from atmospheric transport modelling. This can be used to create a station-specific categorization scheme with levels according to the station’s fingerprint.

T2.4-P12. Source Term Estimation by Combination of Atmospheric Transport Modelling and Dose Rate Measurements

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It has been shown in the past that the noble gas background resulting from civilian nuclear applications can make the discrimination between nuclear tests and civilian sources difficult. A good knowledge of this background is required to enable this discrimination. However, the radioxenon emissions from civilian sources are not always known and are quite complex. In this context, the estimation of the source term from stack releases based on nearby (dose rate) monitoring stations was studied. As a test case, the Ar41 releases from the Belgian Reactor 1 at SCK•CEN were used. These releases are detected by the early warning network TELERAD, operated by the Federal Agency for Nuclear Control, surrounding the reactor. A one day period, in which the reactor was operated, meteorological and radiological measurements were available, was selected to determine the Ar41 source term. The source term estimation was done with a simple diffusion-convection model, which was created in Comsol Multiphysics®. The source term obtained was then compared to the Ar41 release based on the power at which the air-cooled reactor operated. This methodology could be applicable to other sources, such as radioxenon emissions.

T2.4-P13. The Global Radioxenon Background: An Update

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The 40-station IMS radioxenon network is now nearly complete. By now, tens of thousands radioxenon samples have been collected and measured. We present an analysis of general features this data set, analysed and compiled using software developed at the Swedish NDC. The results can be used in many applications, including assessment of the capability of the IMS network, development of categorization schemes, and when identifying and quantifying the impact of major release sources.
The 2013 National Data Centre Preparedness Exercise (NPE) scenario was chosen and developed individually by the team of the German NPE NDC. The basic idea of 2013 NPE is that a third state party announces to have information on a Treaty relevant event in a certain area. The task of the exercise is to check 2013 NPE justified suspicion. In this poster, we will present the different results of the data Fusion (radionuclide and SHI) for the 2013 NPE using the different tools in the NDC-in-a-Box (Web-Grape, geootool, openspectra) provided by the CTBTO, in order to give technical and diplomatic decision. Our participation in the NPEs and experience in radionuclide data analysis show the importance of SHI radionuclide & data fusion with ATM and WMO.
THEME 3:
ADVANCES IN SENSORS,
NETWORKS AND PROCESSING
3.1: Design of Sensor Systems

Oral Presentations

T3.1-O1. Compact Seafloor Cabled Seismic and Tsunami Observation System Enhanced by Information and Communications Technology

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Seafloor cabled seismic and tsunami observation systems have been deployed around the Japan islands arc to monitor seismic activities and detect tsunamis offshore. Because the number of cabled observation system on the seafloor is limited, the number of observational stations of cabled system should increase. Therefore we have developed a new compact seafloor cabled observation system with low cost. The new cabled system is characterized by system reliability using TCP/IP technology and down-sizing of an observation node using up to date electronics. In 2010, we had developed and installed the first system in the Japan Sea. The first system has 3 seismic stations and total length of cable is 25 km. After the installation, the first system is being operated continuously and we have continuous seismic data for more than 4 years. The second system has pressure gauge and seismometers in a node. In addition, an external port for additional sensor can be equipped instead of a pressure gauge. The power will be supplied to additional sensors using Power over Ethernet technology. The capsule for observation node has diameter of 26 cm and length of about 1.3 metres. The second system is planned to be installed in summer 2015.

T3.1-O2. Considerations for the Design of Future CTBT Monitoring Seismic Arrays

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This research started with writing the specifications that were discussed in the early Working Group B meetings back in the late nineties, coupled with a number of lessons learned in the subsequent decade and a half from the installation of a number of these arrays. Also included were a number of upgrades to the existing arrays, and more recently, improvements in the hardware (for example: hybrid seismometers), communications, etc. Lastly, and importantly, what information do we need to acquire from the newer versions soon to be deployed. An important element of this research includes detailing those features of the deployed arrays that have served so well that any new array should take advantage, by starting with these features; thereby, making even greater capabilities in our monitoring capability. The recent events in the Democratic People’s Republic of Korea have helped in the improved design of the arrays; probably improvement can be summed up in the array design needs by reducing the effect of noise; however, equally important is stressing the character, and the number of signals to be detected so that processing such as correlations can be performed. Another important feature is the increased sample rate required in the future.
**T3.1-O3. Real Time Monitoring System of Earthquakes and Tsunamis for Advanced Early Warning System and Prediction Research: For the Disaster Mitigation of Earthquakes and Tsunamis**

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For the last few decades, many destructive earthquakes and tsunamis occurred in the world. Based on lessons learnt from 2004 Sumatra earthquake/tsunamis, 2010 Chilean earthquake/tsunami and 2011 East Japan earthquake/tsunami, we recognized the importance of real time monitoring on earthquakes and tsunamis. There are some kinds of real time monitoring system such as Dart buoy and ocean floor network. Especially, the real time monitoring system using multi kinds of sensors such as the accelerometer, broadband seismometer, pressure gauge, difference pressure gauge, hydrophone and thermometer is indispensable for earthquakes/tsunamis monitoring. Furthermore, using multi kind of sensors, we can analyse and estimate broadband crustal activities around mega thrust earthquake seismogenic zones. Therefore, we deployed DONET1 and are developing DONET2 which are dense ocean floor networks around the Nankai trough south-western Japan. DONET1 have deployed on the Tonankai earthquake seismogenic zone, then DONET2 is deploying on the Nankai earthquake seismogenic zone. DONET/DONET2 with 51 observatories will be expected to monitor slow events such as low frequency tremors and slow earthquakes. Based on the long term observation using DONET1/DONET2 and advanced simulation researches, we can estimate the seismic stage which is the inter-seismic or pre seismic stage.

**T3.1-O4. The SAUNA III Project**

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The radioxenon system SAUNA II is now installed at 17 locations in the International Monitoring System. A new development project has been launched at FOI, SAUNA III, with the goal to result in a major improvement of performance and capability of the current SAUNA II system, including increased air sampling capacity, time resolution, detection sensitivity and stability, and user friendliness. Goals, plans and current status of the project will be presented.

**T3.1-O5. Ubiquitous Infrasound**

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Recent work has demonstrated on-board barometers and microphones in the present generation of smartphones are infrasound-capable, and provide an existing, dense ubiquitous global sensor network that can supplement the IMS. Extreme natural events in sensitive regions can trigger false alarms in Treaty verification systems. The 0.5 Mount Chelyabinsk explosion was well recorded by IMS IS31 in Kazakhstan at a range of 600 km. Even at this range, the signal amplitude was in excess of the 1 Pa pressure resolution of the Nexus 5 barometer, and had substantial energy above the 1 Hz cutoff frequency of the iPhone 5 microphone. The number of smartphones is expected to reach ~10 billion globally by the end of the decade. Even if one in a million smartphones were available for infrasound applications, ~10 thousand additional data channels would need to be validated and processed. Ongoing work explores frameworks that can utilize these data in compliance with privacy and open data policies. Mobile sensor networks also present challenging problems on how to best process moving, unevenly sampled sensor data with variable timing and position accuracy and undocumented transfer functions.
T3.1-P1. Carbon-13 Content as a Monitoring Tool for Subsurface Gas Sampling Methodology in an On-Site Inspection

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The detection of anomalous concentration of noble gas (NG) radionuclides in the subsurface gases during an on-site inspection (OSI) is a strong indicator of a suspicious underground nuclear explosion. This implies that the sampling methodology ensure the collection of a reliable representative subsurface gaseous sample, avoiding the mixing with atmospheric gases. Sampling NG in shallow layers can provide reliable results for desert areas (like in the 2014 Integrated Field Exercise in Jordan), but different local geological features could result in more complex migration of subsurface gases to the very near superficial layers limiting the representativeness of the sample. We propose to use the measurement of CO₂ and CH₄ isotopic composition to investigate the saturated/unsaturated transition area, by the implementation of an experimental protocol that implies the detection of conventional subsurface gases (i.e. methane and carbon dioxide), which propagation could be triggered by the explosion. Portable isotopic analysers (that measures the C-13 in CH₄ and CO₂) could be used to exclude the infiltration from atmospheric gases and to localize the faults and fracturing that could lead to a seeping of the subsurface gases. Therefore this technique could be proposed as an auxiliary equipment for the subsurface sampling gases field activity in the OSI.


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High quality data from regional and local seismological networks can increase the effectiveness of State Party monitoring and analysis under the CTBT. Currently, many networks still operate older electromechanical seismometers with digitizers which, unfortunately, are poorly calibrated. Calibration of these stations is difficult because of impedance mismatches, coil loading, and amplifier gain differences that vary by station and digitizer model. Therefore, it is necessary to calibrate stations as a complete system. We have developed a field deployable calibration method that utilizes an inexpensive and commercially available laser position sensor. Using a signal generator and a small excitation coil, we force the mass of the instrument to oscillate at frequencies across the pass band. We then measure the station output and compare it to the laser-measured mass motion and determine the instrument response at each frequency. If free-period and damping ratio are measured, an accurate calibration curve can be generated. A grid search algorithm optimizes the curve and determines the instrument response in Seismic Analysis Code (SAC) poles & zeros format. Results are within a few percent of a standard laboratory calibration. This method is an effective and affordable option for networks that employ electro-mechanical seismometers.

T3.1-P3. A Literature Review of Seismic Signal Detectors

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Seismic signal detectors are extremely important, not only because an earthquake or a seismic event of interest must be detected automatically in real time to launch an early alarm, but also to optimize the necessary storage memory. Furthermore, it is always indispensable to identify seismic signals from noise so that they can be analysed. Therefore, an automatic identification algorithm that examines continuously incoming seismic data to
detected seismic signals is of great importance. The need for a seismic detection task has led many researchers to investigate various techniques. Several different detection methods are presently known in literature. These methods are mostly based on finding remarkable changes in some characteristic properties of the seismic trace with reference to the preceding seismic noise. The present paper addresses the seismic signal detection problem and gives a literature review of the most popular and used detectors.

**T3.1-P4. Achieving Lower Detection Limits with the Sage Well Detector for a Variety of Samples Relevant to On-Site Inspection**

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CANBERRA’s Small Anode Germanium (SAGe) Well detector is a new type of low capacitance germanium well detector manufactured using small anode technology. The detector has energy resolution performance similar to semi-planar detectors, and offers significant improvement over the existing Coaxial and Well detectors. Mathematical efficiency calibration using ISOCS/LabSOCS framework offers great flexibility for different sample sizes and shapes. Automatic true coincidence summing correction for a wide variety of nuclides, including the most common fission products, can be applied to measured spectra using the standard Genie 2000 algorithm. The performance of this detector and the true coincidence correction algorithm have been evaluated for a range of sample sizes and geometries counted inside the well and on the end cap of the detector. The improved resolution performance of SAGe Well detector greatly enhances detection sensitivity and offers benefits in measuring OSI relevant radionuclides in a variety of sample holders delivering reductions in minimum detectable concentration over the existing traditional Well detector.

**T3.1-P5. Determination of Full Energy Peak Efficiency of HPGe for Volume Source by Monte Carlo**

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The HPGe detector represents one of the fundamental instruments in noble gas measurements. Operating these systems requires an accurate knowledge of detection efficiency, which varies strongly with the source–detector distance. This means that we need a recalibration of detector efficiency for each sample–detector configuration. Big volume sources like Marinelli geometries can provide the best detection limits. But the establishment of the efficiency calibration curve is particularly complex because the calibration procedure needs standard volume sources which are not always accessible and its production has some difficulties. Alternative of volume sources is some standard point sources with several different energies. Also, development of Monte Carlo based calculated codes, such as MCNPX, give us the possibility of accurate simulation of these detection systems. In this work, the accurate configuration of HPGe is simulated by MCNPX code and the simulated model is verified by several experiments with point sources. After being sure that the model is correct, the efficiency curve of a volume source is determined by MCNPX and then is verified by experiments using some standard point sources. The point source-detector position is in such a way that the point sources act as an equivalent volume source.

**T3.1-P6. Development of JISView: System to Determine Earthquake Parameters and Focal Mechanism**

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Development of JISView, the earthquake monitoring system has been done in Research and Development Centre of Indonesia Meteorological, Climatological and Geophysics Agency (BMKG) to support operations on
earthquake monitoring and analysis. Stages of the research study initiated in software development, AMZTAK to determine of earthquake focal mechanisms. System development include the processing of data in a single workflow system and conduct for the automation system and then building a system that can give information of earthquake parameters and focal mechanisms. JISView system is a program portable as media processing, that can be installed anywhere. Making interfaces done in order to operate with the Windows Operating System that makes JISView user friendly. Input data is able to using public networks (Internet) Arclink and Seedlink either. After processing the waveform data input will produce earthquakes parameters and focal mechanisms information. The modules in JISView has been designed to perform automatic processing in real time data and waveform database of earthquake monitoring network. Coverage access for real time is 1748 censor/seismic stations, consist of 163 BMKG’s station, 339 IRIS’s station and 1246 GFZ’s station. The outcome of the system can be used as a dissemination material of earthquake parameter information for the public.

T3.1-P7. Development of a Phoswich Detector for Radioxenon Field Measurements

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Most radioxenon detector systems employed by the CTBTO are stationary by design, with heavy lead shields and delicate components that do not match the requirements of on-site inspections. We present in this paper a novel detector designed for field measurements, based on a simple phoswich geometry where beta and gamma scintillators are read out by a single photomultiplier and coincidences are detected by digital pulse shape analysis. Size, weight, and complexity have been reduced with only minor compromises in sensitivity. The overall weight is \(\sim32\) kg including the lead shield. Gain stabilization utilities have been integrated into photomultiplier base to compensate temperature drifts. Several options have been studied to mitigate the memory effect of Xe trapped in the beta scintillator, including use of crystal Stilbene for the Xe cell.

T3.1-P8. Development of a Mobile Noble Gas System for On-Site Inspections in Support of the CTBT with Direct Support from the European Commission

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The technical research and development of the most advanced equipment in support of the CTBT verification regime is to a large extent multilateral international affairs in coordination with CTBTO and involving institutions and technical experts from all over the world. One of the organizations significantly supporting CTBTO since many years and in a variety of technical fields is the European Commission. This presentation provides an overview of the R&D process, final prototype, tests and verification of the first CTBTO owned mobile noble gas processing and detection system especially developed for on-site inspections (OSI) and funded by the EU Commission. The presentation will in technical terms and some detail describe the new OSI noble gas system, i.e. the OSI-SAUNA (Swedish automated unit for noble gas acquisition) developed by FOI (Sweden), the special requirements on such systems for the intended use in OSI, the development process, the technical tests and verification measures taken by the CTBTO and a short discussion of the deployment in CTBTO’s large Integrated Field Exercise in Jordan in November 2014 together with outlooks for the future developments for the OSI noble gas processing systems.
T3.1-P9. Environmental Studies in Support of the International Monitoring System Hydroacoustic Installation HA4, Crozet Islands, France

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The re-establishment of hydrophone monitoring station HA04 Crozet Islands, Southern Indian Ocean French Southern and Antarctic Territories, is underway. The dynamic environment at Crozet is governed at the surface by winds and sea states which can be higher than in many other locations. Below the surface, the Crozet plateau is affected by local circulation emanating from the sub-Antarctic front and the Agulhas return current, moderate surface tides and relatively strong internal tides. Deploying submarine cables and hydrophone triplets in such an environment requires careful evaluation and mitigation of risks, e.g. by minimizing the exposure of the system to excessively strong currents. The local currents in the deployment area have been evaluated with state-of-the-art models by CNRS/Toulouse University (France), which relied on high quality multibeam sonar bathymetries to define the boundary conditions. The bathymetries also made it possible to identify candidate hydrophone triplet locations and trunk cable routes for the station. These studies, together with acoustic coverage predictions based on three-dimensional long-range propagation modelling presented in SnT2013, have made it possible to optimize potential sensor locations and deployment depths for the hydrophones.

T3.1-P10. Field Installation and Real-Time Data Processing of the New Integrated SeismoGeodetic System with Real-Time Acceleration and Displacement Measurements for Earthquake Characterization Based on High-Rate Seismic and GPS Data

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We will discuss and show the results obtained from an integrated SeismoGeodetic System, model SG160-09, installed in the Chilean National Network. The SG160-09 provides high rate GNSS and accelerometer data, and create combined GNSS and accelerometer high rate (200 Hz) displacement time series in real time. The SG160-09 receiver incorporates on-board GNSS point positioning using Real Time Precise Point Positioning (PPP) technology with satellite clock and orbit corrections delivered over IP networks. The seismic recording element includes an ANSS Class A, force balance triaxial accelerometer with the latest, low power, 24-bit A/D converter, which produces high resolution seismic data. The SG160-09 has been installed in the seismic station close to the area of the M8.2 Iquique earthquake of 1 April 2014, in northern Chile, a seismically prone area at the current time. The hardware includes the SG160-09 system, external Zephyr Geodetic-2 GNSS antenna, and high speed Internet communication media. Both acceleration and displacement data was transmitted in real time to the National Seismological Centre in Santiago for real time data processing using Earthworm/Early Bird. Data from the SG160-09 system was used for seismic event characterization along with data from traditional stand-alone broadband seismic and geodetic stations installed in the network.

T3.1-P11. International Monitoring System Meteorological Data: Current Status and Improvement of Data Quality

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The objective of the poster is to present the efforts made by the CTBTO over the last 3 years to assess and improve the quality of the meteorological data recorded at International Monitoring System (IMS) infrasound stations. This includes the processing and assessment of the data recorded since 2000, the organization of Expert Group Meetings, comparison of the IMS and World Meteorological Organization requirements to the meteorological data and the list of actions taken/to be taken for improving the reliability and accuracy of IMS meteorological data.
T3.1-P12. IRIS Activities in Seismic Network Technology Development and Evolution

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IRIS has deployed thousands of seismic stations as part of the EarthScope USArray and other efforts. In particular, the Transportable Array (TA) has completed its ten-year, 1700 station rolling deployment across the continental United States. The TA network has delivered high quality data and network uptimes exceeding 98%. Motivated by the success of the TA and other IRIS programmes, and to address key science objectives, IRIS is exploring new technologies that can enable even larger array deployments that record unaliased wavefields. Improvements in packaging and power systems can provide equipment with reduced size, weight, and power that simplify logistics for large experiments, and make a critical difference for deployments in harsh environments or other situations where rapid deployment is required. New posthole-style sensor emplacements provide both simple installation and low-noise performance. We will explore the key factors enabling IRIS’ efficient and successful large-scale seismic station operations. We will highlight projects that are exploring new array capabilities and future directions for IRIS instrumentation facilities, including the results from testing techniques for emplacing posthole seismometers. We will provide examples from a prototype experiment that utilized a sparse array of high performance broadband posthole seismometers combined with a dense in-fill of short-period geophones.


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Detection of four radioxenon isotopes (Xe-131m, Xe-133m, Xe-133 and Xe-135) is typically based on beta–gamma coincidence spectroscopy system. In the most of detection systems, plastic scintillator is used as container of radioxenon isotopes and beta particles detector. Because of unusual geometry of beta detector, optical photons undergo attenuation and scattering. These effects can change the energy resolution of beta detector. To improve non-uniformity of optical photon collection, some systems (ARSA and SAUNA) use two PMT’s to collect scintillation on both side of plastic scintillator. This method can improve energy resolution but gain matching of PMT’s increases the complexity of systems. In this paper, a new detection system consist of a well-type NaI(Tl) detector as gamma detector and plastic scintillator with a PMT as beta detector is introduced. The geometry of system was simulated with Gate7 Monte Carlo code and reflective layer effect on energy resolution of plastic scintillator was studied. The Xe-131m radioxenon was injected in the beta cell and conversion electron peak was obtained. The best condition that has best resolution was selected by comparison of simulation and experiment results.

T3.1-P14. Improving Reliability of Radionuclide Samplers for the International Monitoring System

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The International Monitoring System (IMS) consists of 80 radionuclide stations all of which can detect particulate radioactivity, and 40 of which can also detect noble gas xenon. As key equipments for radionuclide monitoring, the reliability of the samplers, have a direct impact on the minimum detectable concentration and the data availability of IMS radionuclide stations. As continuous running mass-transfer equipments, radionuclide samplers are exceptionally complicated Measures to improve reliability of samplers should be based on their characteristics. Most particulate samplers have relatively simple structure and run outdoors, so environmental conditions have much more impact on their reliability than other factors according to our experiences. Xenon samplers, however, are complicated mass- and heat-transferring equipments that usually run indoors, so attentions should be paid to both their design and maintenance. Simple and effective processes should be chosen
to lower the complexity of the whole sampler. Essential state monitoring and prompt maintenance are crucial to keep the samplers in good condition. Sharing the ideas and experiences for improving reliability of samplers will be helpful to improve the data availability of IMS.

T3.1-P15. Modernization of the Yellowknife Seismic Array (PS09)

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In late 2011, an agreement was made between the Department of Natural Resources Canada (NRCan) and the CTBTO to invest in the recapitalization of the aging infrastructure of the Yellowknife Seismic Array (YKA) in Yellowknife, Northwest Territory, Canada. Originally constructed in 1962, YKA is currently one of the primary seismic arrays of the International Monitoring System (PS09). The recapitalization and modernization of the seismic array was extensive, requiring replacement of remote power systems, seismometer vaults, digitization systems and radio communications to all 18 elements of the short period array. In addition, new sensors replaced aging broadband sensors along with a complete replacement of the Central facility’s acquisition computers. Significant challenges were overcome in the process of the reinvestment, since much of the array’s infrastructure is scattered across ~125 km² of northern Canadian muskeg. To ensure data quality of the new array, both the new YKA and its predecessor were run simultaneously for nearly a year for side-by-side comparison. Details of the process and new infrastructure will be discussed along with array comparisons.

T3.1-P16. Multi-Parameter Stations: Electric, Magnetic, Seismic, Radon Gas and GNSS Data Measurements, as a Comprehensive Method for Identifying the Anthropogenic Effect on Triggering Seismicity on the Central Region of Colombia

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The tectonic convergence process, which takes place in the north-west part of South America, due to Nazca, Cocos, South American and Caribbean Plates interaction has been aim of study with different methods; however, most of them have been applied one after another, but not simultaneously, resulting on an extended in time set of data, but, which includes contributions from different methods applied in different time periods. Such methods have been applied in the central region of Colombia, particularly in the Piedmont of the Eastern Cordillera. A number of multi-parameter stations are being deployed in the central region of Colombia. The measurements are beginning to provide electric, magnetic, seismic, radon gas, and GNSS data. The registered data will be processed and analysed with the aim of getting a better understanding of the seismic sources physics in this region, and in order to determine how significant is the effect of anthropogenic activities (including nuclear tests) on triggering seismicity. Here we will show the preliminary results of instrumental deployment, as well as, we will discuss the repercussion of the anthropogenic activities developed nowadays in the Piedmont of the Eastern Cordillera in Colombia. This work is supported by COLCIENCIAS (project No. 0361-2013).

T3.1-P17. Network Monitoring Seismic and Volcanic OVSICORI-UNA COSTA

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The Volcanological and Seismological Observatory of Costa Rica, National University (OVSICORI-UNA) is a University Research Institute dedicated to research of volcanoes, earthquakes and other tectonic processes. Network monitoring seismic and volcanic OVSICORI-UNA The seismic and volcanic network consists of instruments period short Ranger (SS-1), broadband (BA) Type: Güralp (CMG-6TD), Streckeisen (STS2), Nanometrics (Trillum 240 and compact Trillium), accelerometers SMA and FBA. The data are transmitted in
real time from different sites. At present, there is renewed the analogue network by a digital broadband in more than 90%, which consist of about 70 stations that have national coverage. This broadband network consist of strong motion and weak motion (seismometer) and low frequency offset using GPS. In the Data Centre of OVSICORI-UNA the EARTHWORM software (free software) and ANTELOPE software and SEISCOMP software to acquire, manage and process seismic signals is used. Our Data Centre has been expanded with a contribution of CTBTO / Vienna with a National Data Centre installed in September 2010, to acquire seismic data from stations in the region and the globe. In August 2014, we are cooperating with about 35 seismic broadband stations in real time with IRIS (Incorporated Research Institutions for Seismology).

T3.1-P18. New Beta–Gamma Coincidence System for Measurement of Radioxenon Isotopes Using Well-Type NaI(Tl) and Plastic Scintillator Detectors

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In order to detect radioxenon isotopes, a homemade geometry detection system based on beta–gamma coincidence has been developed. The system consists of a well-type NaI(Tl) detector that surround plastic scintillator in the solid angle near the $4\pi$. The well-type NaI(Tl) detector measure gamma or X-ray and plastic scintillator detect electron particles. The beta detector was calibrated using Cs-137 gamma Compton scattering in the plastic scintillator. It has been found that beta calibration curve depends to CS-137 position therefore; to suppress this effect an effective point for beta calibration was determined and verified with Xe-131m conversion electron. The efficiency of gamma detector was measured using standard point sources. Since the detection system has a volume source therefore, the detection system was simulated by Gate7 and correction factor was obtained by least squares fitting of simulation results to experiment results. The accuracy of detection system performance was checked by injection of Pb-214 (daughter of Ra-226) gas source.

T3.1-P19. New Optical Microbarometer

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Transducers implemented in microbarometer are mainly composed of two associated elements. The first one converts the external pressure variation into a physical linear displacement. The second one converts this motion into an electrical signal. According to this configuration, MB3, MB2000 and MB2005 microbarometers are using an aneroid capsule for the first one, and an electromagnetic transducer (Magnet-coil or LVDT) for the second one. We think that changing the electromagnetic transducer by an interferometer is a solution to increase the dynamic and the resolution of the sensor. Firstly, we will present the new transducer principles, considering the aneroid capsule and the interferometer using integrated optics technology. Secondly, we will present the first part of this project in which the interferometer is positioned outside the aneroid capsule. In this configuration, interferometer mechanical adjustments are easier, but measurement is directly disturbed by environmental effects like the thermal variations. Six prototypes and an optical digitizer were specifically designed. Then, we will present the first measurement results compared to those of a MB2005 microbarometer. Finally, a new design of the optical microbarometer will implement the interferometer into the aneroid capsule under vacuum to protect the optical measurement from environmental effects.
T3.1-P20. Noble Gas Sampling and Field Laboratory for On-Site Inspections in Support of the CTBT

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The on-site inspections (OSI) constitute the final verification measure under the CTBT and the Treaty lists all permitted activities and techniques. One of these is the environmental sampling of noble gases (NG), which can be deployed at any time during an OSI. For the CTBT relevant radioactive noble gas isotopes are Xe-133, -133m, -131m, -135 and Ar-37, specialized equipment is developed for their collection, processing and detection during an OSI and for the stringent procedures to ensure the security, integrity and confidentiality of the samples and data. Over the past decade the techniques for NG sampling, processing and analysis have been developed further in order to fit the OSI conditions and requirements. This has been a major international effort with a global set of collaborators. Especially as of 2011 the efforts intensified in order to finalize the scientific and technical developments of the OSI NG sampling regime and Field Laboratory for the first ever deployment under OSI conditions during CTBTO’s Integrated Field Exercise 2014. This presentation will describe the current status as well as an outlook on future technical developments for NG detections in OSI based on the first conclusions from the last development cycle.

T3.1-P21. Optimization of Beta–Gamma Detector Calibration for Xenon Detection

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Three of four radio-xenon monitoring systems have been developed based on beta–gamma coincidence system. Most important step in operation of Xe detection system is calibration by standards. An efficient method to accomplish this step is established using $\beta-\gamma$ spectrum of Cs-137. In that case the source position and detector geometrical design might effect the results. A $\beta-\gamma$ coincidence spectrometer was developed using a 1” by 1” plastic scintillator as beta detector and 3” by 3” NaI(Tl) as gamma detector. Detection system is surrounded by a 5 cm thick lead shield with 2 mm inner Cu layer. The thickness of the scintillator layers (2.0 mm) is adequate for detection of $\beta$ particles of the Xe-135 spectrum with an end-point energy of 905 keV. A Compton scattered $\beta-\gamma$ spectrum of a Cs-137 point source (42 kBq) was used to calibrate the detection system. The position of calibration source has been changed with respect to the gamma detector. Results obtained from calculating the FOM for different source positions has been shown that there is a preferred position for energy calibration of the system.

T3.1-P22. Pilot Interlaboratory Comparison Study


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The objective of this poster is to present the background, scope, objective and technical protocol of a Pilot Interlaboratory Comparison Study organized between three research laboratories to refine sensor specifications and testing methodologies for the infrasound technology. In the initiation phase of the Pilot Study, participating laboratories and the CTBTO came to a consensus on working terminology for quantities to be measured: self-noise, frequency response, sensitivity, dynamic range and pass-band. The poster will include the agreed set of definitions. The poster will also describe how this Pilot Study relates to CTBTO development axes and mid-term plan.
T3.1-P23. Pinedale Seismic Research Facilities Expanded Infrasound Capability

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The Pinedale Seismic Research Facility (PSRF) is establishing an infrasound sensor calibration system and field test bed. The goal is to provide the infrasonic research community with a neutral platform to compare, test, and optimize infrasonic recording systems. The PSRF is in a unique location to record signals from a variety of man made sources. There are also areas of high topographic relief, varied temperature range, snow accumulation, and weather patterns that will further the understanding of infrasonic signal propagation and detection. The sensor calibration system is a unique common manifold system with a piston driven source. Up to three sensors can be bench tested against a control sensor, before and after deployment. The field test bed will be configured to have a small and large aperture array. Systems can be tested as components of the array or side-by-side. We will establish modular noise suppression systems to identify better methods to enhance signal detection. We will also continue the work on infrasound bulletin generation (Park et al. 2014) and infrasonic signal coupling to seismic sensors.

T3.1-P24. Re-Establishment of International Monitoring System Hydroacoustic Station HA3, Robinson Crusoe Island, Chile

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Water column hydrophone stations of the CTBT International Monitoring System (IMS) are typically comprised of two triplets of moored hydrophones deployed on opposite sides of an island. Once deployed, the systems relay underwater acoustic waveforms in the band 1–100 Hz in real time to CTBTO via a shore based satellite link. The re-establishment of hydrophone station HA03 at Robinson Crusoe Island (670 km west of the Chilean mainland) is presented here. The station was destroyed in February 2010 by a tsunami induced by an 8.8 magnitude earthquake. After a major engineering and logistical undertaking, HA03 was completed and returned back in operation in March 2014. Examples of data acquired by HA03 are also presented. These include hydroacoustic signals from the 1 April 2014 magnitude 8.2 earthquake in Northern Chile, bursting underwater bubbles from a submarine volcano near the Mariana Islands (15 000 km away from the station), and vocalizations from the numerous marine mammals which transit in the vicinity of HA03.

T3.1-P25. SAUNA III Detector Studies

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The design requirements for the SAUNA III radio-xenon measurement system pose several challenges for beta–gamma detector development. SAUNA III shall use nitrogen as carrier gas rather than helium as in the current SAUNA. It shall be capable of collecting 4 atmospheric air samples per 24 hours and achieve a sample minimum detectable concentration (MDC) of better than 0.3 mBq/m³ and for Xe-135 better than 1.0 mBq/m³. This shall be achieved using two beta–gamma coincidence counters. To reach the specified system MDC using a detector of sensitivity comparable to the current SAUNA, the xenon sample counted by the detector will need to be considerably larger than in the current SAUNA, and increased electron energy straggling effects must be expected. To maintain or preferably somewhat improve the detector sensitivity despite the increased xenon volume and the change of carrier gas, various electron detector geometries have been studied using the Monte Carlo code Geant4. Other avenues of development for the SAUNA III beta–gamma detectors include suitable methods for coating of detector cells to avoid gas memory effects, study of possible impact of such coating on detector resolution and methods to automatically detect and correct for changes in detector response functions over time.
T3.1-P26. SAUNA: Equipment for Low Level Measurement of Radioactive Xenon

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Today, more than 25 SAUNA Systems are installed around the world, operated by national and international organizations. The activity measurement of the four xenon isotopes, Xe-133, Xe-131m, Xe-133m and Xe-135 is performed using the very sensitive beta gamma coincidence technique allowing high sensitivity also for the meta-stable states resulting in MDCs of 0.3, 0.3, 0.3 and 0.7 mBq/m³ respectively. In the SAUNA Systems product portfolio there are systems for; continuous monitoring, in-field sampling, and reanalysis of archived samples. We also have a container solution for continuous monitoring with all infrastructure integrated. The SAUNA systems in the network are now being upgraded with the latest developments; memory free detector cells, new digital detector electronics, in house developed high voltage supply, new data acquisition software, new safety solutions, and a new sample archive. New developments for coming improvements and upgrades will be presented.

T3.1-P27. Status and Development on the Calibration Programme

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The objective of this poster is to present the status and latest achievements on the calibration of the IMS seismic, infrasound and hydroacoustic stations. This includes CTBTO progress on scheduled calibration of IMS seismic stations, the development and testing of a new calibration technique for Infrasound stations using a reference sensor and ambient noise, and related software developments. The poster will also describe CTBTO development axes and mid-term plan to fulfil the IMS Operational Manuals minimum requirements and objectives set in the CTBTO Midterm Strategy 2014–2017 on the calibration of waveform stations.

T3.1-P28. Status of Digital Infrasound Sensors Developed by the NCPA

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In collaboration with Hyperion Technology Group, Inc, the National Center for Physical Acoustics (NCPA) has developed a digital infrasound sensor that can be configured for broadband outdoor measurements (flat within 3 dB from 0.03–150 Hz) and a nominal maximum transducible pressure of 200-Pa peak-to-peak, ultra-broadband measurements for calibration systems (flat within 3-dB from 0.0003-Hz to 150 Hz) and very high level sounds (up to 110 kPa peak-to-peak). This sensor has a GPS-locked digitizer that store over four months of continuously sampled data digitized at 1000 samples per second. The measurement performance of this system, including noise floor, reproducibility of measurements between sensors, linearity, mechanical robustness, etc. will be summarized.

T3.1-P29. Studies of Increased Air Collection Capability for SAUNA III

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The current SAUNA II system, installed worldwide in the IMS network, detects radioactive xenon isotopes in an atmospheric air sample. Ambient air is continuously collected, xenon is extracted and measured in sensitive beta–gamma detectors in an automated process. Current development on the new SAUNA III system is aimed at improving the time-resolution for the system a factor of two, from 12 to 6 hours, at the same time more than doubling the sample size for each individual sample giving a more sensitive system. A pressure swing adsorption (PSA) step, to be used before the sampling oven, is evaluated to accomplish this performance upgrade. The full
gas process will also be optimized to allow for a six hour time resolution and switched to nitrogen as the carrier gas. This upgrade will fit into the existing footprint of the SAUNA II system and will be available within the current infra-structure.

**T3.1-P30. The Japan Trench Earthquake and Tsunami Monitoring Network Project of Cable-Linked 150 Seafloor Observatories: The S-Net Project**

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The S-net Project is currently in progress in Japan to construct a large-scale seafloor monitoring network of earthquakes and tsunamis along the Japan Trench. NIED takes in charge of the project which is supported by MEXT financially. A disaster prevention is a major purpose of the network by providing earthquake and tsunami data on the seafloor in real time. Such real time data make it possible to forecast the next-generation early tsunami warning which could precisely predict a coastal tsunami height. Also the real time earthquake data on the seafloor make it possible to forecast an earthquake warning much earlier than the present system. The seafloor observatories of 150 sites are connected by an optical cable of 5800 km in a total length. Each observatory is equipped with seismometers of several types and two hydro-pressure gauges of the same type. The seismometers cover a dynamic range of 4G in acceleration and a frequency range of 0.05 Hz to 30 Hz. The hydro-pressure gauges which are used as a tsunami meter have a resolution of a few millimetres in a water column height change. The completion of the S-net project is in FY 2015.

**T3.1-P31. Thermal-Image Monitoring System at El Reventador and Tungurahua Volcanoes, Ecuador**

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We have implemented volcanic-surveillance systems based on thermal imaging at El Reventador and Tungurahua volcanoes (Ecuador), which provide the capability to compare visible-range images with the correspondent apparent-temperature images at near real time. The installed equipment consists on a netcam that shows real time images, and a thermal camera, which provides images on demand. The system automatically saves the historical record of images in an FTP server and publishes the last 10 images on the webpage of the Instituto Geofísico de Escuela Politécnica Nacional of Ecuador (http://www.igepn.edu.ec). By using this system it is evident the identification of the intense ongoing effusive and explosive activity of those volcanoes. In the case of El Reventador, more than 100 explosions and 7 lava flows were identified by this system during 2014, one of them went down through the eastern flank for the first time since 2002, when the eruptive period started. In the case of Tungurahua, hundreds of small and medium-size explosions were detected during 2014 and at least 30 small pyroclastic flows went down through the eastern and north-eastern flanks. Even in partially clouded weather conditions this monitoring system is an important tool for prevention risk and volcanic crisis management.

**T3.1-P32. Upgrade of the Swedish Noble Gas Laboratory System**

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The latest development of the SAUNA laboratory system for noble gas samples at FOI will be presented. The system is used for a variety purposes ranging from routine reanalysis of samples from the IMS station SEX63, verification of samples during noble gas system development (such as the OSI SAUNA), processing and analysis of subsoil samples. To improve the quality control and to simplify trouble-shooting a state of health system has been installed. Sensors measuring gas pressure, gas flow and temperatures are logged in a database
similar to SAUNA-II systems. To simplify the sample processing also the latest version of the SAUNA data acquisition software, developed from the OSI software, has been installed. This result in a much more automated system greatly reducing the manual interaction needed when processing and measuring on samples.

**T3.1-P33. Wind Noise Reduction Systems in the International Monitoring System Infrasound Network**

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The objective of this poster is to present the efforts made by the CTBTO over the last four years to assess and improve the robustness and efficiency of Wind Noise Reduction Systems (WNRS) used within the IMS (International Monitoring System) infrasound network. This work includes modelling of the frequency response of the different types of WNRS. It also includes the investigation and testing of new materials / components to improve the robustness of the WNRS. Efforts were also made to better adapt WNRS to the environment through the design of flexible systems. Finally, WNRS design was also enhanced to reduce manufacturing, installation and maintenance costs, as well as to extend their life cycle.
T3.2-O1. Emerging Small Satellite Constellations for Verification Support

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Large, agile constellations of small earth-imaging satellites are an emerging trend in the commercial earth observation industry. This trend has important potential for supporting nuclear test monitoring efforts due to the ability to rapidly and affordably collect imagery or HD video of a suspected nuclear test site. The capability could be useful both before and after an explosive event, due to the foreseen ability to access large historical archives of global imagery, as well as to efficiently task small satellites to a site in the aftermath of an event. The public and commercial nature of these information resources makes them of particular valuable to international organizations with large and diverse membership bodies for the increased ability to share the information amongst member states and freely access the sources. The presented project will be an examination of how high temporal satellite imagery and video provided by Google/Skybox Imaging can support international treaty verification in the areas of non-proliferation, arms control and disarmament. The work will feature a case study on the Punggye-ri test site in the Democratic People’s Republic of Korea, detailing the unique insight small satellites can provide in monitoring testing activities, for tasks such as establishing the chronology of vehicles, tunnelling activities, and ground disturbance.

T3.2-O2. Evaluation of Sensitivities and Minimum Detectable Activities for Test Relevant Radionuclides Using Aerial Gamma Surveys

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Aerial radiation surveys provide a method for surveying a potential inspection area for the presence of radioactive material from a possible nuclear test. Large areas can be covered relatively quickly with reasonable sensitivity. Understanding of the sensitivity through the evaluation of minimum detectable activities in the presence of real backgrounds and under operational conditions would be an important contribution to the determination of the proper application of this technique. Using actual data from natural backgrounds and defined radioactive sources, as well as simulations, this presentation describes the calculation of sensitivities, and expected minimum detectable activities for test relevant radionuclides for the CTBTO aerial radiation survey system.

T3.2-O3. New Development in Ruggedized HPGe Detectors for Outdoor Gamma Spectroscopy

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This paper presents the configurations and performances of novel CANBERRA detection and identification solutions of radioactive nuclides. Based on new HPGe spectrometer designs notably using a proprietary encapsulation technique and autonomous electrical coolers, these systems address outdoor monitoring and mobile surveying with performances similar to lab conditions. Precise dosimetry and source identification are offered even if the background count rate is high, or in simultaneous presence of a source mix at the same
location, especially where natural and anthropogenic nuclides have to be separated. These capabilities are exemplified first by presenting a high efficiency (up to 1300%) HPGe array developed for remote radionuclide identification and mapping, and key performances are explained in the case of an airborne application. Also a new immersible HPGe probe will be presented and its in-situ operation as an effluent, ground or portable monitoring device is described.

T3.2-O4. On-Site Inspection RadioIsotopic Spectroscopy (OSIRIS): A Spectrum-Blind Gamma Ray Spectroscopy System for On-Site Inspections under the CTBT

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We are developing and testing a spectrum-blind system for the acquisition and analysis of high resolution gamma ray spectra during on-site inspections under the CTBT. The On-Site Inspection RadioIsotopic Spectroscopy (OSIRIS) system includes software filters that limit the display of spectral data to radioisotopic information relevant to CTBT on-site inspections, e.g. I-131. OSIRIS performance has been evaluated on the basis of two hardware and three software performance criteria. The energy-calibration accuracy and electronic-gain stability of an ORTEC trans-SPEC-DX-100 mechanically cooled high purity germanium gamma ray spectrometer have been measured from 0 °C (32 °F) to 40 °C (122 °F). OSIRIS software performance has been evaluated on gamma ray net-peak-area measurement fidelity, Treaty-relevant fission product isotope detection true positives, and fission product detection true negatives, using a set of over 150 fission product spectra. The test spectral compositions include non-nuclear-explosion scenarios, e.g. a severe nuclear reactor accident, and nuclear explosion scenarios such as a vented underground nuclear explosive test. Compared to expert manual analyses of over 100 of these test spectra, the OSIRIS analyses were over 95% correct for identification of Treaty-relevant fission-product isotopes.

T3.2-O5. Snapshot Spectral Imaging Technologies for On-Site Inspection

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Multispectral and infrared imaging technologies are used in a CTBT on-site inspection (OSI) to search for anomalies and artifacts. During an OSI, spectral imagers can be used from the ground, as well as from the air during an additional overflight. For the airborne acquisition of spectrally resolved images, one common approach used throughout the remote sensing community is a pushbroom scanning spectrometer. However, over the past two decades, snapshot spectral imagers that simultaneously acquire spatial and spectral information have been developed. The advantages of snapshot imaging spectrometers over their scanning counterparts (such as a pushbroom spectrometer) are often application dependent. For example, transient phenomena are difficult to measure accurately with scanning instruments. For OSI, snapshot spectral imagers could enable more flexibility in data acquisition and simplify data processing, but may result in an unacceptable loss of resolution in one or more domains. In the work presented here, we examine the utility of snapshot spectral imagers for OSI. We examine a number of snapshot technologies and determine which are most promising for OSI needs, and compare the performance of these snapshot imagers to conventional scanning approaches with respect to spatial and spectral resolution, as well as signal to noise ratio.
T3.2-O6. The Potential Use of Unmanned Aerial Vehicles During On-Site Inspections

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Due to the rapid development of Unmanned Aerial Vehicles (UAVs) in recent years they have become a tool that could be applied during an on-site inspection (OSI). This talk will give an overview of the types of UAVs currently available and comment on how they could be used during an OSI. The talk will focus on how small to mid-sized UAVs could be used to take conventional and Multi-spectral and Infra-Red (MSIR) imagery of the whole inspection area or individual polygons of interest in an OSI. The current and potential future capabilities of UAVs applied to the unique challenge of an OSI will be discussed. The technical and non-technical challenges facing UAV use in an OSI, such as payload size and aviation regulations, will also be discussed.

Poster Presentations

T3.2-P1. A Gamma–Gamma Coincidence System for Radionuclide Quantification

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A high resolution gamma–gamma coincidence system has been developed at GBL15 for fast quantification of both cascade and single gamma emissions from CTBT relevant radionuclides. This consists of two BEGe-6530 crystals and an active cosmic veto. CAEN digitizers collect all data in list-mode, allowing offline sorting and processing with ROOT based analysis routines. Energy and time gated coincidence, sum-coincidence, and anti-coincidence modes are all possible with the current setup. Substantial MDA improvements have been achieved, which will be presented alongside various characterizations required for such measurements.

T3.2-P2. A Two-Element Coplanar CZT Detector for Radioxenon Measurements

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Atmospheric radioxenon detection, specifically the measurements of low concentrations of Xe-131m, Xe-133m, Xe-133, and Xe-135, has proven to be an important method for monitoring nuclear weapons testing. To improve the reliability and maintainability of current radioxenon detection systems employed in the International Monitoring System (IMS), a two-element coplanar CZT detector has been designed, constructed, and experimentally tested at Oregon State University. The detection system comprises of two $20 \times 20 \times 5$ mm$^3$ coplanar CZT detectors assembled face-to-face in a 7.8 cm$^3$ Al gas cell, four charge-sensitive preamplifiers, and a two-channel FPGA-based digital pulse processor. In this paper, detector design and our preliminary measurement results with lab sources and activated xenon radioisotopes will be discussed.
T3.2-P3. A Comparison of Gamma Spectrometers for Airborne Radiation Monitoring

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The measurement of gamma emitting airborne particulates collected on filters is a vital monitoring activity for both CTBTO and national radiological early warning networks. In the event of a radiological incident the measurements made by these networks must be rapidly collected, analysed and assessed. The results are then forwarded to national governments where decisions with far reaching consequences may have to be made. For this reason it is critical that the gamma measurements are as accurate and complete as possible. The gamma detectors currently used represent tried and tested technology, such as Geiger Muller tubes and NaI(Tl) scintillators. New and emerging detector technology offers the potential to improve isotope identification and quantification though improvements in energy resolution, efficiency, background reduction and detection limits.

Presented is a comparison of gamma detection technologies that have the potential to improve the ability of the CTBTO and national early warning networks to monitor airborne radiation. Particular interest will be paid to coincidence measurements made with fast LaBr₃ detectors that have been used to identify radioisotopes based on ‘fingerprint’ gamma cascades. This work is part of the European MetroERM project, which aims to harmonize the measurement and analysis of airborne radiation following a radiological event.

T3.2-P4. A System for the Simultaneous and Continuous Measurement of Airborne Gamma

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A system for the simultaneous and continuous gamma spectrometry measurement of particulate airborne radioactivity that combines a high purity Germanium detector with scintillation detectors is presented. Performance of this system is being evaluated in the framework of a project funded by the EURAMET programme. The main goal of this activity is the improvement of the capabilities of the current airborne spectrometry system, based on a HP germanium detector, at the same time that this detector is compared with new scintillation spectrometers, such as Lanthanum Bromide and Cerium Bromide. The system is being developed in the ESMERALDA reference site at CIEMAT where other automatic stations for early warning and environmental radiation monitoring are operating.

T3.2-P5. Acoustic-Seismic Coupling of Broadband Signals: Analysis of Potential Disturbances During CTBT On-Site Inspection Measurements

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In the framework of the verification of the CTBT the localization of possible underground nuclear explosion sites is important. In order to localize these sites sensitive seismic measurements of so-called aftershocks can be performed, which, however, can be disturbed by different signals. We focus on disturbances caused by airborne sources: When sound of aircraft hits the ground it excites soil vibrations which can mask weak aftershock signals. The research aims to develop recommendations for sensitive seismic measurements during CTBTO on-site inspections to reduce such disturbances. To gain a better understanding of the process of acoustic-seismic coupling we measured sound pressure and soil velocity from various sources e.g. jet aircraft. In the seismic data we observed interference patterns which can be used to estimate the path(s) of propagation of acoustically induced soil vibrations. The frequency-dependent phase offset between different sensors is used to estimate the propagation velocity. Additionally, some sensors were shielded from the incident acoustic waves in order to distinguish between seismic signals excited locally from ones produced at larger distances. The shielding results
in a decreased seismic signal amplitude, depending on frequency and depth in the ground, which is, however, much less than the decrease of the acoustic amplitude.

**T3.2-P6. An EMP-Based Method for Discriminating Between Nuclear and Chemical Explosions**

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The CTBT monitoring technologies such as infrasound and seismic waves are capable of detecting aggressive events, including earthquakes, chemical and nuclear explosions. Further analysis is required in order to characterize the nature of each event and its relevance to the Treaty. Here we propose a rapid and automated method for discriminating nuclear explosions from other sources of infrasound signals. Gamma rays emitted by a nuclear explosion produce an electric current via emission of Compton electrons. This current is the source of a strong electromagnetic pulse (EMP) which can be detected large distances away. There are also natural sources of EMP, namely lightning. However, the spectrum of nuclear EMP has significantly different characteristics than that of lightning EMP, enabling reliable and simple discrimination between them. Non-nuclear sources of infrasound such as chemical explosions lack the unique signature of EMP. Thus, accompanying the infrasound monitoring by continuous measurements of electromagnetic signals may provide a powerful tool for highlighting the nuclear events among all infrasound events. Infrasound alerts which have no mutual nuclear EMP signal can be immediately classified as non-nuclear events, eliminating the need for further analysis.

**T3.2-P7. Benefits Gained from the Use of a Silicon Beta Detector and Potential Cell Designs**

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Accurate detection of radioxenon sources is an important aspect of the International Monitoring System (IMS). Lowering the minimum detectable concentrations (MDCs) and increasing the power to discriminate between anthropogenic sources and nuclear explosions can each aid in the identification of radioxenon events. Current radioxenon detectors use beta–gamma coincidence detection to limit backgrounds and achieve the current MDCs. Sodium iodide (NaI) is used for detecting the gamma rays and plastic scintillator for detecting the beta particles. The use of silicon instead of plastic scintillator for detecting beta particles has the potential to both decrease the MDCs and increase the ability to identify the source of the radioxenon detected through the use of the ratios of the radioxenon isotopes. Xe-131m and Xe-133m both emit conversion electrons with energies that reside within the beta continuum of Xe-133, which is always present with Xe-133m and Xe-131m. The increased resolution of silicon results in narrower conversion electron peaks, and reduced backgrounds observed from Xe-133. We present the benefits of the different silicon detector types and cell designs currently of interest for improving beta–gamma coincidence detection.

**T3.2-P8. Considerations on the Application of Preparative Chromatograph in the On-Site Inspection Radioxenon Processing System**

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A gas chromatograph (GC) with a thermal conductivity detector (TCD) is indispensable for OSI radioxenon measurements in order to analyse the concentration of stable xenon to calculate recovery. The function of a GC is not only to analyse the concentration of stable xenon but also to resolve other technical problems in the radioxenon system, including concentrating xenon and removal of impurities such as H2O, CO2 and radon. The paper focusses on preparative chromatography and explores the potential of GC to simplify the system structure, to accelerate sample processing and to reduce the concentration of impurities in samples prepared for the radioxenon measurement system. The basic operation is described as follows: an appropriate volume of gas
sample is injected into the GC by means of a syringe or cylinder to enrich and analyse xenon as well as to separate the impurities. The xenon component is then collected at the outlet of the GC for radioxenon measurement.

**T3.2-P9. Cosmic Muon Veto Project Update**

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Cosmic Muon Veto Systems (CMVS) are used for suppression of the signals produced by HPGe detectors as effect of the interaction of cosmic radiation with the lead shielding of the detector. A customized CMVS has been installed at the VIP00 test station of CTBTO Headquarter in Vienna, with the scope to assess the impact of electromagnetic particles showers produced by the interaction of cosmic muons with the lead shielding and potential improvements in the sensitivity of the particulate systems operating at radionuclide stations of the International Monitoring System (IMS) of the CTBTO—with special focus on stations installed at high altitudes or in places subject to intense cosmic radiation. The poster presents system’s design, data acquisition modes and analysis and also describes the potential use of the CMVS for onsite re-measurements of samples of interests at remote IMS radionuclide stations.

**T3.2-P10. Detection of Thermal Signatures as a Function of Transferred Heat and Weather Conditions**

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Underground nuclear explosions can have detectable impacts on hydrogeological conditions; potentially affecting aquifers and wells as well as soil moisture. A potential impact of a detonation is cool subsurface or geothermal water being brought to the surface or to the near-surface, manifesting as OSI-relevant thermal anomalies. The use of infrared imaging equipment at the surface and from the air is permitted during an on-site inspection. On this basis, a series of tests were performed using thermal imaging equipment to assess their ability to detect simulated heat sources in the near subsurface. Recording of input energy, soil and meteorological conditions enabled heat transfer to be modelled, and allowed the sensitivity of thermal imaging cameras under different conditions to be quantified. Variations in weather conditions over testing days enabled the team to evaluate the appropriateness of the application of thermal imaging equipment for the detection of OSI-relevant thermal anomalies under different environmental conditions.

**T3.2-P11. Developing a Easily Deployable Airborne MSIR Suite for On-Site Inspections**

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The CTBTO has used airborne remote sensing suites to collect MSIR data relevant to an OSI during several exercises and field tests: notably a suite was deployed during the 2014 Integrated Field Exercise (IFE). These systems have been used for proof-of-concept tests and to develop operating principles and therefore are not optimized for use in an actual OSI. For example, the system used in the IFE was technically very capable but had a significant number of cables to connect and took a relatively long time to install and remove from the aircraft. During this talk options for progressing from a development system to an operational system suitable for use in an On-Site inspection (OSI) will be discussed including the work is required to construct such a system. To that end, critical questions that must first be answered such as, “What data should an MSIR suite collect?” and “How should an OSI system collect that data?”, and “How will that data be analysed and used to support the OSI.”, these questions will be addressed during the talk.
T3.2-P12. Enhanced Search Methods for Finding and Identifying Radioactive Material for On-Site Inspection Deployment

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The CTBTO verification system comprises on-site inspection (OSI) to verify the suspicion of a banned nuclear test. One of the methods of verification is the radiological survey of the inspection area. The measurement car DeGeN of our institute, which is equipped with highly sensitive neutron and gamma detectors, is well suitable for car borne survey. The quality of the results of such a survey is in the first place dependent on the performance of the measurement system but in the second place it is also depends on the experience and the training of the user. To investigate this second factor we carried out a measurement campaign on a test area. We invited different persons with different abilities ranging from simple fireman to expert user to use our measurement car in a test course with different radioactive sources. Each participant who drove our measurement car or operated the measurement system as co-pilot was asked to fill out a questionnaire to state his previous experience. The results of the test runs were collected afterwards and compared to the information in the questionnaire. The evaluation yielded interesting results which may also be relevant to enhance OSI procedures as well as system designs.


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In the framework of the CTBT verification regime, recent developments related to IMS station detection systems involving semi-conductor detectors for both electron (silicon) and photon (germanium) high resolution measurements will lead to a major breakthrough in fission product traces analysis in the atmosphere. Coupled to an efficient xenon air extraction and concentration process, high resolution electron photon coincidences performed in listmode acquisition allow reliable quantification of the 4 relevant CTBT radioxenons at levels as low as 0.1 mBq/m³. The same innovative detection system is also of interest by adding new capabilities such as beta–gamma coincidence signatures in certain IMS particulate measurements (3M type filter).

T3.2-P14. LaBr Online Filter Monitoring System: Testing Results and Future Projects

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As a consequence of the Fukushima accident it became obvious that the IMS filter could potentially cause radiological concern for the station operators due to the high air flow rate which can lead to accumulation of sizeable activities on the filters. Also, the data from the filter analysis is not available until more than 52 hours from the collection start (the time of the first preliminary spectrum is sent to IDC). Therefore, CTBTO started investigation into an early warning online filter monitoring system with low resolution detectors. LaBr was selected as one of the best solutions. Its resolution allows to distinguish radioactive iodine isotopes from the radon progenies and has orders of magnitude better sensitivity than conventional in-situ dose monitoring devices. This system gives possibility to warn station operators well in advance of any radiological hazards a filter can represent, and provides early notification to the CTBTO to timely implement necessary actions in response to such an event. The poster presents the system design, efficiency validation, results of the long term testing at the test station at VIC and comparison of LaBr data with the HPGe measurements of the filters.
T3.2-P15. Monitoring of Environmental Radioactivity at the Trace Level Using the New Gamma3 Spectrometer

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IMS support laboratories are in charge of the expertise of both particulates and noble gases samples collected by the CTBT radioactivity monitoring network. Due to radioactive decay and transportation delays, the highest detection sensitivities for CTBT relevant isotopes must be achieved by laboratories. FRL08 laboratory has designed and built a new low-level gamma/electron spectrometry setup. Most recent state-of-the-art techniques have been implemented to achieve high detection sensitivities and very low background. The Gamma3 setup is composed of a versatile array of three high efficiency HPGe gamma spectrometers surrounded by an optimized passive/active shielding. The integral background count rate is as low as 3.0 counts min⁻¹ (20–2500 keV range) which is among the lowest published values for a surface level instrument. Data acquisition is performed by a multichannel digital system, this configuration produces listmode files that are processed offline using home-developed ROOT-based routines. The feature allows to process signals produced by the detectors in various configurations: single/additive mode, coincidence/anti-coincidence mode. For noble gases measurement, a dedicated gas cell fitted with two silicon detectors is used in combination with two HPGe detectors to perform coincident b/g detection of radioxenon. Performances of the system will be illustrated for various CTBT relevant samples.


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IMS noble gas stations require to purify and to concentrate Xe by using compact and cost-effective processes. Noble gas separation is also of crucial importance regarding the xenon mitigation to prevent strong releases from nuclear facilities. CEA has been working for a few years on the development of a new adsorbent material to purify and concentrate Xe: silver exchanged zeolite (MFI), Ag@ZSM5. This adsorbent exhibits two order of magnitude higher retention capacities than activated charcoal. We showed that this material presents two different adsorption sites. The strong adsorption site is observed into the 0.087–100 ppm range that makes it efficient to treat Xe from the air or other low concentration samples. Experimental and simulation data have been then coupled to attribute the strong adsorption site to the presence of silver nanoparticles into the zeolite network. The strong capabilities have been illustrated by using Ag@ZSM5 into the SPALAX leading to reduce the column sizes by about a factor 15. Moreover, we showed also the outstanding performances of this new material to separate Xe and Kr that open promising prospects in other crucial applications such as industrial Xe production, nuclear waste management or xenon mitigation.

T3.2-P17. Non-Typical Using of Portable Field Gamma Spectrometer for Radon Concentration Measurement

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Within the framework of the BlackSeaHazNet project (FP7 MCA PIRSES-GA-2009-246874), pilot research was undertaken to collect radon and gamma radionuclide samples from three karstic caves in Slovenia (Postojna Cave System, Županova Jama and Škocjan Caves) and one cave in northern Italy (Grotta Gigante). In all four caves, radon and gamma ray monitoring was performed to understand the relation between radon and its daughter products. In-situ monitoring of natural levels of radon and gamma radiation and spectrometry of gamma radionuclide in karstic caves was for the first time accomplished in this study. Measurements were
performed by the radiometric and spectrometric instrument PRS–01 (produced by AtomKompleksPribor, Ukraine), which is designed for determining the qualitative and quantitative composition of gamma-emission radionuclides in field and laboratory conditions, as a means of investigation radioactive sources and anomalies, and for gamma-survey at the surface.

**T3.2-P18. Optimizing Airborne Sensor Configuration for an On-Site Inspection**

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Whilst the value of airborne technologies to an on-site inspection (OSI) was highlighted during the 2014 Integrated Field Exercise, further synergies are possible between all airborne systems that could decrease instrument footprint, ease equipment installation and reduce training needs. These benefits are driven by the overarching need to facilitate the work of inspectors during an OSI when Treaty-imposed constraints and the requirement to deliver mission data in a timely manner impose considerable demands on inspection team members. Optimization would result in greater flexibility, reduce manpower requirements and expedite system turnaround times enabling the inspection team to respond more efficiently to changes in operational requirements and prevailing weather conditions. Furthermore, by miniaturizing instruments and increasing system robustness, the aim is to increase the range of airframes for which the system could potentially be certified and deployed during an OSI. In addition to hardware, optimization also includes greater integration of software and analysis tools when possible.

**T3.2-P19. SiPIN Efficiency Calibration Validation and Direct Measurement Comparison with an HPGe Detector**

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The newly developed SiPIN beta–gamma coincidence measurement system for noble gas monitoring systems produced by Lares Ltd has been procured and tested by the CTBTO for OSI purposes. To assess its usability and sensitivity in the IMS noble gas network context the SiPIN detector was connected in parallel to the HPGe system at the test noble gas SPALAX system at VIC. The poster presents the results of the direct comparison as well as preliminary results of the calibration validation for the SiPIN system using radioxenon spikes and Monte Carlo simulations.

**T3.2-P20. Spatial Deconvolution of Aerial Radiometric Survey Results**

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An essential component of an on-site inspection is a gamma radiation survey, which is preferably carried out on an aerial platform. An aerial radiometric survey is capable of mapping dose rate or isotope-specific concentrations with high density over a large area in a relatively short time (eg. 8 km² in 2.5 hrs with typical flight parameters). The contoured concentration distribution provides a good measure of total radioactivity and of the locations of high and low concentration. However, the aerial system is sensitive to a large area on the ground—of order H², where H is the survey altitude. Thus, each measurement in the grid represents an average over this region of sensitivity. This has the effect of smearing the ground-level spatial variation, with the potentially harmful consequence of underestimating the strength of highly localized deposits. We have developed a method to deconvolve a spatial distribution for the smearing caused by the large region of sensitivity. The method can recover some of the sharpness of the ground-level features, including the magnitude of spatially restricted hot spots. In this presentation we show the spatial deconvolution method, and demonstrate the results of the method on both synthetic and real-world data sets.
T3.2-P21. Use of Satellite Remote Sensing Imagery for CTBT Verification

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Remote sensing imagery is a powerful tool for the international organizations, states and interested individuals to monitor compliance of states parties with nuclear security related treaties. The CTBT that has not yet entered into force, recognizes the use of remote sensing technology for the CTBT verification as part of the national technical means and during on-site inspection activities. Very high spatial resolution satellite imagery is usually used to investigate an area of an alleged nuclear test explosion. However, because the precise location of this area may not be known, the use of medium spatial resolution imagery could initially be helpful for a wider “view”. This study investigates by using Landsat images the sites of several underground nuclear tests carried out by USA, ex-USSR, China, India, Pakistan and the Democratic People’s Republic of Korea. Change detection based on satellite imagery animation and visualization techniques was used. The use of medium spatial resolution imagery gave good results for the detection of the surface disturbance produced by the underground nuclear tests. However, low yield tests may not have surface expression to be detected by the satellite imagery. In these cases, high spatial resolution satellite imagery may indicate activities related to nuclear testing.

T3.2-P22. Xenon Inter-Comparison Exercises with Traceable Activity Concentration Standards

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Preparation methods for traceable xenon standards and the results of the 2014 xenon laboratory intercomparison exercise are presented. One element of the quality assurance/quality control (QA/QC) programme for noble gas systems of the IMS radionuclide network will be based on sample reanalyses at IMS laboratories. In order to ensure the credibility of IMS laboratories as providers of reference results, these laboratories will require certification as well as participation in a QA/QC programme. Part of the laboratory QA/QC programme will be regular intercomparison exercises. The quantity measured at laboratories is the activity concentration (e.g. Xe-133/(stable xenon) in Bq/ml). However, until recently activity concentration standards which are traceable to international reference standards were unavailable. Consequently, previous inter-comparisons between laboratories lacked references values for benchmarking. Therefore, two Xe-133 activity concentration traceable reference standards were produced independently and used for the 2014 xenon laboratory intercomparison exercise.
3.3:  
Data Processing and Interpretation

Oral Presentations

T3.3-O1. Advancement of the CTBTO Link to the International Seismological Centre Database

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The Link to the database of the International Seismological Centre (ISC) provides both CTBTO and National Data Centres with dedicated access to seismological data sets maintained by ISC using specially designed graphical interfaces and database queries. This service gives access to several products: the ISC/ISS bulletins of natural seismicity of the earth, mining induced events as well as nuclear and chemical explosions; the EHB bulletin and the IASPEI Reference Event list (GT). The database searches are tailored to the needs of the monitoring community and are divided into four categories: the Area based spatio-temporal search (based on ISC Bulletin), the REB based spatio-temporal search (based on specific REB events), the GT event based search and the IMS station based search (historical reporting patterns of stations close to IMS sites). Recently, we made considerable improvements to the waveform preview/request tool that deals with non-IMS waveform records of the REB and GT events as well as to the tool that allows on-line relocation of REB events using additional station data available at the ISC. The service has been extensively used by the NDCs and CTBTO and proved useful during both the 2013 NDC Preparedness Exercise (NPE) and the 2014 OSI Integrated Field Exercise.

T3.3-O2. An Integrated Data Acquisition, Processing and Analysis Platform for National Data Centres: The Extended NDC-in-a-Box (EU/CTBTO Joint Action V)

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CTBTO provides technical assistance that enables Member States to work with monitoring data and IDC products. This assistance includes the distribution and installation of software package, so called NDC-in-a-box (NIAB) which gives the NDCs the capability to receive, work with and analyse seismic hydroacoustic and infrasound data. In 2013, in the framework of European Joint Action V under NDC Capacity Building Programme (EU Council Decision 2012/699/CFSP), CTBTO has engaged in efforts to extend the current NIAB waveform package by adding the capability of common processing on the same operational platform real time data from regional and global networks (e.g. IMS, FDSN). The new package integrates SeisComP3 software with IDC-like environment. It also provides new expert tools (DTK suite: GPMCC, DIVA and Jade) specially designed for NDCs for processing, visualizing and analysing seismoacoustic data, with a particular emphasis on infrasound technology. These tools will complement Geotool software application. This project is an unprecedented opportunity for NDCs to enhance their national capability and best interact with CTBTO. A
group of alpha testers representing 10 volunteer NDCs actively contribute to the project by providing developers and CTBTO with requirements and feedback on the delivered products before a broader distribution planned in 2016.

T3.3-O3. Association of Array Processing and Machine Learning for the Detection and Classification of Seismic Events

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We associate an array processing method to detect seismic events and a machine learning classification method to classify the detections. The detector is the progressive multi-channel correlation (PMCC) technique, which has been developed at the Environmental Assessment and Monitoring Department (DASE) of CEA. It is designed to detect any coherent wavefront crossing a seismometer array, and to estimate its propagation parameters. Due to coherent noise, PMCC can trigger detections that are not related to a seismic event of interest, hence the need to classify the detections. The classification method is called hidden Markov models (HMM). HMMs are trained to model feature vector sequences, which are extracted from the seismic signal, and they are used for classification. The features we choose combine features computed directly from the signal, and outputs from PMCC describing the detected wave. We apply our method to the automatic discrimination of PMCC detections between regional seismic events, teleseismic events, and noise. We use signal records from the IMS Songino array station in Mongolia, and the seismic catalogue provided by the Research Center of Astronomy and Geophysics (RCAG) of the Mongolian Academy of Sciences. The classification performance is above 80%.

T3.3-O4. Automatic P-Onset Precise Determination Based on Local Maxima

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Seismic phase arrival time identification is a fundamental and vital task in seismic signal processing as it enables seismologists to derive important geological and seismological information. This includes location of earthquakes and other seismic sources such as nuclear explosions and quarry blasts. Additionally, seismic phase properties have served in many other studies, including source mechanism and seismic signal identification. Accurate and reliable automatic picking of very low and emergent seismic arrivals is still a major challenge in seismic signal processing. Due to the importance of accurate picking tasks, a large effort has been put into finding efficient and sophisticated algorithms that can detect and precisely pick arrivals of seismic waves. The aim of the current study is to propose a robust method for picking the arrival of the P-wave based on Local maxima. Such a technique provides a reliable detector for both frequency and amplitude variations. Therefore, it mainly addresses the problem of automatic picking of low signal-to-noise ratio P-arrivals. Experimental results on real seismic data, consisting of seismic events of different signal-to-noise ratios, and comparison with commonly used methods in practice demonstrate the reliable performance of the proposed method.

T3.3-O5. Creation of a High-Resolution Catalogue of Mining Explosions Within the Russian Platform Using Joint Capabilities of Seismic Array Mikhnevo and the International Monitoring System

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The Institute of Geosphere Dynamics has operated the Mikhnevo (MHVAR) small aperture seismic array since 2004. The location and historical bulletins/catalogues of mining explosions recorded by Mikhnevo, as well as
data from the seismic array AKASG (primary station of the International Monitoring System), prove advantageous in improving detection and identification of mining activity within the Russian platform. The data are obtained under a Limited Access contract with CTBTO via the virtual Data Exploitation Centre. Continuous data from MHVAR and AKASG are processed together using both standard and waveform cross correlation techniques. The latter technique can provide a reduction in the detection threshold by an order of magnitude, as well as accurately locating and identifying mining explosions. To test the performance of the cross correlation technique, we selected the best sets of master events for the Mikhailovskiy, Lebedinskiy, and Stoilenskiy mines and processed continuous data. Using Principal Component Analysis for dimensionality reduction we produced synthetic waveform templates allowing faster data processing and improvement in resolution and sensitivity.

T3.3-O6. Searchlight Correlation Detectors: Optimal Seismic Monitoring Using Regional and Global Networks

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The sensitivity of correlation detectors increases greatly when the outputs from multiple seismic traces are considered. For single-array monitoring, a zero-offset stack of individual correlation traces will provide significant noise suppression and enhanced sensitivity for a region surrounding the master event hypocentre. This region’s extent is limited only by the decrease in waveform similarity with increasing hypocentre separation. When using a regional or global network, the zero-offset approach is only optimal when the master and detected events are co-located exactly. In many monitoring situations, events may be separated by up to many hundreds of metres while retaining sufficient waveform similarity for single-channel correlation detection. However, traveltime differences resulting from the hypocentre separation may result in significant beam loss on the zero-offset stack and a deployment of many beams for different hypothetical source locations in geographical space is required. The beam deployment necessary for optimal performance of the correlation detectors is determined by an empirical network response function which is most easily evaluated using the auto-correlation functions of the waveform templates from the master event. The correlation detector beam deployments for providing optimal network sensitivity for the nuclear test site in the Democratic People’s Republic of Korea are demonstrated for both regional and teleseismic monitoring configurations.

T3.3-O7. Signal-Based Bayesian Monitoring

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We present SIG-VISA (SIGnal-based Vertically Integrated Seismic Analysis), a next-generation approach to Bayesian seismic monitoring. This work builds upon the success of NET-VISA, recently recommended for production deployment at the IDC. While NET-VISA focuses on network processing, SIG-VISA subsumes station and network processing using a probabilistic model of continuous seismic waveforms. Inference in this model yields a new algorithm for simultaneous detection and location of seismic events, unifying signal-based techniques such as waveform matching and double-differencing with traditional detection-based monitoring in a single framework with principled handling of uncertainty. SIG-VISA represents a seismic phase arrival as a parametric envelope perturbed by a random modulation given by a location-dependent Gaussian process (kriging) distribution on wavelet coefficients. Model parameters are learned from historical data, so that the signal from an event with a nearby historical doublet will tend to match the previous observation, with uncertainty increasing as distance. When no historical events are nearby, the predictions smoothly degrade to parametric envelopes. We show preliminary results demonstrating detection and localization with waveform matching on synthetic and real data, and discuss progress in scaling up our system for computation on a global network.
T3.3-O8. Toward High-Confident and Full Automation of Seismic Data Processing for CTBT Monitoring

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Seismic monitoring activities, either for CTBT or earthquake-induced disaster control, are facing a new era of big data as the number of seismic stations rapidly and significantly increases. However, the reality that up to date routine seismic data processing still heavily relies on manual interactive analyses hardly fits the new era. The aim of this work is to develop technologies for the full automation of seismic monitoring. In recent years we have carried out research to explore novel techniques for high confident seismic data processing. The research involves techniques to characterize and use the integral features of ‘seismograms’ for phase identification and association; techniques that reliably associate teleseismic signals recorded at regional seismic networks; CASM (Computer Analyst for Seismic Monitoring) techniques whose objective is to replace the task of human analysts for seismic event review; and techniques to automatically identify seismic events by knowledge-match including envelope or waveform cross-correlation. Some of the new techniques have been applied or tested for regional seismic networks with satisfying results. A brief review of these techniques with some discussion on their prospect to be applied to the global seismic network will be presented in this report.

T3.3-O9. Using International Seismological Centre Data to Build a Prior of Seismicity for NET-VISA.

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Previous work on NET-VISA (Network Processing Vertically Integrated Seismic Analysis) has shown that a Bayesian approach to global seismic monitoring can be very effective. Such an approach builds on probabilistic generative models of seismicity, signal propagation, noise, and detector performance. Crucial to NET-VISA’s performance are empirically calibrated measures of the uncertainty associated with each of these models. Together, the models and their associated uncertainties allow NET-VISA to propose bulletins that are consistent with known geophysics and combine evidence (or the lack of evidence) appropriately from all sources. In this work we focus on improving NET-VISA’s Bayesian prior for global seismicity, i.e. the probability of occurrence per unit time of an event with a given location, depth, magnitude, and source type (natural vs. man-made). To do so we draw on the extensive International Seismological Centre (ISC) catalogue of known natural seismic events. The new prior leads to significantly more accurate predictions of event locations. Using ISC’s database of known explosions, we also evaluate the extent to which an event’s predicted location provides an indication of its source type.

Poster Presentations

T3.3-P1. A General Data Converter of Seismic Data, Saving Huge Amount Time of Seismologists

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Seismography is the science of exploring the earth via the recording of seismic waves that travel from source to the receiver inside the earth. Seismologists are usually working with a huge amount of data and often encounter data format problems. Many companies and groups define their specific data format, and while scientists are working on their projects they usually have the problem of converting one data format to another. This data
management procedure can waste remarkable amounts of time and can heavily impact the main project. A general data converter is developed, based on the usual data formats (SAC, GSE, MiniSEED, SEED, GCF, Seisan, ASCII, SSA2 V1), that will convert data in one format to another. This utility is developed in MATLAB and effectively reduces the time spent by researchers converting data. Detecting the data type is done by the program and the user just need to select their desired format. Merging and splitting various components is also possible with this program. It could be useful for many global scientists to more easily achieve their desired format.

T3.3-P2. ANGLE 4: A New Version of Quantitative Gamma-Spectrometry Software Suitable for International Monitoring System Radionuclide Stations and Supporting Laboratories

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The ANGLE software for quantitative gamma-spectrometry is routinely exploited in hundreds of gamma spectrometry-based laboratories worldwide (see www.anglex.dlabac.com). Its applicability in CTBTO test-ban-related radionuclide monitoring has been demonstrated earlier (SnT2013). The ANGLE software application allows for accurate determination of the activities of gamma spectroscopic samples for which no “replicate” standard exists in terms of geometry and matrix. A semi-empirical “efficiency transfer” approach is employed, combining advantages and minimizing the drawbacks of both absolute (e.g. Monte Carlo) and relative (traceable source based) methods to determine sample activity. A new version of the software (ANGLE 4) has subsequently been developed and is about to be released by Q2 2015. In the present paper, the ANGLE 4 characteristics, which make it even more suitable for CTBTO radionuclide stations and supporting laboratories, are outlined—particularly those concerning automation, networking, standardization and advanced data processing. A new XML based file format allows easy manipulation of input/output files by third party software and, thus automation and complex analyses. There is also a scaled graphical preview of input/output parameters, exportable to bitmap or vector file formats, multilanguage support, upgraded user interface, etc. Being fully transparent to the user, its educational and training potential is outstanding, particularly for distance learning applications.

T3.3-P3. An Approach for Seismic Detection with Model-Based Array Waveform Correlators

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Empirically derived waveform correlators often are exquisitely sensitive detectors and robust event classifiers when applied to search for highly repetitive events. Their usefulness is limited, however, by the absence of training events in many regions. An ability to extend waveform correlation techniques to aseismic regions would be highly desirable and motivates a search for model-based methods. As three-dimensional earth models become more detailed through ambient noise and adjoint tomography, the prospects for model-based signal processing improve, albeit slowly. This study examines how more detailed models might be used to drive array correlation detection, considering overlays of stochastic heterogeneity to account for model uncertainty. The introduction of stochastic medium models leads to a subspace representation for the signal to be detected. An efficient means for generating the subspace representation from a stochastic model is discussed.
T3.3-P4.  Application of a Wavelet Transform as Pre-Filtration Unit for Strong Noisy Seismic Records

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One of the significant current tasks in seismology is the improvement of automated processing of seismic records on a time scale approaching real time. The use of the wavelet transform allows one to simultaneously run any necessary filtering and easily detect a different phase of the input signal that are not visible on the original seismograms, especially in case of strong noise. The entire process of filtering and analysis can be represented as three-dimensional graphic images, which greatly simplifies interpretation of the seismograms. Since this method does not require large computational effort there is a possibility of its realization in the form of real time algorithms. Specific requirements are presented for registration and processing of poor and strong noisy seismic signals. These signals can be received from mobile stations or seismic stations installed in the “wrong” places, such as the territory of industrial plants or settlements (it simplifies and reduces the cost of installation and operation, but significantly impairs the quality of the seismic signals due to high noise levels). In this case pre-filtering is indispensable. Unfortunately, widely used methods for filtration such as the STA/LTA, LPF, HPF, etc. do not lead to satisfactory results.

T3.3-P5. Application of the Framework for Detection Software Evaluation

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The IDC receives and processes data from the global network of the IMS for seismic, hydroacoustic and infrasound sources. The analysis involves a multistage automatic processing at station and network levels, followed by an interactive review of the results performed by waveform analysts. The study summarizes the results of the project “Framework for detection software evaluation” that was reviewed by a group of Experts at the Technical Meeting in October 2014. The project aimed at establishing metrics and methodologies for quantifying the performance of signal and event detection algorithms of the kind that are in regular use at the IDC. Typically the software under benchmark provides a detection bulletin from observed data. In this framework the software is seen as a single process, even though it is composed of several sub-processes. The evaluation makes use of a database of synthetic (and pseudo-synthetic) data sets to exhibit specific aspects of the detection. The following items will be considered in the presentation: (i) a list of indexes to evaluate the performances of the software under test; (ii) a list of technology specific attributes; (iii) a list of selected parameters to generate realistic synthetic data; and (iv) the application to a concrete case study.

T3.3-P6. Could the International Monitoring System Infrasound Stations Support a Global Network of Small Aperture Seismic Arrays?

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The IMS infrasound arrays have up to 15 sites with apertures up to 3 km. They are distributed remarkably uniformly over the globe, providing excellent coverage of South America, Africa, and Antarctica. Therefore, many infrasound arrays are in regions thousands of kilometres from the closest seismic array. Existing 3-component seismic stations, co-located with infrasound arrays, show how typical seismic signals look at these locations. We estimate a theoretical array response assuming a seismometer at each infrasound sensor, although the true performance would depend upon both SNR and coherence. These properties can however only be determined experimentally and borehole deployments may be needed to record seismic data of sufficient quality. We demonstrate, from a purely geometrical perspective, that essentially all IMS infrasound array configurations would provide seismic arrays with acceptable slowness resolution. Such arrays in many regions would likely enhance significantly the seismic monitoring capability in parts of the world where only 3-component stations
are currently available. Co-locating seismic and infrasound sensors would mitigate the development and operational costs due to shared infrastructure, and hosting countries might find such added capabilities valuable from a national perspective. The seismic data may allow far more information to be gleaned from the infrasound data.

**T3.3-P7. Data Processing in Ukrainian National Data Centre**

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UANDC performs processing of seismic and infrasound data 24/7. UANDC uses data from IMS station, IRIS and GEOFON servers and data from national system of observation. Data processing of seismic data is performed in real time and in three steps. The first one is automatic analysis. The 3-pipeline SeisComp3 system for different regions of interest and our own software are used. Automatic processing is used just as a preliminary result, and as initial data for manual analysis. The second step is manual processing. For manual processing, we use Geotool, SeisComp3 and our own software developed by UANDC specialists. UANDC software are used to obtain accurate processing results such as depth, magnitudes etc., and additionally perform cross-correlation analysis in some cases such as in nuclear tests. The last step is expert group analysis. For this step, we use all available data and software. Expert analysis is performed only in cases when the on-duty analyst has doubts about the nature of the source (for example a nuclear test) or the source can impact on the Ukrainian territory (such as events from Romania). For infrasound data, the on-duty analyst uses PMCC (WinPMCC) software. Such schema allows in the short term to provide reports about processing, which can go to different state authorities.

**T3.3-P8. DataScale Project: Seismic Event Location Using Waveform Correlation Techniques at Global Scale**

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DataScale is a French Software Project born at call number 3 «Cloud Computing» and «Big Data» of French “Investissements d’avenir”. The goal of the project is to develop a data analysis tool leading to a revision of seismicity at a global scale between 2002 to 2012. Seismic waveform data are obtained from the CTBTO using the primary seismic network of the International Monitoring System (i.e. 23 seismic arrays, distributed globally). We present a waveform cross-correlation algorithm and the associated processing workflow. This process leads to the creation of a new seismic bulletin taking as input event subsets from the Reviewed Event Bulletin (REB). A detailed study of the template selection is presented and the results suggest that broad monitoring using historical templates of interest is feasible and increases detection capabilities and location precision. The computing platforms and preliminary performance tests are also presented.

**T3.3-P9. Enhanced Capabilities of Custom GIS Solution for CTBT On-Site Inspection Application**

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In order to support scientifically credible investigations during OSI, enhanced capabilities of custom GIS solutions for the OSI application has been developed. The principal purpose of the enhancements were to establish an easy-to-use enhanced human-machine interface prototype GIS suitable for data and map management related to OSI workflows during operations. CTBTO used professional GIS software to plan, manage and review the OSI geospatial data, but its use was limited to trained GIS professionals working with specialized GIS software. As the resources both in time and personnel of an Inspection Team are limited by the CTBT and on-going operations during OSI, GIS services needed to be expanded to a wider range of users in order to streamline the information flow during an OSI. The goal was achieved by using custom developed, task
orientated applications that are accessible offline using a web interface. The enhancement of the system included the Mission Planning Application, the Field Team Planning Application, and the Viewing Application. A system with the mentioned enhanced capabilities was deployed during the 2014 Integrated Field Exercise and proved its efficiency during conduct of the field missions supporting scientific teams in their forensic investigations.

**T3.3-P10. Expert Technical Analysis Procedures at the International Data Centre**

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Expert Technical Analysis (ETA) at the International Data Centre (IDC) is a complex and not well defined area of the information analysis. It involves different and not always directly interconnected instances, such as data, products, methods, software, etc. Setting up the ETA at the IDC should initiate the work related to these instances in parallel, to have it working as a tested and approved service for State Parties before entering the Treaty into force. In this presentation we focus on methods that may complement the tools already set up at the IDC and can be used for the ETA, taking into account recent advantages in data processing, mostly related to the IDC waveforms technologies. The methods include: seismic event location based on master event (cross-correlation, CC) approach, estimating the depth of presumably shallow events, and event waveform decomposition. The CC branch includes a dimensionality reduction which would improve not only the monitoring performance but also the detection of explosions lacking any SHI signatures up to now. The shallow event depth estimation involves both synthetic simulation and cepstral estimation. The event decomposition will likely help in resolving the problem of revealing clandestine nuclear tests.

**T3.3-P11. Extended NDC-in-a-Box (EU/CTBTO Joint Action V) Data Model: Integrated Data Acquisition, Processing and Analysis Platform for National Data Centres**

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CTBTO provides technical assistance that enables Member States to work with monitoring data and IDC products. This assistance includes the distribution and installation of NDC software package. This NDC-in-a-box consists of software to receive, work with and analyse the data. CTBTO is extending the current NDC-in-a-box with additional software enabling users to easily combine data from regional and global networks (e.g. IMS, FDSN) and to significantly improve the NDCs processing capabilities. To achieve this, the NDC will use an open source database (PostgreSQL) that replicates the CSS database table from the IDC, and applications will exchange information with SeisComp3 or NDC processing pipelines. In the NDC platform, formats are standardized with CSS and CSS-miniSEED (i.e. miniSEED binary data referenced in CSS Wfdisc structure). New tools operate data format conversion between SEED/miniSEED and CSS/CSS-miniSEED. New expert modules for seismoaoustic analysis (DTK-GPMCC, DTK-DIVA and DTK-Jade) as well as processing tools (detector and locator) used in IDC operations will be made available to NDCs, either connected to the IDC environment or plugged in near real time to SeiscomP3 mediator. The poster explains how the new functionality in the extended NDC-in-a-Box provides to NDCs an integrated acquisition, processing and analysis platform for S/H/I data.
T3.3-P12. Hierarchical Prior for Source Term Determination and Its Variational Bayes Estimation

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Tools for the fusion of atmospheric transport models with data are of a great importance in many fields where characteristics of a source term are sought. The most promising tools seem to be those based on Bayesian analysis, with the most appealing feature being the inherent capability to treat the full probability distribution of involved uncertainties. Since the output is a posterior probability distribution, probabilistic interpretation of results can be drawn. However, practical application of Bayesian methods can be difficult because a proper specification of the a prior distribution is needed. The tools must ensure that the prior selection procedure is robust enough to work under various circumstances, particularly in the case of continuously operating non-supervised analysis. A solution to this problem can be the use of simple parameterized priors. Here, we present a method based on prior hyper-parametrization and estimation of these parameters using Variational Bayes method. The method can be applied in different setups with different complexities: from estimation of diagonal elements of a covariance matrix under the assumption of homoscedasticity (having the same variance), to estimation of all elements of a covariance matrix (given a large number of data). The method will be demonstrated with an example.

T3.3-P13. International Data Centre Infrasound Pipeline Initiative for Technology Development

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The first atmospheric event built exclusively from infrasound arrivals was reported in the Reviewed Event Bulletin in 2003. Currently 48 infrasound stations from the IMS are installed and transmitting data to the IDC. The infrasound component of the IMS daily registers infragenic signals originating from various natural sources such as volcanic eruptions, earthquakes, meteorites entering the atmosphere and anthropogenic sources such as mining and accidental explosions. The IDC routinely processes infrasound data and creates automatic bulletins reviewed interactively. The IDC advances its methods and continuously improves its automatic systems. It focuses on enhancing the automatic system for the identification of valid signals and the optimization of the network detection threshold by identifying ways to refine signal characterization methodology and association criteria. The current operational system handles seismic, hydroacoustic, and infrasound technologies within one instance of the Global Association automatic association algorithm. The Infrasound Pipeline initiative consists in separating infrasound technology at the automatic association stage. An objective is to reduce the number of automatically associated infrasound arrivals that are rejected by analysts. This study prepares the way for implementing the next generation of automatic waveform association algorithms. Infrasound association is revisited to pursue a lower ratio of false alarms.

T3.3-P14. IDCDACS: The International Data Centre’s Distributed Application Control System Ported to Open Technologies

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The Distributed Application Control System (DACS) is the backbone of the automatic processing of seismic, hydroacoustic and infrasound (SHI) waveform data at the IDC. It drives the execution of processing applications by organizing data into time intervals, processing steps into pipelines, and using message queues for task scheduling. Because licensed software hampers free distribution and use of IDC software to and by National Data Centres, IDC eliminated the dependency on the proprietary Tuxedo middleware. We redesigned the
existing system and implemented the new IDCDACS based on an open-source messaging solution in combination with existing in-house IDC libraries and a custom-developed application framework, which together replace Tuxedo in a robust, reliable and scalable way. Our solution utilizes the RabbitMQ high availability message broker and the Advanced Message Queuing Protocol (AMQP), an open industry standard and wire-level protocol mandating that senders and recipients can interoperate irrespective of their specific implementation. The new IDCDACS was implemented using the Scrum agile development methodology, aligned with evolving requirements and priorities. IDCDACS is flexibly configurable to control different processing applications and pipeline-like processing workflows, i.e. it is by design not limited to SHI data processing, which is the primary use case at the IDC.

**T3.3-P15. Improvement of the Array Processing System at the Kazakhstan National Data Centre**

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Since 2001, the Center for Acquisition and Processing of Special Seismic Information of RSE IGR (KNDC) in Kazakhstan has been using the NORSAR array processing software together with its own developed software tools. More than 10 years of on-line data processing using this technology has shown its reliability and effectiveness for automated detection and processing of seismic events from different regions in Kazakhstan and Central Asia. The key features of the updated processing system is that it runs on the Linux OS instead of the Solaris OS, and the additional possibility of using data from the large-aperture Kurchatov-Cross seismic array, originally designed to record teleseismic events. This array is an auxiliary station of the IMS network and has a non-standard configuration in comparison with other seismic arrays in Kazakhstan and of the IMS. The signal detection algorithm for this array is significantly different from that used for seismic event recording by small-aperture arrays of a standard configuration. The inclusion of this array in the daily regional monitoring task can enhance significantly the event location accuracy of automated processing software and improve the quality of the KNDC automated bulletin.

**T3.3-P16. Improved Bulletin Generation Using an Iterative Processing Framework**

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The IDC automatic seismic event bulletin is generated by performing two sequential processing steps: first station processing to find detections, and then network processing to form events. This processing paradigm differs significantly from that applied by human analysts. Analysts bring to bear considerable human intuition acquired during the processing of past events and use that to iteratively reprocess data resulting in a significantly improved bulletin. Our Iterative Processing Framework (IPF) attempts to mimic analyst behavior during automatic bulletin generation. After a first pass through signal detection and signal association, the resulting events are compared to historical information with the goal of identifying expected signals which are missing from the set of signals currently available, or which are present but erroneous in some respect. Waveform data is reprocessed to improve the set of available signal detections and signal association is repeated when changes are made. The process is repeated until stability is achieved. IPF also introduces seismic events detected using waveform correlation into automatic processing prior to signal association, which can significantly reduce the number of signal detections available to confuse the automatic signal associator. We present results comparing IPF to traditional methods.
T3.3-P17. Improved Detection and Parameter Estimation for Regional S-Phases Using the Fully 3-Component ARCES Array

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In September 2014 all 25 sites of the ARCES seismic array in Norway were upgraded to 3-component stations, making it the first fully 3-C IMS array. S-phases are of paramount importance for detecting and locating seismic events at regional distances and it is important that these phases are both detected and attributed accurate slowness estimates. The estimated apparent velocity and backazimuth identify the detection and provide phase association algorithms with information necessary to form a high quality seismic event hypothesis. Previously, ARCES had 3-C stations at four sites only. While these 3-component seismometers were highly beneficial for detecting regional S-phases, it was often more reliable to perform f-k analysis on the 25 vertical sensors rather than on the rotated horizontal traces. We compare systematically the SNR on transverse and vertical beams for S-phases from regional events recorded since the upgrade. The horizontal traces provide both increased SNR and coherence, improving the stability of f-k analysis. The improved S-phase coherence on the transverse rotations provides the basis for superior S-phase detection capability using F-detectors and other coherence-based algorithms. The upgrade of other IMS seismic arrays to fully 3-C arrays would likely improve global event detection and location capability significantly.

T3.3-P18. Is More Less in Signal Detection?

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Seismological signal detection is the process of identifying those parts of a recorded waveform that may contain information about seismic events of interest. Detected signals can be associated to define, locate, and characterize these events. Recent work has demonstrated that advanced signal detection algorithms such as the generalized F detector (Selby; 2008, 2011, 2013), when compared with the existing detector used at the International Data Centre, detect as many signals associated with events (e.g. those listed in the Reviewed Event Bulletin) while greatly reducing the number of unassociated signals. Here I investigate factors that may explain this difference, including the detection statistics, the algorithm logic, and detection thresholds. Further enhancement of signal detection algorithms requires that the behaviour of current systems is thoroughly understood.

T3.3-P19. Joint Hypocentre Determination Along the Gulf of Aqaba by Using Seismic Stations in Egypt and Saudi Arabia

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Bulletin data from the Egypt and Saudi Arabian Seismic Networks are used for the period January 2003 through June 2004 to relocate over 100 earthquakes occurring in and around the Gulf of Aqaba. The earthquakes have picks in the bulletin for stations surrounding the Gulf (Egypt and Saudi Arabia). Joint hypocentre determination methods are used to estimate the seismic station corrections and earthquake relocation. Eight stations KAT, DHB, TR2, RDS, BDA, TAY, JMQ and TBK have minus signs in the station P-wave travel time corrections and their values -0.765, -0.126, -0.332, -0.402, -0.302, -0.501 and -0.416. It is possible to assume that the underground structure in this area has a particular characteristic of a high velocity structure and other stations BST, TR1, SHR, HAQ, JMO and ALW have positive sign and their values 0.776, 0.405, 0.900, 0.233, 0.262 and 0.638 respectively. It is possible to assume that underground structure in this area has the particular characteristics of a low velocity structure. The method simultaneously solves for earthquake location and station correction.
**T3.3-P20. Melcepstral Coefficients Used as Input to a Neural Network for Identification of an Expanded Set of Atmospheric Nuclear Explosions and Bolides**

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In our previous research, Melcepstral coefficients were extracted from a number of infrasonic hand-digitized atmospheric explosion waveforms from the 1962 Operation Dominic series of atmospheric nuclear tests. These explosions were shown to have a distinctive pattern of melcepstral coefficients which can be modeled with synthetically generated waveforms. In this follow-on research, the authors have accomplished two major additions: the first being the expansion of the database to include additional atmospheric nuclear explosions, and a significant number of additional Bolides, as well as a number of surface chemical explosions. More importantly, we have designed a Neural Network that takes these coefficients and outputs the class that best fits (explosions or bolides). Finally, we have done a preliminary investigation on how the melcepstrum/neural network identifies underground nuclear and chemical explosions which are detected by one, or more, infrasound arrays, as compared with earthquakes.

**T3.3-P21. Model Visualization for NET-VISA**

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NET-VISA is an open universe generative model for seismic event location that is currently being evaluated for use at the International Data Centre (IDC) of the CTBTO. Underlying the model is a set of probability distributions that are learned from IDC bulletins, primarily the LEB and SEL3. NET-VISA explicitly models many parameters that have physical meaning, such as delay in travel time from one-dimensional earth models and azimuthal shifts as well as operational parameters such as the probability that detections will be made of a particular seismic phase at a particular station. Being able to look closely at the probability distributions inside of NET-VISA is not only an excellent way to learn how NET-VISA works, but it gives insight into the International Monitoring System (IMS) itself. An IDC website has been developed that makes it possible to view the NET-VISA model in detail. This Interactive Model Visualization (IMV) can be used as a training tool, a scientific portal and an educational tool. Its use for education is particularly important because of the frequent staff turnover at IDC. In this presentation, the IMV will be demonstrated live by projecting it onto a blank poster.

**T3.3-P22. Modelling and Detection of Regional Depth Phases at the GEREES Array**

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The Vienna Basin in Eastern Austria is a region of low to moderate seismicity, and hence the seismological network coverage is relatively sparse. Nevertheless, the area is one of the most densely populated areas in Austria. The Vienna Basin fault system (VBFS), which branches beneath the Basin, occasionally shows earthquakes with magnitudes larger than 4. Accurate earthquake location, including depth estimation is not only important for understanding tectonic processes, but also for estimating seismic hazard. In particular, depth estimation needs a dense seismic network. If station coverage is not sufficient, depth can only be roughly estimated. Regional Depth Phases (RDP) like sPg, sPmP and sPn have been used successfully for depth calculations even if only observed on one station. For this study we use seismic array data from GEREES. It is 220 km to the North West of the Vienna Basin, which according to the literature is a suitable distance to recover PmP and sPmP. We use array processing on earthquake data from the Vienna Basin with local magnitudes > 4 to reduce the SNR and to search for RDP. We compare real and synthetic results to assert which phases can be identified and to what extent depth estimation can be improved.
T3.3-P23. On Refinements Which Could Be Integrated into the Data Fusion Process

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Different physical phenomena underlying the pillars of CTBT monitoring and verification result in a different culture of accessing CTBTO data, vocabulary employed while analysing it and, most importantly, different products built with this data. However, an idea of associating information from these different pillars, namely waveform and radionuclide technologies, has been on CTBTO’s agenda for a long time. The existing interactive and non-interactive tools rely on a simple concept of overlying waveform events with the geographical regions constituting possible sources of the detected radionuclides. Recently, based on the very same concept, a design of a Fused Event Bulletin was put forward. In this presentation we will discuss possible refinements to the already implemented concepts. The refinements could benefit from combining several radionuclide detections in the same region and using non-detections alongside detections, possibly in reference to the concept of a radionuclide event. Additionally, one could envisage making a better use of the consistency of a radionuclide release, timeliness and quantity, with a potentially associated waveform event.

T3.3-P24. On Use of Artificial Neural Networks as a Classifier of Strong Noisy Seismic Signals

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Automatic identification of noisy seismic events is still a problem. The process involves analysing complex relationships between huge amounts of data originating from different sources. The main disturbing factors with seismic data are: poor signal-to-noise ratio; the presence of accidental bursts of man-made noise; and changes in the phase and amplitude of the signals while travelling through the medium. With the need to find relationships in ever increasing data volumes, the use of neural networks in seismology is expected to become more popular in the future. This will be because neural networks are easy to apply and the results often outperform alternative methods. This technology is rapidly moving from the research environment into the routine observational domain. Here, we present prospects for the development of the technology, an overview of neural networks for the classification of noisy seismic signals, and a routine strategy for the use of neural networks as a classifier of seismic signals. We are proposing a processing chain for seismic real data analysis, based on neural networks that will be an aid to the human interpreter.

T3.3-P25. Polarity Identification Techniques and Quality of the First Impulse of P Wave and Digital Signal Processing in JISView Earthquake Monitoring System

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The accuracy of the determination of earthquake parameters and focal mechanism is dependent on the development of polarity identification techniques, the quality of the first impulse of the P wave, and digital signal processing methods used in the earthquake monitoring system JISView. The implementation includes defining and testing the methods and procedures appropriate to the earthquake monitoring system, with the aim of improving the system’s ability to present earthquake information and focal mechanism quickly and accurately, while providing a strong scientific foundation for the data processing methods used. Testing and validation is performed in order to determine the level of accuracy and performance improvements that are expected. Tests on the digital signal processing method uses a sample of seismic data recorded on the UGM station vertical component (BHZ). For validation, the output signal and its spectrum is compared to the output signal of the SAC.
software DIMAS2003 through similar processes. Aspects of the detection method of determining the magnitude of the event was tested using seismic data recorded on 10 occurrences of earthquakes in Indonesia in 2014, with a magnitude of 3.8 to 7.3 SR. The results are further validated by the analysis of earthquake parameters that were released from BMKG, GFZ and USGS. The results of the testing and validation of the digital signal processing method comprising filtering mechanism, restitution and replication signal shows the test results are quite good.

T3.3-P26. PSAR: Experiments with a Medium-Sized Full 3-Component Seismic Array

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Since 2012, Geoscience Australia is operating a full 3-component seismic array with an aperture of ~20 km in north-west Australia. This presentation uses data obtained from this array to investigate the usefulness of having a full 3-component array versus one with vertical components only. First, a comparison is made between two coherency based detection algorithms for 3-component data. One is based on rotating the horizontal components to radial and transverse before detecting on each of the three components individually, and one based on using the coherency of the 3D surface motion vectors directly. The latter method is found to be much faster and more stable. Subsequently, we investigate the coherence of P and S wave fronts arriving at the array. It is found that at the location of PSAR, regional S waves are much less coherent than P waves. At frequencies above 1 Hz that are of interest for smaller events and nuclear monitoring, S waves are coherent over distances of a few kilometres at best. This indicates that a medium size 3-component array only marginally improves S wave detection capability over a single 3-component instrument.

T3.3-P27. Rapid Search of Large Seismic Signal Archives

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The exploitation of similar waveform signals from historic seismic events to detect, locate, and study new events is widely accepted as a key capability for modern nuclear explosion monitoring systems. The basic underlying calculation—time series cross correlation—is simple to implement and the ever-increasing online archives of signals suggests that the technique will become increasingly important. Yet there is an inherent limitation in how widely the technique can be applied due to the computational demands of searching large signal archives. In this study, we investigate the applicability of Kernelized Locality-Sensitive Hashing (KLSH) to significantly decrease the search time for large signal archives. KLSH probabilistically interrogates the database such that much of the database is ignored when searching for closest matches. We evaluate KLSH using data from the IMS primary station PS23 (MKAR). First we built a KLSH indexed archive using all associated signals from the IDC Late Event Bulletin (LEB) for 2000–2012. We then tested the signal matching capability using new IDC-detected signals from 2013, including a variety of regional and teleseismic phases. We used the LEB phase assignments as ground-truth to score the results. Metrics for the evaluation include precision, recall, and speed of search.

T3.3-P28. Recovery of Seismic Events with Blind Source Separation

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In CTBT related applications Blind Source Separation (BSS) methods can be used for signal recovery from the mixture using minimal a priori information about the signals composing the mixture. Expert Technical Analysis (ETA) conducted in CTBTO to improve the estimated values for the standard signal and event parameters according to the Protocol to the CTBT may face problems which cannot be resolved with certified CTBTO applications and may demand specific techniques. Here, we examine two scenarios of interest: (1) separation of
two almost co-located explosions and conducted within fractions of seconds, and (2) extraction of explosion signals merged with wavetrains from strong earthquake. Independent Component Analysis (in its FastICA implementation) implying non-Gaussianity of the underlying processes signal’s mixture is a blind source separation method that we apply to resolve the mentioned above cases. We have tested this technique with synthetic waveforms, seismic data from explosions in the Democratic People’s Republic of Korea and mining blasts conducted within East European platform as well as with signals from regional and strong teleseismic events. Our approach demonstrates a good ability of waveforms separation. We also share our experience in applying the ICA in cepstral domain for separation of seismic signals based on the finite convolution representation model.

T3.3-P29. Reducing Analyst Burden Using Real Time Event Cross Correlation


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The United States National Data Center (US NDC) monitors international compliance to nuclear test ban treaties through the real time acquisition, processing, and evaluation of seismic, hydroacoustic, and infrasonic data. The US NDC geophysical data processing system uses this data to automatically build seismic events which are reviewed and refined by a collection of human analysts. Manual event review is a time consuming process that is largely focused on correcting mistakes made by the automated system (e.g. onset time refinement, incorrect phase names, adding missed detections, deleting false detections). All automatic and human reviewed event solutions are stored in a data warehouse that currently contains over 15 years of alphanumeric information and waveform data. In an effort to reduce the time burden associated with manual event refinement, the US NDC processing architecture was modified to employ the data warehouse in real time to automatically recognize similar historic events built in the past. Similar historic events are identified through real time cross correlation of selected seismographs from automatically formed events against those stored in the data warehouse. Event similarity information and arrival pattern templates for relevant historic solutions are passed to the analyst to assist their evaluation of automatically formed events.

T3.3-P30. Regional Seismic Monitoring Using 3-C array

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An array consisting of seven 3-C sensors was tested for the purposes of regional seismotectonic monitoring. The aperture of several hundred metres is suitable for detection and identification of regional phases. This portable array was installed within the Russian platform, which is an aseismic zone where regional sources with magnitudes 1.0 to 3.5 are chiefly associated with mining. We use seven quarries to compare detections obtained by vertical (V) and horizontal (N-S, E-W, T, and R) sub-arrays. The V-array demonstrates a superior detection capability for the P-wave arrivals, but misses many S-waves well measured by the H-arrays. In many cases shear waves are most prominent at horizontal channels and are below the level of microseismic noise at vertical channels even after stacking. In a few cases, the S-waves at H-arrays are the only detected phases. Therefore, the relevant events would be missed without the horizontal components. The 3-C array demonstrates a higher detection and phase identification capability than the vertical sub-array and provides a significant improvement in regional monitoring.
T3.3-P31. Registration of Regional and Local Seismic Activity on Seismic Station PS44, GEYT, Turkmenistan: Appraisal of Station Capabilities and Perspectives for Seismic Network Development in Turkmenistan

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The commissioning of the seismic array PS44 is associated with the beginning a new era of seismology in Turkmenistan, the era of digital data. The Institute created the program Sw-View for processing seismic data. It is designed for detailed processing and visual analysis of digital seismic signals coming from various data collection systems. Digital recording files in the main seismic formats are used as raw data. These formats include miniSEED and mwf, which contain data of the 3 component digital registrations of vibrational speed and acceleration of the ground by Guralp seismometers. The program is specifically designed for users whose task is to determine the parameters of the earthquake from specific characteristics of the signal. Sw-View is equipped with a simple and functional user interface that allows the user to conduct a variety of manipulations with the seismic signals. Sw-View is the result of mathematical calculations that display the speed and acceleration of the event. Currently, the Institute of Seismology and Physics of atmosphere of Science Academy of Turkmenistan with the help of this program conducts operational and final processing of earthquake data.

T3.3-P32. Seismic Event Detection by Correlation at Stations in the Middle East

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The number of seismic networks and stations in the Arabian Peninsula/Middle East is rapidly increasing. Even so, due to heterogeneous geometries, the network coverage is insufficient to fully describe the wide range of seismicity (e.g. mining and small aftershocks). Although seismic networks primarily employ incoherent detectors, Junek et al. (2014) demonstrated a reduction in magnitude completeness of more than one magnitude unit by processing the 2008 Storfjorden sequence observed at IMS auxiliary seismic station AS72 (SPITS, Spitzbergen, Norway) with subspace detectors. Also, Dodge and Walter (2015) have shown that at distances less than ten degrees a very high fraction of events can be detected by correlation. Because nearly all Middle East seismicity falls within this distance range, we believe there is potential to improve bulletin completeness in the Middle East by augmenting the network pipeline software with pattern-matching detectors (e.g. correlators and subspace detectors). We test waveform correlation detection performance using broadband station data from Kuwait and nine-element seismic array data from Saudi Arabia. We process continuous data at station MIB and the QWA seismic array. For configurations, an autonomous event detection and clustering framework is employed to build a more complete catalog with lower magnitude thresholds.

T3.3-P33. Seismic Event Discrimination Using Diffusion Maps

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Discrimination between earthquakes and explosions is an important component of the CTBT verification regime. Currently used seismic discrimination methods give a partial solution to the problem. In this work, we apply advanced machine learning methods and in particular diffusion maps for automatic earthquake-explosion discrimination. Diffusion maps is a nonlinear kernel method, which learns local similarities between data points to create a global parameterization of the observed data set. The kernel is based on a Markov diffusion process and spectral analysis of this kernel provides a compact representation of the data in Euclidean space. We apply diffusion maps for constructing a geometric representation of the seismograms that capture the intrinsic structure of the signal. In the obtained low-dimensional representation, seismic events with similar source mechanism
from the same region have a similar representation. This enables to discriminate earthquakes from explosions. We demonstrate our approach on several seismic data sets.

T3.3-P34. Testing the Global Grid of Master Events for Waveform Cross Correlation with the Reviewed Event Bulletin

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The CTBT’s verification regime requires uniform distribution of monitoring capabilities over the globe. The use of waveform cross correlation as a monitoring technique demands waveform templates from master events outside regions of natural seismicity and test sites. We populated aseismic areas with masters having synthetic templates for predefined sets (from 3 to 10) of primary array stations of the International Monitoring System. Previously, we tested the global set of master events and synthetic templates using IMS seismic data for 13 February 2013 and demonstrated excellent detection and location capability of the matched filter technique. In this study, we test the global grid of synthetic master events using seismic events from the Reviewed Event Bulletin. For detection, we use standard STA/LTA (SNR) procedure applied to the time series of cross correlation coefficient (CC). Phase association is based on SNR, CC, and arrival times. Azimuth and slowness estimates based f-k analysis cross correlation traces are used to reject false arrivals.

T3.3-P35. The Integrated Waveform QC Library

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The seismic, hydroacoustic and infrasonic processing system installed at the International Data Centre (IDC) of the CTBTO continually processes waveform data from the global International Monitoring System (IMS) network. In order to better address data quality issues, a dedicated waveform quality control application has been developed. This new algorithm takes over the responsibility of assessing waveform data quality from various independent applications such as the DFX signal detector, and persists the information to the database for the benefit of subsequent processing stages; previously this information was being discarded. Since data quality information is now being recorded it is possible to re-construct at a later date the exact processing history and thereby duplicate earlier processing. The algorithm identifies several classes of problematic data including spikes, constant values, errant channel noise, authentication and timing problems. The option to repair the data or mask from further processing is at the discretion of the algorithm processing the data.

T3.3-P36. The Waveform Analyst Workload Paradox

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‘Improvements’ in automatic waveform processing that would reduce analyst workload are distinguished from those that would increase it. Analysts are the most numerous specialists in CTBTO, and their tasks the most costly. So reducing their number is an important long term goal. Nevertheless, the average time taken to analyse one hour of events (first pass analysis) has increased from 1.5 hours in 2003 to over three hours in 2014. Densification of the IMS network and the introduction of infrasound analysis are two reasons; automatic seismic data processing has changed little. Any improvement in automatic processing that increases the number of events increases analyst workload whether those additional events are ‘good’ or ‘bad’. Genuine improvement in the performance of automatic processing through the detection and location of more real events using valid signals must be more than outweighed by a reduction in time-wasting analyst actions such as retiming signal onsets, re-beaming array signals and discarding ‘bad’ events. It is therefore concluded that improvement should focus on station-specific tuning of processing parameters, automatic onset timing, and signal association, rather than (say) introducing algorithms designed to build more events automatically.
T3.3-P37. Trends in Waveform Data Processing and Analysis at the International Data Centre, January 2000 to June 2013

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The statistics of signals associated to events in the IDC’s final automatic event list (SEL3) and after analyst review (LEB) reveal features and trends that may assist in prioritizing work to improve both. Since 2005 the number of manually detected signals at primary seismic arrays has increased substantially. Major differences are revealed in the performance of automatic signal association between different station types and certain stations in particular; this points to non-optimum tuning of automatic processing for specific stations, which is also suggested by variations in the prevalence of analyst re-beaming of array signals. The percentage of automatically detected signals retimed by analysts is substantial and increasing; this implies deficiencies in automatic measurement of signal onset times. The first half of 2012, when analysts were exceptionally presented with all auxiliary seismic data rather than only the segments automatically requested, witnessed a dramatic increase in manually detected signals. This suggests non-optimum automatic requesting of auxiliary data. Other features explored are a doubling of the percentage of signals automatically identified as noise from 2005; the wisdom of excluding unidentified coda phases (tx) and ‘defining’ Rg arrivals from the reviewed event bulletin, and an apparent deficit in the automatic association of regional phases.

T3.3-P38. Waveform Correlation Effectiveness During High Analyst Workload Sequences

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Waveform correlation used as a signal detector not only produces much higher quality signal detections (including reliable phase identifications) than traditional methods (e.g. STA/LTA), but also provides immediate information about corresponding events including estimates of location, magnitude, and source type. As a result, both the quality of the automatically built events and of the associated signals are higher; hence the amount of analyst time needed to review and correct automatically built events should be significantly reduced. The goal of this study is to assess whether waveform correlation can indeed provide value in the times when analysts are most taxed. We estimate analyst workload for all events in the Late Event Bulletin (LEB), and identify source regions and time periods that required significant analyst effort. We then create template libraries for key IMS stations for these regions/time periods and set appropriate thresholds to achieve a desired false alarm rate. Finally, we re-process the historic waveform data with our template libraries and compare our waveform correlation results with those produced by the IDC’s traditional signal processing. We present our results and discuss the potential for waveform correlation to decrease analyst workload during the most time-consuming event sequences.

T3.3-P39. iLoc: New Developments on the ISC Locator

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The new location algorithm developed for the International Seismological Centre (ISC) has been operational since January 2011. By providing improved hypocentre and magnitude estimates, the ISC locator has increased the efficiency and productivity of the ISC review process to generate the reviewed ISC bulletin. A new development branch has spun off the ISC locator in 2014, the iLoc locator. iLoc by default supports local and regional travel-time predictions provided by the Regional Seismic Travel Time (RSTT) software package developed by the US DoE National Laboratories. Albeit not fully integrated with SeisComp3, iLoc can communicate with the SeisComp3 database. It also supports the new International Seismic Format (ISF2) as well as the new standards for the International Registry of Seismographic Stations. Further development plans include support for full 3D velocity models, such as LLNL-G3D, as well as for local velocity models. The performance
of iLoc is demonstrated by relocating recent, globally distributed events from the PDE bulletin. The iLoc locator can be downloaded from the ORFEUS software depository.
T3.4-O1. A New Verification Tool of Nuclear Explosions Using Ambient Noise

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Various types of vibration sources are always producing the so-called ambient vibrations on the earth ground (also called ambient noise). Each vibration source is divided into high or low noise model as a function of frequency. The main goal of this study was to recognize two new applications of ambient noise as a verification tool of nuclear explosions. These applications are: (1) Identifying the branded vibration phase of the nuclear explosion, which is based on the idea that each event has a specific vibration signature in the seismic record. Signature of nuclear explosion can be identified through cross-correlation of the ambient noise before and after the event and compared it with that of the moderate earthquakes, nuclear and chemical explosions. (2) 3D-imaging velocity structure of the on-site inspection (OSI) area using small circle configuration of seismic microtremor array. This method is called ambient noise tomography (ANT) and its application to the data of narrow seismic arrays has led to the development of small-scale seismic image of the spatial shallow velocity variations at unprecedented resolution. These new applications of ambient noise seem to be fast, simple, very cheap, and highly efficient a verification tool of nuclear explosions for CTBT.

T3.4-O2. The 2014 Integrated Field Exercise Seismic Event Identification by Spectral Pattern Recognition and Combination of Array and Network Localization

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Due to the location of the the 2014 Integrated Field Exercise inspection area in Jordan on the Dead Sea Rift, an abundance of natural seismic events and quarry explosions had to be ruled out as possible aftershocks from an underground nuclear explosion for the OSI seismic aftershock monitoring system (SAMS). The extreme topography and restrictions led to a reduced number in deployed mini-arrays. Nevertheless SAMS successfully detected all scenario relevant events. This study shows the current SAMS manual detection and localization techniques and how they can be extended with automatic routines. The detection of local events with low signal-to-noise ratios at very few stations (<3) with a duration of few seconds cannot be realized with detectors based solely on coincidences of amplitude variances (e.g. STA/LTA) or changes in the statistic distribution of ground velocities. An abundance of local noise sources triggers false detections continuously. The use of matched filters is limited due to the low-SNR and short epicentral distances. Instead a pattern recognition based on robust noise adapted spectrograms is used. The automatic localization is done through a combination of beam-forming, fk-analysis, phase-picking and a weighted 3D grid-search which takes the certainty of each information and the topography of the area into account.
T3.4-O3. Numerical Study of Acoustic Waves Around and Inside an Underground Cavity

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While the logistic aspects of an OSI have already been tested several times in realistic exercises, the technical questions are quite new and a strong scientific base is still pending. Furthermore, only very few experiments have been conducted using the seismic techniques listed by the Treaty to detect evidence of a cavity caused by an underground nuclear explosion. This motivates to investigate this problem on a purely numerical level and to simulate these events, taking into account recent advances in the mathematical understanding of the underlying physical phenomena. We believe that this will help provide a strong scientific base for OSI. To begin with, we focused our numerical study on the propagation of P-waves in two dimensions. An extension to three dimensions as well as an inclusion of the full elastic wave field is planned in the following. Our computations are done with the parallel High-Order Finite Element Library Ngsolve on top of the automatic 2D/3D tetrahedral mesh generator Netgen. The accurate numerical modelling will help to facilitate the development of proper analysis techniques to detect the remnants of an underground nuclear test, strengthen the scientific base of OSI and contribute to bringing the Treaty into force.

T3.4-O4. Testing the Use of Passive Seismic Methods to Detect Underground Cavities

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A set of seismometers were deployed around the site of known underground nuclear explosions (UNE) at the US Nevada National Security Site. The purpose was twofold: to test the use of seismic interferometry to image UNE sites and to evaluate effects that might be caused by resonances in the damaged subsurface (e.g. “resonance seismometry”). We also generated 3D synthetics using a finite difference technique on a smoothed and idealized representation of the cavity and chimney. Examination of the observed data does not show clear indications of resonance within the cavity and chimney caused by seismic waves from teleseismic, regional, or local earthquakes although analysis is continuing. Green’s functions of raypaths between station pairs have been generated using seismic interferometry based on ambient seismic noise and these will be used to generate a tomographic model. Prepared by LLNL under Contract DE-AC52-07NA27344.
non-compliance with the CTBT. Some results will be discussed: Upgrading of software for training systems with regard to methods and procedures for on-site inspection (OSI), making use of technologies such as the geographic information system ArcGIS, the WEB management system CartoPac, and interfacing with the CTBTO information management systems FIMS and IIMS; Development of an expert system model for OSI using the Exsys Corvid programming environment; Designing a system “MIX” for registration of xenon isotopes as a modernization of the system “Arix” and improving the reliability of the system; Co-processing of seismic and acoustic signals from repeating blasts in the Democratic People’s Republic of Korea area have been carried out by phase association. Estimates of the location of the events have been obtained using azimuth and apparent velocity.

**T3.4-P2. High-Resolution, Ultra Low Power, Intergrated Aftershock and Site Characterization System**

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Trimble has developed a self-contained, fully integrated Aftershock System, model 160-03, providing simple and quick deployment during aftershock mobilization, site characterization and microzonation studies. The 160-03 has no external cables or peripheral equipment for command/control and operation in the field. It contains three major components integrated in one case: (a) 24-bit state-of-the-art low power ADC with CPU and Lid interconnect boards; (b) power source; (c) three component 2 Hz sensors, and ±4g accelerometer. The self-contained rechargeable battery pack provides power autonomy up to 7 days during data acquisition at 200 sps on continuous three weak motion and triggered three strong motion recording channels. For longer power autonomy, the 160-03 Aftershock System battery pack can be charged from an external source (solar power system). The data in the field is recorded to a built-in swappable USB flash drive. The 160-03 configuration is fixed based on a configuration file stored on the system, so no external command/control interface is required for parameter setup in the field. For visual control of the system performance in the field, the 160-03 has a built-in LED display which indicates the systems recording status as well as a hot swappable USB drive and battery status.

**T3.4-P3. Results of Seismic Study on the Upper Part of the Section at Semipalatinsk Test Site Area (for On-Site Inspection Purposes)**

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A study of the structure of upper part of the section at the location of boreholes of former nuclear explosions at Semipalatinsk Test Site area is presented. The data from eight 6 km long parallel profiles with 500 metres spacing were used. First arrivals of the refracted waves were used in the ray tracing method. Velocity structure of the section has been determined up to the depth of 200–250 metres. In the vicinity of UNE borehole locations, a technogenically changed layer with the thickness of 40–80 metres and velocity that is reduced with regards to undisturbed rocks by the value of up to 1–2 km/sec has been detected. Thickness of this layer changes proportionally to the yield of the nuclear charge. The obtained information can be used to update the database as part of the study of traces from the underground nuclear explosions for a more effective implementation of On-site inspection.
THEME 4: PERFORMANCE OPTIMIZATION
The development of radioxenon monitoring technology and methodology should be guided by systematic and
detailed study of the overall capability of the network for alternative system characteristics, network
collection and analysis methodology. For this purpose, suitable metrics are needed to evaluate and optimize
relevant properties of the overall network verification capability. Because the verification mission goes well
beyond simply detecting radioxenon, such metrics also need to go beyond single-isotope detection probability
maps for given source strengths, network density and measurement system sensitivity. An initial study has been
performed that attempts to define and use suitable metrics to investigate the impact of network configuration and
measurement system characteristics on overall verification capability, including how well radioxenon sources are
detected, located, timed, and discriminated from other sources.

The International Monitoring System (IMS) is designed to ensure compliance with the CTBT by detecting,
locating and characterizing explosions worldwide. Simulation methods incorporating realistic source and
propagation effects have been developed to quantify the detection capability of this network and also to optimize
the network configuration. Even not yet fully established, the infrasound network already allows studies on a
global scale such as remote volcano monitoring. It provides a sensing tool to study the dynamics of various
eruption styles and to infer useful information about eruption dynamics. Comparisons with near-field recordings
allow evaluating the potential of these observations to better constrain source parameters when other monitoring
techniques are not available. Because of its regular activity, the well-instrumented Mount Etna is in Europe a
unique natural repetitive source to test and optimize detection and simulation methods. During downwind
conditions, its eruptions are quasi-permanently well detected by IS48 in Tunisia, the closest IMS infrasound
station. Under the European ARISE project (Atmospheric dynamics InfraStructure in Europe, FP7/2007–2013),
experimental arrays have been installed in order to characterize infrasound propagation. Such an experimental
setting offers an opportunity to address the societal benefits that can be achieved through routine infrasound
monitoring.
T4.1-O3. Investigating a New Paradigm in Delaying Impending Earthquake in Indo-Nepal Himalaya

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The Himalaya and its surrounding regions are highly complex in terms of its evolution, tectonics and seismicity. Indo-Nepal Himalaya displays all major tectonic features of the Himalayan mobile belt and is seismically one of the active regions in the Himalayan arc. Observations indicate that there is a significant fluctuation in seismicity at different times but mostly prior to large earthquakes. Five cases of anomalous seismicity have been identified. Of which, three medium size earthquakes of 1980 (mb 6.1), 1984 (mb 5.6) and 1999 (mb 6.6) already occurred in the Western Nepal and its adjoining Indian region were preceded by well-defined patterns of precursory swarm and two cases for which quiescence episodes still continues be investigated for impending earthquake. It has been estimated that an earthquake with M 6.5±0.5 should have occurred till December 2011 within an area bounded by 29.3°–30.5° N and 81.2°–81.9° E, in the focal depth range 10–30 km. However, analysing seismicity data from period 1963–2006 advocate that delay in impending earthquake is the case of a repeated swarm sequence in which the second activity has occurred in the gap episode of the first which was continuing, that has enhanced both the preparatory period and the magnitude.

T4.1-O4. Improvement in the Seismic Detection Threshold in the Brazilian Amazon

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The Brazilian Amazon is located within the stable interior of South American plate; a region characterized by low magnitude seismicity with few earthquakes having magnitudes above 5. There are numerous magnitude 3–4 events, but these are detected by a sparse network and consequently are poorly studied. Recently this situation changed with the implementation of the Brazilian Seismographic Network (RSBR); a joint project by the universities of São Paulo, Brasília, Rio Grande do Norte and National Observatory (funded by Petrobras) composed of 80 stations, of which 25 are in the Amazon. The stations are equipped with broadband sensors and real time satellite data transmission, and the data are open to the international community. The Amazon network already has shown an improvement to the detection threshold and location accuracy. The previous regional threshold for the primary and auxiliary International Monitoring System (IMS) stations showed magnitudes of about 4. With the new RSBR network this threshold dropped to around magnitude 3. The current network will help monitor the seismic activity and record events that might meet the requirements of a ground truth event. In this work, we study the improvement of IMS network threshold detection after the installation of the RSBR network.

T4.1-O5. Local Weather Condition Effects on Detection Capability of South Eastern African Infrasound Station

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Station detection capability is important in infrasound technology, especially for International Monitoring System. Knowing detection capability helps in recognizing nuclear explosion signal. The purpose of this work is to check if effect of local weather condition varies according the station configuration or station location. Study was done for single station I3MG and is extended to other stations which have different configuration and
different weather condition. Using the infrasound bulletin of I33MG, effects of local weather conditions are noticed. When processing infrasound data of south eastern African infrasound station, detected signal decreases when temperature or surface wind speed rises. To confirm, south and eastern African infrasound station are used for the study of the background noise behaviour under the action of local weather conditions such as temperature and surface wind. Data processing is performed with PMCC method. Data are filtered and split into four frequency bands, 0.0156 Hz, 0.0625 Hz, 0.25 Hz and 1 Hz in order to fit the frequency band of permanent sources such as: mountain associated waves, microbaroms and storm activities. Diurnal variation and seasonal variation of background noise power under the action of surface wind and temperature are studied.

**T4.1-O6. Optimization of the Network Coverage of the International Monitoring System Noble Gas Component**

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The IMS noble gas network has been designed with 40 monitoring stations to equally monitor the earth’s atmosphere for releases of radioxenon from nuclear explosions. The first step in this work is to assess the coverage of the current network design with regard to underground, atmospheric and underwater nuclear tests and to the radioxenon background produced by nuclear power plants and medical isotope production facilities. Atmospheric transport modelling is applied to simulate whether the emissions from nuclear tests reach one or more monitoring stations and can be detected before the radioxenon decays. A lowered network coverage is found downwind from medical isotope production facilities and in equatorial regions due to the meteorological patterns. In the second step recommendations are given on how to overcome these negative impacts on the IMS and improve the network coverage. It is discussed how different network configurations with additional stations would affect the network coverage. The goal is to bring the IMS noble gas component closer to a worldwide equally distributed coverage.

**T4.1-O7. The Influence of the CTBTO in the Establishment of the Seismological Network of Namibia**

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The Seismological Network of Namibia consists of seven operational broadband and single-phase seismic stations located across Namibia. It is a capital project funded wholly by the Government of the Republic of Namibia. Initiated by the Geophysics Division of the Geological Survey of Namibia to better understand the geo-environment, it is also used to develop a national archive, monthly event bulletin and a seismic hazard map. The Geophysics Division is responsible for the expansion, maintenance and management of the network. Although more stations are planned in future, seismic stations are located on average more than 500 km apart and therefore significant challenges are faced with respect to event characterization, real time data streaming and data availability. The network is operated and managed by a very small complement of staff responsible for installations, maintenance, repairs, configuration changes, waveform and event analyses and archiving. The staff involved with the network relies heavily on the advice, assistance and training of the CTBTO. They also use their knowledge and training gained and gathered at the CTBTO to establish the seismic network and will be challenged in the coming years to integrate this network with the NDC of the IMS.
T4.1-P1. “Hot Sample” Transport Exercise: Radiation Safety Aspects and Quality of Analytical Results

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Among the lessons learned from the Fukushima accident is that procedures should be developed for handling and shipping of Level 5 samples which exceed exempt quantities for safe transport from a station to a certified laboratory. In parallel, laboratories which have the capability to receive and measure these non-exempt samples should be identified, in case they are needed. An exercise involving the shipment, handling and analysis of a reference “hot” sample was organized to: (1) identify and address radiation safety and high dead time issues when measuring a relatively high activity sample; and (2) validate the analytical techniques employed, by comparing laboratory results with certified values. Laboratory results were assessed for correct identification of nuclides present in the sample and accuracy of the measurements. The performance statistics used in the evaluation of results were from ISO13528. Five certified IMS laboratories volunteered to participate. The poster describes the conduct of the exercise and provides a summary of observations and results. Precautions implemented by participating laboratories to prevent cross-contamination and ensure radiation protection are also presented.

T4.1-P2. A Failure Mode and Effect Analysis (FMEA) of the International Monitoring System Radionuclide Station Network for the Years 2013 and 2014

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This poster presents the Failure Mode and Effect Analysis (FMEA) of the IMS radionuclide station network for the years 2013 and 2014. In this time period, 63 certified radionuclide particulate stations and 19 certified noble gas systems were sending data to the IDC. The Performance Reporting Tool of the CTBTO, the daily state of health monitoring of the stations and incident tracking through the IMS Reporting System (IRS), provide the basis for classifying and analysing different types of failure modes of radionuclide stations. FMEA enables the CTBTO to develop engineering solutions and systematic strategies for the network to increase data availability and its robustness. The poster provides an overview of FMEA and the failure categories used for the IMS radionuclide network. The particulate and noble gas networks are presented separately as FMEA takes into account the different technologies of the stations. The distribution of failure modes among total station downtime is presented. On the station equipment level an in-depth analysis is provided for failures related to the HPGe (High Purity Germanium) detector systems installed at the radionuclide stations.

T4.1-P3. Applying CTBTO Capacity Building Training Gained to Strengthen Local Verification Capacity in Ghana

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The CTBTO is a non-discriminatory legal and democratic body with the responsibility to verify the compliance to the CTBT. To fulfill this task, the Treaty enjoins the CTBTO to offer technical assistance to States Signatories
to fulfill their verification responsibilities under the Treaty, since final determination of non-compliance to the Treaty rest with the States Parties. The introduction of the Capacity Building project by the CTBTO with funding support from the European Union (EU) has been of immense significance to beneficiary States Signatories, particularly those from developing countries such as Ghana. Under the capacity building project, Ghana has benefited from training courses, workshops, technical follow-up visit and equipment support. As a result the experiences gained by participants (NDC staff) from such trainings/workshops have been applied to strengthen local capacity for Treaty verification. Also significant event such as the Democratic People’s Republic of Korea’s announced nuclear test on 12 February 2013, the CTBTO detected data was analysed in relation to the IDC analyst results and reported to the national authority.

T4.1-P4. Boundary Layer Characteristics Associated with Proposed Monitoring Sites for Regional Suspected Particulates in and Around the Kathmandu Valley, Nepal

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A science team of CTBT and Central Department of Physics, Tribhuvan University had explored several possible sites to monitor suspected particulates in and around the Kathmandu valley during the year of 2008. Based on existing knowledge of atmospheric transport processes over the valley, four sites were identified from where representative data can be generated. However, the boundary layer activities over those sites were not fully understood during the period. This paper presents the boundary layer activities over those sites as well as some other sites as observed by deploying FAS64 sodar, Scintec Co., Germany during the period of 2012 to 2014. The findings of this study are expected to help better understand the situation that could possibly prevail in and around the valley and to identify the most suitable site to monitor regional/global suspected particulate from Kathmandu.

T4.1-P5. Challenges in Operation of Radionuclide Monitoring Station, Tanzania

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The radionuclide monitoring stations utilize complex and sophisticated equipment. Building and operating a station requires an initial capital investment for infrastructure and human resource development for station operators. The CTBTO is responsible for operating the radionuclide stations and both trains operators through training programmes for manpower development and provides equipment and facilities. The participating Member States make available laboratory space and staff with basic qualifications required for work at radionuclide stations. Challenges faced by operators include following some standard operational procedures such as for re-sending spectral data. The procedures are not operator friendly. Unreliable LN2 supplies for HPGe detectors are caused by either the distance from the supplying firms or unreliable production. Frequent power failures are also problematic and require a standby generator and/or other facilities at the station. Usage of IDC data is minimal although some research institutions have shown interest in accessing some radioactivity data for environmental research. The highlights of some challenges, possible solutions and respective upgrades for improving the working conditions at the station are presented.

T4.1-P6. Comparison of Access to Data and Products for Different Types of Designated Establishment under Secure Signatory Accounts

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An Establishment is an institution registered under the Secure Signatory Account of a Signatory State for the CTBT for access to IMS data and IDC products as defined by the Preparatory Commission and its Working
Group B. The current policy allows access by up to six establishments per State Signatory. An establishment might be the provisional National Authority, a National Data Centre (NDC) or subdivisions of the NDC. Some of these Establishments are in countries that host IMS facilities. Comparisons have been made to show the extent to which the hypothesis holds that States Signatories hosting the IMS stations and laboratories or have institutions with expertise and experience in monitoring technologies are typically accessing more data and products compared to those who do not. The statistical analysis was further applied to derive suggestions what the CTBTO can do to encourage and support those States Signatories that do not host facilities or do not have institutions with functions that are in line with monitoring technologies to actively participate in access of data and products.

**T4.1-P7. Developing a Recording System to Establish Inexpensive Telemetric Earthquake Networks on the Basis of GPRS Technology**

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Increasing the population of cities, developing civil projects and urban areas near active faults and lots of similar phenomena pushes the development of seismic networks. These types of networks are rapidly increasing in the Islamic Republic of Iran. Using the highest advantages of these networks will happen when they became telemetric while it is impossible financially point of view. Overcoming this problem a new recording system is developed with the ability of transferring data on the basis of GPRS. This is effectively overcoming the problem for there are cellular data accesses all over the country. Using a sim card shielded beside the recorder it is possible to construct a low price telemetric network. The huge amount of data is managed transferring only triggered events instead of continues stream. It also gives the ability of checking station health state by cellular SMS. Authorized contacts can add to the system receiving daily state of health report. It is possible to monitor the station time accuracy on each report for the cases of GPS problem, checking the station storage media reporting the used and free space, changing system parameters with SMS commands and any kind of access to the station managing it with the lowest cost.

**T4.1-P8. Developing New Waveform-Fetching Schemes for the CTBTO Link to the International Seismological Centre Database Services**

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The International Seismological Centre (ISC) offers a special visualization interface of its database to State Parties of the CTBT. One of its scopes is the visualization of the waveform availability of non-IMS (International Monitoring System) stations that refer to the events of the International Data Centre Reviewed Event Bulletin (REB). A problem often encountered when downloading and processing is the lack of distinction between station waveforms with clear seismic signal and those dominated by noise. To overcome this difficulty, we developed new probabilistic seismic station selection schemes based on (i) station, and (ii) event capability detection maps. The maps are built from mb1 body-wave magnitude detection threshold estimates, based on the IDC-REB that uses stations in the epicentral distance range 2°–105°. To assess their efficiency, we compare the results of a waveform-fetching algorithm by using the two selection schemes mentioned above. We find no significant differences for events with $mb_1 < 4.2$, whereas larger events ($4.2 \leq mb_1 \leq 4.8$) show that the algorithm based on the event detection map systematically filters out stations at long epicentral distances that are less likely to record seismic signal, and fills in gaps due to lack of detection threshold estimates up to 40° in epicentral distance.

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Automatic processing system at IDC is a large complex software system; even minor modifications of this software require rigorous testing. Much of the IDC legacy software currently lacks any kind of unit or regression testing, with most of the testing being performed by domain experts running the software manually. Development of the Continuous Automated Testing System (CATS) is an ongoing project (started at the end of 2013) to integrate, standardize, and automate testing of IDC processing software. In 2014 we have designed and implemented the CATS open-source testing framework. This framework is capable of automatically executing a full range of tests, from unit tests to regression and full integration tests. Unit testing is triggered by modifications of the software code in the source repository. Integration tests are continuously executed by the CATS framework. If the test fails, CATS automatically generates an error report and posts into the CTBTO issue tracking systems so developers can rapidly fix the problems. Current target of the project is to maximize test coverage of IDC software. Development of the actual unit and integration tests help us to improve the CATS framework and set standards for the testable development of future software projects at IDC.

T4.1-P10. Evaluation of the CTBT Seismic Monitoring System Performance in the Middle East Region

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The building of the IMS seismic network is reaching its final stages. The installation of 160 seismic stations out of 170 stations planned is completed. Out of the 10 non-operational stations 4 are in different stages of installation, and for 6 stations no action was done yet. Moreover, some of the installed stations have not transmitted data for several years, and therefore should be considered as non-operational too. The number of non-operational seismic IMS stations in the Middle-East Extended Region (MEER) is high relatively to worldwide distribution. The objective of this work is to assess the effect of those non-operational IMS seismic stations on the performance of the CTBT verification regime in MEER. Comparison of the IDC products for MEER to worldwide and to local and international seismic bulletins is used as basic for analysis. Several parameters are evaluated including empirical detection threshold, first and second azimuthal gap and event scoring. A limited simulation is used in order to extend the empirical results to regions without information. It is demonstrated that the non-operational stations slightly affects the performance of the system.


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The CTBTO provides access to IMS data and IDC products through the single secure signatory account (SSA) established for each State Signatory. Each State Signatory with a SSA has established at least one National Data Centre (NDC) through which data and products are accessed. As of December 2014, there were 134 SSAs. Statistics show that, overall, volume of data and products sent to NDCs has increased over the years 2005–2014. The maximum (over 10 TB) was achieved in 2012 due to the high demand for data and products related to the Fukushima nuclear disaster caused by the 11 March 2011 Great Tohoku earthquake and tsunami as well as the anticipated third nuclear test in early 2013 by the Democratic People’s Republic of Korea. Such events are part of the major drivers for increased access. The total data volumes per year are a significant indicator for adjusting the standard distribution, or daily volume, of data to individual NDCs. Most of the approximately 130 NDCs that have accessed data during the decade have done so on a fairly routine basis. The CTBTO is working on
measures to sustain the active participation of NDCs, especially those who have never accessed data and products.

**T4.1-P12. International Training Centre in Support of the CTBTO for the Central Asia Countries**

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An International Training Centre was established at the premises of the Kazakhstan NDC (KNDC) in Almaty with financial and technical support of the Norwegian Ministry of Foreign Affairs and NORSAR. The Centre’s task is to re-establish the cooperation of Central Asian seismologists that was lost after the USSR collapse, arrange data exchange, and activate joint research work. Since 2010 there have been 12 one-month courses on interpreting and processing seismograms in support of the CTBTO, 4 seminars on techniques of analog seismogram digitization and technical maintenance of monitoring stations, and courses on GEO TOOL operation. In total, 58 specialists from five Central Asia countries participated in the training courses. Lectures and practical exercises for the trainees are given by the KNDC staff who have practical experience working with seismological data; some lectures are given by specialists invited from abroad. The participants mastered the common data formats for storage and exchange of information, and the techniques on source location and discrimination of events. During the courses the trainees are informed about the monitoring networks’ development and new methods for data processing. The next aim of this cooperation is the creation of an operational seismic bulletin for Central Asia countries.

**T4.1-P13. Monitoring of Radionuclides in Aerosols: Different Approaches and Optimization**

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Different approaches and philosophies can be applied for measuring concentrations of radionuclides in the environment and evaluation of results. Usually the frequency and requirements for precision are important subjects for the subsequent usage of results and decisions that are made with reference to these results. For example, the CTBTO and the European Commission have different approaches for reliability and verification of data of radionuclides in aerosols and the accessibility of measured results for wide society. Other important issues include: who takes responsibility for data reliability; who takes action based on the results; are results used for tracking banned activities, other possible events (accidental or planned releases from nuclear objects or medical facilities, etc.) or just knowledge of the general situation. The last, but not the least issue is the availability of resources—technical, human and financial. Usually high reliability results have a high cost, so all factors should be carefully evaluated and the most optimal variant, without losing reliability and efficiency, chosen.

**T4.1-P14. National Data Centre Suriname**

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The National Data Centre Suriname receives data from the International Data Centre (IDC) in Vienna on a daily basis for three seismic stations. If there is any event, then we ask for additional data from the IDC. We analysed these data to determine if this event is natural (earthquake, volcano eruption etc.) or man made (nuclear explosion, mine explosion, etc.). The characterization of the event is very important to know if there is any violation of the CTBT. Whenever there is a suspicious event an on-site inspection can take place, but this is only possible when the Treaty enters into force. The conferences and trainings organized by the CTBTO build up the understanding that the Treaty should enter into force as soon as possible.
T4.1-P15. Operationalization of All International Monitoring System Stations

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The IMS is capable of recording the energy emanating from natural events, human activities, airplane crashes, etc. and transmitting those data to the International Data Centre (IDC). The geometrical layouts of the networks have resulted in further wave coverage for the seismic stations, detection of distributed frequencies in the atmosphere and underwater for the IS and HA facilities, and in the tracking of the atmospheric air currents for radionuclide facilities. Significant changes to the coordinates of International Monitoring System (IMS) stations such as infrasound station IS60, which was moved 1540 km, alter the network’s detection and location capabilities. Such a change, which alters the geometric arrangement of the IMS stations in the vicinity, may cause uncertainty in the locations of magnitudes of events and increase the probability of computational errors. Operationalization of all seismic stations in the IMS (recognizing the rules and regulations of the Treaty and bilateral obligations) also has an effect, as adding the data from these stations will increase the ability of the IMS to locate any event.

T4.1-P16. Overall Effect of Capacity Building Programme on National Data Centre Access to Data and Products

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The Capacity Building Programme aims at integrating States Signatories to fully participate in and contribute to the implementation of the CTBTO monitoring and verification system. The CTBTO using its own funding as well as EU voluntary contributions (through EU Council Decisions III, IV and V) aimed at facilitating and strengthening States Signatories’ participation in the CTBTO verification regime through enhanced access to IMS data and IDC products. These data and products may also be used for civil and scientific applications. The CTBTO has provided support in form of training and workshops for NDC technical staff, CTBTO experts-in-the-field visits at NDCs, provision of a software package called NDC-in-a-box and donation of NDC basic equipment. The targeted regions so far were, Africa, MESA, EE and SEAPFE. It has been shown that over the past years between 2008–2014 there has been a 7-fold increase in data access in Africa and LAC, a four-fold increase in both EE and SEAPFE. There is a direct correlation between the start of the programme in individual countries with their increase in data access activities. There are still challenges to be overcome at many NDCs. Follow-on capacity building activities are designed to address those challenges.

T4.1-P17. Performance of the Primary Seismic Array Stations of the International Monitoring System Network for the Year 2014 (Part I): An Analyst’s Perspective

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During interactive analysis re-timing and frequency wave number (F-K) analysis are performed to refine arrival time, azimuth and slowness estimates of automatic detections. Differences between automatically and interactively obtained parameters are investigated using data from all primary seismic array stations of the International Monitoring System (IMS) network during the year 2014. The differences shed light on analyst workload. In addition, performance of the network is evaluated from an analyst’s perspective. Differences in the estimates for arrival time, azimuth and slowness between the automatic processing results and interactive analysis shows that analysts have to recalculate parameters for many of the automatic detections during interactive analysis. For example, the results indicate that of the total number of common detections at the Waramunga array station in Australia (WRA), 15 009 (65.8%) were retimed by analysts. The results of the study should help CTBTO develop plans to improve performance of the IMS network of primary seismic array
stations, ensuring that the quality of the input data for interactive analysis is high so as to enhance the quality of the Reviewed Event Bulletin as well as its timely issuance.

**T4.1-P18. Preliminary Study of the International Monitoring System Seismic Station Characteristics Using Spectral Analysis Method in Indonesia**

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We use waveform data from the CTBTO’s seismic stations in Indonesia to analyse the local characteristics of each station using the Spectral Analysis Method. From this analysis we can determine the local characteristics such as background noise and dominant period. From the width of the background noise frequency we assume the sources of the noise disturbance. The results provide insight into where the next sensors should be placed in Indonesia to get great quality seismic recordings.

**T4.1-P19. Project of the Construction of New National Data Centre of Bangui as a Contribution to Verification Process for the CTBT in the Central African Republic**

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Stations PS11 and IS12 of the International Monitoring System (IMS) will be located in the Central African Republic (CAR). This poster addresses the activities undertaken and the difficulties encountered in establishing the IMS stations PS11 and IS12 as well as the National Data Centre (NDC) in Bangui. Topics will include how the station management will be assured in the CAR; which organizations will be in charge of station installation, operation and maintenance; and how the NDC will be established for supporting the verification process in Central African Republic.


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Until 2009 the quality control function within the International Data Centre (IDC) of the CTBTO carried out quality assessments of the Reviewed Event Bulletin (REB) through comparisons with the two other global seismological bulletins, i.e. the Preliminary Determination of Epicentres Monthly Listing of the US Geological Survey and the bulletin of the International Seismological Centre (ISC). The results of the corresponding comparisons with the prestigious ISC bulletin have been published by Koch (2012) for the first eight years since the IDC started official bulletin production in February 2000. In this work we show corresponding results for the following years 2008–2012 of the comparison between the REB and ISC bulletins. As to the location accuracy we find similar results as before in that location differences of common events are in 95% of the cases below 1 degree (and within 0.5 degrees for 90%), even though the number of common events has further increased in recent years to more than 30 000 events/year. The proportion of sole IDC events remained at about one third thereof. Most notably, however, is the significant rise in the number of events that have been discarded by the ISC as ficticious.
T4.1-P21. Recent Advances in Signals Characterization Using Data from Nigerian Network of Seismic Stations

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The Nigerian National Network of Seismic Stations (NNNSS) has been generating data since 2009 that have given operators some insight into a trend connecting instrumentally recorded events with historic events observed in Nigeria within the last 70 years. The detection of local and teleseismic events by the network has been boosted by recent deployments of advanced seismic equipment to Nigeria. With these improvements and recently implemented noise reduction measures, new approaches have been adopted in data processing, analysis and routine screening to thoroughly scrutinize seismograms for signals arising from local events such as landslides, rock falls, quarry blasts, and other artificial sources hitherto buried in noise. This signal characterization has helped the operators of NNNSS to retrieve local and teleseismic events that were earlier discarded with noise, and to identify and analyse unusual signals. With these capabilities, NNNSS could also serve as a network for detecting nuclear test explosions within Nigeria and its environs, thereby contributing to the monitoring of prohibited nuclear tests around the world, and through robust collaboration with end users of results.

T4.1-P22. Reconstruction of Weather Situations and Aerosol Transport over the Himalayan Complex Terrain

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An accurate reconstruction and reliable prediction of weather situation are desired to understand, model and predict suspected particulate transport and deposition over the region of interest. Reconstruction and prediction of diverse weather situations that could possibly prevail over the extreme terrains of Himalayas at high spatial resolution have been remained to be of great challenge. In this paper, we will present some of the successfully reconstructed weather situation over the extreme terrains encompassed by the Nepal Himalaya at the resolution of 1 km × 1 km horizontal grid size. Fictitious particulates released in different parts of the southern plain and their transport and deposition patterns over the mountainous areas as revealed by numerical simulation will also be presented. The knowledge of transport and deposition patterns of fictitious particulates can have significant applications in assessing possible risks of human suffering from suspected particulates.

T4.1-P23. Strategic Importance of the Involvement of the Academia in the Implementation of the CTBTO Programmes in West Africa

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The Science and Technology of the CTBT offer very important opportunity for collaboration in Research and Development efforts which holds potentials for identifying new areas where the use of the CTBT data and products, verification technologies, education resources and the e-learning availability can be effective towards making the world more secured. Participation in the 2014 CTBT Academic Forum was an eye-opener for us at the Nigerian NDC. It showed us the critical importance of the Academia in achieving the overall goal of strengthening and effectively implementing the CTBT and its established verification regime. It is to address this huge gap that informed this study. It is focussed on carrying out survey, questionnaire administration, focussed group discussions, one-on-one communication etc to determine the level of awareness on what the CTBT and CTBTO stand for within the various academic environments in the sub-region and the level of involvement of the members of the academia. The results showed only a paltry 27% know what the CTBT is all about. It is the object of this study to identify possible ways and means on how to get the academic community from the region to be fully involved.
T4.1-P24. The Application of International Monitoring System Data and International Data Centre Products at the Malaysian National Data Centre

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Malaysia has established the CTBT National Data Centre (MY-NDC) in December 2005 which is located at the Malaysian Nuclear Agency. This poster aims to present the application of International Monitoring System (IMS) data and International Data Centre (IDC) products at the Malaysian CTBT National Data Centre (MY-NDC). Since its establishment, MY-NDC received data from a few IMS stations. MY-NDC also utilizes the IDC Secured Website to retrieve the IDC products from time to time. For analysis activity, MY-NDC used a software package provided by CTBTO. MY-NDC uses the IMS data and IDC products for various purposes such as internal training for NDC staffs, radionuclide monitoring, as well as exercises conducted by the CTBTO. As a result from the application of IMS data and IDC products, MY-NDC is able to strengthen its in-house capability particularly in data analysis as well as participate in any NDC related exercises organized by the CTBTO. The IDC products have enabled MY-NDC to compare the accuracy of its analysis findings. MY-NDC has greatly benefitted by the application of IMS data and IDC products in the aspect of building up its capability as well as enabling its participation at the international level.


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The Global Seismographic Network (GSN) is a state-of-the-art, globally distributed network of 150+ permanent seismological and geophysical sensors, and is a cooperative partnership between the Incorporated Research Institutions for Seismology (IRIS) and the US Geological Survey (USGS). The GSN coordinates closely with other international seismic networks through the International Federation of Digital Seismograph Networks (FDSN). In collaboration with the USGS National Earthquake Information Center (NEIC), the network provides a community resource for earthquake monitoring, research and education. The GSN streams critical data to the National Oceanic and Atmospheric Administration (NOAA) Tsunami Warning Centers for rapid response to large, tsunamigenic earthquakes. Recently the GSN upgraded all stations to the next generation DAS and, starting in 2015, will develop the Very Broad Band Borehole Seismometer (VBBBS) to replace obsolete sensors. In parallel, the GSN is implementing a data quality assurance system to ensure that quality of the data from the GSN is as high as possible and to communicate the level of data quality in a consistent manner both within the network operational groups and to the GSN data user community.

T4.1-P26. The All Three-Component Broadband Seismic Array ARCES/PS28

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The ARCES seismic array is currently in a major recapitalization/modernization phase. In a first stage in September 2014 NORSAR replaced all essential acquisition and recording equipment. Each of the 25 sites is now instrumented with a three-component broadband seismometer (Guralp CMG-3T hybrid) and a Guralp EAM digitizer. The central site has a very-broadband instrument (360s–50 Hz), whereas the other sites have sensors with a bandwidth from 120s–50 Hz. In the central recording facility we replaced the central timing system, the fibreoptic modems for intra-array communication and the acquisition computers. We also established two new communication solutions (broadband over satellite and GSM) additional to the existing VSAT communication in order to accommodate higher data transmission volumes. During the upgrade we have been operating the old and new system as far as possible in parallel and accomplished a smooth transmission without any downtime of the array. It took a total of 3 days (18–20 September 2014) from the installation of the first new instrument to the
shutdown of the last old instrument. The ARCES array is now the first fully 3-C IMS seismic array, and we have implemented the processing of the horizontal traces into our automatic routines.

T4.1-P27. The Application of Local Seismic Networks as National Technical Means

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The CTBTO basically established to monitor any probable nuclear tests all around the world with the goal of putting an end to any kind of tests and consequently nuclear weapons as well. Beside main verification regime technology and instruments, national technical means could be used as a strong verification mean too. Local instruments could be a useful mean while going into depth in an area, especially when a member state request any claim against another. Local seismic networks could effectively use checking seismic activity of any area with highest resolution and precision. Lots of small events could not record on global networks and the magnitude of completeness of local network catalogs are always less than regional or global ones which is a great advantage of these kind of networks as national technical mean. To define a procedure detecting and registering these kind of networks either online or offline will strength the Treaty. In this study, some local networks of the Islamic Republic of Iran are presented and their activity compare with regional and global networks are shown emphasizing the remarkable natural difference of seismic activity detection.


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The modern system of seismological monitoring of the Republic of Belarus includes continuous 24-hour observations of seismic events both natural and induced of the wide range of energy and distances, data processing, storage and analysis. It provides the effective on-line monitoring of the seismic situation. But it meets the new requirements of seismic protection in connection with the new data about the geodynamic situation in Soligorsk mining region of Belarus and adjacent territories, the high rise building and the construction of the Belarusian nuclear power plant. These factors are the cause of the process of the optimization of the Belarusian system of seismological monitoring at all levels. The new methodological, instrumental, hard- and software complex was proposed. It permits to optimize the data transfer from the moment of registration of a seismic event up to the providing users by the analytic and generalized information. The acquisition and collecting of qualitative data, their on-line transmitting, reliable storage and efficient processing, the qualitative analysis and objectivity of results are ensured. The optimization of the system of seismological observations in Belarus in its development is oriented to the further integration into the international global system including data exchange formats, dataware, instrumentation, software etc.

T4.1-P29. Understanding the Amplitudes of Seismic Signals and Station Noise

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We have engaged in a multiyear effort to measure seismic amplitudes for regional phase (Pn, Pg, Sn, Lg) seismic amplitudes in order to accurately map out the attenuation structure of the lithosphere. Each phase has different sensitivity, allowing us to tomographically map out the Qp and Qs structure of the crust and upper mantle. We have already obtained attenuation models of Eurasia and North America, with the goal being the development of a high resolution global lithospheric attenuation model. Using information on the earth’s attenuation structure and combining this with source models, we can estimate the amplitudes expected to be observed by recording
seismic stations. Coupled with noise estimates, we can map out station and network sensitivity, indicating which regions and what magnitude events we can hope to record. We can also use the attenuation model to correct for the observed variations in regional amplitudes and, hence, reduce the scatter in regional magnitude estimates, such as \(m_b(\text{Pn})\), \(m_b(\text{Lg})\) and \(M_w\). This will allow us to have more confidence in single or sparse station regional magnitudes, which are common for smaller magnitude events.

**T4.1-P30. Use of Data and Products: Experiences Gained from the CTBTO Capacity Building Activities**

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The aim of this study is to examine the impact of capacity building activities of the CTBTO on the use of IMS data and IDC products by State Parties in the Africa region. The CTBTO capacity building activities were funded by contributions from voluntary organizations. State Parties in Africa received donations of capacity building systems (CBS). Before the arrival of the CBS most State Parties in Africa were lagging behind in the use of data and products from the CTBTO. The identified reasons for this lag include inadequate skilled personnel and computing equipment, poor power supply and communication with international agencies. These identified challenges were addressed through workshops, training courses, online forum, mentorship and equipment provision. The positive impact of the capacity building activities in Africa was felt during the 2014-2013 National Data Centre Preparedness Exercise with the participation of more State Parties in the exercise. The experiences gained by these State Parties strengthened the deployment of the CTBT verification technologies for civil and scientific purposes. Further funding of the capacity building activities will enhance the ability of more State Parties participating in the monitoring of nuclear explosion.
T4.3-O1. Increase Data Availability and Reduce Logistical Support Cost Through Maintenance Management Information Systems

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Maintenance management information systems (MMIS) have evolved over the past decade to provide real time system design configuration with “error free” data, maintenance tasks with step by step instructions, and auto-populate reports used for logistical support and resource optimization is enabled by integrating parts marking with machine readable code with the MMIS. As the number of parts and system increases the need to provide “error free” data also increases. Limiting the number of data fields a user has to input reduces the opportunities for error because the MMIS auto-populates required data fields or provide drop down menus. Reports constructed within the MMIS are standardized and formatted to show the necessary information required in many different types of report. Step by step maintenance instructions can be integrated into the MMIS and will track all maintenance actions performed on the system. When procedures change, they are quickly and easily transmitted to all users throughout the globe. Incorporating the advances in MMIS will reduce logistical downtime, increase data availability, and cost effectiveness through logistical support optimization and improved process management capability.

T4.3-O2. System Topology and Fault Tree Analysis (FTA) for Seismic and/or Infrasound Sensor Sites

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Maintenance of sensor systems can be codified to increase operational efficiency and decreased down time. We used successive refinements of failure definitions to define a fault tree analysis (FTA) structure. Benefits of FTA include: FTA provides a visual, logic model of the basic causes and intermediate events leading to the top event. FTA can help prioritize resources and costs. FTA can identify vulnerable areas in a system. Upgrades to the system can be objectively evaluated for their benefits in reducing the probability of the top event. Another benefit from FTA is the prioritization of the contributors to the top event. FTA can be used as a tool to assist in designing a new system thus incorporating all of the above benefits in any new design. The root cause can be assigned to the failure of a single component or the interdependencies between multiple components producing a unique system level failure. The aggregate processes defining what items are repaired, where they are repaired, and by whom they are repaired creates the system’s maintenance concept. Our presentation will discuss the application of the FTA methodology to the maintenance concept for a generic infrasound station, similar to IS31 Aktyubinsk, Kazakhstan.
T4.3-P1. Life Cycle Management at I32KE

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I32KE is a seven element array infra-sound station located in Karura forest 6 km north-northeast of Nairobi, Kenya. The elements are interlinked by fiber optic (FO) to the central processing facility (CRF). The station has experienced logistical as well as security challenges in the past few years. These include obsolesce, cable vandalism, lack of readily available spares, long periods between requisition and supply, communication and power supply challenges. In view of the above challenges, the station underwent a major upgrade in 2013 to enhance and optimize performance. As a result, the station has managed to attain and maintain the required 98% data availability since then.

T4.3-P2. Maintaining the Mission Capability of Primary International Monitoring System Station in Crisis Period, Through the Use of Rationalization Inventions on Example of PS45 (AKASG), Ukraine

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The Malin seismic array (AKASG), PS45, was certified in December 2002. It consists of 24 seismic sites and a central recording facility CF-AKASG (CRF). This array is based on SAIC technology. AKASG has a telemetry system architecture, designed around eight nodes (key sites), that act as concentrators for the data produced by connected sites. During the last 13 years, AKASG has remained operational. This, despite the following setbacks: the loss of support of the supplier of the station technology, lack of spare part, delays of the planned AKASG upgrade and in addition the risks caused by severe annual thunderstorms. This operational result has been achieved through introduction of various rationalization improvements regarding the station equipment and software at AKASG. Nowadays AKASG presents a unique mixed system that includes Nanometrics and SAIC technologies. Furthermore, for potential future deployment also the usage of Guralp digitizers has been successfully tested at the site. Regardless of the technology, the site’s sensor data can be transmitted to the CRF via radio, underground low-frequency cables or underground fibreoptic cables. Although these improvements are highly effective, they can only be considered as temporary measures. In my report I want to present the basic implemented improvements: methods to improve channels of radio communication; coordination protocols and interfaces of telemetry system, and implementation of quality monitoring and data equality software.

T4.3-P3. Modern Seismological Monitoring System as a “Big Science” Engineering

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In recent years, the number of seismic stations in a seismograph network and/or a seismic array increased dramatically. Real time transmission and processing of continuous waveform data has been facilitated by modern digital technology. ‘Data intensive research’ becomes one of the characteristics of the application of such a monitoring system. As a result, modern seismological monitoring has evolved into a complex system which has started to possess some features of ‘big science’ engineering. This provides seismological observation and interpretation with new clues to the rethinking of the traditional test areas of earthquake prediction experiments and the newly developed earthquake early warning systems. The former has not been as successful as expected, and the later faces to the challenge of effective functioning and sustainability. One of the unique, and sometimes neglected, contributions of the International Monitoring System (IMS) is that it has provided good experiences for such rethinking. The IMS establishment experiences, as well as their methodological formulation, can
provide empirical solutions for the design and planning of the next generation seismic networks, the novel test areas of earthquake prediction experiment, and earthquake early warning system.

**T4.3-P4. Performance Optimization of Stations PS36 and IS44, Kamchatka**

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Features of operation of vaults of infrasound station on peninsula Kamchatka are presented. The objective of this poster is to present operational problems of underground vaults of the infrasound station IS44, and to show results of replacement of the vaults from TRINAS GmbH. Automation of the process of conducting of daily state of health checks is described. The purpose is to present the programmed solution for time abbreviation on daily checks of functioning of the equipment, which is applied on stations PS36 and IS44.

**T4.3-P5. Preventative Maintenance for Sustaining the International Monitoring System**

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The International Monitoring System (IMS) Network of the CTBT, is to consist of 337 monitoring facilities, scattered around the globe, of four different technologies. One of the mandates of the CTBTO, in cooperation with the Station Operator and Host Country is to ensure that the global network remains operational and reliable. The entire system life cycle starts with conceptual design, followed by fabrication and installation/ to operation and maintenance until it is disposed of and replaced. This is referred to as through life sustainment. Optimal and cost effective sustainment of the network can be achievable only through proper planning and execution. The IMS Monitoring Facilities Support, maintenance team is responsible for the oversight associated with maintenance of the monitoring facilities. Regular tasks consist of planned & scheduled maintenance, unscheduled maintenance, repair and replacement (out of life cycle). This paper details how sustaining the facilities through preventative maintenance and adopting practices such as maintenance planning and document management can have important long term benefits and can ensure that the CTBT network remains operational, reliable and credible.

**T4.3-P6. Sparing and Life Cycle Modelling: Sustaining the International Monitoring System Network**

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The International Monitoring System Network will consist of 337 facilities, composed of four different technologies with a variety of designs, deployed in diverse environments around the globe. The sustainment of such a network over many generations and to high level of availability is challenging, and the cost could become unbearable. The Monitoring Facilities Support (MFS) section is already performing Logistics Support Analysis (LSA) enabling estimation of optimal sparing policies at existing facilities, as well during the design phase of new stations and when planning major upgrades. LSA also enables examination of alternative designs or maintenance policies before investing in a particular solution. In addition to ongoing modelling activities, MFS has started the preparation of life cycle cost analysis as the next step in modelling, which could assist the CTBTO make decisions on resource allocation, logistics operational planning, and will ensure the reduction of Total Cost of Ownership. Initial results have been obtained and have proven the benefit of such analysis. The results of such simulations will be instrumental in validating the Integrated Logistics Support system supporting the cost-effective sustainment of the IMS network. Some initial results are presented in this poster which attempts to illustrate their present and future potential benefits.
Poster Presentations

AF-P1. Citizenship in the Nuclear Age: Incorporating Role-Playing as a Tool for Student Learning and Engagement

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American college students, often unfamiliar with the intergovernmental organizations and regimes in place to reduce the dangers of nuclear weapons, tend to hold an ethnocentric perspective on nuclear weapons issues. My experience teaching an interdisciplinary course on “Citizenship in the Nuclear Age” in the Department of Political Science at the University of Massachusetts, Amherst, suggests a role-playing negotiation can be a useful tool for engaging students about key international actors and differing perspectives. I report here on my experience using a role-playing simulation developed by the ICONS Project at the University of Maryland featuring international reaction and response to an explosion in the vicinity of the Yonbyon nuclear facility in the Democratic People’s Republic of Korea. Findings are presented based on debriefing the students about their experience over the course of ten separate sections between 2009 and 2014. The experience demonstrates that placing students in a simulated international situation in which a nuclear incident is coupled with a dearth of reliable information can significantly increase their interest in and appreciation of the value of a robust monitoring and verification regime such as that offered by the CTBT.

AF-P2. The CTBT: Political, Legal and Technical Aspects

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SASSI University offers a course, entitles “Comprehensive Test Ban Treaty: Political, Legal and Technical Aspects”. It is a three credit course and offered as a part of masters’ programme for security studies to university students. This course was designed to provide students with both theoretical and technical knowledge on the Treaty, including prospects and challenges to entry into force (EIF) of the CTBT, role of CTBT in global security and its verification mechanisms. This course enables the students to confront the complexities of the twenty-first century’s shifting security landscape and also promotes recognition of the importance of the CTBT.

AF-P3. Contemporary International Law Revisited Through Examining the CTBT

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Examining CTBT and its character in the international legal order is thought-provoking when considered in the context of the present state of contemporary international law. The aim of the course, entitled “International Law” and taught to third-year students majoring in a field of humanities and social sciences in the Nagasaki University, is to focus on the current form and problems of contemporary international law by considering the following three questions: (1) How should the CTBT be categorized in international law? In the field of international law, the CTBT tends to be mentioned simply as the law of arms control. Students should recognize the various functions of the CTBT and diversity of international norms. (2) Who should be engaged in the law-making? It is important for students (especially those majoring in law) to understand that the law-making definitely requires multiple approaches from law and science equally. (3) How should we approach the global issues? This question is set to encourage students to have wider, many-sided and well-balanced view.
AF-P4. The CTBT as a Teaching Tool on International Relations Classes

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The CTBT serves as a useful tool with which to illustrate and/or discuss a variety of topics, including the threat of nuclear proliferation, the use of diplomacy, the art of negotiation, the functioning of international organizations, and the impact of science and technology (SnT) on international relations. CTBT has been utilized in several classes at Georgia Tech, each with its own distinct context. The Problem of Proliferation reviews the history of WMD technology and proliferation, focusing on the mechanisms by which states and the international community have sought—and continue to seek—to halt their spread. CTBT Policy and Technology examined the impact of SnT on Treaty verification. We looked closely at how SnT affected the negotiations of the Treaty over its history, and how it is affecting the Treaty’s ratification today. Science, Technology and International Affairs covered the emergence and ongoing prominence of SnT as drivers of domestic policy and international affairs, using topical studies of nuclear proliferation, infectious disease, climate change and science and technology education. The poster submitted reviews the ways in which the CTBT was used within each class, the teaching methods utilized, as well as the successes and challenges.

AF-P5. CTBT Education at the Ural Federal University

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Ural Federal University (UrFU) is a member of the Test-Ban Academic Network and has been engaged in CTBTO-related activities since 2012. CTBTO-related activities at UrFU could be divided into three main stages. The first stage was devoted to diving into CTBTO issues: Treaty, ratification problems, activity and effectiveness of CTBTO (2012–2013). During this stage we organized with the help of the CTBTO team the course: “Multilateral Verification, and Collective Security: The Contribution of the CTBT”. The second stage was to reach the sustainability of CTBTO related topics into bachelor and masters’ curriculums in International Relations (2013–2014). This stage was devoted to the integration of CTBTO related topics into syllabi of courses such as “Non-proliferation and Disarmament Issues”, “Global Trends and Security Issues”; developing this topic in student’s research and bachelor’s thesis; participating of UrFU’s students in CTBTO events and seminars. The next stage is aimed to develop a special course on CTBTO (2015) for master’s degree students. This course will be simulation-type course, in which we could integrate theoretical basis on CTBT and the role game on CTBTO activity. Our master’s degree students who participated in CTBTO’s seminars are able to help us to develop this course.

AF-P6. CTBT Education in Kazakhstan: Overview and Plans

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Promoting CTBT education in Kazakhstan, a country that housed a major nuclear test site; voluntarily renounced the world’s fourth-largest nuclear arsenal; played a leading role in the establishment of the Central Asian Nuclear-Weapons-Free Zone, and is home to five IMS stations, is critically important. Nuclear non-proliferation and disarmament courses I taught to date at the Al-Farabi Kazakh National University and the Shakarim State University of Semey for more than 60 students specializing in International Relations, Political Science, and Nuclear Physics, as well as individual lectures delivered at other educational institutions, comprehensively covered, among other topics, nuclear test-ban issues, including CTBT’s political and legal aspects, as well as health and environmental consequences of nuclear testing. I plan that future courses will focus more on the Treaty’s technical aspects and its verification regime, including test-ban monitoring elements and scientific applications of monitoring/verification data. Classes will also include interactive activities, such as simulations of CTBT related negotiations and on-site inspections. As Kazakh becomes a major learning language in Kazakhstan, a Kazakh-language CTBT course should be developed, along with relevant terminology and course materials. The next two years will be conducive for further integrating CTBT-related topics into the existing
academic curricula, as Kazakhstan, along with Japan, will coordinate international efforts towards the CTBT’s entry into force.

AF-P7. **CTBTO Infrasound Science and Technology for Education in Iran**  
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‘Speech Recognition’, ‘Text to Speech’, ‘Biomedical Acoustic Engineering’ and ‘Mechanical Acoustic Engineering’ lectures have been taught at most Iranian universities for two decades. There have also been a lot of BSc, MSc and PhD theses and industrial and hospital projects in these fields. However, the field of ‘infrasound acoustic science and technology’ is familiar only to a subset of Iranian experts who participated in the CTBTO Working Group B (WGB) meetings or Iranian professors and students who took part in the annual training courses offered by the CTBTO. I designed my ‘Acoustic Signal Processing’ lecture based on the documents on infrasound science and technology from the WGB38 meeting, which includes a chapter on ‘infrasound signals processing (civil and CTBTO applications). This lecture has been taught for a few years in some universities where I am a term faculty (lecturer). Now it is the time for the CTBTO to promote this education in the Islamic Republic of Iran by cooperating with Iranian universities. This presentation investigates the capacity of Iranian universities to develop CTBTO infrasound science and technology relevant education in Iran.

AF-P8. **CTBT-Related Topics at the Middlebury Institute of International Studies**  
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The poster highlights the challenge of teaching science to policy students with a particular focus on the science course that I coordinate and the virtual verification course that I teach. The Middlebury Institute of International Studies, is known for its emphasis on foreign language education. The approach we take in science education is to consider science as essentially a third language, and to teach students that they don’t need to know how to speak the language perfectly but they need to be conversant enough to be able to communicate with the experts. I will also present another course that I teach called Nuclear Treaty Verification in a Virtual World, which used avatar-based virtual reality to simulate the verification of nuclear weapons by fictional host and inspecting party teams. The goal is for the students participating as avatars to design a verification protocol to make the inspection possible without divulging weapons information to the inspecting party. A video describing the course can be seen at: http://tinyurl.com/otetutv. I plan to use avatar-based virtual reality to simulate particular situations in an OSI which may be difficult to exercise in practice. I have presented this concept to the Training Section of OSI in 2013.

AF-P9. **CTBT-Related Topics at the School of International Relations of Beijing Language and Culture University**  
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Since 2012, I have combined my regular course “Arms Control and International Security” for graduate students majored in international politics with the CTBTO on-line course. CTBT issue has become an important integral part of my course. I take three weeks to introduce CTBT related issues and require students to read CTBTO on-line materials after class followed by in-class discussion. I also encourage students to follow online courses offered by the CTBTO. I also have a course “International Security” for undergraduate students. I use about a month to introduce nuclear arms control, including the history and role of the CTBT. Younger students are usually more interested in the CTBT issue and the on-line course. Some of them chose to write their theses on CTBT related topics after on-line studying and some decided to pursue their master degrees on CTBT. As the CTBT is critical to nuclear arms control and international security, it is natural to integrate the CTBT-related
topics into my curricula. By combining the CTBTO yearly online course with my formal and regular courses, my students (50–60 each year) have gained more broad and deep acknowledgment and impression on CTBT-related security issues.

**AF-P10. Experience of Teaching CTBT Relevant Courses in Botswana**

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The use of CTBTO educational materials in the teaching of some geophysics courses at the University of Botswana was introduced in 2012. This was facilitated by the availability of relevant online repository course content on the CTBTO’s e-learning platform. CTBT materials were introduced to undergraduate students as general reading materials for the introduction of four monitoring technologies used by the CTBTO: seismic, radionuclide, hydroacoustic and infrasound monitoring. These students went on to register to get access and even attempted some of the quizzes. One undergraduate student used seismic events from our local network to correlate with that from the IMS bulletin for 2010. Graduate students used the material in highlighting the importance of Seismology to Diplomacy (using the CTBTO as a case study). In 2014, some lectures in Applied Geophysics covered some IDC standard products and an AutoDRM requested waveform data was used to determine the location of an event that had shaken Gaborone city and its surrounding. In 2016, some of the 2013 National Data Centre Preparedness Exercises will be used as case studies in Applied Geophysics.

**AF-P11. Integrating CTBT Education into “China Trade and Security Policy” Course**

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I have integrated CTBT-related topics into my course “China Trade and Security Policy” at Fudan University through the following three perspectives. First of all, I have employed historical perspective. More specifically, one session of my course has been devoted to introducing the evolution of China’s non-proliferation and export control policy. In third stage, that is, from 1990 to 1999, China’s policy toward CTBT is introduced in detail. Secondly, my course investigates non-proliferation and export control through a perspective of bilateral and multilateral relations. In the session on China–US relations in the arena of non-proliferation and export controls, my course briefly introduces interactions in the process of the CTBT negotiations in the mid-1990s, and examines how these two countries and other countries had engaged in the negotiations and eventually reached this Treaty. I have also employed a comparative perspective. My course compares the similarities and differences of China’s non-proliferation and export control policies with those of the US, the EU and India’s. To sum up, I have employed historical, international relations and comparative perspectives to have integrated CTBT related topics especially non-proliferation and export controls into my course.

**AF-P12. Integrating CTBT-Related Topics in Academic Curricula at St. Petersburg State University**

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There are approximately 600 State Universities in the Russian Federation. Only five of them have courses on nuclear non-proliferation and arms control. The School of International Relations at St. Petersburg State University is the only academic institution in St. Petersburg that has classes on arms control. Since 2012 two such courses are available. “Russia and international arms control regimes” is an optional course for bachelor and master exchange students. “Contemporary problems of the evolution of international arms control regimes” is a mandatory course for graduate students. Both courses consist of four modules and cover nuclear, biological, chemical and conventional arms control issues. The nuclear non-proliferation regime is studied as a combination of several sub-regimes established on national, regional and global levels. The CTBT is overviewed as a unique
global sub-regime with a high degree of interdependence. The courses are focused on analysing challenges that face international arms control regimes and on studying cooperative efforts to make these regimes stable, sufficient and effective. Teaching methods include lectures, case studies, discussions, individual research projects. Out-of-the-class activities involve CTBT educational resources and CTBT e-learning modules.

AF-P13. Living with Nuclear Weapons? Focusing on the Nexus of Science and Politics

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At the University of British Columbia, in 2014, we have completed two pilots of the trans-disciplinary course, “Living with Nuclear Weapons? Arms Control and Verification Technologies”. Supported jointly by the Departments of Political Science and Electrical and Computer Engineering, this course is unique in its blended and flipped delivery and its enrolment (2/3 Political Science and 1/3 Engineering). Group learning is the principle focus for classroom activities that are based on online components consisting of videos from the CTBTO repository, policy videos (Allen Sens) and science/math videos (Matthew Yedlin). Classroom activities include the use of clickers to assess the learning of online components, interactive discussions and negotiations focussing on ethics and arms control and problem solving sessions centred on the basic science of nuclear weapons. One of the key assessment components is a group essay “Strengthening the CTBTO: A Way Forward”. One of the principle challenges that we have encountered is engaging the political science students in solving the science problems. This course, now formally integrated into the UBC curriculum, in the Faculties of Arts and Applied Science, will be launched, September 2015, on the edX platform.

AF-P14. Nuclear Disarmament and CTBT Education in Nagasaki University

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We offer a disarmament education programme called ‘Toward a World without Nuclear Weapons’. This programme is a part of liberal arts education for those students with a nuclear disarmament major. During 2013–2014, 90 students from various backgrounds enrolled. This programme contains three mandatory subjects, namely, “Peace and International Society” (International Relations), “Atomic Bomb and Nagasaki” (History and Medical Science), “What is Nuclear Weapons” (Political Science & Physics) and five selective subjects, out of which each student must take three or more, namely “Citizens’ Movement, NGO and Nuclear Weapons Abolition” (Political Science), “A Bomb Survivors and Medical Assistance” (Medical Science), “Nuclear Weapons Abolition and Education” (Education & Journalism), “Literature, Arts and Nuclear Weapons” (Literature, Arts, & Sociology), and “Law and Politics of Nuclear Disarmament” (International Law & Political Science). All subjects include certain elements of nuclear testing and the CTBT. Therefore, after finishing this programme each student is expected to have comprehensive knowledge of nuclear disarmament, including the CTBT. A majority of students expressed their satisfaction but some assessed the programme as rather difficult, both qualitatively and quantitatively.

AF-P15. Nuclear Security Education: Bulgarian Experience

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University Department "National and Regional Security" (UNWE) is in process of preparation of international Master's programme (in English) in Nuclear Security starting in October 2015. The programme is structured according to the State's requirements for the Master degree and International Atomic Energy Agency (IAEA). It is a result of an agreement between the IAEA and UNWE, Sofia, Bulgaria. UNWE Department ‘National and Regional Security’ is in charge of preparation of the programme. The presentation will embrace three main
issues: (1) Global framework: study of similar programmes, similar experience, target groups, demand and needs for such kind of education, context of nuclear security education. (2) Organizational issues: curriculum, learning materials, educational methods and lecturers, opportunities for e-learning and practical exercises and information. (3) Opportunities for cooperation and assistance, including IAEA efforts, International Nuclear Security Education Network (INSEN) efforts, funding organizations, training of trainers, strategic partnerships. A significant part of curriculum and the learning materials are related to the issues of the CTBT and non-proliferation.

AF-P16. **Prospects and Challenges Associated with Integrating CTBT Academic Curricula in the University of Benin**

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Although the integration of the CTBT into academic curricula was initially viewed with pessimism at the University of Benin, Benin City, Nigeria, the number of teaching staff as well as students’ population drawn across the realms of physical and human sciences has grown. Within the limited resources, efforts are currently being intensified to encourage more students to participate in the teaching of CTBT-related activities. Presently, the integration of CTBT-related activities into the curriculum of the institute is recording gradual progress. Interests in the CTBT-related activities have grown especially when the prospect of using IMS data to carry out research was explained to the students and management during a presentation, which they believe will open a vista of research opportunities to them. The main challenges include the task of convincing students to participate in the CTBT activities that they believe would not add credit to their overall grades; issues on internet connectivity to aid the use of CTBT online resources; and, the perception by some teaching staff on CTBT activities as not relevant to the Nigerian University’s curricula since Nigeria is not accustomed to matters like nuclear proliferation and nuclear testing.

AF-P17. **Seismology in Schools Programme in Ireland**

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The School of Cosmic Physics, at the Dublin Institute for Advanced Studies, embarked on an outreach programme in 2007 to promote earth science, particularly seismology, in schools, up to pre-university level. In addition to forming the basis for studies in earthquake behaviour, the project addresses ‘forensic seismology’ in understanding signals generated by, for instance, the Kursk submarine explosion, Twin Towers Disaster in USA in 9/11 and the use of seismology as one of the verification techniques of the CTBT. The Seismology in Schools programme seismometers are installed in over sixty schools. Given that the population of Ireland is four million this number of 1 per 66 000 compares favourably with the UK (70 in a population of 70 million, or one per one million). The phenomenal success of our Seismology in Schools programme has been the result of close partnership with the British Geological Survey (BGS) and IRIS (Incorporated Research Institutions for Seismology). The Directors of the Educational Centres (ATECI, Association of Teacher’s/Education Centres in Ireland) funded the purchase of 34 additional seismometers. The seismometer helps students visualize what seismology and the recording of earthquakes comprises. It was essential on providing teacher training days on the set-up and operation of the seismometer, and associated software.
AF-P18. Strengthening Nuclear Science and Education: Application of Advanced CTBT Monitoring and Verification Technologies for Education

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Tanzania is strengthening its nuclear science education programmes to support the peaceful application of nuclear science and technology for socio-economic development. The overall objective of this programme is to establish a sustainable national capability for using the potential of advanced information communication technologies for training and education in the field of nuclear science and technology. The verification technologies of the International Monitoring System (IMS) and the data, technologies and products of the International Data Centre (IDC) have the potential to offer, in addition, a range of useful civil and scientific applications which could contribute to sustainable development and human welfare. These civil and scientific applications demonstrate, in part, how States Signatories could gain additional benefits from participation in the Treaty verification regime. Tanzania operates the CTBTO radionuclide station as well as a National Data Centre and is continuing to expand its educational programmes in line with the National nuclear science and technology policy and strategy. This presentation identifies these potential and its application in educational programmes in Tanzania.

AF-P19. Strengthening the CTBTO Through the #BanTheBomb Campaign

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In 2014 the University of British Columbia implemented the course, “Living with Nuclear Weapons”, an interdisciplinary course that allows political science and engineering students alike to collaborate on the topic of nuclear weapons. The course places an emphasis on the CTBTO and works in collaboration to engage students in nuclear politics, scientific methodologies and verification practices associated with the CTBT. We students have developed a public information campaign with the goal of strengthening the CTBT. In engaging the general public through accessible, interactive mediums, the intention is to pressure signatories to ratify the Treaty. The proposed social media campaign, known as “Ban The Bomb,” encompasses three components: a hashtag (#BanTheBomb), a campaign video, and an accompanying campaign website. We have created a preliminary short film (https://vimeo.com/111315982) that reviews the dangers of nuclear weapons testing and warfare, as well as a template website (http://bridgittetaylor.wix.com/banthebomb) for the campaign to be hosted. Future development of this website could include a CTBTO-partnered online academic curriculum that centres around interactive learning. The experiential learning demonstrated in “Living with Nuclear Weapons” inspired this campaign, which intends to engage the public in the ratification of the CTBT.

AF-P20. Teaching Engineering Ethics with the CTBTO

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Objective-driven development is an important methodology for technological and engineering ethics. One important task is find examples that fit this methodology. CTBTO can be used as an example of it. To achieve the objective of promoting a peaceful world, it implemented an extraordinary infrastructure and mechanisms to strengthen confidence world-wide. For years I have introduced aspects of the Treaty and of the Organization in my teaching practice of engineering ethics. Role-playing games and simulations, topic research and speeches are among them. Student have found very formative to study the organization. The results were the following: 14 role-playing games, seven in simulated country ratification of CTBT, and seven simulated decision on an OSI by the Executive Council, eight student projects on different aspects of CTBT and CTBTO. I devoted two sessions in my courses to introduce the CTBT and its relevance for world peace.
AF-P21. Teaching the CTBT: An Example Class Exercise

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For the past two years I have taught a weekend workshop on the CTBT at the Middlebury Institute of International Studies at Monterey. Master’s degree students receive one unit of credit for a programme that starts at 6 pm on Friday evening and runs all day Saturday and Sunday. Because this is an intensive time for the students I have found that some role-playing exercises can not only flesh out the terms of the Treaty, prompting the students to read and understand portions in detail, but also provide a welcome break from what could become monotonous lectures. Article II sets out the composition of the Executive Council in Part C. The 51 members are chosen from the regional alignments set forth in Annex I to the Treaty. Paragraph 29 (a) through (c) of Article II sets forth criteria for selection of Executive Council members from each Annex 1 region, but beyond that there is no guidance. Picking a region and having students represent countries of the region and letting them struggle with how to select the Executive Council members has proven to be an interesting exercise that often sparks lively debate and uncovers undefined aspects of the Treaty.

AF-P22. The Challenge of Integrating CTBTO Verification Technologies in Geophysics Lectures

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Since 2010, new topics related to civil and scientific applications of the data and products released by the CTBTO were gradually integrated into the Geophysics lectures at the Innsbruck University. A general description of the four monitoring technologies (seismic, hydroacoustic, infrasound and radionuclides) is now part of the geophysics lectures. In 2013, two geophysics lectures were complemented with an introduction to the general dataflow including sensors, data acquisition, data transmission (telecommunications) and data processing. Some CTBTO public media and e-learning material are used. A lack of CTBTO public educational material involving software and real data for designing exercises in applied geophysics was identified. Applied geophysics lectures involve final verification measures and OSI-related questions like location of cavities and changes in geological structures using geoelectric-, seismic-, gravity field mapping, electromagnetic, Ground Penetrating Radar (GPR), and environment-sampling Methods. Teaching of additional CTBT verification technologies like dynamic location of events, automatic correlation of events in the main bulletins and global seismicity are planned for 2016. First steps for creating an online course of applied geophysics were started in January 2015. A questionnaire for checking understanding and interest in CTBTO related activities was created. Survey will be carried out in 2015/2016.

AF-P23. The Integrated Field Exercise as Case Study for High-Fidelity Joint Team Training in Multilateral Complex Sociotechnical Systems

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The CTBTO employs various approaches for familiarization, instruction and validation of the Treaty’s verification regime. In this context, the Integrated Field Exercise (IFE) represents its highest fidelity method, and is conducted in an actual operational environment with a fictitious, realistic scenario. Next to demonstrating technical feasibility, its aim is the rehearsal and refinement of collaborative distributed decision-making processes between the constellations of parties involved in an on-site inspection (OSI) request and implementation. This case study describes the recent 2014 IFE from a sociotechnical systems design and analysis perspective, based on archival material from previous inspection exercises such as debriefing documents, technical documentation and visual material. It relates to overall work domain goals and values of the heterogeneous groups of participating constituents who must reconcile not only different political interests in
the scenario, but also have to interact effectively across professional disciplines (e.g. international relations, physical science, operations, civil engineering). Particular emphasis is placed on the dimension of internal organizational strategy governing the fidelity of the exercise, and a comparison is offered to similar exercises in other safety-critical multilateral settings beyond nuclear security.

AF-P24. The Role of the CTBTO in Non-Proliferation Treaty Teaching Activities in Ukraine

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Odessa National University is offering a range of courses, dedicated to the issues of non-proliferation and arms control. In both cases the CTBTO e-learning platform provides optimal support for understanding historical and political background of NPT and CTBT regimes, as well as the technical concept of their functioning, enriching learners with understanding of the verification mechanisms and procedures. In particular, I have developed two courses for the International Relations Department (BA and MA students), which to a substantial extent is based on the CTBTO learning platform, not only in the field of lectures, but also seminars and simulation games, which can give students range of opportunities to clarify the practical details of how the regime works. Also, CTBTO e-learning platform became a very useful tool of training students during Odessa Summer Schools on Non-proliferation where they are able not only to learn more by using it, but also to test their knowledge as well as to exchange the results with colleagues and experts. Students also attend CTBTO courses in Vienna, where they can continue to improve and to deepen their education in the framework of the CTBTO activities and their significance for the international non-proliferation regime.

AF-P25. Workshop on Global Nuclear Politics and Strategy

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The Annual Residential Nuclear Workshop is a flagship feature of the Institute of Peace and Conflict Studies (IPCS). This year’s edition—Global Nuclear Politics and Strategy 2015—witnessed, for the first time, the participation of government representatives from the scientific, military and bureaucratic establishments, in addition to academics, which facilitated more holistic debates on nuclearization in Southern Asia in particular and global nuclear politics in general. The Workshop also sought a balance between the technical and political aspects of nuclear weapons and nuclear energy, which was achieved through a comprehensive course curriculum and faculty profile that included scientists, academics, and former Indian diplomats and military personnel. Against this background, the poster will demonstrate how debates on the logic of international arms control and nuclear non-proliferation regimes and their possible linkages to global power politics were incorporated into the Workshop curriculum. It will also contain feedback from participants and faculty members on the proceedings of the Workshop, in particular, on discussions relevant to the CTBT.
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