Verification science and potential civil applications

The importance of Atmospheric Transport Modelling: Over ten years of cooperation between the World Meteorological Organization and the CTBTO

by Peter Chen, Gerhard Wotawa and Andreas Becker

FACT BOX – ATMOSPHERIC TRANSPORT MODELLING (ATM)

ATM is an integral part of radionuclide monitoring, which is carried out by the CTBT's radionuclide facilities that belong to the International Monitoring System. Radionuclide monitoring technology is complementary to the three waveform verification technologies – seismic, infrasound and hydroacoustic – employed by the Comprehensive Nuclear-Test-Ban Treaty's (CTBT) verification regime to monitor compliance with the Treaty. While waveform monitoring is utilized for event detection and location and could be used to differentiate between an earthquake and an explosion, detecting relevant radionuclides or noble gases is essential for the unambiguous identification of the nuclear origin of an event. Radionuclide technology combined with ATM thus provides the means to identify the "smoking gun" needed to prove a possible violation of the Treaty. With its "forensic proof" of nuclear explosions, radionuclide technology is of crucial importance to the entire verification effort.

When high levels of radiation (caesium-137) set off alarms at the Forsmark Nuclear Power Plant in Sweden on 26 April 1986, the world was taken by surprise. There had been a complete melt down of the reactor core at a nuclear power plant in Chernobyl in the Soviet Union, on 25 April at 21:23 local time. Over the next 10 days, the amount of radioactive caesium[1] released into the atmosphere amounted to 10 percent of all the caesium injected into the environment during the entire period of atmospheric nuclear testing between 1945 and 1980.

Major advances in ATM calculations since Chernobyl

At the time of the Chernobyl nuclear accident, provisions for near-real-time ATM calculations, which would have helped to detect the source of the caesium radionuclides earlier, hardly existed.

Nowadays, the measurement of radionuclides with concentrations dramatically lower than the 1986 values detected in Sweden would trigger a swift response: several World Meteorological Organization (WMO) Centres would be requested to supply atmospheric backtracking calculations to the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) to supplement their own calculations. In the event of an anomalous radionuclide being detected, the CTBTO's International Data Centre (IDC) staff would try to identify its possible source region and then provide Member States with relevant information.

ATM backtracking reveals sources of radionuclides

This was the case when measurements of caesium as low as one micro-Becquerel[2] per m3 were detected in northern Canada between 2003 and 2004. They were analyzed carefully by the IDC and traced back to forest fires in Siberia and Alaska. The burnt trees had taken up the caesium decades earlier during nuclear testing and later during the Chernobyl accident. This study was carried out in cooperation with experts from the WMO Centre in Montreal and other organizations in Canada.

Another example illustrating the importance of ATM backtracking was when the Democratic People's Republic of Korea (DPRK) announced that it had conducted a nuclear test on 9 October 2006. Two weeks later, the CTBTO's International Monitoring System (IMS) radionuclide noble gas station at Yellowknife, Canada, registered an unusually high concentration of xenon[3] 133 (in the order of milli-Becquerel per m3). Applying ATM to backtrack the dispersion of the gas, the noble gas detection at Yellowknife was found to be consistent with a hypothesized release from the event in the DPRK.

Potential civil, humanitarian, and scientific applications

These cases illustrate the importance of ATM technology: it is not surprising that this is the key area among meteorological applications in which the CTBTO and WMO work together. In addition to emergency response, data from the CTBT's IMS have been useful in other areas such as disaster mitigation. In 2007, for instance, the CTBTO entered into a collaborative project with WMO, involving one of its centres at Toulouse, France, which has been designated as an International Civil Aviation Organization (ICAO) Volcanic Ash Advisory Centre (VAAC).

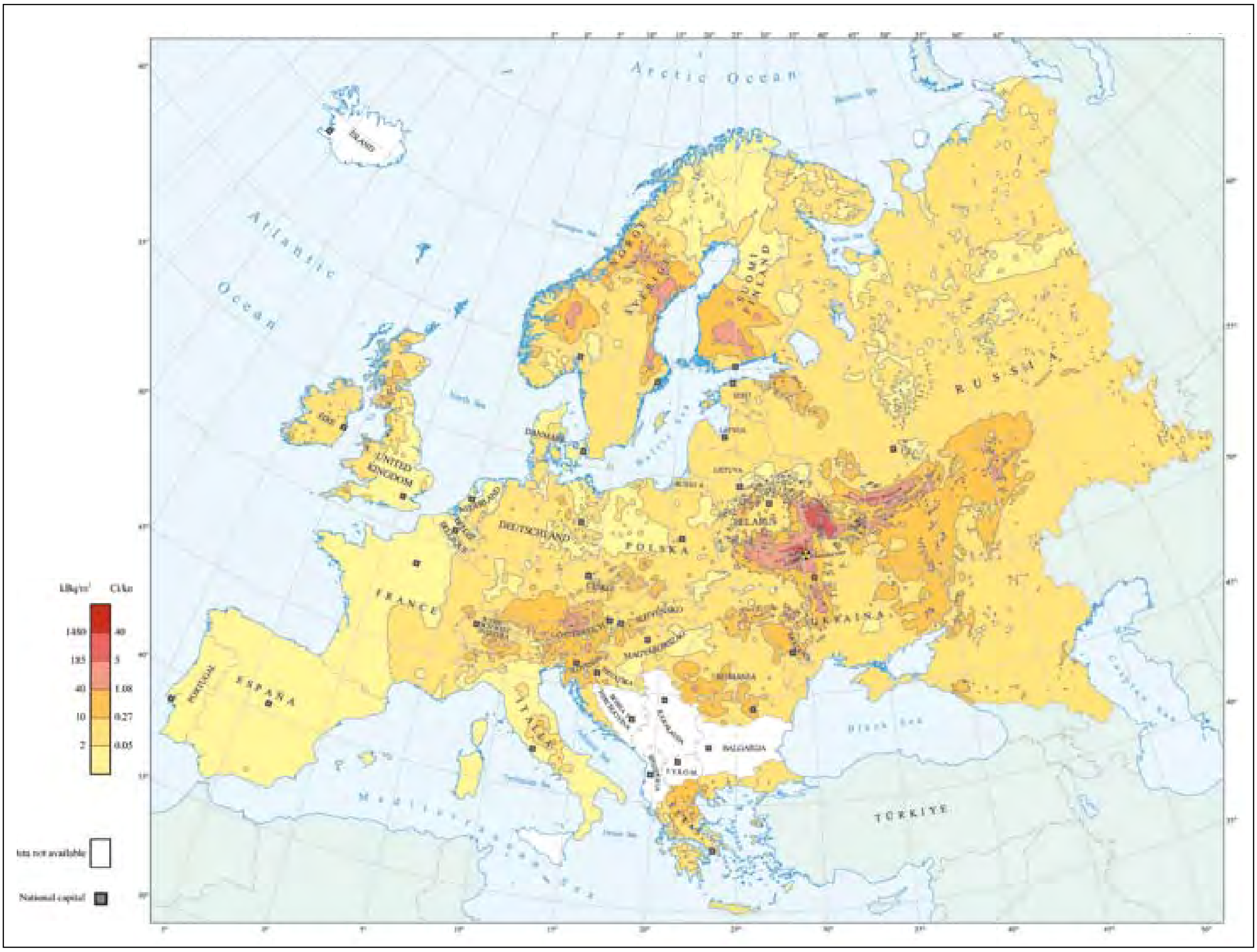
Volcanic ash represents a serious aviation hazard. Its prompt detection and location through the use of infrasound data and the prediction of its movement through forward ATM calculations can be very useful. Such information provides aircraft with early warnings of possible airborne ash plumes and could also provide guidance for air traffic re-routing decisions. The exploratory phase of this project covers selected volcanoes in the European and African regions and some initial contacts have been established with other

---

[1] Caesium (or cesium) is a soft, silvery-gold alkali metal with a melting point of 28° C.Radioactive forms of caesium are produced by the fission of uranium in fuel elements during the normal operation of nuclear power plants, or when nuclear weapons are exploded.

[2] Becquerel is the amount of radioactive material in which 1 atom transforms every second.

[3] Xenon is a chemical element in gaseous form, which is called a noble gas since it is inert and rarely reacts with other chemicals. Several of its radioactive isotopes, of which one of the isotopes is xenon-133, can only be produced by a nuclear reaction and are therefore measured to detect clandestine underground nuclear explosions.



SURFACE GROUND DEPOSITION OF CAESIUM-137 RELEASED IN EUROPE AFTER THE CHERNOBYL ACCIDENT.
ILLUSTRATION COURTESY OF EC/IGCE, ROSHYDROMET (RUSSIA)/MINCHERNOBLY (UKRAINE)/BELHYDROMET (BELARUS), 1998.

VAACs to extend the investigations to other regions in the world.

ATM also plays an important role in the CTBTO's International Scientific Studies project *(see article on page 22)*, which aims to estimate the capabilities of current ATM procedures and explore ways of further improving their accuracy. WMO acts as the Topic Coordinator for ATM in this project. Future cooperation may be extended to other important areas such as climate change.

WMO's role in the design of the CTBT's radionuclide network

Even before the formation of the CTBTO, WMO and several of its members were involved in the design of the CTBT's radionuclide network. During the CTBT negotiations from 1994 to 1996, the Group of Scientific Experts (GSE) that had been created to lay the scientific and technical ground for the Treaty negotiations, conducted several global experiments in international data exchange. WMO provided its Global Telecommunications System (GTS) for use in these exchanges.

At the same time, ATM was used together with historical global weather data to simulate the spread of airborne radionuclides in various fictitious atmospheric explosion scenarios. The results enabled the GSE to make significant advances towards designing what later became the model for the current IMS, especially the

ATM is an advanced computer-based technology for the calculation of the travel path of a given radionuclide, using meteorological data. This calculation can be performed in one of two ways:

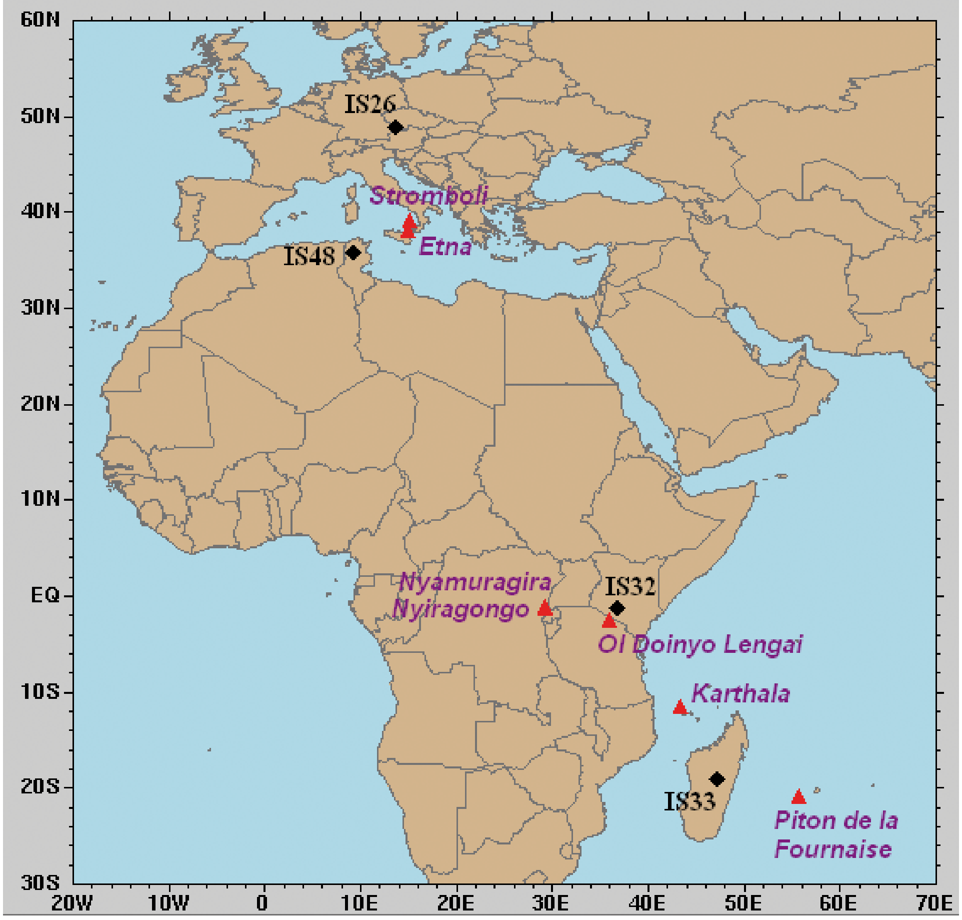
- As **backtracking ATM**, which tries to identify the area from which a radionuclide may have been released calculated from the location where it was observed; or as
- **Forward ATM**, which predicts where radionuclides may travel from their known point of release.

final configuration of the CTBT's radionuclide network. WMO also conducted research on the use of measurement-based ATM to determine the possible source region of an airborne material detected at the surface of the Earth, and presented its findings to the Treaty negotiators.

The "Informal Meeting to Discuss the Applications of Atmospheric Modelling to CTBT Verification" hosted by the WMO Centre in Canada, also provided a forum for scientists to exchange ideas and ongoing research that were thought at the time to contribute to ATM applications for Treaty verification.

Mutual organizational arrangements

Prior to the establishment of the CTBTO, Ambassador Wolfgang Hoffmann of Germany, who became the CTBTO's first Executive Secretary in March 1997, contacted WMO to explore the possibility of applying ATM in conjunction with radionuclide technology as part of the proposed IMS. This would enhance Treaty verification and would mean that the proposed monitoring system would not rely primarily on seismic monitoring, as had been foreseen initially.



SELECTED VOLCANOES (RED TRIANGLES) UNDER RESPONSIBILITY OF VAAC IN TOULOUSE AND IMS INFRASOUND STATIONS USED FOR DETECTION REVIEW (BLACK DIAMONDS).

A small WMO-CTBTO task group also reviewed possible areas of technical cooperation between the two organizations in 1998 and identified mutual benefits in ATM and potential data exchange. WMO's Commission for Basic Systems, the technical commission responsible for the World Weather Watch Programme, first invited CTBTO representatives to its meetings of technical experts involved with ATM technologies in 1999. These meetings initially focused on environmental emergency response such as in the event of a nuclear accident, later incorporating new requirements related to CTBT verification.

Joint activities and exchange of data and expertise

The two organizations formalized their cooperation in an agreement in 2000, which entered into force in May 2003 after approval by the CTBTO and the WMO Congress. The exchange of data and expertise within this framework has greatly contributed to the work of both organizations.

Below are a few examples of this collaboration, which dates back to 2002 in anticipation of the agreement entering into force:

- Continuous provision of meteorological data measured at the Treaty's radionuclide stations by the CTBTO to WMO since 2002. These data are then distributed globally through WMO's GTS.
- First coordinated experiment between the organizations on source region estimation in 2003. This was a major breakthrough in terms of real-time data exchange and analysis and was repeated in 2005.
- Agreement by the CTBTO, in principle, in early 2005 to release IMS data on natural radionuclides for WMO Programmes (see *Spectrum 7*, December 2005). These data

can be used for the verification of weather models as well as for science and research.

- Inclusion of the CTBTO-WMO response system for atmospheric backtracking in the WMO Manual for the Global Data Processing and Forecasting System in 2007. A third joint exercise was conducted in December 2007 to perform a final verification of this response system, which became operational on 1 September 2008

- Joint article on quality assessment of ATM backtracking in support of CTBT verification, published in *Atmospheric Environment* 41 (2007) pp 4520-4534.

This article will continue in the next edition of Spectrum, describing in more detail the 2007 CTBTO-WMO exercise mentioned above and other ongoing activities. ■

Biographical note

Peter Chen is Chief of the Data Processing and Forecasting Systems Division at WMO. He joined WMO in 2004 and is currently in charge of coordinating operational weather forecasting for National Meteorological Services of WMO, including numerical weather prediction, and ATM for environmental emergency response.

Dr. Gerhard Wotawa is a specialist in the modelling of atmospheric chemistry and transport. He joined the CTBTO in October 2000 and currently works as an Atmospheric Sciences Officer at the IDC.

Dr. Andreas Becker is an Atmospheric Sciences Officer in charge of ATM software development at the IDC. He joined the CTBTO in 2001 and is a specialist in the field of coupling of ATM systems in support of environmental measurement campaigns. ■

The Race between Cooperation and Catastrophe

by Sam Nunn

continued from page 9

> “The common interests of the United States, Europe, Russia, China, Japan, and many other nations are more aligned today than at any point in modern history. I believe that we must seize this historic opportunity and act accordingly.”

question, of course, must be asked by the Russians. If our answer is outside, then it’s simple – we both just keep doing what we are now doing. If the answer is inside, we and Russia must make adjustments in strategy and tactics.

The common interests of the United States, Europe, Russia, China, Japan, and many other nations are more aligned today than at any point in modern history. I believe that we must seize this historic opportunity and act accordingly.

Bottom line: In an age fraught with the dangers of nuclear proliferation and catastrophic terrorism, global security depends on regional security. Twenty years after the fall of the Berlin Wall, establishing a more cooperative and productive relationship with Russia will require Europe’s leadership as well as the United States’.

A world free of nuclear weapons

The reaction of many people to the vision and steps to eliminate the nuclear threat comes in two parts – on the one hand they say: “That would be great.” And their second thought is: “We can never get there.”

To me, the goal of a world free of nuclear weapons is like the top of a very tall mountain. It is tempting and easy to say: “We can’t get there from here.” It is true that today in our troubled world we can’t see the top of the mountain.

But we can see that we are heading down – not up. We can see that we must turn around, that we must take paths leading to higher ground and that we must get others to move with us.

Nearly 20 years ago, U.S. President Ronald Reagan asked an audience to imagine that “all of us discovered that we were threatened by a power from outer space—from another planet.” The President then asked: “Wouldn’t we come together to fight that particular threat?” After letting that image sink in for a moment, President Reagan came to his point: “We now have a weapon that can destroy the world -- why don’t we recognize that threat more clearly and then come together with one aim in mind: how safely, sanely, and quickly can we rid the world of this threat to our civilization and our existence.”

If we want our children and grandchildren to ever see the mountain top, we must begin to answer this question. ■