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

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PART 2: THE NEW CTBTO-WMO RESPONSE SYSTEM AND OTHER RECENT HIGHLIGHTS

Part 1 of this article appeared in Issue 11 of Spectrum in September 2008. It outlined advances in Atmospheric Transport Modelling (ATM) since Chernobyl and areas of cooperation between the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) and the World Meteorological Organization (WMO) including ATM, especially since their cooperation agreement was formalized in 2003.

When a joint response system between the CTBTO and the WMO entered into provisional operation on 1 September 2008, it represented a major step forward in detecting nuclear explosions.

The system uses ATM to backtrack the three-dimensional travel paths of radionuclides from where they were detected by one of the 80 radionuclide stations belonging to the CTBTO's International Monitoring System (IMS), to the area where they may have originated. As of March 2009, 55 of these stations had already been certified as meeting the CTBTO's strict standards and were transmitting data to the International Data Centre (IDC) in Vienna on a continuous basis. Another 17 radionuclide stations were either installed or under construction.

The response system: what happens if an anomalous radionuclide is detected

The IMS's radionuclide stations around the world send data to the IDC, where they are processed and analyzed. Whenever a radionuclide measurement from one of the stations is categorized by the IDC as indicative of a possible violation of the Comprehensive Nuclear-Test-Ban Treaty (CTBT), which bans all nuclear weapon testing anywhere on Earth, the following sequence of events takes place:

- The IDC sends notifications requesting support to nine WMO Regional Specialized Meteorological Centres/National Meteorological Centres around the globe.
- The requests inform the Centres of the measurement period and location of the IMS station that has detected the suspicious radionuclide and the five closest radionuclide stations. While the computations from the station that detected the event are the most relevant, backtracking by the neighbouring stations can help to further constrain the possible source region of a radionuclide.
- The WMO Centres submit their high-quality global ATM computations for all requested stations to the IDC within the next 24 hours.
- In case several radionuclide stations detect suspicious radionuclides, IDC staff would use the ATM results calculated in-house together with the results delivered by the WMO Centres to assist Member States to identify the possible source of the event.

Between September 2008 and March 2009, five requests for support were sent out to WMO Centres. None of the suspicious radionuclides examined were part of a multiple station detection scenario or indicated a possible nuclear test.

Why we need the response system

The reason why this corroborative response system is needed is simple. The reliability of one model calculation alone is limited. A number of calculations originating from the world's leading meteorological centres, however, significantly improve the reliability and certainty of the results through a diversity of computational methods that account for uncertainties in the atmospheric modelling. This method increases the confidence of the CTBTO's Member States in the IDC's related data analyses. The complementary information from the WMO specialized meteorological centres thus adds considerable credibility and reliability to the whole system and greatly enhances the CTBTO's ability to determine the location of a possible nuclear explosion.

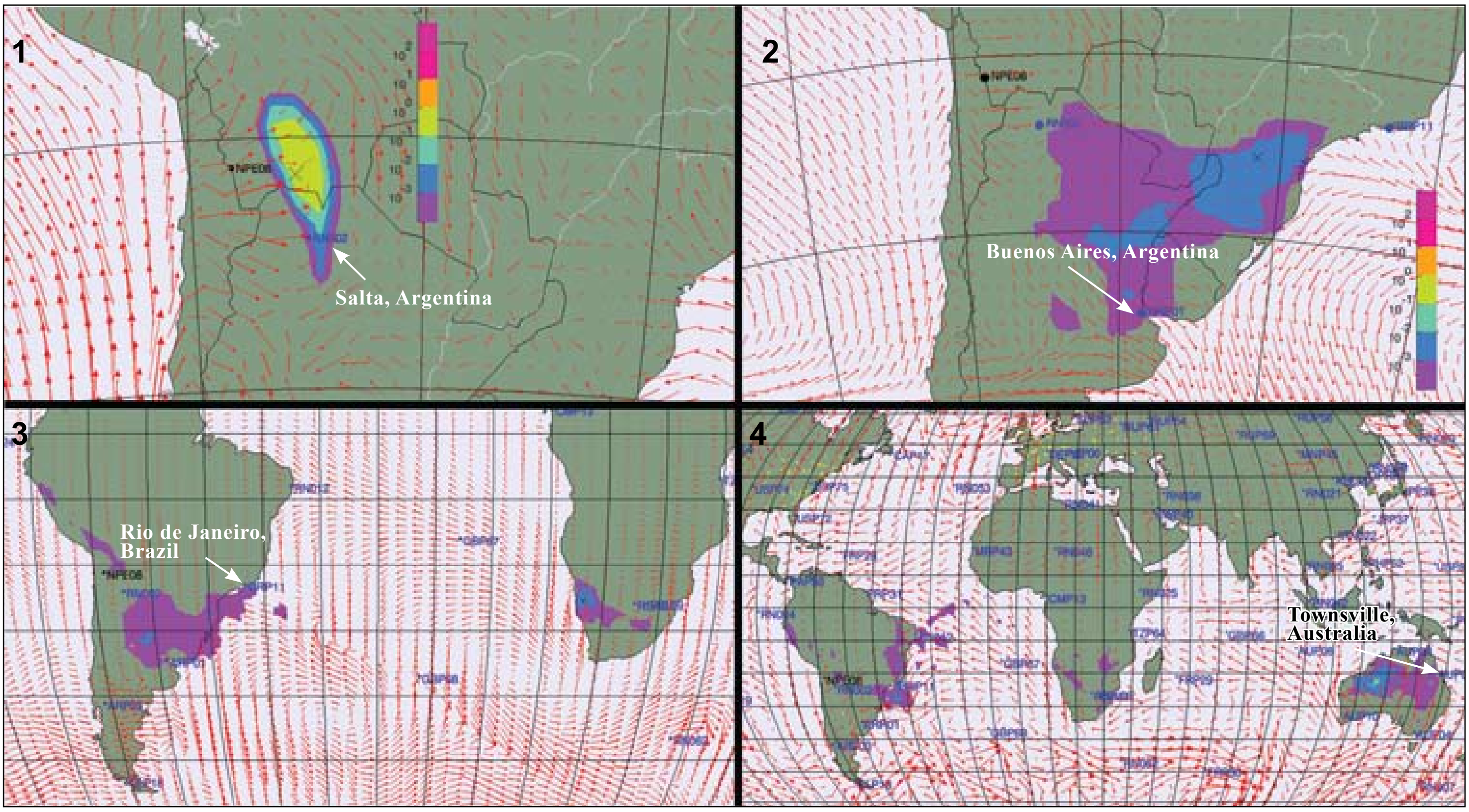
Data fusion: helping to find a needle in a haystack

The overall objective of possible source region analysis is to look for co-location with seismic explosion signals. This helps to establish whether the suspicious radionuclide measured by the radionuclide station could possibly have originated from a seismic event recorded at the same place and time. This analysis is called data fusion.

The IDC uses a software tool called WEB-GRAPE (web connected graphics engine) to identify the possible emission points of a radionuclide event and to perform the data fusion analysis mentioned above. The results are then communicated to the Member States to assist them in their assessment of the event.

Regular experiments ensure that the system is reliable

In order to ensure that this joint response system is well-maintained and fully functional, regular exercises are necessary. Joint global



THE FOUR STAGES OF A SIMULATED FORWARD NUCLEAR PLUME OVER A 17 DAY PERIOD FOLLOWING THE ASSUMED SURFACE RELEASE OF 10^{15} BECQUEREL OF THE RADIOACTIVE ISOTOPE, BARIUM-140. IT WAS DETECTED BY FOUR RADIONUCLIDE (RN) STATIONS: FIRST BY RN02 IN SALTA, ARGENTINA, THEN RN01 IN BUENOS AIRES, ARGENTINA, FOLLOWED BY RN11 IN RIO DE JANEIRO, BRAZIL, AND FINALLY RN06 AT TOWNSVILLE, AUSTRALIA. THE WIND THAT TRANSPORTED THIS PLUME IS DISPLAYED AS RED ARROWS. THIS TOOK PLACE DURING THE NDC PREPAREDNESS EXERCISE 2008.

exercises between the CTBTO and the WMO are therefore conducted once a year.

The goals of the exercise are threefold:

1. To test the timeliness and quality of the response of the WMO Centres.
2. To assess the reliability of the CTBTO's atmospheric transport computations.
3. To validate IDC data fusion capabilities under the assumption that a complete radionuclide network is already in existence.

In order to investigate IDC data fusion capabilities, the design of the exercise scenario has to be linked with a pre-selected seismic event. Such an event (the epicentre of an earthquake) is selected from the IDC's Standard Event List, a list which includes the location of seismic events. For the purposes of the exercise, it is then assumed that the selected event was a nuclear explosion, which released 10^{15} Becquerel[1] of a hypothetical, inert and long-lived radionuclide into the atmosphere. The assumption corresponds to the amount of the noble gas xenon-133[2], expected to be released during the first hours after the detonation of a one kiloton underground nuclear explosion that was not fully contained.

On that assumption, the CTBTO uses its ATM tools to predict a radionuclide measurement scenario that would suggest a Treaty violation, thus triggering the response system. This exercise is conducted along identical timelines to those applicable in the case of a real nuclear event so as to make the exercise as realistic as possible.

CTBTO-WMO exercises based on a hypothetical measurement scenario triggered by a selected seismic event were conducted in 2007 and 2008. In 2007, the event was selected by the CTBTO. In the subsequent exercise, the event was selected by the German National Data Centre (NDC) as part of the NDC Preparedness Exercise 2008[3].

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.

[1] Becquerel is the amount of radioactive material in which one atom transforms every second.
[2] 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.
[3] The aim of this exercise was to enhance the ability of NDCs to detect and identify nuclear explosions.

Verification science and potential civil applications

Important lessons learned

A number of lessons were learned from both exercises. The CTBTO-WMO response system proved that it was able to perform at full efficiency in 2008, with all participants responding in a timely and accurate manner. In both exercises, the interactive data fusion method described above was able to narrow down the number of relevant seismic events that could have caused the radionuclide event from several hundred to two, illustrating the system's effectiveness.

With the CTBTO-WMO response system up and running and procedures for radionuclide source location and data fusion undergoing testing, an important element of the Treaty's verification regime when it enters into force is now in place. This system is unique and will add considerable value to the radionuclide monitoring efforts of the CTBTO.

Other synergies: scientific-technical cooperation

The WMO Secretariat continues to play an important role in ongoing ATM activities, including the International Scientific Studies (ISS) project, acting as an ATM topic coordinator *(see page 24 for more information about the project).*

The CTBTO and the WMO are open to extending their collaboration in line with the provisions of the 2003 cooperation agreement between the two organizations. This includes any field where IMS data may be useful for scientific research and development, such as emergency response or disaster mitigation. All of these potential civil and scientific applications of the CTBT's verification technologies serve as a means for enhancing capacity building, especially in developing countries. Further opportunities may also arise in the future for Member States, especially countries that host IMS facilities, for example, to participate more directly in climate change efforts if use can be made of the CTBT's verification data and/or communication infrastructure.

REGIONAL SPECIALIZED METEOROLOGICAL CENTRES (RSMCS) AND THE NATIONAL METEOROLOGICAL CENTRE (NMC) THAT ARE PART OF THE CTBTO-WMO RESPONSE SYSTEM

Climate change presents an unprecedented challenge for humanity and requires coordinated action by the international community. The WMO was designated by the United Nations Secretary-General to act as convener, together with United Nations Educational, Scientific and Cultural Organization (UNESCO), for the proposal of joint activities in the cross cutting area of climate knowledge: science, assessment, monitoring and early warning as part of the UN initiative "Acting on Climate Change: The UN System delivering as One."

In the past, the CTBTO has taken maximum advantage of the WMO's global data and operational numerical model infrastructure in the area of emergency response. The CTBTO could also derive additional benefits from exploring other existing infrastructures maintained by WMO and cooperating organizations. In turn, WMO could benefit from the collaboration by further considering the use of data and information that are by-products of the CTBT's verification efforts, which could feed and validate weather, climate and air quality models. ■

Biographical note

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