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Atmospheric Transport Modelling for Radionuclide Monitoring after the Nuclear Tests of the DPRK on 6 January and 9 September 2016

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Introduction

The International Monitoring System (IMS) developed by the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) is a global system of monitoring stations, using four complementary technologies: seismic, hydroacoustic, infrasound and radionuclide. The radionuclide network comprises 80 stations, of which more than 60 are certified. The aim of radionuclide stations is a global monitoring of radioactive aerosols, radioactive noble gases and atmospheric transport modelling (ATM). To investigate the transport of radionuclide emissions, the Provisional Technical Secretariat (PTS) operates an Atmospheric Transport Modelling (ATM) system based on the Lagrangian Particle Dispersion Model FLEXPART. The air mass trajectory provides a "link" between a radionuclide release and a detection confirmed by radionuclide measurements. The aim of this study is to demonstrate the application of ATM to investigate the episodes of elevated levels of radioxenon observed by IMS stations after the fourth and fifth nuclear tests, announced by the Democratic People's Republic of Korea (DPRK) at the Punggye-ri Nuclear Test Site on 6 January and 9 September 2016.

Atmospheric Transport Modelling (ATM) from the location of the waveform event

Atmospheric transport modelling (ATM) in a forward mode is used to predict which of the IMS radionuclide stations are likely to be affected by a potential radioactive release from the DPRK event site and to infer the time of detections. In order to produce such a prediction an atmospheric transport model requires information about a source of radionuclides and the meteorological conditions during the radionuclide release and in the days that follow.

The ATM simulations in a forward mode are performed for a hypothetical release that coincides with the location of the waveform event. The simulations differ by a temporal hypothesis on the source, which is specified in each case. To account for an unknown strength of a potential release, a unit release is hypothesised for each simulation.

ATM from the receptor's location: Field of Regard (FOR) and Possible Source Region (PSR)

If an IMS station detects an elevated level of radionuclide the ATM in a backward mode is used to identify the origin of air masses. In case of a single detection the FOR concept is used; in case of multiple detections, the PSR is created (CTBTO, 2016).

The FOR denotes the possible source region for material detected within one single sample. It is a binary field in the sense that all points on the globe are either inside or outside the FOR. The FOR concept is closely related to the standard Source Receptor Sensitivity (SRS) fields i.e. the output of the FLEXPART model.

The Possible Source Region (PSR) allows for estimating the geographic origin of a release by combining SRS information with the pertaining scenario of measurements (radionuclide detections) in the IMS network.

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ATM related to the DPRK event 6 January 2016

Elevated concentrations of Xe-133 have been observed at the IMS noble gas system JPX38 (Takasaki, Japan) in five consecutive samples (12h cycle duration) from 17 to 19 February 2016 (Kalinowski et al., 2017, Gheddou et al. 2017). These values were used to determine the Possible Source Region (PSR) associated with the number of detections observed at JPX38 (Figure 1). As a result, the correlation coefficients between the measured and simulated activity concentration values based on the ATM are calculated, for each grid point in space and time. The results are displayed in Figure 2.

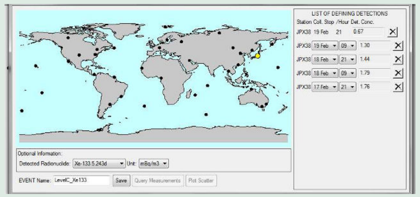
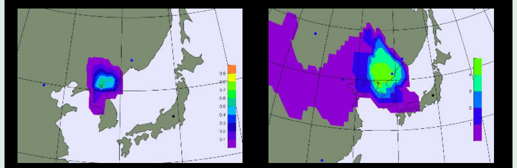


Figure 1. Defining an event with one radionuclide: Xe-133, used to create PSR. Each black dot represents a location of IMS noble gas station; yellow dot indicates JPX38. Please note that for the purpose of PSR the collection stop is used.

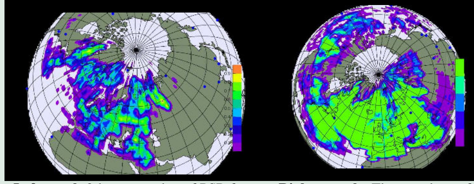
Possible Source Region: 16-02-2016, between 3 and 6 am



Left panel: 3-hour snapshot of PSR. The best fit between simulated and observed concentrations is found for a hypothetical release time of 16 February 03:00 to 06:00.

Right panel: The number of samples contributing to the PSR shown on the left panel is displayed.

Possible Source Region: 05-02-2016, between 9 and 12 am



Left panel: 3-hour snapshot of PSR for 5 February i.e. ~2 weeks prior to the Level C episode. The relatively high values of the correlation coefficient indicate for other potential sources throughout Asia and Europe.

Right panel: The number of samples contributing to the PSR shown on the left panel is displayed.

Figure 2. PSR created using the input data shown in Figure 1. The color scale represents values of the correlation coefficient.

ATM related to the DPRK event 9 September 2016

Similarly like in the case of previous DPRK events, as soon as the location of the seismic event was known, a series of ATM forward simulations started to be produced everyday in order to predict which of the IMS radionuclide stations are likely to be influence by a potential radioactive release from DPRK event site. A prompt release would have reached JPX38 within a couple of days. The air masses coming from DPRK site were passing over JPX38 many times during the next 3 months after the nuclear test, however elevated radioxenon concentration was not detected.

Atmospheric transport modelling assuming a 3 hours release on 9 September 2016 (0-3 am) from the seismic event location

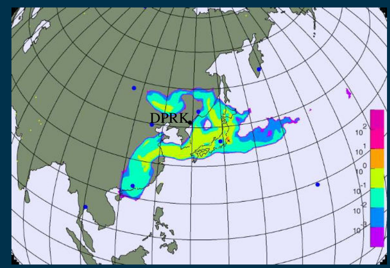


***Figure 3**. Snapshot illustrating the plume arrival at JPX38 on 16 September 2016 i.e. 7 days after the DPRK event on 9 September (0-3 am). Simulation based on ECMWF analyzed data.*

Atmospheric transport modelling in a forward mode

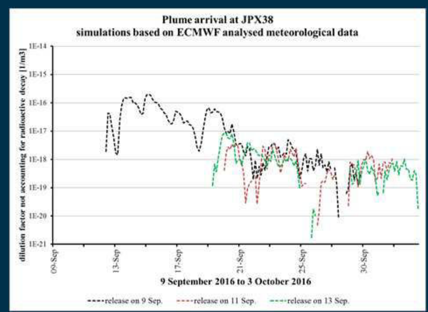


***Figure 4**. Predicted dilution factors curves at JPX38 (Takasaki, Japan) assuming a 3 hour release starting on 9 September 2016 (0-3am), 11 September (0-3 am) and 13 September (0-3am).*

ATM statistics for 2016

The important aspect of radionuclide monitoring after the nuclear test is related to meteorological conditions. The fact whether a given station is likely to be affected by a potential release strongly depends on the strength of a release, the MDC (minimum detectable concentration) value but also on the season i.e. seasonal changes in the wind field. Figure 5 reveals how many days in a month the air masses coming from the DPRK event site pass over the IMS station JPX38. The study assumes two hypothetical releases: 10^{13} Bq and 10^{11} Bq. Values below 10^{10} likely would not be detected because the simulated activity concentration is a few times lower than the MDC for this station.

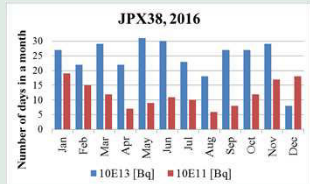


Figure 5. Number of days in a month during which a hypothetical release of Xe-133 could be detected by a station .

Concluding remarks

The following conclusions can be drawn from the observations at IMS radioxenon systems in combination with ATM analysis:

1. A prompt release following the two announced DPRK events in 2016 would have reached JPX38 within a couple of days. There was no detectable prompt release after the seismic events.
2. The Level C episode at JPX38 in February is the only one of all that occurred within the first three months after the two DPRK 2016 events which could have been caused by a hypothetical delayed release from the DPRK test site.
3. The Possible Source Region (PSR) for this Level C episodes includes other potential sources throughout Asia and Europe.

References

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