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# IMS radioxenon monitoring after the announced nuclear tests of the DPRK on 6 January and 9 September 2016

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## Introduction

By the end of 2016, five underground nuclear tests were announced by the Democratic People's Republic of Korea (DPRK) at the Punggye-ri Nuclear Test Site and detected by the International Monitoring System (Kitov et al, 2017). In the aftermath of the first test in 2006 and the third one in 2013, radioxenon observations were made at IMS stations that were consistent to be associated with the time and location of the relevant seismic events. The fourth and fifth tests were announced on 6 January and 9 September 2016. This paper describes analytical methods and results of the relevant data from neighbouring IMS stations with emphasis on episodes of elevated levels of radioxenon that could be consistent with a late release from the location of the seismic event. Several standard and additional exploratory methods were applied to test the hypothesis whether the observed radioxenon can be correlated to the seismic event. The final judgement is the responsibility of the State Signatories.

## Radioxenon monitoring

For the purpose of monitoring for compliance with the Comprehensive Nuclear-Test-Ban Treaty (CTBT), the International Monitoring System (IMS) is being established that includes 40 sensor systems for atmospheric xenon radioactivity. 28 of these sensors were in operation for part of the first two months following the nuclear test of January 2016, and 27 sensors similarly for the test of September 2016.
JPX38 at Takasaki, Japan, is the IMS noble gas system that was most of the time the first one that would have reached by an emission from the DPRK test site. The timeline of Xe-133 observations at JPX38 is shown in Figure 1.

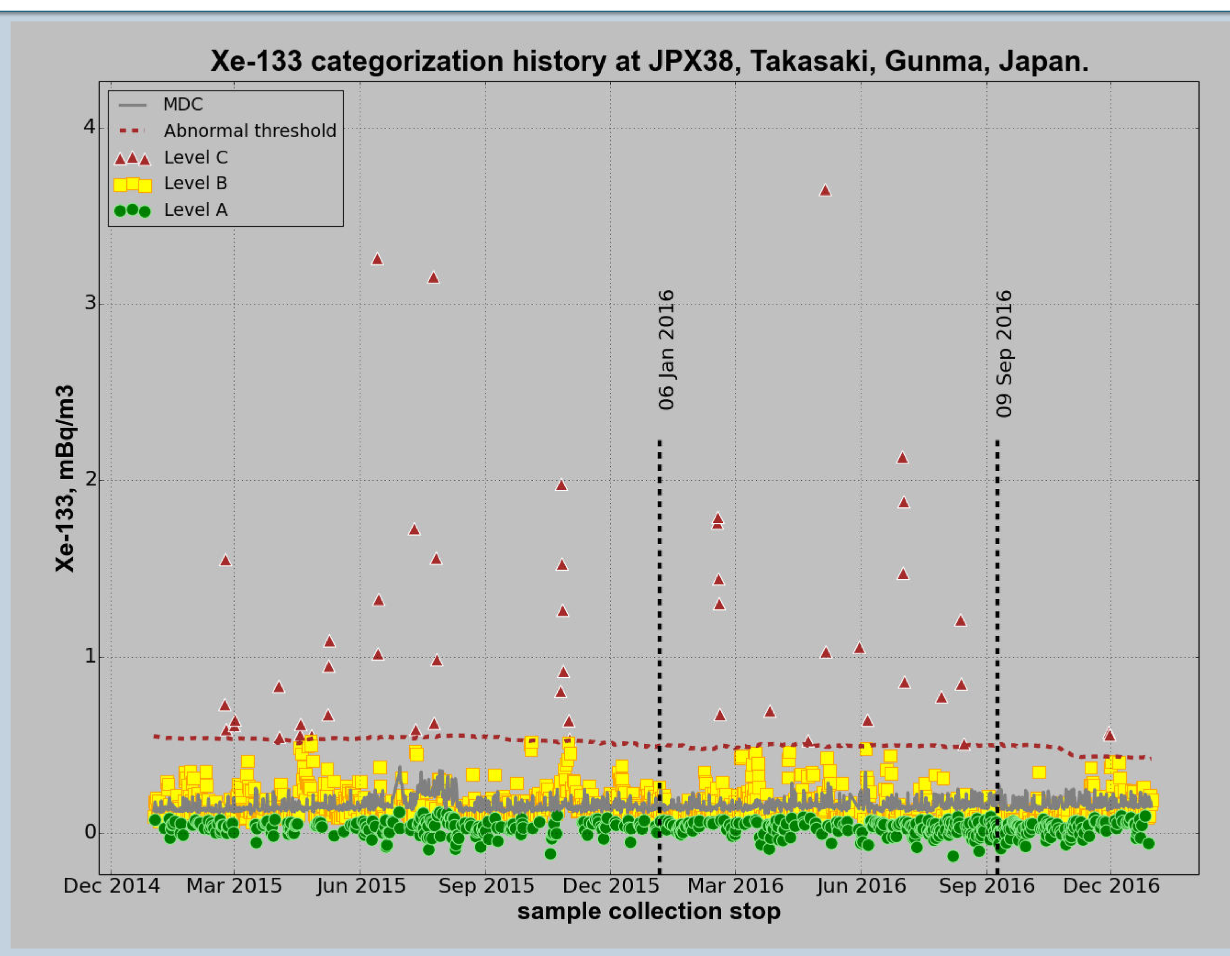


*Figure 1. Categorization parameters of Xe-133 at JPX38*

The following conclusions can be drawn from the observations at IMS radioxenon systems:

- There was no elevated concentration of Xe-133 in any of the samples of JPX38 with collection periods a few days after the announced tests.
- There were a few Level B and Level C episodes at several regional IMS stations within the first three months after the tests.
- At JPX38, Level C episodes occur about 10 times per year with 1 to 6 level C samples clearly above the normal background variation.

## Conclusions of atmospheric transport modelling (ATM)

The following conclusions can be drawn from the observations at IMS radioxenon systems in combination with ATM according to Kusmierczyk-Michulec et al., (2017):

- 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.
- As is shown by ATM, 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.
- As can be seen in Figure 2, the simulated concentrations assuming a short-term release from the DPRK test site match very well with the actual observed concentration profile of the five Level C samples.
- However, the Possible Source Region for this Level C episode includes other potential sources throughout Asia and Europe.
- Anyway, many other Level C episodes at JPX38 are consistent with a release from the DPRK test site as well.

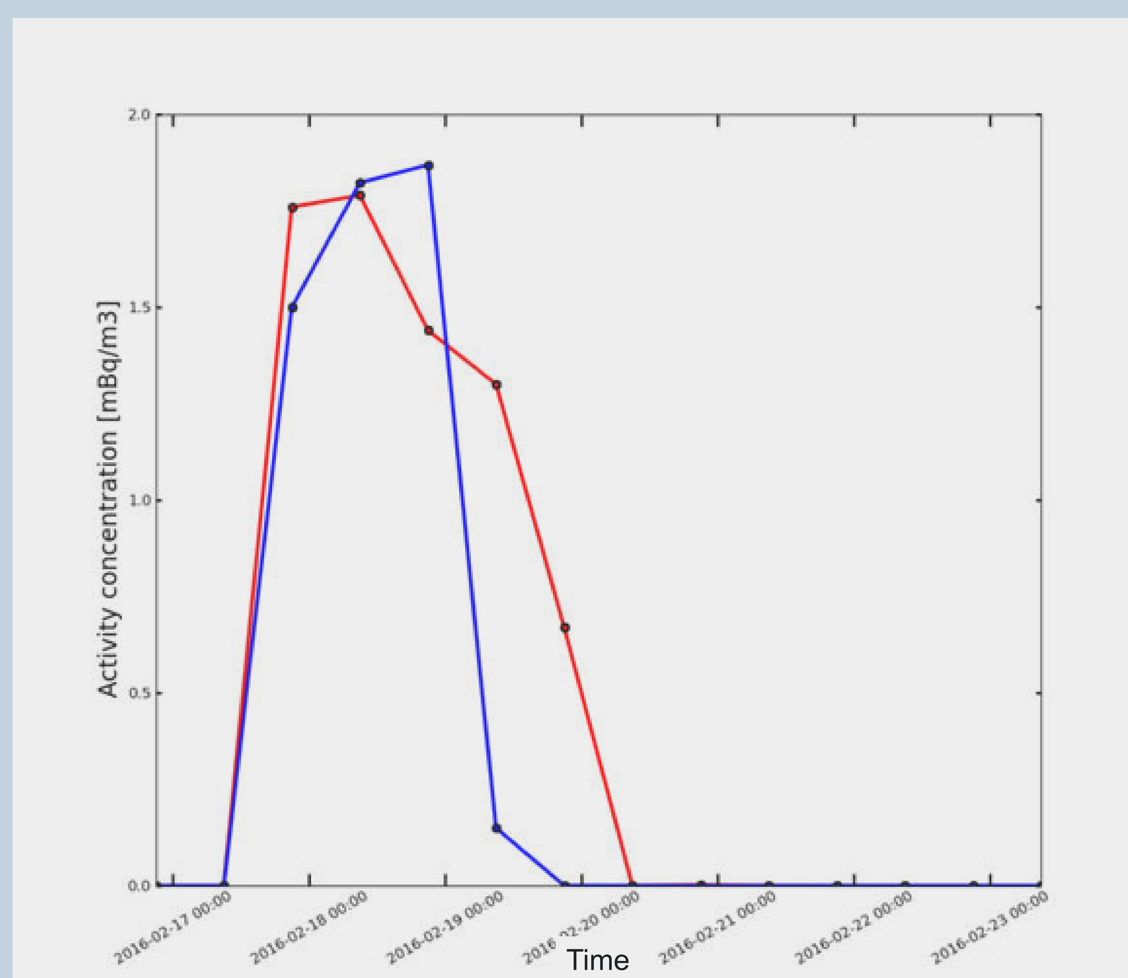


*Figure 2. Xe-133 concentrations at JPX38. Forward ATM simulation (blue) – Measurement (red).*

Prior experience with the DPRK 2013 event shows (Ringbom et al., 2014; Carrigan et al., 2016), that the observation of Xe-131m could establish the proof that is required to draw a conclusion about the 6 January 2016 event being the source of the Level C episode in February 2016.
However, no Xe-131m was detected in any of the samples of the Level C episode that ATM identified as relevant. This motivates additional efforts towards reducing the MDC for Xe-131m.

## Efforts to search for Xe-131m

In order to search for any traces of Xe-131m or at least to lower the MDC, special analytical efforts were undertaken:

- Re-analysis of the air samples in IMS radionuclide laboratories,
- Summation of multiple spectra acquired at the station (Gheddou et al, 2017).

Table 1 shows the Lc and MDC achieved by these methods in comparison with those achieved in routine spectrum analysis.
The laboratory results depend on the delay time before spectrum acquisition at the laboratory and the method used. For two samples, the MDC of Xe-131m is lower than for the spectrum measured at the station. The summing method achieved a further reduction.

| Sample # | Collect. Stop | Station Lc / MDC mBq/m$^3$ | Lab. | Laboratory Lc / MDC mBq/m$^3$ | Summing Lc / MDC mBq/m$^3$ |
|---|---|---|---|---|---|
| 1 | 17 Feb 8:35 | 0.132 / 0.283 | ATL03 | - / 0.81 | 0.06 / 0.13 |
| 3 | 18 Feb 08:35 | 0.123 / 0.266 | GBL15 | 0.040 / 0.090 | |
| 5 | 19 Feb 08:35 | 0.098 / 0.216 | USL16 | 0.163 / 0.360 | |
| 2 | 17 Feb 20:35 | 0.137 / 0.293 | ATL03 | - / 0.58 | 0.08 / 0.17 |
| 4 | 18 Feb 20:35 | 0.119 / 0.256 | USL16 | 0.083 / 0.170 | |

***Table 1**. Lc and MDC for Xe-131m in all JPX38 samples of the Level C episode in February 2016 achieved with different methods.*

Even though the Lc is improved, neither the laboratory re-analysis nor the IDC analysis of combined spectra shows any detection of Xe-131m. As a conclusion, the Xe-131m concentration can now be confined to a lower maximum value to be used in isotopic ratio analysis.

## References

**Carrigan, et al.** (2016): Delayed signatures of underground nuclear explosions. Scientific reports, 6, 23032

**Gheddou et al.,** (2017). Summing Particulates and Noble Gas Spectra to Improve Detection Sensitivity and Reduce Statistical Uncertainty. SnT2017 Conference, poster T2.1-P17.

**Kitov et al.,** (2017). Absolute and Relative Location at the IDC: Five DPRK Events . SnT2017 Conference, poster T2.1-P3.

**Kusmierczyk-Michulec et al.,** (2017). Atmospheric Transport Modelling for Radionuclide Monitoring after the Nuclear Tests of the DPRK on 6 January and 9 September 2016. SnT2017 Conference, poster T2.1-P6.

**Ringbom et al.,** (2014). Radioxenon detections in the CTBT international monitoring system likely related to the announced nuclear test in North Korea on February 12, 2013. Journal of Environmental Radioactivity 128, 47-63.

## Isotopic ratio of Xe-133 and Xe-131m

Figure 3 shows the simulated Xe-133 and Xe-131m activity timelines assuming the fission scenario that was successfully used to demonstrate the consistency of the detections made at JPX38 around 50 days after the DPRK 2013 test with the assumption of a delayed release. That case defines the end point of the simulated curves.

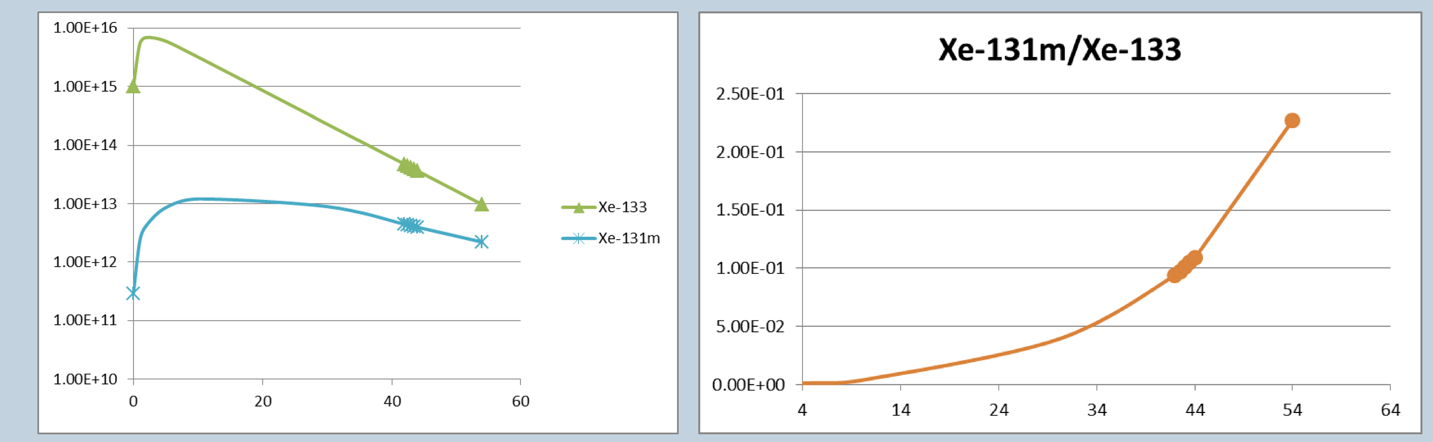


***Figure 3**. Timeline of simulated Xe-133 and Xe-131m activities resulting from a 1 kt TNT equivalent nuclear explosion at time zero (left) and their activity ratio (right).*

Figure 3 also includes five markers at the delay of 42 to 44 days between the 6 January 2016 test and the five Level C samples at JPX38 in February 2016. From this, the expected Xe-131m concentration can be determined using the same scenario as in 2013 (Table 2). Even though with one exception the estimates are still below the MDC, this comparison proofs the high relevance of radionuclide laboratory re-analysis and the new summation approach. However, even if Xe-131m would have been detected, at such low concentrations it could be a false positive or normal background.

| # Station | Collect. Stop | Xe-133 observed mBq/m$^3$ | Xe-131m estimate mBq/m$^3$ | Below or above Laboratory MDC | Below or above Summing MDC |
|---|---|---|---|---|---|
| 1 JPX38 | 17 Feb 8:35 | 1.76 ±0.09 (5.11%) | 0.165 | below | above |
| 3 JPX38 | 19 Feb 08:35 | 1.44 ±0.09 (6.25%) | 0.145 | above | above |
| 5 JPX38 | 19 Feb 08:35 | 0.67 ±0.07 (10.3%) | 0.073 | below | below |
| 2 JPX38 | 17 Feb 20:35 | 1.79 ±0.09 (5.03%) | 0.174 | below | equal |
| 4 JPX38 | 18 Feb 20:35 | 1.30 ±0.08 (6.15%) | 0.136 | below | below |

***Table 2**. Comparing estimated Xe-131m concentrations with the MDCs given in Table 1.*

## Conclusions

The main conclusion of ATM is that only one Level C episode (at JPX38 in February 2016) can be clearly and fully linked to a hypothetical delayed release after one of the two DPRK announced tests in 2016.
Since Xe-131m was not detected in any of the spectra measured at JPX38 during this episode of abnormal Xe-133 concentrations, special analytical efforts were undertaken to try to find Xe-131m traces:

- Re-analysis of the air samples in radionuclide laboratories,
- Summation of multiple spectra acquired at the station.

Both approaches achieved a significant reduction of the MDC but still no presence of Xe-131m was confirmed.
As a conclusion, taking the measured concentrations of Xe-133 and the MDCs for Xe-131m and their isotopic activity ratios into consideration, these observations are not sufficient to draw a conclusion on this episode being associated to a late release from the announced nuclear test of DPRK on 6 January.