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Impacts on Characterization of a CTBT Relevant Nuclear Event Using Isotopic Ratios caused by Radioxenon Background Subtraction at IMS Stations

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CTBTO PREPARATORY COMMISSION

INTRODUCTION

Radioxenon background at IMS stations might mask the signals from a release of nuclear explosion.

METHODS/DATA

Concentrations originating from hypothetical releases of nuclear explosion are simulated by atmospheric transport modelling.

START

RESULTS

Xenon activity ratios are compared between real IMS observations, simulated concentrations of nuclear explosion and synthetic ones.

CONCLUSION

Subtraction of radioxenon background is necessary for event discrimination.

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Summary

- Radionuclide stations in the International Monitoring System (IMS) network routinely collect air samples and assess activity concentrations. Activities collected in samples are often caused by emissions from nuclear facilities, but they could also indicate a noble gas release from an underground nuclear explosion. A discrimination can be done by estimating and analysing activity ratios of CTBT-relevant radioxenon isotopes under assumed scenarios.

- One of the issues in the isotopic ratio estimation is whether the contribution of the radioxenon background at IMS stations needs to be subtracted. This work will investigate the impact of the radioxenon background subtraction on the discrimination of a nuclear release event.

- Simulations are performed with atmospheric transport modelling to determine the concentrations originating from hypothetical radioxenon releases of pre-defined underground nuclear explosions distributed over a global semi-regular grid at different times of the day. The latter are studied independently and in the form of synthetic concentrations on top of real observations to account for the radioxenon background.

- The ratios of detected radioxenon isotopes are compared between the real IMS observations (typical radioxenon background from 2014), simulated concentrations from hypothetical nuclear explosion sources (pure signals without radioxenon background) and synthetic ones.

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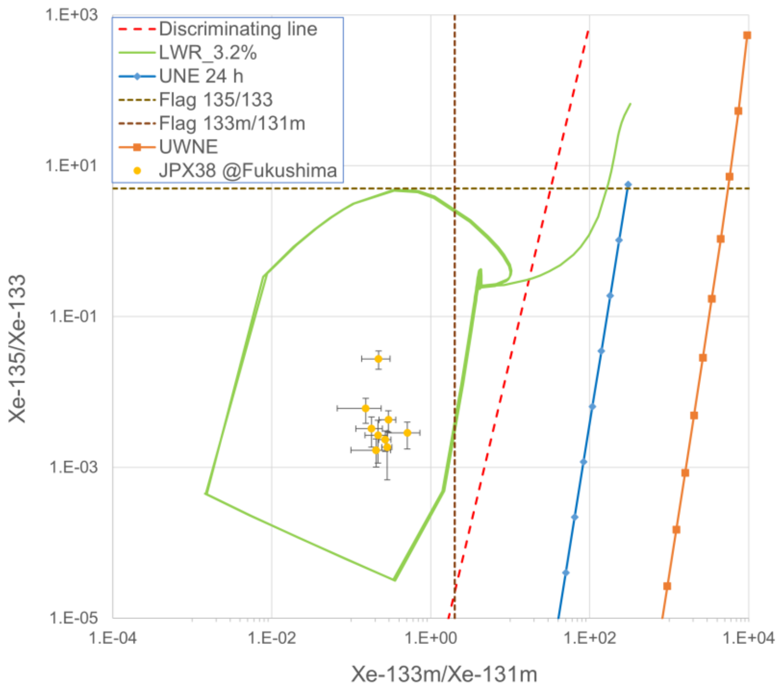
Objectives

Discriminating a nuclear explosion release from nuclear facility releases:

- Hypotheses based on isotopic activity ratios
  - ✓ Null hypothesis H_0: nuclear facility releases
  - ✓ Alternative H_1: nuclear explosion release
- Estimation of isotopic activity ratios
  - ✓ IMS measured activity concentrations
  - ✓ Radioxenon background estimated and subtracted
    - ✓ Residual for each sample
- Methods
  - ✓ Coverage interval
  - ✓ Z-test
  - ✓ ML method



Radioxenon background subtraction:

- Estimation using IMS observation minus atmospheric transport simulations
- Impacts on isotopic ratios and event discrimination

	True nuclear facility releases	True nuclear explosion release
Do not reject H_0	Correct nuclear facility releases	False negative
Reject H_0	False positive	Correct nuclear explosion release

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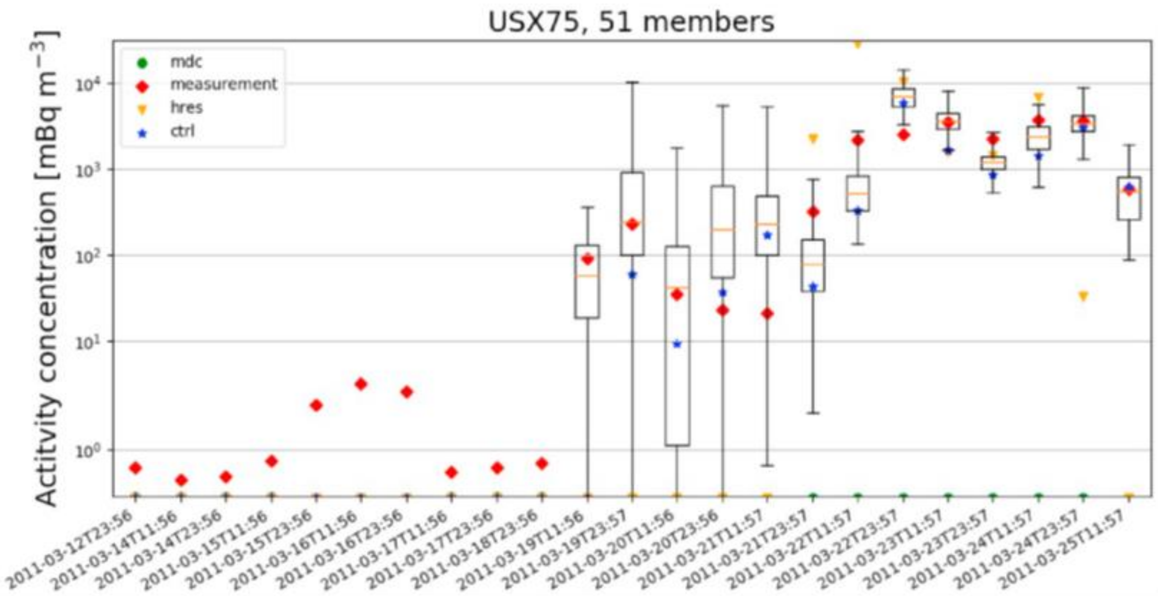
Methods

- Simulations of civil background are performed with atmospheric transport modelling (ATM) to determine an activity concentration and its associated uncertainty from known releases of nuclear facilities for each IMS sample, resulting in a residual between the IMS observation and ATM simulated concentration. Then, event discrimination can be performed based on the residual.
- However, there might be relatively large fluctuations in ATM simulated activity concentrations, resulting in outliers in the distribution of the residuals.

- Distributions of the activity concentrations for each sample at an IMS station
  - IMS observations and uncertainties
  - ATM concentrations and uncertainties
  - Residuals of IMS observations minus ATM concentrations

- Ensemble dispersion simulation is under development at IDC, see an example in “The potential benefit using data from the ECMWF-Ensemble Prediction System (EPS) for possible CTBTO applications”.
- https://doi.org/10.1016/j.jenvrad.2021.106649

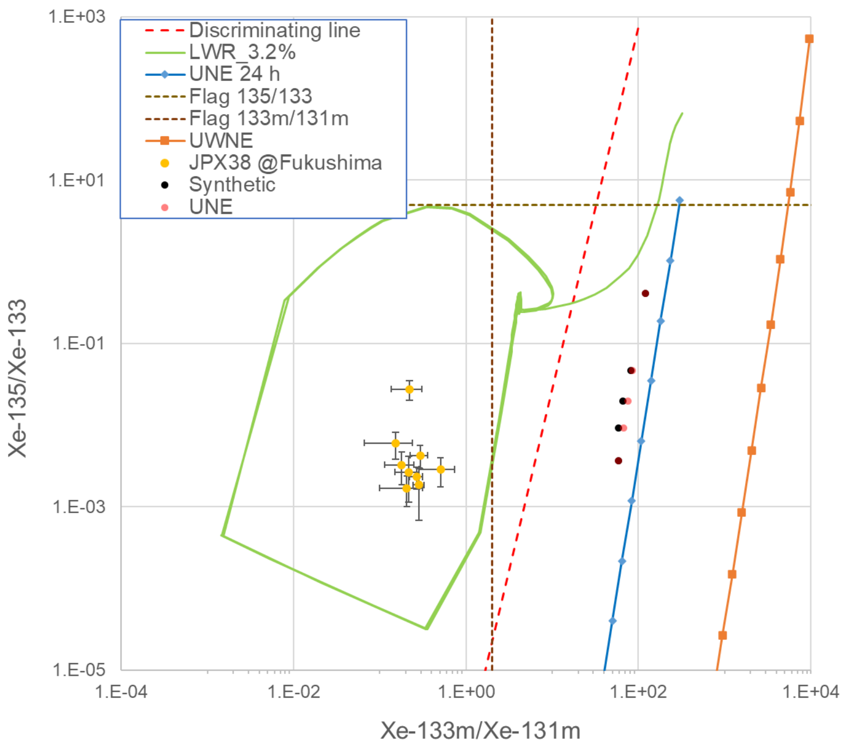


Results-1

Four Radioxenon plot

- Data set of 1st Nuclear Explosion Signal Screening Open Inter-Comparison Exercise 2021 is used in this investigation.
  - Real IMS observations,
  - Simulated concentrations of nuclear explosions and
  - Synthetic concentrations, i.e., simulated concentrations of nuclear explosions added on top of IMS observations
- All four radioxenon detected in both synthetic and UNE signals.
  - Only 5 samples (right figure) with IMS activity concentrations < 0.1 mBq/m3.
  - All points locate in the nuclear explosion domain, close to the evolution curve of UNE.
  - Slight differences between IMS observations and Synthetic signals

UNE signals might be the only contribution for the synthetic signals > LC.



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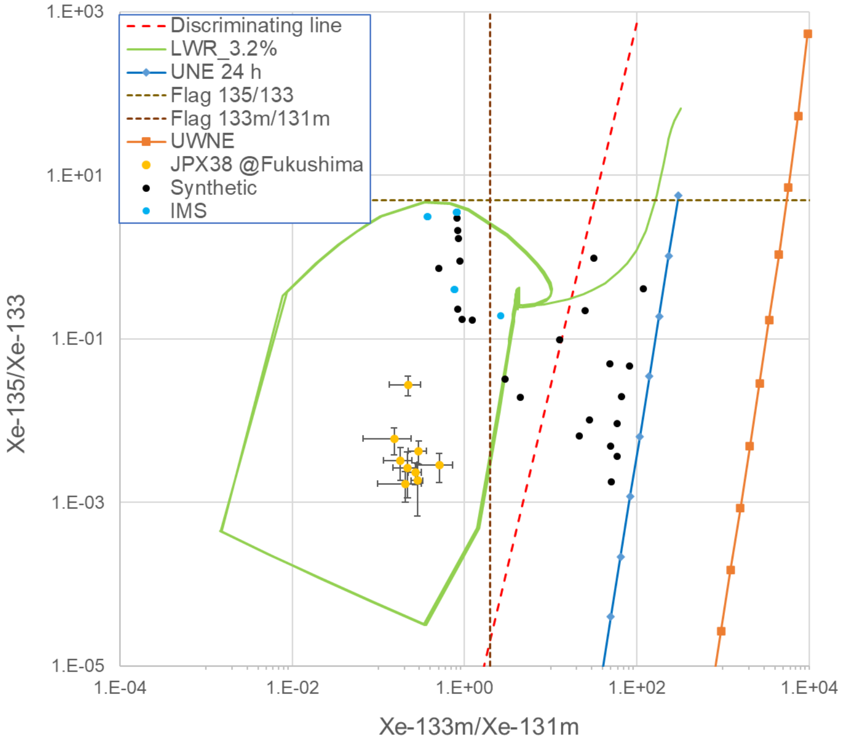
Results-2

Four Radioxenon plot
- All four radioxenon detected in synthetic signals.
    - Data points of 23 samples scatter in both domain, crossing the discrimination line.
    - Detections in synthetic signals (> LC)
        - Case 1 and Case 2
- All four radioxenon detected in IMS observations.
    - Radioxenon background
    - Data points of 12 samples (overlapped) locate in the domain of nuclear facility releases.

Subtraction of radioxenon background is necessary for event discrimination.



Case 1:
- Radioxenon background < LC plus
- UNE signal > LC,
- Resulting in a synthetic concentration > LC.

Case 2:
- Radioxenon background < LC plus
- UNE signal < LC,
- Resulting in a synthetic concentration > LC.

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