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CTBT: SCIENCE AND TECHNOLOGY CONFERENCE

How the UK National Data Centre utilises Stack monitoring data in support of the Comprehensive Nuclear Test-Ban Treaty

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Background

The UK Radionuclide National Data Centre (NDC) hosted at AWE provides advice to the MoD on the verification regime of the CTBT. The UK NDC has access to both the raw data from the International Monitoring System (IMS), and the analysed data from the International Data Centre (IDC).

The NDC team at AWE have developed a custom radionuclide analysis pipeline (a series of tools to download, process and interpret data) utilising a number of high performance computers and a standalone internet connection.

The continued development of an in-house system yields additional advantages, including a full understanding of the algorithms and logic used. It provides the UK NDC with the flexibility to evaluate vast datasets, continually improve algorithms, and incorporate data that might be of use to AWE and the UK above and beyond what is available via the IDC.

The UK Radionuclide NDC was invited to be an international collaborator on the US led Source Term Analysis of Xenon (STAX) Project.

The STAX project will develop a network to share radioxenon release data from Medical Isotope Production (MIP) facilities worldwide with the nuclear explosion monitoring community.

The Problem

Radioxenon isotopes released from MIP facilities are detected daily by the CTBT IMS and can interfere with nuclear explosion detection activities.

The global background of radioactive material varies in time, and cannot be predicted due to the nature of release and transport mechanisms:

- NPPs (~GBq levels of release, ad hoc basis , e.g. ^{133}Xe)
- MIPs (~10 GBq levels of release, ad hoc basis, e.g. ^{133}Xe)
- Location (often dependent on local geology/construction materials, e.g. ^{222}Rn)
- Weather (disperses/concentrates plumes of material in chaotic ways)

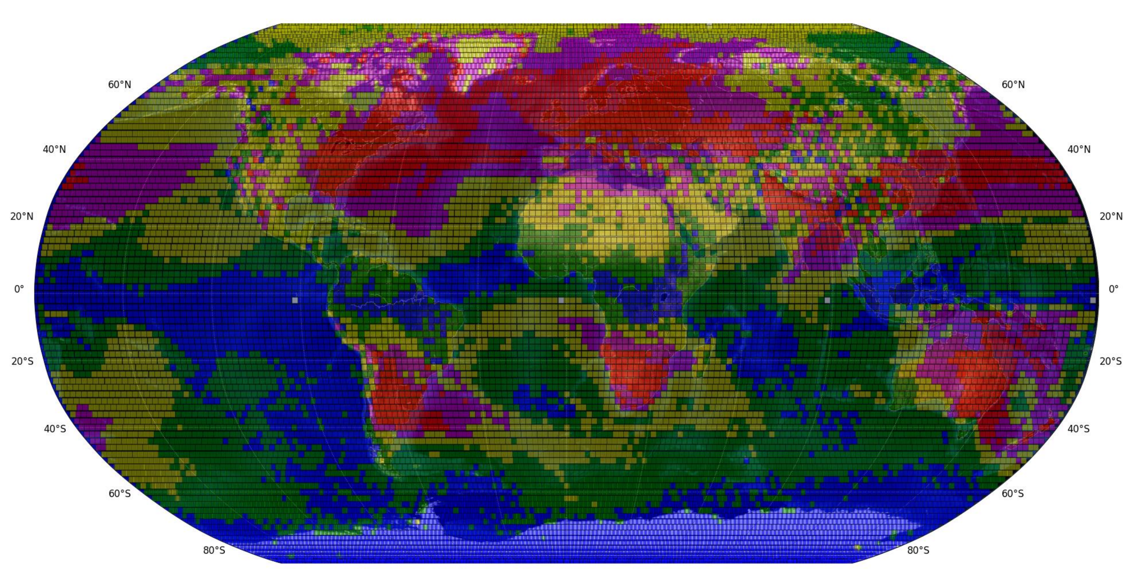


Fig 1: Noble gas background of xenon in the world due to civilian nuclear activities

The constantly changing fission inventory in the atmosphere cannot easily be distinguished from fission releases from nuclear tests:

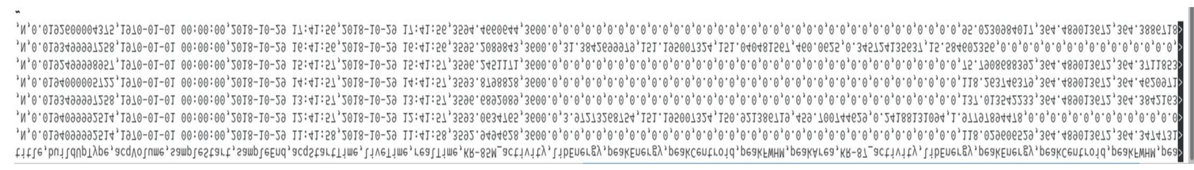
- Magnitudes of global radioxenon background consistent with possible releases from underground testing
- These 'false positives' create a lot of work for an NDC
- Unknown sources / releases of material could be confused with a Nuclear Weapons test

Accurate source terms would allow us to eliminate false positives, greatly reducing workloads for NDCs and create a more effective and robust verification regime.

The STAX project is an experiment to develop a worldwide MIP stack detector network to aid in the discrimination between industrial activities and nuclear explosions.

GBL15 Developed STAX Data Tools

Time series generated by RN Pipeline (every 15 minutes):



Graphical Tools produced to view/interrogate data

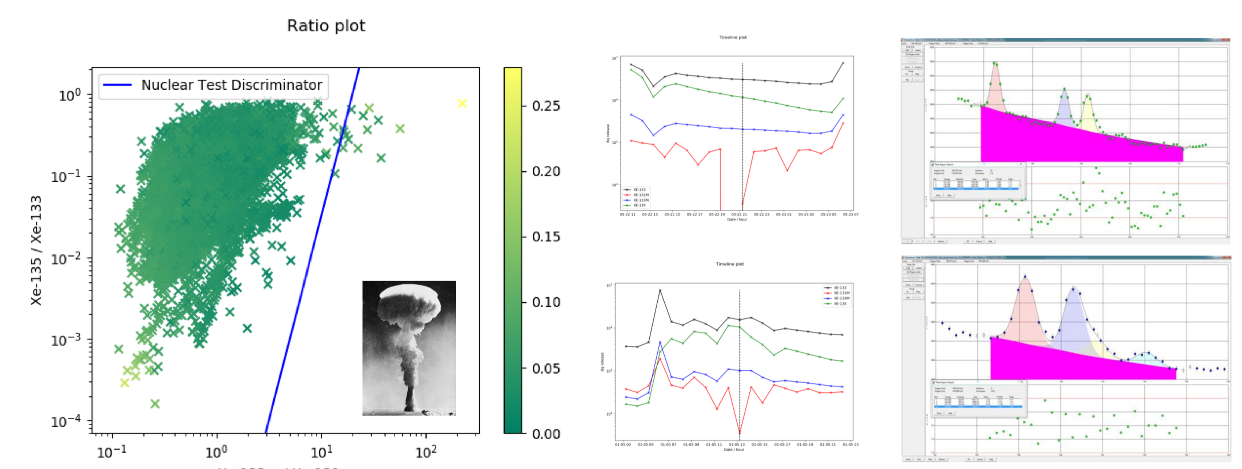


Fig 2: Left - Four Isotope plot (^{133}Xe, ^{133m}Xe, ^{135}Xe, ^{131m}Xe) with all IRE stack data from 2018 (~100,000 spectra) plotted with an indicative discrimination line. Centre – Detailed time series of outliers on the four isotope plot. Right – Peak fitting of spectra that contained the anomalous isotopic concentrations.

These tools allow quick, intuitive analysis of an extremely large dataset. The automated analysis of these spectra is highly optimised, and proved more robust than the standard manufacturer analysis. Up to 10 radioisotopes were detected in the majority of spectra, and 'outliers' (those that were to the right of the discrimination line in the four isotope plot) can be interrogated simply by clicking on the point. This shows the concentrations in detail as part of a timeline, and identifies the spectra used for this datapoint. In the above example, outliers were quickly identified as an anomalous ^{131m}Xe activity. Closer investigation identified poor automated peak fitting as the cause during periods of low activity.

A Potential Test Scenario

Note - real IMS data used – scenario fabricated to demonstrate use of STAX data

A series of IMS detections (containing ^{133}Xe, ^{131m}Xe, and ^{133m}Xe) at SEX63 (Stockholm), between 11th March 2018 – 13th March 2018 (collection stop were **automatically flagged as 'events of interest'** by the UK RN Pipeline due to the nature of the detections.

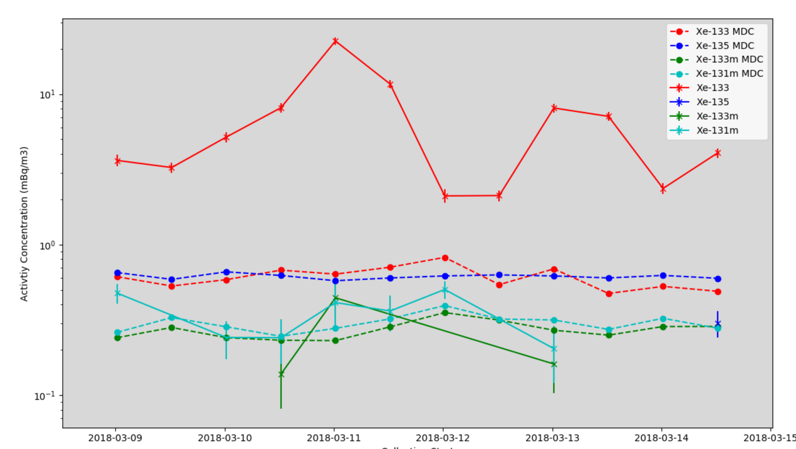


Fig 3: GBL15 RN pipeline NDC analysed results

- Detection magnitudes between 2.1 – 22.5 mBq ^{133}Xe
- Ratio analysis limits age of fission > ~2 days
- Magnitude analysis limits age of fission < ~8 days

CTBT SRS Fields

Backward transport modelling simulations indicated that the plume could have originated from Wales, the south of England, northern France, Belgium, Poland, or Western Russia. Possible source locations were then limited by fission age estimates, and forward models ran from potential source locations to confirm they were possible emitters.

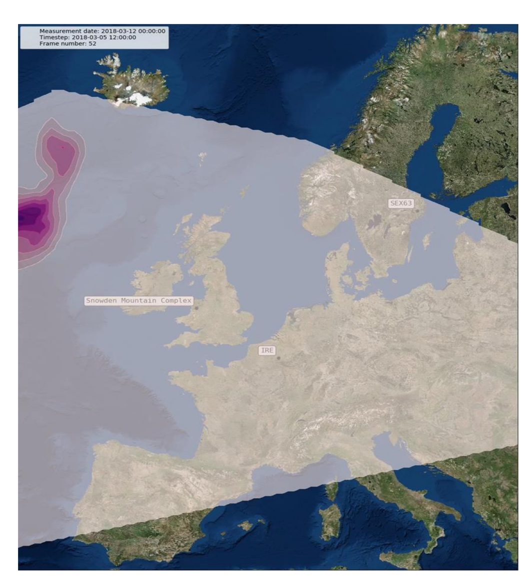


Fig 4: GBL15 RN pipeline SRS field viewer

Seismic Data Checked For Any Possible Events

Using both CTBT data and that available from the BGS (British Geological Survey), a number of potential events were identified. The most prominent of these occurred in Wales, and referred to a magnitude 2.7 'earthquake' on the 9th March 2018.

Ratio analysis was unable to eliminate Wales as possible source (due to large uncertainties on the measurements). The UK NDC was therefore unable to eliminate a Welsh Nuclear Weapons test scenario (without STAX data). Could this be a clandestine Nuclear Weapons test by a breakaway Welsh state?

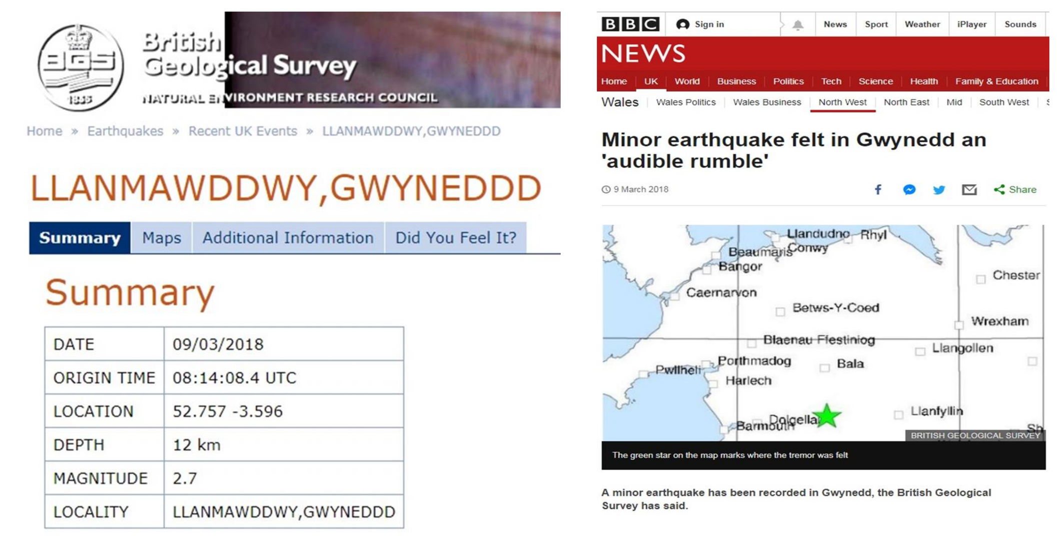


Fig 5: BGS and BBC reporting of earthquake

STAX Data Searched For Potential Release Candidates

Fortunately, STAX data was available for this period (kindly provided by IRE during the testing phase of new STAX monitor). The automated STAX pipeline at the UK NDC identified a number of release events from the 15 minute spectra available from the STAX monitor (1 hour and 4 hour integral data was also available).

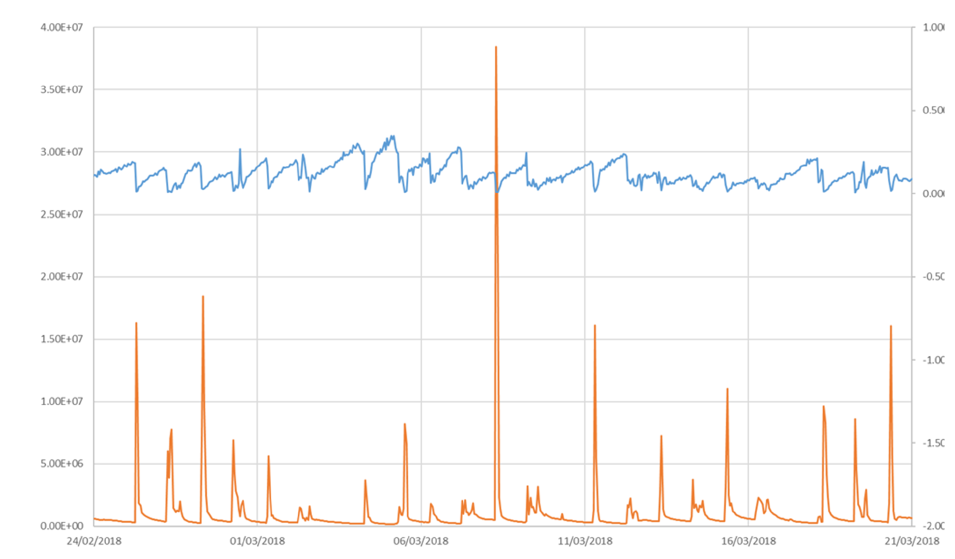


Fig 6: STAX Pipeline identified release event on the 8th March 2018

The IMS measurements (decay corrected to potential release) were used to constrain possible locations on the four-isotope plot, which could then be compared to the STAX release data.

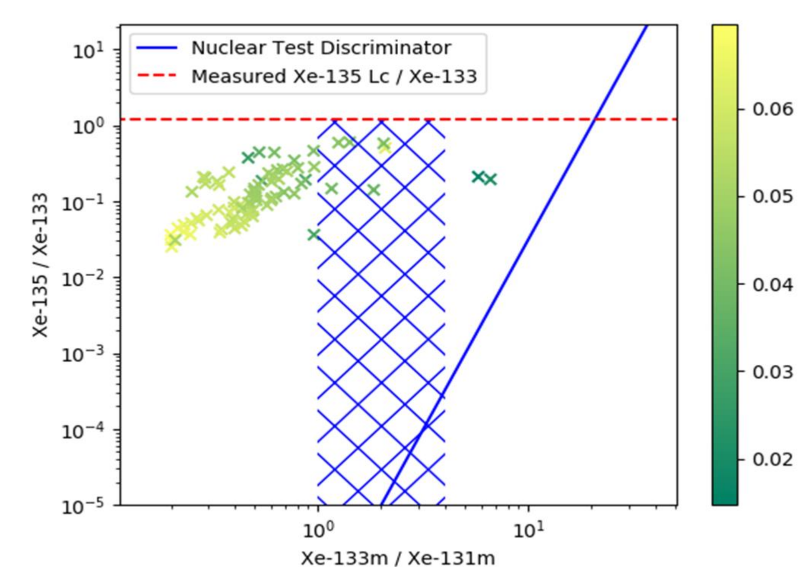


Fig 7: Region for decay corrected IMS measurements compared to a number of potential candidate releases on the four isotope plot

Considering Release Magnitude and Isotopic Composition

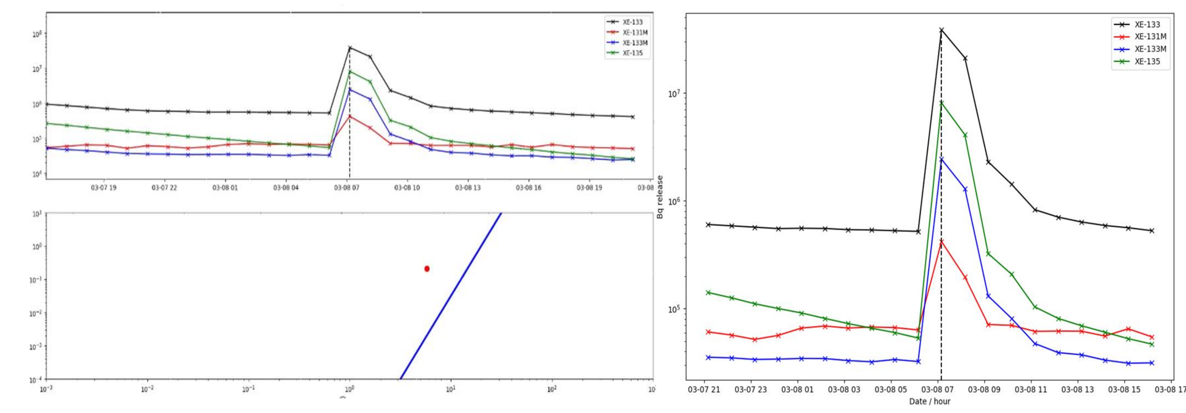


Fig 8: Tool to replay event showing both isotopic magnitudes and four isotope ratio plot with discrimination line

Due to the magnitude of the release on the 8th, this was the primary candidate release event. A 'data-play' tool was used which animates the evolution of the isotopic ratio on the four isotope plot (figure 8, left) in response to the position on the concentration timeline (figure 8, right). This proved extremely useful for tracking the evolution of the release concentrations throughout the release event.

By calculating a weighted average for the ratios during the extracted release event, a representative four isotope point could be created, and compared to the blue hatched area (IMS measurements).

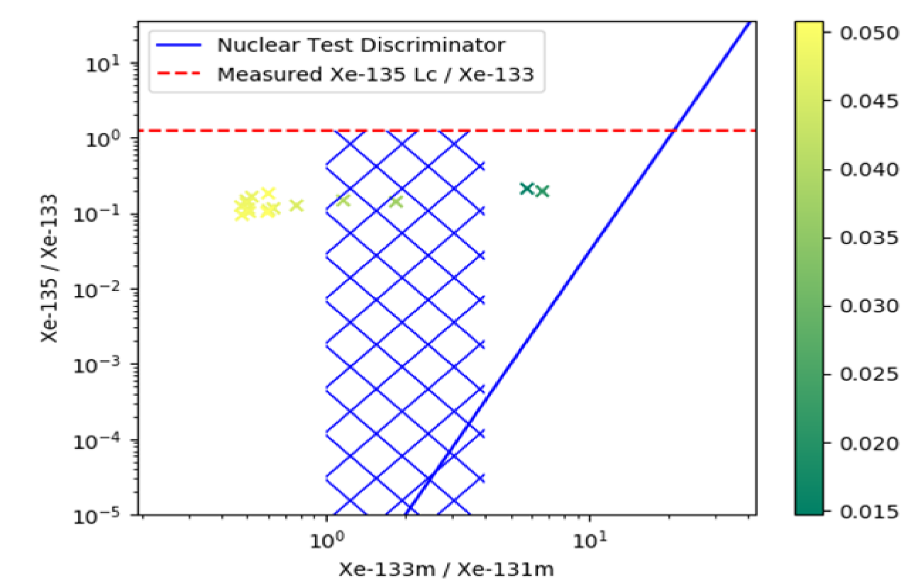


Fig 9: Stack measurement during the identified release and region for decay corrected IMS measurements plotted on four isotope plot

Conclusions From the Potential Test Scenario

The calculated average ratio from the release candidate plume is consistent with the measured IMS data (constrained by the critical limit for the undetected ^{135}Xe). The IRE emission identified is therefore consistent with the IMS measurements recorded at SEX63 (Stockholm).

This allows us to rule out a potential Treaty violation by a breakaway Welsh state, and assign this series of detections to an anthropogenic, routine release.

Although a fabricated scenario, this proves the utility of STAX data. Routine STAX monitoring would greatly assist NDC's in identifying the source of many IMS detections, providing crucial ground-truth that will ultimately lead to a more effective monitoring regime. Additional benefits, such as the evaluation and improvement of Atmospheric Transport Models are also possible with this unique dataset.

With thanks to IRE and PNNL for provision of test data

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