Atmospheric transport modeling and radioxenon analysis methods to distinguish civilian from nuclear explosion signals

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Overview

The goal of this new project is to introduce new approaches into the CTBTO's noble gas screening procedure in order to detect nuclear explosions. The focus will be on the application and combination of atmospheric transport modeling and the information about known xenon sources.

Introduction: Sources of radioxenon

Amongst other things a nuclear explosion produces radioxenon. The four isotopes (and isomers) **Xe-131m, Xe-133, Xe-133m, and Xe-135** are used as a tracer for nuclear explosions.

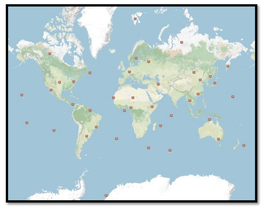


Figure 1: The noble gas component of the International Monitoring System (IMS). [CTBTO]

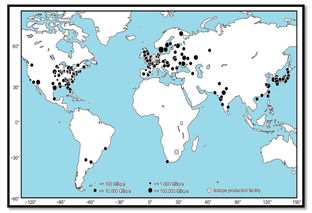


Figure 2: Calculated and estimated generic annual radioxenon source term strengths of operable NPP sites. [1]

However, there are other anthropogenic sources of radioxenon: Nuclear power plants and isotope production facilities. Comparing with **Figure 2** it is obvious that these legitimate sources produce a heterogenic background, which could conceal the radioxenon signal of a nuclear explosion.

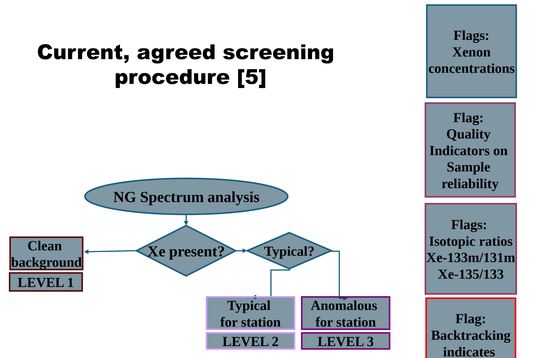
At the moment the following methods have been discussed for an application in the xenon screening process in order to optimize the detection capability of the IMS noble gas component:

- Anomaly observations with respect to the history of concentrations found at the site. [2]
- Isotopic activity ratios can be used to separate a nuclear reactor domain from the parameter space that is specific for nuclear explosions. In addition they can be applied like an inherent clock to determine the explosion time. [3]
- Long-term frequency analyses to remove memory effects and locally induced feedback patterns. [4]
- **Correlation with source-receptor-sensitivities (SRS) related to known civilian sources. These are determined by atmospheric transport modelling (ATM) and reflect the influence of meteorological patterns between a legitimate source and the xenon sampling site.**

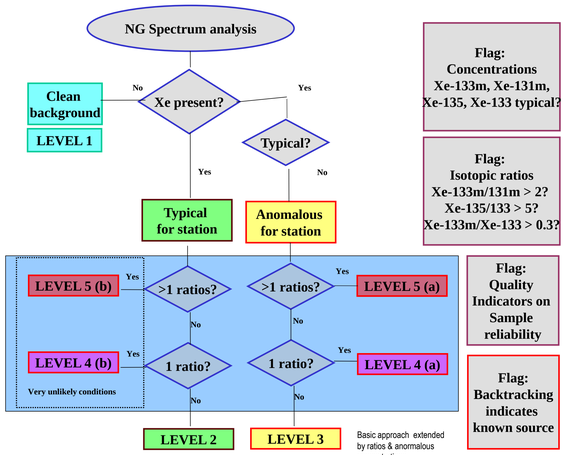
The goal of this project is to optimize the role ATM in the CTBTO xenon screening process, and develop new procedures that combine ATM and the existing knowledge about legitimate xenon sources.

Screening by CTBTO

Current, agreed screening procedure [5]



Screening procedure proposed at WGB 36 (2011) [6]



Data sources

The availability of empirical data, i.e. time series of radioxenon concentrations for multiple stations, is a cornerstone for the testing of new methods and the combination of them.

The actual data are taken by the IMS noble gas stations (see Figure 1). Foremost, for the data selection one has to take into account the continuous availability of data, but also the geographical environment of the station and its upwind, known sources of radioxenon.

Also, the detection of a hypothetical nuclear explosion should be tested. Since the presently existing data are too rare, it is planned to simulate the plumes of nuclear test emissions.

Possibilities for ATM (to be tested)

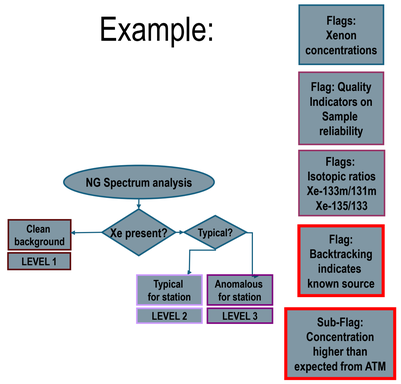
In the frame of this work the possible roles of ATM-based xenon-screening are classified in three categories: Flagging, filtering, and analysing (i.e. level influencing) methods.

Flagging methods

= an extension to the existing procedures.

- Flag: Backtracking indicates known source.
- Sub-Flag: Concentration can be explained with emissions from known sources (order of magnitude or similar).
- Sub-Flag: Higher or lesser concentration than estimated from ATM [1].
- Sub-Flag: Number of concerned known sources.

Example:

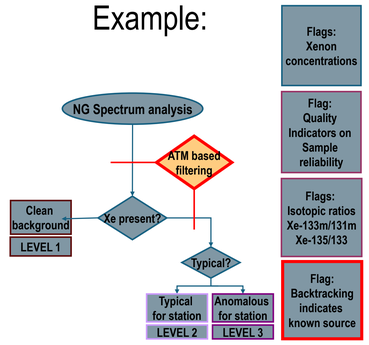


Filtering methods

= improving the data set for the existing procedures.

- Estimate the contributions from known sources to the signal at a certain IMS station based on xenon emission reports or estimations [1].
- Then the contributions could be subtracted from the IMS signal.

Example:

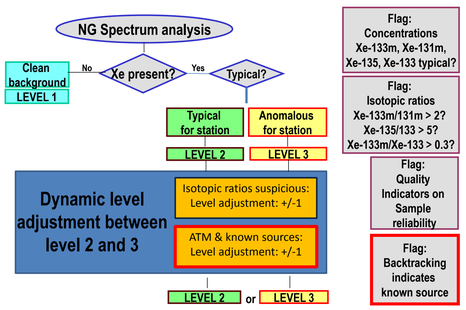


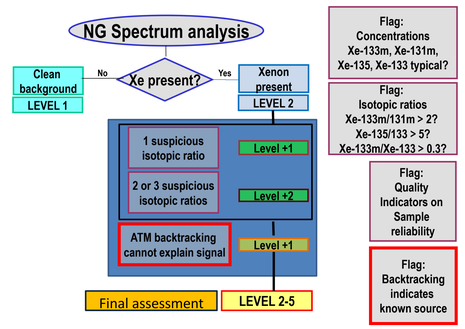
Analysing methods

= developing a new xenon screening procedure = **long-term goal.**

- ATM and known sources would have an impact on the automated level decision.
- With all xenon screening methods in mind, what would be the optimal role of ATM?
- How many levels are needed and how can ATM and known sources change the level decision process?

Examples:





Project Status

At the moment the scripts and databases for flagging the xenon samples have been accomplished. The calculated source-receptor sensitivity matrices are checked for correlations with known xenon emitters.

The numerous calculations of source-receptor sensitivities via ATM will be necessary for the testing of newly developed methods. Therefore, the ATM software Flexpart has been ported to a cluster computing facility at the University of Roma Tre.

References

[1] Global radioxenon emission inventory based on nuclear power reactor reports - Martin B. Kalinowski, Matthias P. Tuma (2009)

[2] Nuclide ratios and source identification from high-resolution gamma-ray spectra with Bayesian decision methods - Zähringer, M. and Kirchner, G. (Nucl. Instr. and Meth. A. 594, 400-406, 2008)

[3] Discrimination of Nuclear Explosions against Civilian Sources Based on Atmospheric Xenon Isotopic Activity Ratios – Martin B. Kalinowski et al (2010)

[4] Radioxenon Time Series and Meteorological Pattern Analysis for CTBT Event Categorisation – Wolfango Plastino et al (2009)

[5] Testing Noble Gas Categorization with IMS data - Matthias Zähringer, Andreas Becker, Mika Nikkinen (Scientific Methods, IDC Division, WGB Presentation, 2009)

[6] Noble Gas Categorization scheme - Mika Nikkinen, U. Stoehlker, A. Gheddou, M. Verpelli (Scientific Methods. IDC Division, WGB 36 Presentation, 2011)