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 strength 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.

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.

Screening by CTBTO
Current, agreed screening procedure [5]

Flagging concentration Xe-133m, Xe-133, and Xe-135 typical

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

Filtering methods = improving the data set for the existing procedures.

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

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 lower concentration than estimated from ATM [1].

Filtering methods = an extension to 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.

Analysing methods = a new xenon screening procedure.
- 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:

Example:

Example:

Example:

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