Inversion Modelling of the Radioxenon Detections in Takasaki, April 2013, as a Step towards Data Fusion

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ABSTRACT

Our analysis uses source-receptor sensitivities calculated with FLEXPART and ECMWF data on a 20° resolution and an output grid of 20 km resolution. Xe-133 measurements at Takasaki and four surrounding stations are included, with the three significant detections at Takasaki, plus non-detections / not significant detections before and after. The inversion follows a Bayesian approach and minimizes the weighted deviations model – measurement and the deviation from a prior source term, plus deviation from smoothness. The source is resolved in time and vertically.

We are both investigating the scenario where the source is unknown, and a comparison among the cost function values for all candidate grid cells is used to narrow down the possible source region, and a scenario where the DPRK test site is assumed as the source location. In the first scenario, a step towards data fusion is made by overlaying seismic events from a four-weeks time window, solving these events with the cost function. The method finds the DPRK test site as being among the top ten events.

We obtain a release of 4.11E+11 Bq, attributed to a vertical column of about 1000 m above model surface, lasting for 12 hours in the first half of April.

The problem

- DPRK announced nuclear test on 12 Feb 2013
- 3 unusual Xe detections at IMS/BN station Takasaki, Japan, on 8/9 April 2013, attributed to a delayed release from the DPRK test sites (CTBTO, 2013a)
- Existing analyses (Ringbom et al., 2014) of these detections don’t use a full inverse modelling framework including non-detections
- Requires focus on two aspects

- Localising the release, including fusion with seismic data
- Quantifying the release and its temporal shape (assuming the location given, at the DPRK test site (CTBTO, 2013b; Zhang and Wen, 2013).

Radonucide data

Both Xe-133 and Xe-134 were detected at Takasaki. This analysis uses only Xe-133 data – see paper. Inverse Modelling analyses of Xe-134 Measurements over East Asia in April 2013.

References


Conclusions

- Inversion using the Bayes’ approach minimizes the cost function
- Fusion with seismic data is helpful to narrow down possible release locations. The source was found to be associated with the 5th lowest cost function value among all the assumed sources.
- From the point of view of seismic analysis, the number of candidate events could be reduced substantially disregarding events above some value of the cost function.

Options for future work

- Better quantification of errors, especially for the SRS data, using true topography: 500 – 2200 m asl, model topography: 880 – 1500 m asl.
- Inclusion of off-diagonal terms in error covariance matrices
- Better quantification of background uncertainty, including background radionuclide sources through known emissions or through inclusion in inversion

Fusion with seismic data – method

- Inversion methodology
- Problem is ill-conditioned: data cannot constrain enough all elements of the source vector x → need regularisation
- Solution is found via minimizing the cost function
- Model error estimated using “pseudo-ensemble” of model runs and added to measurement error, iterate over solution
- First-guess solution x0 → 1 10^11 Bq (e-2) σx → 3 10^11 Bq per element of solution vector, thus total can be larger!
- Negative parts of solution are suppressed via iterative process reducing first-guess error for improvement part
- We assume point releases only (from a single grid cell – implicit a-priori knowledge)
- To find possible release locations, we try out each grid cell, and then plot colour-coded cost function values on a map. That map will construct a different temporal shape as function of height in each cell.

Inversion results

- Likely release locations are just upwind of Takasaki, a strip extending from eastern DPRK through northern China, and a spot WNW of CNX20 (Beijing).
- Data fusion will help to further narrow down the options.

Fusion with seismic data – results

- Inclusion of seismic events as an additional constraint
- 3D inversion: Xe during about 12 h is found. This is lower than previously suggested.
- With respect to localisation, the DPRK test site is among the region of lower cost function but not near the global minimum.
- Fusion with seismic data is helpful to narrow down possible release locations.
- The source was found to be associated with the 5th lowest cost function value among all the assumed sources.
- From the point of view of seismic analysis, the number of candidate events could be reduced substantially disregarding events above some value of the cost function.