SnT 2025
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE
8 SEPTEMBER ONLINE DAY
9 TO 12 SEPTEMBER AT HOFBURG PALACE, VIENNA & ONLINE

P2.3-417

Estimation of Xe133 release from activity concentration measurements with background signal

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INTRODUCTION AND MAIN RESULTS

Detecting Xe-133 emissions from nuclear tests is complicated by background releases from civilian facilities. We develop methods to separate these signals, enabling more accurate source term estimation. Applied to the 1st Nuclear Explosion Signal Screening Open Inter-Comparison Exercise (NESSI) 2021 data, our model improves identification of nuclear explosion signals in complex atmospheric backgrounds.

Supported by the Czech Science Foundation (grant no. GA24-10400S). The results presented in this study are based on the work performed under the CTBTO awarded contract for "Provision of Software Engineering Services for the Scientific Development of a Source Term Estimator Tool (STE)" under funding from the European Union Council Decision VIII. The views expressed herein are those of the authors and do not necessarily represent the views of the CTBTO Preparatory Commission.

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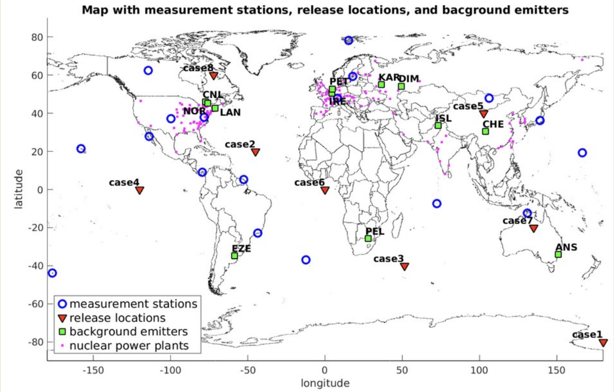
Introduction

The International Monitoring System (IMS) of the CTBTO uses seismic, hydroacoustic, infrasound, and radionuclide technologies to detect nuclear tests worldwide. Among them, radionuclide monitoring is unique as it can confirm the nuclear nature of an explosion by detecting radioactive aerosols and noble gases, particularly radioxenon.

- Radioxenon is a key tracer but is also released from civilian facilities –> complex, variable background.
- Distinguishing test signals from background remains a major challenge.
- The 1st Nuclear Explosion Signal Screening Open Inter-comparison Exercise (NESSI) in 2021 combined real measurements with synthetic signals.
- Our goal: improve source estimation and nuclear test identification under uncertainty using Bayesian inversion.



Dataset

- Based on three components: hypothetical explosion releases, IMS radioxenon measurements, and FLEXPART Source Receptor Sensitivities (SRS).
- 8 hypothetical nuclear explosion sites on a global grid.
- Xe-133 measured at 23 IMS stations.
- FLEXPART simulations (ERA5, 0.5°/1h resolution) provided transport fields to link sources and measurements.

Methods

We assume the SRS matrix linking potencial emission sources to receptors, while background sources are weighted using the vector **s** as

$$\mathbf{y} = \mathbf{M}\mathbf{x} + \mathbf{Y}_b\mathbf{s} + \mathbf{e}.$$

We test a Bayesian model for separation of signal from background only and signal of background mixed with explosion:

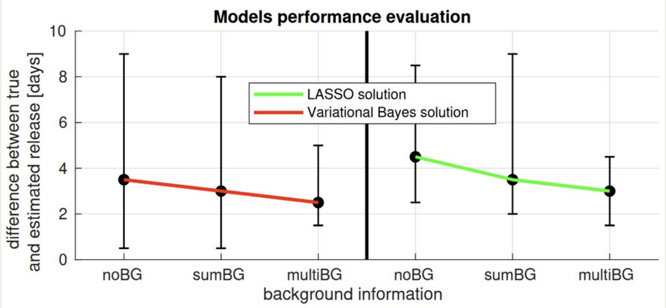
$$y_i = \begin{cases} \mathcal{N}\left((\mathbf{Y}_b\mathbf{s})_i, \omega^{-1}\right) & \text{for } w_i = 0, \\ \mathcal{N}\left((\mathbf{M}\mathbf{x} + \mathbf{Y}_b\mathbf{s})_i, \omega^{-1}\right) & \text{for } w_i = 1, \end{cases}$$

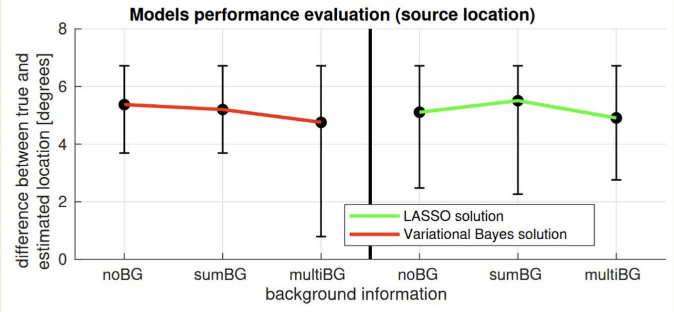
The model's parameters are estimated using variational Bayes (VB) methodology forming an iterative algorithm.

- Results are compared with a standard LASSO method.

Results

Results shows comparison of the VB and the LASSO estimates on three types of background information: (I) no background (noBG), background known only as a sum from all sources (sumBG), and (iii) background known from all individual source (multiBG).





The use of detailed background modeling improves the accuracy of inverse estimates for both release timing and source location.

The use of detailed background modeling together with VB results in slight improvements in release-timing accuracy, relative to the standard LASSO method.

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