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Estimation of unknown source term based on radioxenon observations with the presence of background signal

Ondřej Tichý[1], Václav Šmídl[1], Václav Mácha[1], Jolanta Kuśmierczyk-Michulec[2], Wolfgang Sommerer[2], and Anne Tipka[2]

[1]Institute of Information Theory and Automation, Czech Academy of Sciences, Prague, Czechia (otichy@utia.cas.cz)
[2]International Data Centre, Comprehensive Nuclear-Test-Ban Treaty Organization, PO Box 1200, 1400 Vienna, Austria

The identification of a sample associated with a nuclear test is a challenging task for the CTBTO because of the presence of a noble gas background in the constant evolving atmosphere. This background is caused by nuclear power plants, nuclear research reactors, and medical isotope production facilities and contributes to samples collected by the noble gas systems of the International Monitoring Stations (IMS). Because of that background, standard linear inverse model applied to Xe-133 measurements is prone to substantial errors. To address this problem, we investigate possible methods for separation of the background signal and any signal from a nuclear explosion, which is further processed for estimation of the Xe-133 source term.

We assume that the observed unknown point release of Xe-133 can be modeled as a linear model $\mathbf{y}=\mathbf{Mx}$, where $\mathbf{y}$ is the vector of observations, $\mathbf{M}$ is source-receptor sensitivity (SRS) matrix, and $\mathbf{x}$ is the temporal profile of the unknown release from a nuclear explosion, i.e. its source term. Since the signal in the observation vector is most probably mixed with civilian emitters, we test methods for separation of the contributions from the unknown signal and the background. We compare various approaches, ranging from simple model calibration, to simulated background term and their combinations with anomaly detection.

The results are demonstrated on the data from the 1st Nuclear Explosion Signal Screening Open Inter-Comparison Exercise 2021 where advantages and disadvantages of studied methods are discussed and results are evaluated with the use of ground truth information on temporal and spatial location of the Xe-133 source.

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