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INVERSE ATMOSPHERIC TRANSPORT MODELLING USING THE OPEN-SOURCE FREAR TOOL

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Introduction

Several countries operate high-volume air samplers that can measure tiny concentrations of radioactivity in air. Such measurements are of interest for the purpose of environmental monitoring and treaty monitoring. Traces of radioactivity could be the signatures of regulated releases from civilian nuclear facilities but could also originate from a nuclear incident or accident, or even nuclear weapon testing. Often, the origin is not known. In that case, inverse atmospheric transport and dispersion modelling can be used to determine the source location and release parameters. For this purpose, the FREAR tool was developed.

Inverse atmospheric modelling

Inverse atmospheric modelling involves combining observations with atmospheric transport modelling in a statistically coherent way to determine unknown source parameters. It can formally be written as follows (Seibert, 2000):

$$\boldsymbol{y} = \boldsymbol{M}\boldsymbol{x} + \boldsymbol{\varepsilon}$$

with:

- $\boldsymbol{y}$: a vector of observations
- $\boldsymbol{M}$: a source-receptor sensitivity matrix
- $\boldsymbol{x}$: a vector with releases at each geo-temporal point
- $\boldsymbol{\varepsilon}$: a vector with the combined model and observation error

Results

Figure 1 (right): Source location estimate as obtained by four methods: (top left) source location probability obtained by Bayesian inference, (top right) residual cost following cost function optimisation, (bottom left) maximum-in-time correlation between the observations and the source-receptor sensitivities and (bottom right) fraction of non-zero source-receptor sensitivities. The true source location is marked by a black filled triangle. The locations of the measurement stations are also shown (circles and text labels).

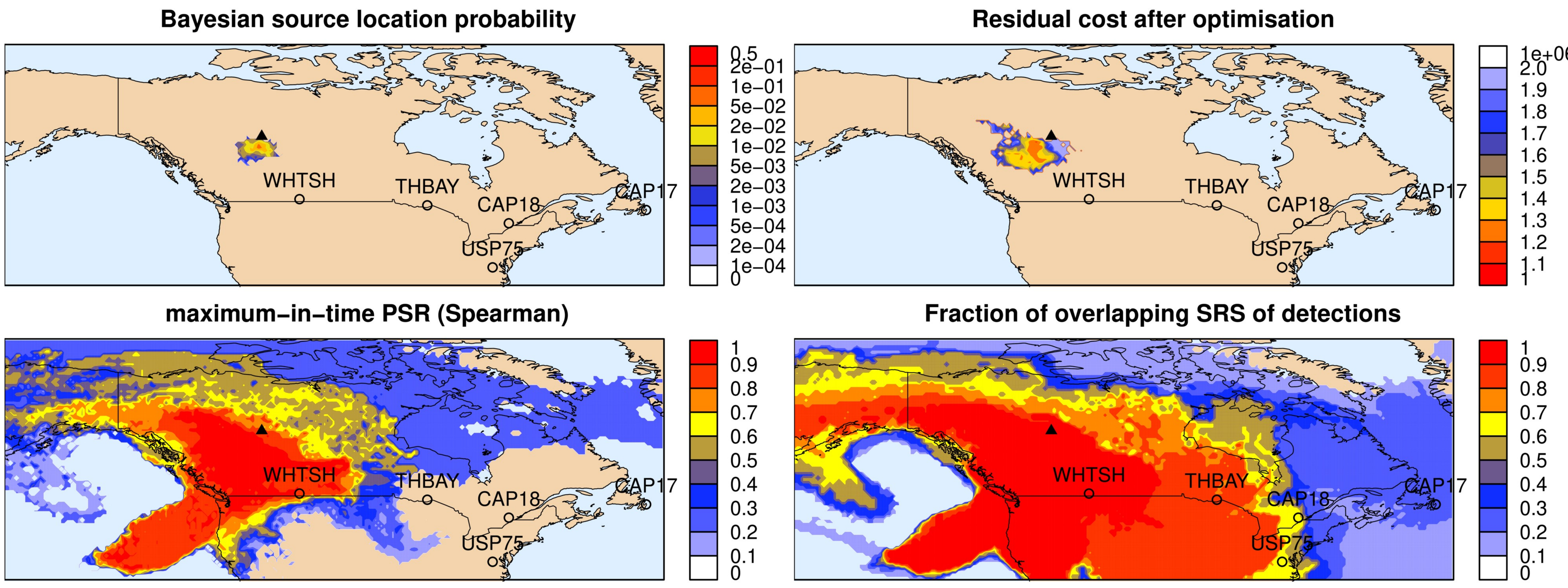
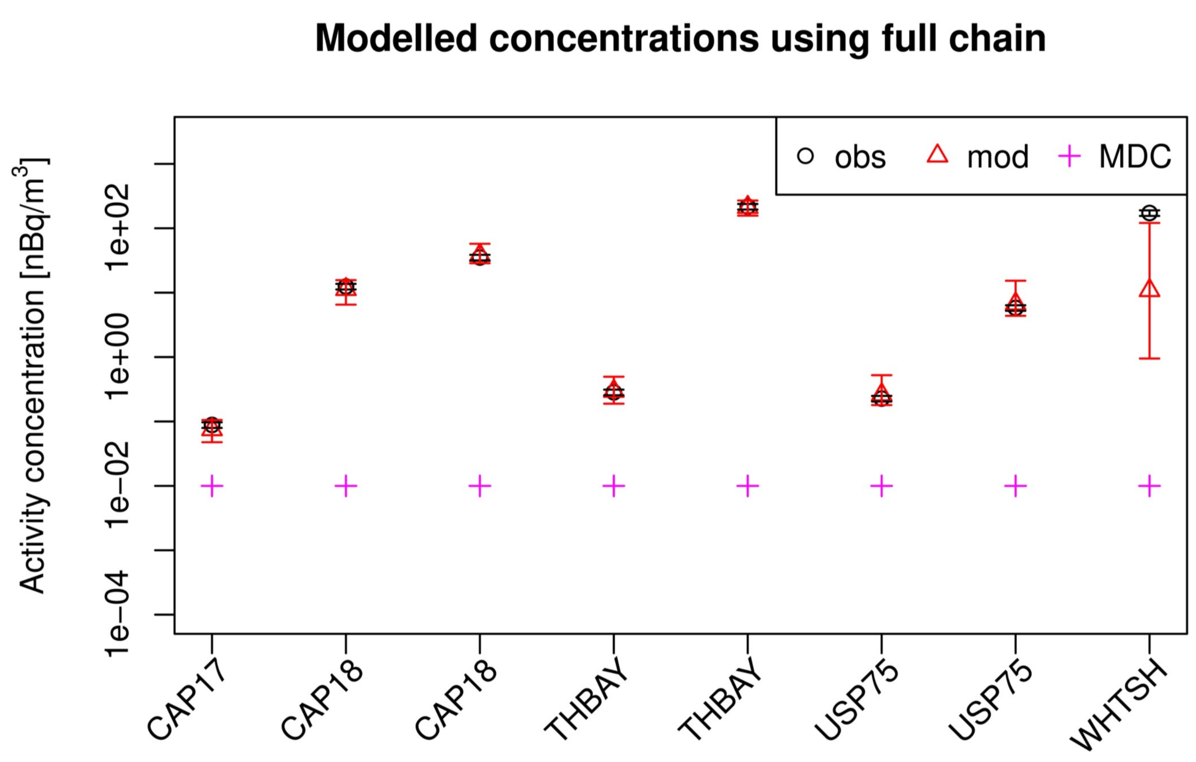
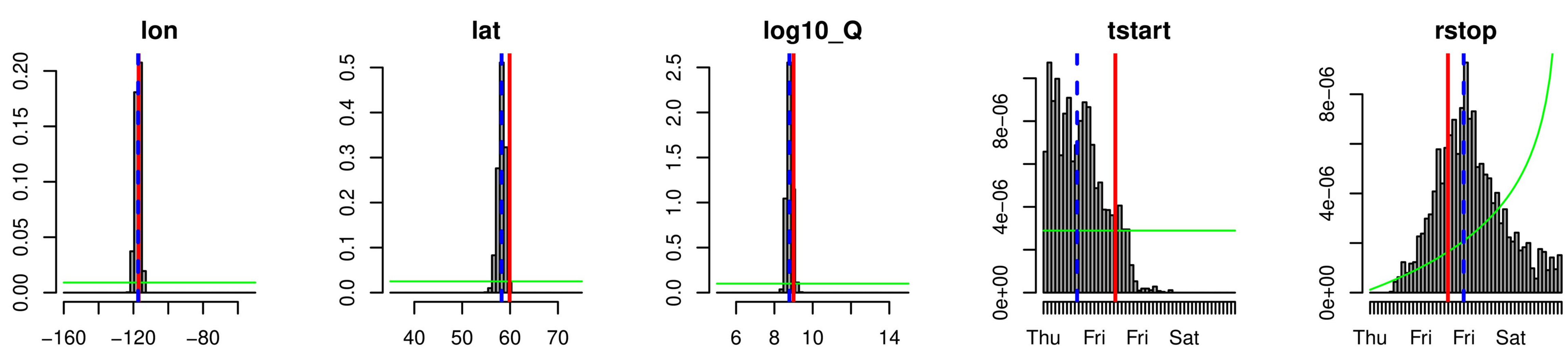


Figure 2 (bottom left): Comparison between the observed ^{137}Cs activity concentrations (black circles) and corresponding modelled activity concentrations (red triangles) following Bayesian inference. The minimum detectable concentration is also given (purple '+'-sign).

Figure 3 (bottom). Posterior distribution for the source parameters following Bayesian inference. From left to right: longitude, latitude, $\log_{10}$ of the total release amount, start time of the release and end time of the release. For each source parameter, the prior distribution (green line), posterior median (blue dashed vertical line) and true value (red vertical line) are also plotted.





Summary and outlook

The Forensic Radionuclide Event Analysis and Reconstruction tool FREAR combines observed activity concentrations and associated source-receptor sensitivities obtained by atmospheric transport modelling to determine the source parameters that explain the observed activity concentrations. Several complementary source location algorithms have been implemented. The tool is useful for verifying compliance with the Comprehensive Nuclear-Test-Ban Treaty and for applications related to radiation protection. Further developments are foreseen to allow for the use of dry and wet deposition measurements for the inverse modelling (**see oral presentation H22-060**). The tool can be downloaded from https://gitlab.com/trDMt2er/FREAR.

References:

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