Estimation of CTBT-Relevant Radionuclides Sources By Ensemble Adjoint Atmospheric Transport Modeling

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ABSTRACT

This work describes the recent development of Egyptian-NDC approach for the source estimation of CTBT-Relevant Radionuclides (RN) by using an ensemble of Adjoint atmospheric transport and dispersion modeling (ATM). A new deterministic method is developed for simultaneous estimation of the possible source location, time of release, and source strength. This method is based on the least square linear regression. The verification of this method, in case of a simplified perfect adjoint ATM and error-free concentrations measurements, shows that the method provides the exact source parameters. Since, in the real atmospheric dispersion of RN, there are many sources of uncertainty, and the deterministic methods fail. Therefore a system of ensemble adjoint ATM and Bayesian inference approach was developed to address the uncertainty in the source term estimation. Some examples by using synthetic measurements experiments, for real atmospheric conditions, illustrate the ability of this combined method to retrieve the possible source parameters and quantify the uncertainty in this estimation. This approach is currently running over a regional scale due to the lack of computing power, but it is applicable also to the global scale.

METEOROLOGICAL FIELDS

In the following experiments, the meteorological fields are from NCEP FNL Operational Global Analysis (1 deg. and 6 hours intervals). The Weather Research and Forecast model (WRF) [3] is used to dynamically downscale these fields into 30km grid distances and one-hour intervals. WRF model is run with different configurations of the planetary boundary layer, microphysics, and cumulus parameterization schemes to produce 23 ensemble members to represent the uncertainty in the weather condition during 6^{th} Oct.- 16^{th} Oct. 2014.

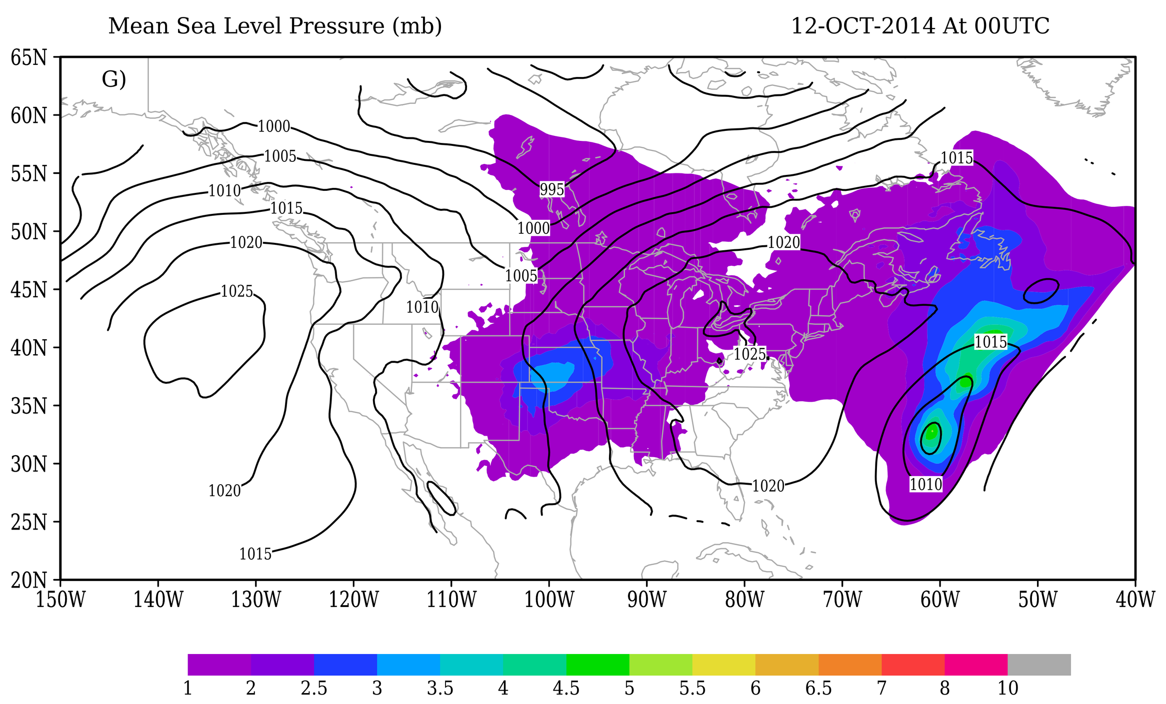

Figure 1: MSL pressure Uncertainty (23 ensemble members).

Figure 1 represents an example of the uncertainty of meteorological fields due to sub-grid parameterization. The Mean Sea Level (MSL) is drawn with contours, and the standard deviation of the values are drawn with shaded colors.

SYNTHETIC EXPERIMENT

The produced ensemble of the meteorological fields are provided into a regional atmospheric dispersion model, FLEXPART-WRF [1], which is run in a forward mode to simulate the dispersion of ^{133}Xe, as an example of CTBT's relevant RN, from six assumed sources. Thus, for each assumed source an ensemble of the forward plumes is dispersed, and an ensemble of ^{133}Xe concentrations are estimated at three IMS stations (RN44, RN74, RN75). Figure 2 shows the locations of these sources (red asterisks) and the three IMS stations (blue dots).

The ATM (FLEXPART-WRF) is run again in the backward mode to simulate the retroplumes released from the three stations. The output of this step is an ensemble source-receptor-sensitivity (SRS) fields.

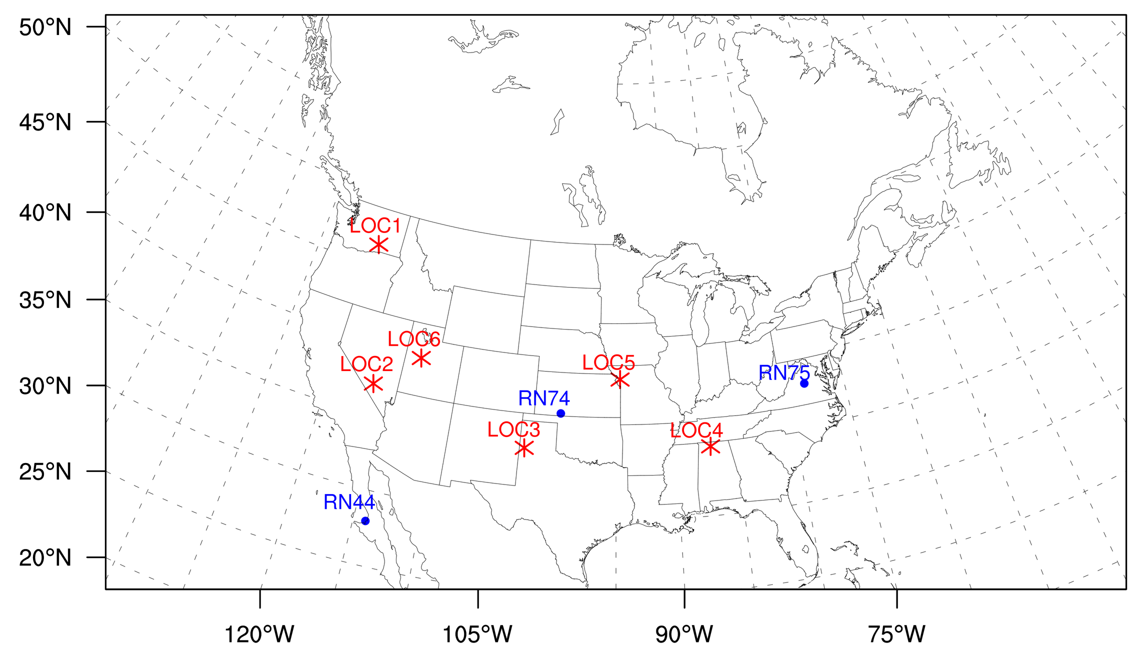

Figure 2: The locations of the assumed sources (red asterisks) and used IMS stations (blue dots) inside the domain of simulation.

METHODOLOGY

The adopted approach flowchart is shown in Figure 3. The ensemble of the adjoint ATM outputs is used to estimate an ensemble of modeled concentration values by linear regression fitting with the ensemble of the synthetic measurements. Then, both the modeled concentrations and synthetic measurements are used to calculate an ensemble of likelihood functions.

The Bayesian inference framework is used to combine all available information (the observed concentrations, the meteorological fields, their uncertainties, and the prior assumptions or information) to estimate the source-term parameters [4, 2]. According to our approach, an ensemble of posterior probability density functions is produced. Finally, the ensemble mean of the posterior PDFs is calculated.

Table 1: Errors in Source Parameters Estimations.

LOCATION	LONG (deg.)	LAT (deg.)	Time (days)
LOC1	-1.75	-0.95	0.0
LOC2	3.35	-0.14	1
LOC3	2.0	1.65	1
LOC4	-1.08	-3.61	-1
LOC5	-1.33	-2.02	-1
LOC6	4.88	-13.22	1

SOURCE-TERM ESTIMATION APPROACH

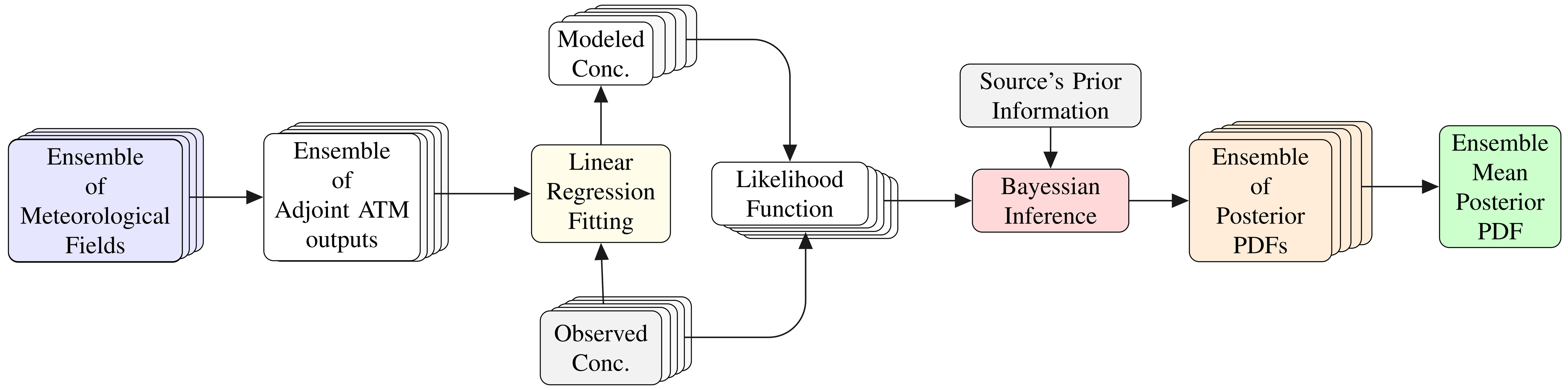

Figure 3: Adopted Combined Ensemble-Bayesian Approach

RESULTS

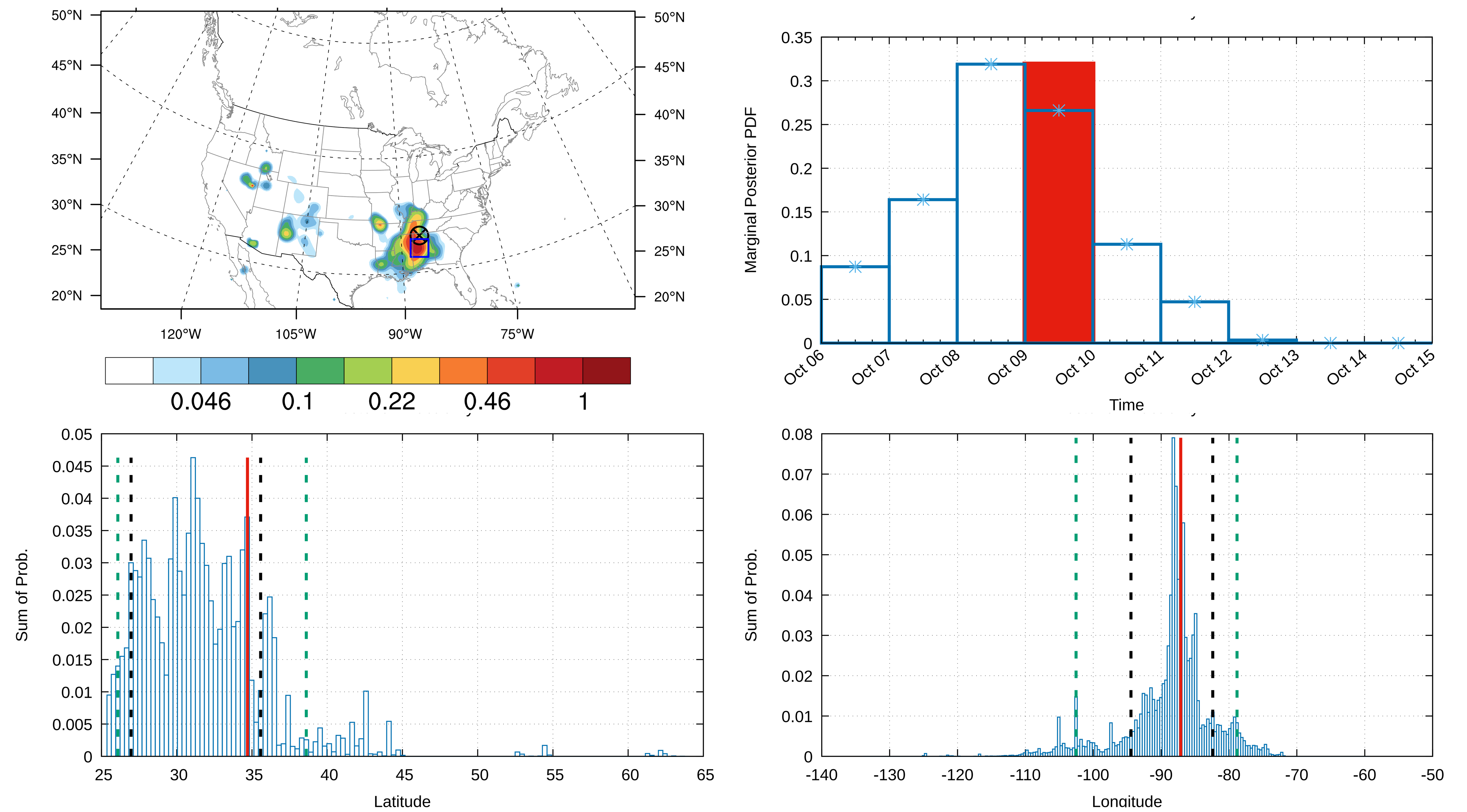

Figure 4: Ensemble Mean of Posterior PDF

DISCUSSION

Figure 4 displays the results of source estimation for LOC4 (as an example). The geographical distribution of the ensemble mean of the posterior PDF (top left map) illustrates that the source location (circled cross symbol) lays within the region of the high posterior PDF. The three histograms, in Figure 4, show the temporal marginal PDF (top right), the latitudinal marginal PDF (bottom left), and longitudinal marginal PDF (bottom right). The actual source parameters are drawn with red bars.

The proposed approach gives the source-term parameters (source location, release time, and source strength) with acceptable accuracy for five of six sites (See Table 1).

REFERENCES

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