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Estimation of the Cesium-137 Source Term from the Fukushima Daiichi Power Plant Using Air Concentration and Deposition Data

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A major difficulty when inverting the source term of an atmospheric tracer dispersion problem is the estimation of the prior errors: those of the atmospheric transport model, those ascribed to the representativeness of the measurements, the instrumental errors, and those attached to the prior knowledge on the variables one seeks to retrieve. In the case of an accidental release of pollutant, and specially in a situation of sparse observability, the reconstructed source is sensitive to these assumptions. This sensitivity makes the quality of the retrieval dependent on the methods used to model and estimate the prior errors of the inverse modeling scheme.
In Winiarek et al. (2012), we proposed to use an estimation method for the errors' amplitude based on the maximum likelihood principle. Under semi-Gaussian assumptions, it takes into account, without approximation, the positivity assumption on the source. We applied the method to the estimation of the Fukushima Daiichi cesium-137 and iodine-131 source terms using activity concentrations in the air. The results were compared to an L-curve estimation technique, and to Desroziers's scheme. Additionally to the estimations of released activities, we provided related uncertainties (12 PBq with a std. of 15 – 20 % for cesium-137 and 190 – 380 PBq with a std. of 5 – 10 % for iodine-131). We also enlightened that, because of the low number of available observations (few hundreds) and even if orders of magnitude were consistent, the reconstructed activities significantly depended on the method used to estimate the prior errors.
In order to use more data, we propose to extend the methods to the use of several data types, such as activity concentrations in the air and fallout measurements. The idea is to simultaneously estimate the prior errors related to each dataset, in order to fully exploit the information content of each one. Using the activity concentration measurements, but also daily fallout data from prefectures and cumulated deposition data over a region lying approximately 150 km around the nuclear power plant, we can use a few thousands of data in our inverse modeling algorithm to reconstruct the Cesium-137 source term. To improve the parameterization of removal processes, rainfall fields have also been corrected using outputs from the mesoscale meteorological model WRF and ground station rainfall data. As expected, the different methods yield closer results as the number of data increases.

Reference : Winiarek, V., M. Bocquet, O. Saunier, A. Mathieu (2012), Estimation of errors in the inverse modeling of accidental release of atmospheric pollutant : Application to the reconstruction of the cesium-137 and iodine-131 source terms from the Fukushima Daiichi power plant, J. Geophys. Res., 117, D05122, doi:10.1029/2011JD016932.