# Source Term Estimation for atmospheric release In Nuclear Accidents Using ensemble Kalman filter: a validation with wind tunnel experiment

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In a nuclear accident, the source term which contains the release rate of atmospheric radionuclide leakage is a key issue of the nuclear emergency response. One effective way to obtain the source term is the inverse modelling method that is based on radionuclide transportation process and environment radiation monitoring data. However, the inverse modelling method may be sensitive to specific site conditions. Therefore, a case-by-case validation is important.
In this study, a source term estimation method based on the Ensemble Kalman filter (EnKF) data assimilation technique was proposed for source term estimation and a wind tunnel experiment that simulated a highly heterogeneous Chinese nuclear power plant site was performed to validate this method.
The EnKF method takes the concentrations measured at different positions as input parameters and iteratively refined the source term estimate by reducing the discrepancy between the experimental measurements and the concentration prediction that is obtained by certain atmospheric transport model based on the estimated source term. In order to improve the accuracy of the transport model, CALMET was used to generate the wind field that is necessary to drive RIMPUFF.
A 1:2000 wind tunnel was performed to comprehensively evaluate the performance of the proposed method, which simulated both ground and stack release scenarios with a dominant wind direction at a typical Chinese nuclear power plant. The incoming flow in the wind tunnel is adjusted according to the annual mean wind speed and vertical profile that has been measured in recent years near the NPP site. The experiment simulated a ground release scenario by using CO as the tracer gas, which the release position is in the center of the nuclear power plant site. Concentrations are measured at 264 positions in the downwind direction of the release, which equals to 6500m away from the source in a real world scale. The estimated release rate was compared with the true release rate that was used in the wind tunnel experiment, in order to assess the convergence and accuracy of the proposed method. Meanwhile, the concentration measured in the wind tunnel was both qualitatively and quantitatively compared with the simulation values that are calculated by CALMET-RIMPUFF using the estimated release rate.
The validation results demonstrate that the proposed method has a fast convergence rate. The estimated release rate matches the real one used in the experiment well for both release cases, which the bias is less than 50% for the worst case estimate. As for the concentrations predicted with the estimated release rate, they are not only qualitatively consistent with the spatial distribution of the measured concentrations, but also show satisfactory results with respect to statistical evaluation metrics for both release cases. The Pearson correlation coefficient is higher than 74~87%, the FAC2 is 42~54% and the FAC5 is 77~80% for all the experiment cases. The source term estimation of the stack release case slightly outperforms that of the ground release case, due to the better atmospheric transport modelling. The experiment also reveals that CALMET-RIMPUFF tends to underestimate the concentrations, which are the primary source of the bias in the estimates. Therefore, the atmospheric model is critical for the performance of the source term estimation, which shall be our future work focus.

Keywords: Source term estimation, Data assimilation, Atmospheric dispersion, Radioactive release

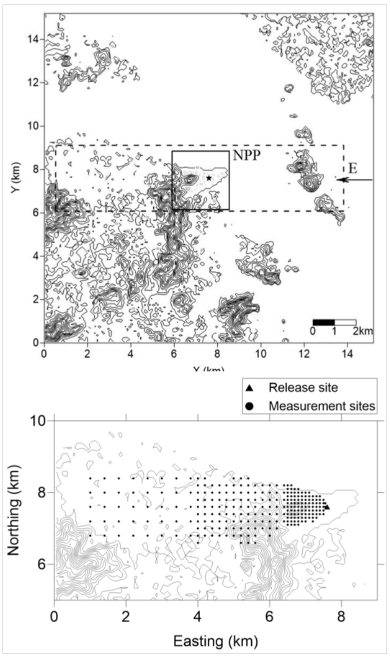


Fig. 1 Topography and measurement network of the wind tunnel experiment

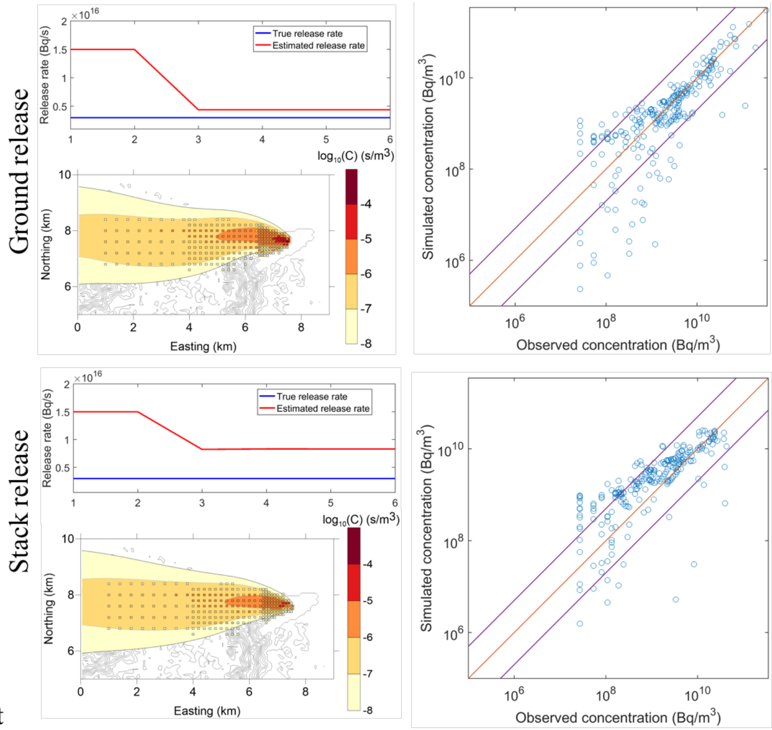


Fig. 2 source term estimation results. Convergence curve, simulated plume using the source term estimate and the corresponding scatter plot