Targeting of Observations
for Radionuclides Accidental Release Monitoring

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Abstract

In the event of an accidental atmospheric release of radionuclides from a nuclear power plant, accurate real-time forecasting of the activity concentrations of radionuclides, is acutely required by the decision makers for the preparation of adequate countermeasures. Yet, the accuracy of the forecasted plume is highly dependent on the source term estimation. Inverse modelling and data assimilation techniques should help in that respect. However the plume can locally be thin and could avoid a significant part of the radiological network surrounding the plant. Deploying mobile measuring stations following the accident could help to improve the source term estimation.

A method is proposed for the sequential reconstruction of the plume, by coupling a sequential data assimilation algorithm based on inverse modelling with an observation targeting strategy. The targeting design strategy (Berliner et al. (1999)) consists in seeking the optimal locations for data assimilation of the mobile monitors at time t+1 based on all available observations up to time time t.

The performance of the sequential assimilation with and without targeting of observations is assessed in a realistic framework. It focuses on the Bugey nuclear power plant (France) and its surroundings within 50 kilometres from the plant. The existing surveillance network is used and realistic observational errors are assumed. The targeting scheme leads to a better estimation of the source term as well as the activity concentrations in the domain. The mobile stations tend to be deployed along plume contours, where activity concentration gradients are important. It is shown that the information carried by the targeted observations is very significant, as compared to the information content of fixed observations. In the realistic context of this experiment, the adaptive observations are 3 to 7 times more informative than the observations from the fixed surrounding network. A simple test on the impact of model error from meteorology shows that the targeting strategy is still very useful in a more uncertain context.

Given the present ratio of targeted observations versus fixed observations, the technique should prove more useful in this context than its known counterpart in meteorological forecast.

Example

The methodology is illustrated by a targeting experiment taken from Abida and Bocquet (2009). An accidental release from the Bugey power plant is monitored by 21 stations. The synthetic measurements at those stations are acquired every 30 minutes. They are perturbed multiplicatively by a log-normal law, with a standard deviation of the related normal law equals to 0.5. 10 mobile stations will be considered in this experiment.

Every two hours a source analysis is performed using the 84 observations acquired, plus 10 adaptive observations. It leads to an analysis of the plume, whose evolution is then forecast over the next two hours. This analysis is immediately followed by a decision to re-deploy optimally the 10 mobile stations, whose adaptive observations will be acquired two hours ahead.

Figure 1 displays the cartoon of the plume evolution knowing the source exactly, which is the reference dispersion event (column on the left), as well as the current wind field. It also shows the plume forecast from an analysis two hours earlier not knowing the source rate, but assimilating only the fixed observations (middle column). The fixed monitoring network used here is represented by crosses. Finally on the right column is shown the plume forecast from an analysis two hours earlier not knowing the source rate, but assimilating all observations, including the adaptive observations (10 every two hours against 84 fixed observations on the same time interval). The targeted observation locations are denoted by discs. The adaptive observations are following the plume contour, and the innovation is strong in this region.

As an illustration, their impact in terms of improvement of the analysis is assessed by a figure of merit and a correlation factor of the analysed activity concentration field with respect to the reference field. This is reported in Fig. 2. The lower curve corresponds to the figure of merit (correlation for the inset) of the analysis using only the fixed observations, while the upper curves correspond to figures of merit using in addition the adaptive observations. In between are the density plot of the figures of merit of 10^4 analyses using 10 targeted locations which are random rather than optimal. Although the adaptive observations represent only one tenth of the observations, it entails a significant improvement on the statistical performance indicators, and a gain of 30% to 70% in information load. As a consequence, optimality is much preferable than random deployment.

References

Abida, R. and Bocquet, M. (2009): Targeting of observations for radionuclides accidental release monitoring, in revision, Atmos. Env.

Berliner, L.M. and Lu, Z.Q., and Snyder, C. (1999): Statistical Design for Adaptive Weather Observations. J. Atmo. Sci., 2536–2552 , 1999.

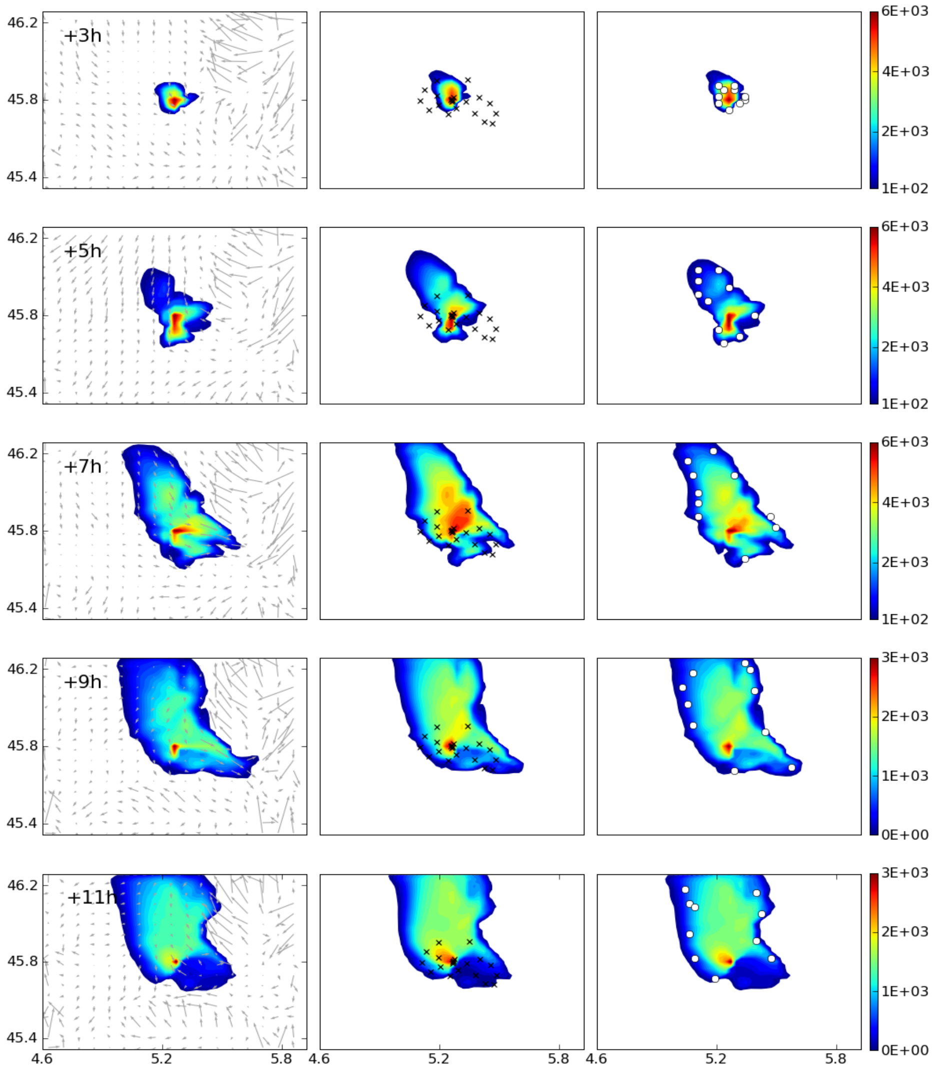

Figure 1: Cartoons of the reference dispersion event and subsequent forecasts. See details in the text.

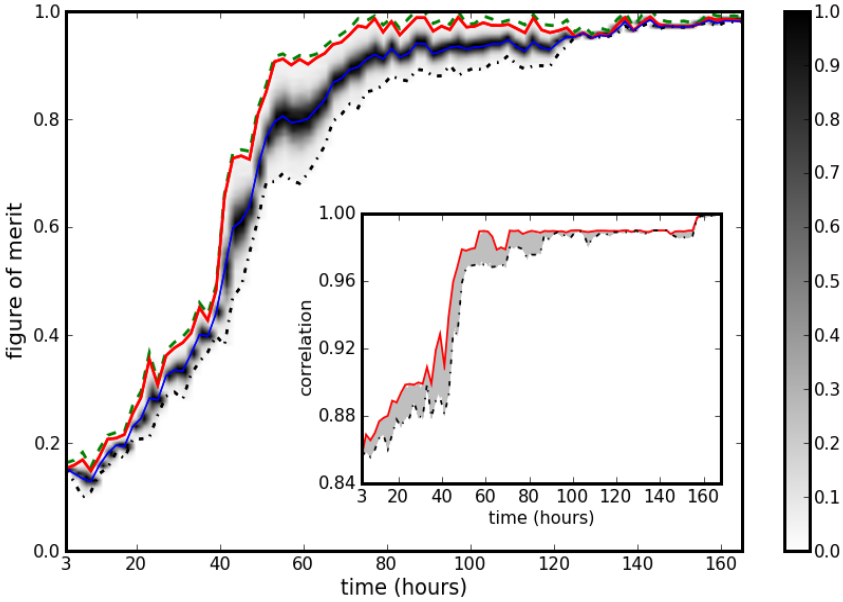

Figure 2: Figure of merit of the analysis assimilating the fixed observations (lower curve), or assimilating all observations according to a criterion based on the source (upper full red curve) or based on the concentrations (upper green dashed curve). The inset corresponds to the correlation between the same analyses and the reference.