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Title

Towards Inverse Source Term Estimation using Big Data Technologies

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Text

In the field of atmospheric dispersion modelling and its application for supporting decision making during events of atmospheric releases of hazardous substances (including radioactive), "inverse source term estimation (STE)" and "source inversion" refer to computational methods aiming at estimating the location and / or the emitted quantities of the hazardous material using both observations (measurements) and results of dispersion models. Such methods are typically used when the presence of a hazardous substance above the background levels in the air is detected by an existing monitoring network, while its origin is unknown. The most characteristic example of a real case involving radioactive substances that have been detected before the release was officially announced is the Chernobyl Nuclear Power Plant accident. The Algeciras incident is another example of an unknown radioactive release that was traced back after radioactivity levels higher than the background have been observed at very long distances from the release location.
Most commonly, inverse STE methods employ a (potentially large) number of forward or backward, in time, runs of dispersion models for the specific meteorological conditions that prevail at the times when the observations were made. Forward in time dispersion calculations can be made using as sources the potential (suspected) release locations, if these are fewer than the monitoring points where measurements exist. Backward in time dispersion calculations can be made by using the monitoring locations as sources and inversing the meteorological fields of wind velocity, if the monitoring locations are fewer than the potential release locations. The results of forward or backward dispersion calculations are then compared with the existing measurements through objective cost functions (that also include uncertainties of computations and measurements) used to identify the most probable release location.
If the meteorological conditions are highly variable in time and space and the terrain is complex, the use of advanced dispersion models is necessary and therefore inverse STE can be very time-consuming, which is a drawback in the frame of emergency response. In this and in a complementary paper (I.A. Klampanos et al., "A Big Data Architecture for Learning-Based Source Term Estimation"), we present and evaluate an inverse STE methodology in which the bulk of computations by advanced meteorological and dispersion models is made before an actual emergency. The modelling results are stored and, in cases of emergency due to detection of hazardous substances in the atmosphere, they are retrieved and, combined with current measurements, they provide estimation of the potential source location. In this respect, the aid of Big Data software technologies is necessary.
The particular use case presented here, concerns release and dispersion of radioactive substances due to a hypothetical accident in a nuclear power plant (NPP) located in Europe. The restriction of potential sources to NPPs is only made here to reduce the computational times in order to evaluate the method. The method can be directly extended to take into account any location of potential sources within the considered computational domain, in this case Europe. Re-analysis weather data covering a period of 30 years are downloaded, with a time resolution of 6 hours and spatial resolution of 0.7 degrees. We made use of NCAR services[1], using data

[1] http://rda.ucar.edu/datasets/ds627.0/

originating from ECMWF[2]. From these data a number of typical atmospheric circulation patterns are extracted aiming to represent almost all weather conditions observed so far over Europe. For each of these typical weather patterns, dynamical downscaling is carried out using WRF modelling system to a finer temporal and spatial resolution. Using the finer resolution meteorological data, dispersion calculations are performed with the model DIPCOT, taking as source locations all the NPPs considered in the frame of this evaluation study. In a real case of detected radiation levels above background, due to an unknown source, the actual weather is matched to one (or more) of the typical weather patterns. The corresponding pre-calculated dispersion results of the matched weather pattern are retrieved. The model-predicted dose rates at the locations of the sensors that detected the radioactive substance are compared with the measurements in order to identify the most probable source location.

[2] http://www.ecmwf.int/en/research/climate-reanalysis/era-interim