Ensemble Kalman Filter for Pollution Source Characterization in Water Supply Systems

Water distribution systems are a core infrastructure in people lives. Intentional or accidental contaminations can threaten their health and have to be detected in the shortest possible period to reduce damages. Early warning systems should be put in place to detect both the source location and the release intensity.

How to identify a contaminant source from concentration observations at monitoring locations can be cast as an inverse problem for which different approaches are available. In this work, the ensemble Kalman filter (EnKF) is chosen.

The EnKF is demonstrated in the Anytown network, which is a benchmark in water supply system analysis. The network is subject to a time variable demand in which a contaminant is introduced. The contaminant source is determined from concentration observations made in time at different frequencies. Measurement errors on concentration and estimation errors on the base demand are included to make the test case more realistic.

The case study deals with a release with uniform intensity that is originated from a source located in a node of the network. The sensors of the network register concentration values in time with a certain frequency. The scheme adopted for concentration sampling considers a malfunctioning of the sensor network, which introduces observation errors, and it is also assumed that sampling starts some time after the release has occurred and the contaminant has already spread through the pipeline systems.

Different locations of the source, frequency sampling and acquisition data period have been considered.

The results of the tests are very satisfactory for all the examined cases, in spite of the limited number of the ensemble members (48 realizations) and the non-stationarity of the concentration field, due to the intrinsic functioning of the network.

Results show that for the Anytown network, an early detection of solute concentration (within 60 minutes from the release beginning) together with a sampling frequency of 30 minutes is sufficient to accurately detect the source parameters in a short time. If the monitoring starts later, e.g. 3 hours after the beginning, the identification takes a longer time.