Application of generic data assimilation tools (DATools) for flood forecasting: A case study for the Rhine

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Abstract The importance of an accurate and early warning in the case of river flooding goes without saying. Within several European funded projects (IRMA-Sponge and EFFS), this wide felt need resulted in the development of a prototype open architecture flood forecasting system. In 2003, the UK Environment Agency (EA) commissioned an assignment to Delft Hydraulics for the development of redesigned version of this prototype now known as Delft-FEWS. Delft-FEWS is an ETL (Exchange, Transform and Load) system. With this system all sorts of hydrological and meteorological data can be imported into a database. Subsequently, this data can be automatically validated and transformed if necessary. Through a published interface (PI) every participating organization can couple its models to the central database. Once coupled, all sorts of tasks can be performed automatically such as running forecasts, importing data, updating the web or intranet sites, etc. (Werner et al. (2004), Werner and Heynert (2006) or in (Delft-FEWS, n.d.). Data assimilation is a key element of real time flood forecasting (Madsen et al, 2000), and most forecasting systems apply some form of data assimilation.

Data assimilation techniques are widely used in areas like meteorology, oceanography and hydrology. Despite the fact that current Monte Carlo type filters are model independent, most implementations of these sequential data assimilation methods however are custom implementations specially designed for, and integrated with the code of a particular model. This is probably a consequence of the lack of generic data assimilation software packages and tools. The use of custom implementations has a number of disadvantages (COSTA, n.d.):

- costs: the development and implementation of these methods is very time consuming and therefore expensive;
- incompatible: it is hard to reuse these data assimilation methods and tools for other models than for which they have originally been developed for.

Therefore, the objective of this study was the development of a generic sequential data assimilation module (DATools) for use within Delft-FEWS, and which can also be used standalone. The developed DATools software has been tested using similar case studies as used in El Serafy and Mynett (2003) and Weerts and El Serafy (2006), which were performed in the recent past using custom implementations instead of DATools. During the course of this study, a lot of information has been exchanged with the COSTA project (COSTA, n.d.) leading to the specification of identical interfaces for building blocks of both COSTA and DATools. The focus of the COSTA project is the development of a programming environment and is therefore more directed towards the programmers instead of the operational forecasters, which is more the focus of the DATools project.

One Twin experiment and one experiment in an operational system has been conducted with the DATools module. The twin experiment is conducted with both the ensemble Kalman Filter (EnKF) and the residual resampling filter (RRF) both can easily be configured in DATools. The model used is the conceptual rainfall-runoff model HBV-96 model for the Rhine basin. Uncertainties are specified for the inputs of the model and the observations used to filter. Figure 1 shows the result of the filtering with the RRF and the EnKF together with the observations (Qobs) and the true discharge (Q_{true}) for the Obsi (Ober Sieg) basin . The line without assimilation is also shown. Table 1 shows the RMSE of the Q_{true} with the forecasted discharges and the observed discharges. Similar results as shown in Figure 1 were found by Weerts and El Serafy (2006) for the twin experiment with the subbasin Nahe1 also shown in Table 1.

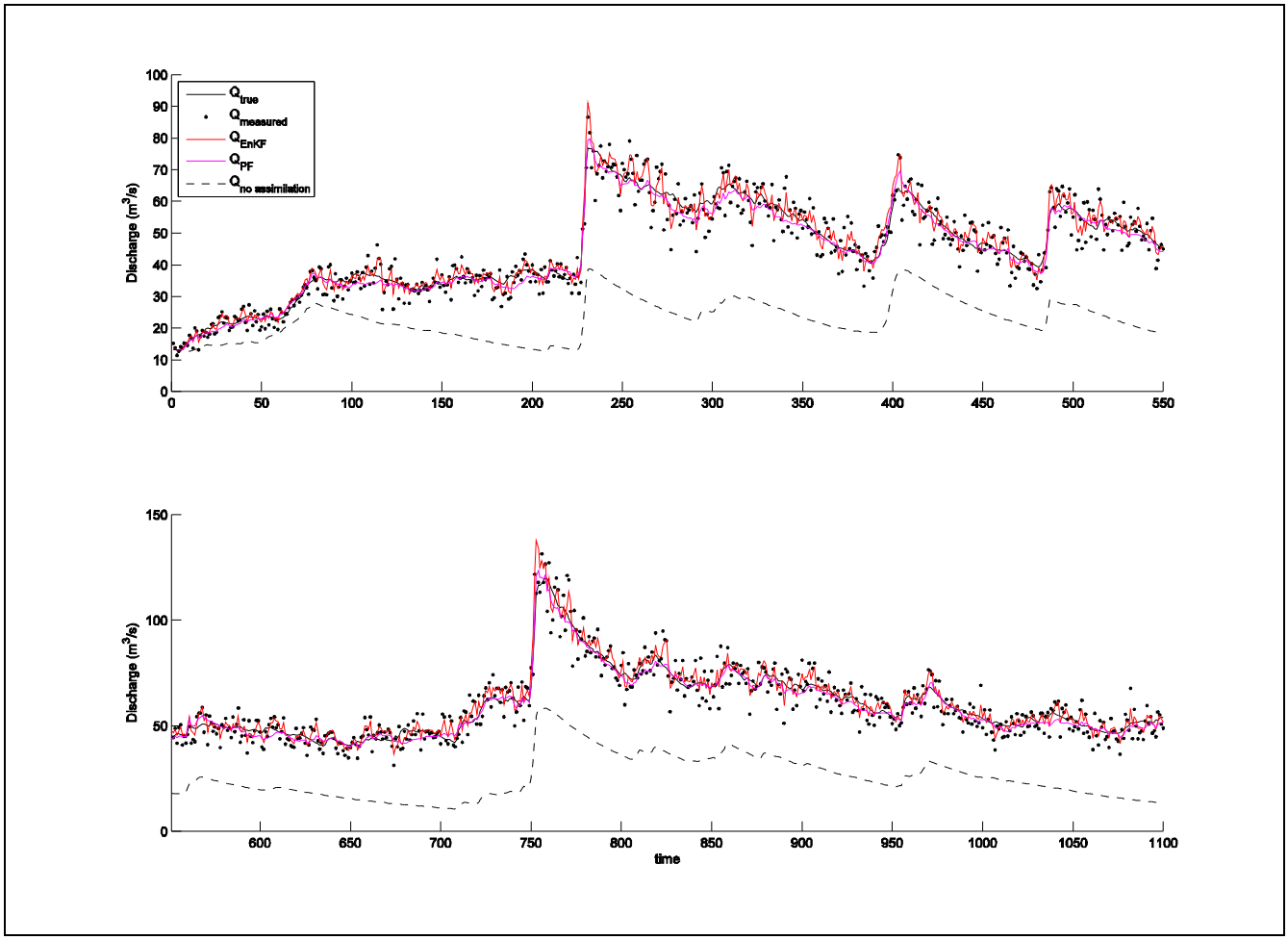

Figure 1. Results twin experiment with Q_{true} (black line), $Q_{observed}$ (black dots), Q_{EnKF} (red line), Q_{RRF} (magenta line), $Q_{no\ assimilation}$ (dashed black line).

Table 1. Root-Mean Square Error (RMSE) of the forcasted discharge using 32 particles/ensembles.

Discharges	$Q_{Observed}$	Q_{EnKF}	Q_{RRF}
RMSE (m3/s)	5.5	3.6	2.0
RMSE (m3/s)[1]	10.12	6.27	5.99

[1] Results for Nahe1 taken from Weerts and El Serafy (2006)

DATools is a generic software package for data assimilation. Using DATools, it is possible to apply data assimilation methods for existing and new models. The focus of DATools lies in enabling data assimilation methods for operational forecasters using Delft-FEWS, but can also be used for academic studies (standalone version). This means that the Published Interface (PI) interface of Delft-FEWS is supported, although some additional requirements with respect to state exchange have been added to the PI interface. Until now DATools has been linked with HBV-96, SOBEK-RE, SOBEK-RURAL, and the representative elementary watershed (REW) model.

The software has been tested with the conceptual rainfall-runoff model HBV-96 and the hydrodynamic SOBEK-RE model. Results of those test are satisfactory and comparable with ad hoc implementation of the data assimilation methods. In the near future links will be realised with

hydrodynamic DELFT-3D model and the groundwater model MODFLOW in cooperation with TNO. Additionally, the descripition of uncertainties will be further improved.

References

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