Geophysical Research Abstracts
Vol. 18, EGU2016-12645, 2016
EGU General Assembly 2016

Assimilation of multiple river flow data for enhanced operational flood forecasts

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Data assimilation (DA) is widely recognized as a powerful tool to improve flood forecasts, and the need for an effective transition of research advances into operational forecasting systems has been increasingly claimed in recent years. Nevertheless, the majority of studies investigates DA capabilities through synthetic experiments, while applications conducted from an operational perspective are rare.
In this work we present variational assimilation of discharge data at multiple locations in a distributed hydrologic model (Mobidic) that is part of the operational forecasting chain for the Arno river, in central Italy.The variational approach needs the derivation of an adjoint model, that is challenging for hydrologic models, but it requires less restrictive hypothesis than Kalman and Monte Carlo filters and smoothers. The developed assimilation system adjusts on a distributed basis initial condition of discharge, initial condition of soil moisture and a parameter representing the frequency of no-rainfall in a time step. The correction evaluated at discharge measurement stations spreads upstream thanks to the coupling between equations of flow channel routing, that results into the coupling between equations of the adjoint model. Sequential assimilations are realized on windows of 6 hours. We extensively examine the performances of the DA system through several hindcast experiments that mimic operational conditions. The case studies include both flood events and false alarms that occurred in the period 2009-2010 in the Arno river basin (about 8230 km2).The hydrologic model is run with the spatial and temporal resolutions that are employed operationally, i.e. 500 m and 15 minutes.The enhancement in discharge forecasts is evaluated through classical performance indexes as error on peak flow and Nash-Sutcliffe efficiency, with strong emphasis on the dependence on lead time. In addition, uncertainty of the estimations is assessed using the Hessian of the cost function that is minimized during the variational assimilation procedure.Results show that more significant improvements are obtained in floods events than in false alarms. For instance, error on peak flow reduces respectively of about 30% and 20% (lead time of nearly 20 hours) at the measurement station that is representative of river network outlet (S. Giovanni alla Vena).The best performances correspond to single peak flood events, while in some more complex cases DA does not significantly improve modeled discharges, possibly because of shortcomings in model structure.Forecasts at downstream locations enhance especially when peak flow of the main upstream tributaries is included in the assimilation window. In conclusion, the operational hydrologic forecasting chain can effectively benefits from the developed assimilation system, although in the limit of the model structure.