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Sub-Optimal Ensemble Filters and distributed hydrologic modeling: a new challenge in flood forecasting

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Data assimilation techniques based on Ensemble Filtering are widely regarded as the best approach in solving forecast and calibration problems in geophysics models.

Often the implementation of statistical optimal techniques, like the Ensemble Kalman Filter, is unfeasible because of the large amount of replicas used in each time step of the model for updating the error covariance matrix. Therefore the sub optimal approach seems to be a more suitable choice. Various sub-optimal techniques were tested in atmospheric and oceanographic models, some of them are based on the detection of a “null space”.

Distributed Hydrologic Models differ from the other geo-fluid-dynamics models in some fundamental aspects that make complex to understanding the relative efficiency of the different suboptimal techniques. Those aspects include threshold processes , preferential trajectories for convection and diffusion, low observability of the main state variables and high parametric uncertainty.

This research study is focused on such topics and explore them through some numerical experiments on an continuous hydrologic model, MOBIDIC. This model include both water mass balance and surface energy balance, so it’s able to assimilate a wide variety of datasets like traditional hydrometric “on ground” measurements or land surface temperature retrieval from satellite.

The experiments that we present concern to a basin of 700 kmq in center Italy, with hourly dataset on a 8 months period that includes both drought and flood events, in this first set of experiment we worked on a low spatial resolution version of the hydrologic model (3.2 km).

A new Kalman Filter based algorithm is presented : this filter try to address the main challenges of hydrological modeling uncertainty. The proposed filter use in Forecast step a COFFEE (Complementary Orthogonal Filter For Efficient Ensembles) approach with a propagation of both deterministic and stochastic ensembles to improve robustness and convergence proprieties. After, through a P.O.D. Reduction from control theory, we compute a Reduced Order Forecast Covariance matrix . In analysis step the filter uses a LE (Local Ensemble) Kalman Filter approach. We modify the LE Kalman Filter assimilation scheme and we adapt its formulation to the P.O.D. Reduced sub-space propagated in forecast step. Through this, assimilation of observations is made only in the maximum covariance directions of the model error.

Then the efficiency of this technique is weighed in term of hydrometric forecast accuracy in a preliminary convergence test of a synthetic rainfall event toward a real rain fall event.