

## ***Interactive comment on “Operational aspects of asynchronous filtering for hydrological forecasting” by O. Rakovec et al.***

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The work titled "Operational aspects of asynchronous filtering for hydrological forecasting" by O. Rakovec et al. presented a data assimilation study for river discharge simulations using the Asynchronous Ensemble Kalman Filter (AEnKF). The experiments are mainly focused on testing the effects of two procedures: lumped filter updates against observations from multiple time steps and partial updating of the model states. The study is very carefully designed and carried out and the paper is well organized and well written. In general, the study and presentation is of fairly good scientific quality. I recommend its publication after minor revisions.

Here are my main concerns:

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First of all, the AEnKF procedure needs some more justification and clarification. The authors described the AEnKF as a "state augmentation". It is not exactly the case because it only updates the current state  $x_k$  and none of the previous ones from  $x_{k-1}$  to  $x_{k-W}$ . (Of course, that probably shouldn't matter much if we only care about the forecasts.) Sakov et al. 2010 claimed that AEnKF is "formally equivalent to EnKS solution." This statement is only true if the dynamic system is strictly linear (see Equation 17 in Sakov et al. 2010). If the dynamic system is not linear, the step-by-step updates will make a big difference w.r.t. the lumped updates because the nonlinearity errors will accumulate during continuous and unconstrained model integration. Is the river routing scheme (kinematic wave) linear? Is the hydrological model linear? I guess not because otherwise the ensemble method wouldn't be used.

Given that, we can say the longer the update window  $W$  is, the more nonlinearity errors to accumulate. However, longer windows will bring more information to the updates. If the nonlinearity is not a problem, then the window should be as long as necessary. Pan and Wood 2013 experimented a river discharge assimilation approach that resorts to a full and explicit state augmentation over the longest necessary window, i.e., across the maximum streamflow travel time of the river basin involved. (Their study only works with a fully linear river routing scheme thus is free of nonlinearity errors.)

It is not clear whether the discharge observations at one gauge station are used to update all the grid cells in the entire basin or just those within the subcatchment that flows down to that gauge station. This is an important issue because the discharge from one gauge does not contain any information about the grid cells outside (i.e. downstream) of its own drainage area. Also, are the discharge data from all 6 river gauges assimilated altogether simultaneously, or one gauge at a time? The discharge from 6 gauges contain information of different lag times with respect to different grid cells. See Pan and Wood 2013 for a fully explicit handling of such lags in time and space.

Another major concern I have is the very short length of the study period. All we can

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see is just one winter event. It is really too short. We can't even see a robust model validation. We can't see how the DA behaves under other conditions (like low flows). This really limits the significance and robustness of any conclusion you can draw here. If extension is impossible, the conclusions have to be very carefully constrained.

I suggest the authors calculate the auto-correlation function of the innovation time series. That's the best way answer Referee 1's concerns on systematic errors. The EnKF types of methods are supposed to correct dynamic errors (i.e. time-random), persisting biases are considered static (time-invariant) errors, and they should be corrected using static methods.

Figure 6: I can't distinguish between the lines of different shades of red (different lead times). I can't even count how many lines there are on the plots. This has to be redone.

#### **Reference:**

Pan, M.. and E. F. Wood, 2013: Inverse Streamflow Routing. Hydrol. Earth Syst. Sci., 17, 4577-4588, doi:10.5194/hess-17-4577-2013.

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