A past discharges assimilation system for ensemble streamflow forecasts over France – Part 1: Description and validation of the assimilation system
G. Thirel et al.

Comment by Ben Zaitchik, Department of Earth & Planetary Sciences, Johns Hopkins University

The authors describe the implementation of a past discharge assimilation algorithm to an operational ensemble streamflow prediction system. This is a welcome effort, as gauged river discharge is an information-rich and relatively reliable hydrological measurement that is underutilized in data assimilation studies. The methodology is clearly defined and appropriate for the problem at hand. The authors report that data assimilation has a positive impact on model skill, which is the most important measure of success for an operational data assimilation technique. As the authors continue to develop and to refine their data assimilation methodology, I would suggest that they consider the following:

1. The BLUE algorithm assimilates actual discharge measurements rather than scaled values or anomalies centered on zero. This approach has the advantage of allowing data assimilation to correct for bias in the hydrological model. However, it also means that assimilation integrations have different mean discharge from open loop simulations, implying that assimilation alters the model's partitioning of the basin water balance and/or imposes an imbalance in the distributed water budget. This may be acceptable for operational streamflow forecasts, but it may disturb the physical consistency of the distributed model. If there are, indeed, persistent wet or dry biases in the hydrologic model (though these biases are not overwhelmingly large in the presented results) then the authors could consider using river gauge observations to optimize model parameterization rather than simply continuing to adjust the mean value through assimilation updates. This seems particularly appropriate since the authors have found it necessary to apply a rule-based truncation to drying increments in order to avoid unrealistic model behavior.

2. The authors note that BLUE can apply a variable time window when averaging past discharge measurements for assimilation. This is valuable, since discharge is a temporally as well as a spatially integrated measurement. However, if one is to be precise, this integration is a backward-looking convolution integral that is a function of the distribution of runoff events within the catchment area over space and time. Taking a simple one day average (or several day average) may be sufficient for operational purposes, but it would seem that skill could be improved further if the authors considered (1) implementing a smoother algorithm that maps an "end-point" discharge measurement onto soil moisture states over a time window of integration, and/or (2) applying knowledge of the distributed hydrologic response functions across the catchment area to allow for spatially non-uniform application of increments to gridded soil moisture fields. The smoother may imply some computational cost, but I would not think that it would be prohibitive operational applications.

3. Following on the question of hydrologic response functions: I don't fully understand why state variables are defined at the basin level, with increments simply applied uniformly to the ISBA grid (equation 7). Assuming that there is variability (and differences in magnitude of variability) between grid cells within a basin, it would seem preferable to create state vectors for each basin, of length N=number of grid cells in the basin. This would allow the assimilation system to be informed by sub-basin scale variability. Again, there would be some computational burden to this approach, but it would seem to merit at least experimental consideration.
4. I would encourage the authors to pursue their proposal to include aquifer states in the assimilation update. The absence of aquifer states from the current assimilation algorithm is an obvious limitation, and it seems that the PALM modeling framework is designed in such a way that it will be relatively easy to add aquifers to the update.
5. While I recognize that the authors are focused on operational streamflow prediction and not on other elements of the hydrological balance, it would be useful for those of us interested in data assimilation research if they could provide some information of the impact that data assimilation has on other fluxes and states. Does this routine provide additional benefits for simulation of soil moisture? What are the impacts on evapotranspiration?
6. The authors note that experiment IS_6 underperformed in some experiments because of a time-scale offset between drainage flux and the assimilation window. This makes perfect sense, but it would be interesting to explore this behavior more fully with varying assimilation windows and different prescribed timescales of temporal autocorrelation for state variables. One would expect that there is skill to be gained by treating soil layers two and three separately—especially in the context of grid-distributed updates, I would argue—so it seems a shame to lump them together into a single state variable.

I would conclude by noting again that this paper and its sequel are a welcome contribution to the literature, and I look forward to seeing further development of the streamflow assimilation algorithm in the future.