Response to Referee #1 for article hess-2013-463

Note: The text in *italic type* is the original comments from the referee, and the text in normal style with 1.5 line spacing, headed with "Reply", is the response from the authors.

Dear Authors, I enjoyed reading this manuscript, which I consider to be very interesting. The study addresses very important issues associated with the assessment of the streamflow prediction in ungauged locations transferring information (in terms of covariance matrix) from gauged locations. An Ensemble Kalman Filter, partitioned forecastupdate scheme, was used to update the states and parameters of a distributed hydrological model, SWAT. The previous methodology was applied to the Zhanghe basin, in China, assuming different scenarios of gauged and ungauged locations. The results of this study showed how the assimilation of streamflow observations at gauged locations can improve the prediction of discharge at ungauged positions. The paper is generally well written and easily understandable by the readers. However, the introduction has to be better organized to focus on the main innovation of this study. The study is, in my opinion, of broad international interest and it can be considered worthy for publication after a minor revision. I list below some main comments which I sincerely hope can become useful.

Reply Summary：

We would like to thank the reviewer for giving positive and constructive comments on our paper. We revised the introduction and provided explanations to the comments. Please see the reply below to each comment. When we mention specific sites (e.g., Line 3 and Page 2) in Reply to indicate revisions, these sites are all with respect to the revised manuscript instead of the printed version of HESSD.

A) As mentioned before, the novelty of this study it is not well presented in the paper. The section "Introduction" of this paper can be schematized in two different parts. In the first one, a description of the PUB initiative and a brief review of the regional methods used to propagate information from gauged to ungauged basins are proposed. Then, methods for data assimilation (Ensemble Kalman filter) with respect to the states-parameters estimation are reported. Honestly, I cannot see a connection between these two parts. Is this study the first one which deals with implementation of a data assimilation method in estimation of streamflow in ungauged sub-basins? My suggestion is to better explain if the proposed approach is actually new, by providing a better review of related publications about this issue (regional methods based on data assimilation techniques).

Reply：

Both of the regionalization and the data assimilation techniques can be used to address the issues associated with PUB. The regionalization technique is intentionally developed for PUB, and it is usually based on either a similarity approach or a statistical approach (Sellami et al., 2013). The data assimilation technique transferring information from gauged to ungauged basins is based on physical correlations between the neighbouring basins. So in the introduction we provide a brief review of the two techniques: regionalization and the data assimilation.

The data assimilation method used in this study (i.e., the PU_EnKF) was proposed by Xie and Zhang (2013) who have presented extensive documentation based on synthetic studies. To our knowledge, this study is the first one which explicitly employs a data assimilation method (i.e., PU_EnKF) with state-parameter estimation to improve streamflow prediction in ungauged locations. We do not find any references discussing regionalization methods based on data assimilation techniques. In the revised version of this paper, but we present more explanations of related publications about hydrological predictions with data assimilation to make the introduction more informative.

The main points of the reply are included in the manuscript, please see Line 20-24 of Page 4, Line 23-27 of Page 5, and Line 1-2 of Page 6.

B) Another issue is related to the concept of gauged and ungauged locations. Sivapalan (2003) mentioned that ungauged case is the case in which observations of the variables we are trying to predict are short, of too poorly quality, or even nonexistent. My concern is that, in the framework of ungauged basin and streamflow estimation, the authors applied distributed hydrological model which usually require a significant amount of data. May the Authors explain this choice (in addition to the reasons described at line 13 of page 13451 of the manuscript)?

Reply：

We agree with the reviewer that the application of a distributed hydrological model (DHM) is limited by its extensive requirements of data sets, including system input and response data (e.g., runoff, evapotranspiration, soil moisture). With the development of observation technology (e.g. remote sensing), most of model input data (e.g., forcing data, land cover, soil

properties, topography) are becoming available in certain precision. So we think the dominant factor restricting the application of DHMs is the system response data, especially the water discharge data which are generally used to calibrate the DHM.

If system response data are not available for a basin of interest (or the data quality is too poor), one may resort to credible input data and a capable DHM, but the model effectiveness is not guaranteed due to various unknown uncertainties. The evapotranspiration, soil moisture data and others from remote sensing retrieval would be useful for model calibration, but they are not so widely used in calibration due to notable uncertainties in these data. Much of the success for PUB decade so far has been in gauged basins instead of in ungauged (Hrachowitz et al., 2013).

In this study, the gauged data are also required for some sites (at least one site) in a basin of interest, and those data information is transferred to ungauged locations in the same basin by the data assimilation method. But the issue of extensive data requirement for DHM can be eased to some degree, because data from a few critical locations (e.g., the data from the basin outlet) can favor acceptable predictions as illustrated in this study and the study by (Xie and Zhang, 2010). The points are included at Line 13-18 of Page 12.

C) As described by the Authors, the correct estimation of the number of ensemble used in the EnKF is a delicate problem since the EnKF performances are directly connected with the model spread. The Authors provide a clear description of the method used to estimate the number of ensemble members but I could not find this last information in the paper. I think that an indication about the number of ensemble members (e.g. 10, 50 or 100) might be interesting for other researchers.

Reply：

The ensemble size in this study is 80. We included this information in the revised manuscript (see Line 19, Page 15). Sure, the larger ensemble size the better assimilation performance, but it will render higher computational cost.

D) In the section "Assimilation setup and scenario design", the Authors proposed to assimilate observations in interior points of the basins (ASS_BD and ASS_AB) in order to improve the streamflow prediction in pseudo-ungauged location (location C). Assimilation of discharge data in interior points of the basin was already analyzed in other studies (Clark et

al., 2008; Rakovec et al., 2012; Chen et al., 2012; Lee et al., 2012; McMillan et al., 2013;). My suggestion is to include these papers in the references of this manuscript.

Reply：

We included these papers as references (Line 27, Page 5). They are valuable for authors and for readers. Thanks.

E) In the section "Prediction in ungauged locations" the Authors state that "Adding an observed gauge (Gauge B) at the upstream in the basin, i.e. the ASS_BD scenario, provides better streamflow predictions in the pseudo-ungauged sub basins than the ASS_D scenario; the RMSE drops to 1.741m3 s^{-1}" (around line 15, page 13456). On the other hand, in the section "Conclusions" it is reported by the Authors that "the downstream data have more important roles in the data assimilation than those from upstream" (line 5, page 13459). In my opinion the interior location B provides an improvement in the model performance in C and this can be related to the spatial correlation between the streamflow in B and C. The sentence in the conclusion should be rephrased and it should include the reason why, using a particular location of interior point, there is an improvement in the model performances.

Reply：

We modified the sentence in the conclusion. The improvement of streamflow prediction using data assimilation depends on the correlation of physical processes between gauged and ungauged locations. If the two locations are very close (which means the correlation of flow processes will be strong), quit encouraging data assimilation performance will be shown. Generally, the downstream data (especially the data from outlet) have important roles to get a big picture of streamflow for the entire basin, since they contain accumulative flow information from all subbasins. Please see Line 13-15 of Page 20 for including of the point in this reply.

References

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