

## ***Interactive comment on “The suitability of remotely sensed soil moisture for improving operational flood forecasting” by N. Wanders et al.***

### **Anonymous Referee #1**

Received and published: 18 November 2013

### **Overview**

The study investigates the assimilation of satellite soil moisture and in situ discharge observations into the European Flood Awareness System (EFAS). The Upper Danube River at Bratislava (135000 km<sup>2</sup>) is used as case study where a dense network of gauging stations (23) is available. The performance of EFAS with and without the assimilation of soil moisture and discharge is evaluated both for simulating and forecasting (lead times up to 10 days) discharge and by using different configurations (also for model calibration).

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## General Comments

The paper investigates a very important topic related to the use of satellite soil moisture data for improving operational flood forecasting. Being highly interested to this topic, I quickly and carefully read the paper that I found well written and structured. Moreover, for the first time the assimilation of BOTH DISCHARGE AND SOIL MOISTURE is tested for a LARGE RIVER BASIN (135000 km<sup>2</sup>) into a DISTRIBUTED and OPERATIONAL hydrological model. All these aspects (in capitals) should be probably better underlined in the paper. Finally, the amount of elaborations and analyses behind the results shown in the paper is quite impressive. However, I found some important issues that should be addressed before the publication.

The paper only shows the final results obtained after the assimilation (or not) of soil moisture and discharge observations into EFAS. However, also the intermediate results should be given to understand the reasons for which improvements (or not) are obtained. Specifically, I listed below the results that should be added (in my opinion) to help understanding the content of the paper (note that some of them could be reported in an Appendix section).

### SOIL MOISTURE

Three different satellite products (from ASCAT, SMOS and AMSR-E) are assimilated. However, they are obtained with different algorithms and sensors (active and passive microwave, C- and L-band) and, usually, they show temporal patterns quite dissimilar in terms of dynamics (not in absolute terms because all the products are correctly rescaled to the same range before the assimilation). Therefore, I expect that their mutual assimilation may generate some issues. How are the products integrated? Are they assimilated at the satellite overpass time or by computing daily averages? This information should be clarified.

Moreover, some figures showing the comparison between modelled and observed soil moisture data, also subdivided by sensors, should be included. Specifically, it could be

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very interesting to see the soil moisture dynamic for the surface layer (where soil moisture data are directly assimilated) and the root-zone before and after the assimilation. In fact, recent studies (*Chen et al., 2011; Brocca et al., 2012*) have obtained that the assimilation of surface soil moisture has a very limited impact on the root-zone. Consequently, the assimilation has little impact on discharge simulation that is mainly driven from the root-zone soil moisture. Reading the paper, it seems that the assimilation of soil moisture has a significant impact (in contrast with previous studies). This depends on the assumptions made for the observations and modelling errors. However, little information is given on these errors. For instance, which is the relation between modelling and observation errors? Why is the impact significant? Which is the correlation between the surface and root-zone soil moisture? Which is the depth of the soil layers used in the model? An answer to all these questions should be provided.

The assimilation of only soil moisture data (without discharge) is only considered for the configuration where no discharge data are used for model calibration ( $Q0_{sat}$ ). For really understand the impact of soil moisture assimilation, the configuration where the model is well calibrated (with 1 or 7 discharge stations) and ONLY soil moisture is assimilated should be considered. This is missing in the paper.

At the same time, the benchmark simulations should be done by using 1 or 7 stations for the calibration, and without the assimilation of discharge. Also this configuration is missing in the paper.

## DISCHARGE

The simulation that considers the discharge observed at Bratislava for the model calibration ( $Q_1$ ) shows a consistent overestimation for the whole period (Figure 3). I do not expect this as after the calibration the modelled discharge should be closer (and unbiased) with respect to observations. Do the authors have some explanations for that? I believe that more information can be found in the paper submitted on WRR (*Wanders et al., 2013*) that is not available to reviewers. I suggest adding this paper

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in future submissions of the paper, as it appears to be relevant for understanding the content of the current paper.

Moreover, it is not clear if the assimilation of discharge is used for correcting the soil moisture states of the model. If yes (as I expect), which are the soil layers for which the assimilation has a significant effect? Which function/operator is used to update soil moisture states from discharge observations? Is it considered a time lag between discharge observations and soil moisture states? Can the authors address these issues?

Finally, the calibration, validation and assimilation periods are coincident. This is usually not good and clearly does not represent the real-time configuration when the model is run for future periods. Is it possible to consider the model calibration in a different time period? Moreover, probably I missed something, but I didn't find how the model performs for the discharge stations not used for model calibration (shown in Figure 1). Can the authors show these results?

In the Specific Comments I reported a number of corrections/explanations that are required.

On this basis, I feel that the paper deserves to be published on HESS as it addresses a very important and new topic but a major revision is required.

### **Specific Comments/ Technical Corrections (P: page, L: line or lines)**

P13785, L20: "... correct incorrect ...". Please revise.

P13786, L15-16: *Bolten et al. (2010)* and *Liu et al. (2011)* did not consider the discharge simulation. Likely they are not appropriate here. On the other hand, some recent papers could be mentioned and discussed (*Chen et al., 2011; Matgen et al., 2012*). Unfortunately, only few studies on this topic are available so far.

P13786, L21-22: "The potential to improve flood forecast...". This sentence is not well connected to the previous one. Please revise.

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P13786, L22: "...studies mainly study...". Please revise.

P13786, L29: Actually, the assimilation of both discharge and soil moisture for a real case study was only considered by *Aubert et al. (2003)* but using in situ soil moisture observations. To my knowledge, the assimilation of discharge and satellite soil moisture data has not been studied so far. I suggest changing the sentence "... not been extensively explored".

P13787, L5: The research questions are three, not two.

P13787, L25: It should be km<sup>2</sup>.

P13788, L8: Change "because" with "become".

P13789, L21: The revisit time of satellite soil moisture data should be 1 day.

P13791, L23: Satellite soil moisture data are not always available, how are they assimilated (see General Comments)?

P13793, L6: Add "soil moisture" between satellite and observations "satellite soil moisture observations".

P13795, L11: It should be  $F...(x, t)$ , t is missing.

P13797, L5-7: It is highly expected that the assimilation reduces the spread of the simulations. With the assimilation, the model is constrained to follow observations and, hence, the spread reduces. This result is not an added-value of the assimilation, please revise.

P13797, L16: Change "of 0.08" with "to 0.08".

P13797, L23: Change "none" with "not".

P13797, L28: Remove "the" from "that this the method".

P13798, L20: Change "assimilation" with "assimilated".

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P13810, L10: Remove "are reduced", it is repeated in the following line.

Figure 3: The last sentence of the captions should be moved in that of Figure 4. The opposite for the last sentence of the caption of Figure 4.

Figure 8: This figure should be explained better both in the caption and in the text of the manuscript.

### **Additional References**

F. Chen, W. T. Crow, P. J. Starks, and D. N. Moriasi, "Improving hydrologic predictions of catchment model via assimilation of surface soil moisture," *Adv. Water Resour.*, vol. 34, pp. 526-535, 2011.

P. Matgen, F. Fenicia, S. Heitz, D. Plaza, R. de Keyser, V. R. N. Pauwels, W. Wagner, and H. Savenije, "Can ASCAT-derived soil wetness indices reduce predictive uncertainty in well-gauged areas? A comparison with in situ observed soil moisture in an assimilation application," *Adv. Water Resour.*, 44, 49-65, 2012

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