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Interactive Comment

Interactive comment on "Calibration and sequential updating of a coupled hydrologic-hydraulic model using remote sensing-derived water stages" *by* M. Montanari et al.

M. Montanari et al.

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We would like to thank the anonymous referee #3 for his helpful suggestions, especially with respect to the remote sensing part of the manuscript. We fully agree that some clarifications on the description of the satellite data are required. We also understand the need for stating the objectives of the research more explicitly (cf. reply to referee #1) and for concluding the paper more concisely. While referring to the comments we obtained from the referees as of today, it becomes quite obvious that the objectives and findings of our research need to be outlined in a more unambiguous way in order to clarify the originality of this paper. Hence, we feel that the negative review of referee #3 originates from a misunderstanding of the intentions of the authors and from a misinterpretation of the results.

To put it very simple, in conceptual hydrologic modelling, the storage of water in the soil column determines the ratio between storm runoff and total rainfall (i.e. the stormflow coefficient). As it was stated in the introduction of the manuscript, one way of using satellite data to control these hydrologic models thus consists in assimilating remotely sensed soil moisture. This methodology, in the eyes of the authors, has two major shortcomings:

i) Remote sensing allows estimating soil moisture of the first few centimeters of soil whereas runoff generation is controlled by the vertical profile of soil moisture over the entire soil column. Surface soil moisture may not be a good enough proxy for assessing the readiness of a river basin to generate a fast response to a rainfall event (i.e. for anticipating the stormflow coefficient). It is possible to circumvent this problem by using more complex physically-based models (which are rarely used in operational hydrology) or by using simple models that allow inferring vertical profiles of soil moisture from surface soil moisture measurements. The associated uncertainties are very high in any case.

ii) One may argue that decently calibrated hydrological models give more accurate estimates of surface soil moisture than currently available remote sensing technologies. Instead of improving the models, an inappropriate use of these remotely sensed soil moisture values might thus deteriorate model performances.

There are a series of papers that study the value of remote sensing of soil moisture for hydrological modeling. In this paper we intended to test an alternative approach which consists in monitoring open water storage via remote sensing, thereby exploiting a direct way for assessing the ratio between incident rainfall and effective runoff. The application of this method to our case study allowed us to infer a stormflow coefficient

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that is very close to the “true” value as it was obtained from in situ rainfall and streamflow measurements. With the advent of more advanced SAR remote sensing technologies one may argue that the accuracy and reliability of this technique for monitoring surface soil water volumes will further increase.

Minor comments:

All the typographical errors will be corrected and the following explanations to the main issues raised by the Referee will be integrated in the final version of the manuscript together with his suggestions and the additional data requested.

1. Page 3216, lines 15-27: A) we are uncertain of our understanding about the first comment of Ref. #3. Has the reviewer got some doubts about the reliability of the references we mentioned at lines 17 and 18? We consider them trustworthy; B) we may have inappropriately used the term “small-scale” and we will replace it with “small areas”. As a matter of fact, we meant to remark the distinction between soil moisture monitoring over small areas (order of magnitude: 1 Km2) and large areas (order of magnitude: 102 Km2); C) in this paragraph we intend to give a general information about the factors affecting all SAR sensors, although we are aware that they can have more or less influence depending on the wavelength, the polarization and the incidence angle. However a detailed discussion about the different SAR sensors for soil moisture retrieval is not the purpose of the paper. Moreover, we consider it to be one of the advantages of the presented approach (i.e. extraction of water bodies) to be less dependent on the signal characteristics.

2. Page 3217, lines 9&12: we mean active microwave sensors and remote sensing of flooded areas respectively.

3. Page 3219, line 14: Marl or Marlstone is a calcium carbonate or lime-rich mud or mudstone, which contains variable amounts of clays and aragonite. The percentages of limestone and sandstone will be added in the final version of the manuscript. Line 26: the discharge is expressed in millimetres per hour because it is conceptually bounded

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with the unit used to measure the rainfall (millimetres). To convert mm/h in m3/s one has to multiply the value of the discharge and the size of the basin and to adjust the units.

4. Page 3221, line 11: the term “recession time scale” identifies a recession time constant that determines the emptying of the linear reservoirs of the Nash cascade as a function of storage.

5. Page 3221, line 16: Equations 1 and 2 represent only the core of the Nash cascade model, which are the instantaneous unit hydrograph and the relationship between the two parameters tp and n, respectively. In order to compute the discharge at the outlet of the basin, it is necessary to multiply together: the size of the basin, the specific discharge derived by the unit hydrograph and the effective rainfall. The latter represents the percentage of rainfall leaving the basin as streamflow during a storm event and is computed by multiplying the rainfall measured at the raingauge and the stormflow coefficient c. We will add the corresponding equation to the manuscript.

6. Page 3223, lines 20-25: A) ground surveyed flood extend marks located in areas without trees or buildings have been used to validate the flood boundaries estimated using the ENVISAT image (the field campaign was undertaken in correspondence to the flood peak). 92% of the ground surveyed flood marks lie within the confidence bounds of the SAR-derived flood boundary. Moreover the mean distance between the marks that lie outside this interval and these limits is equal to 4 m. This is lower than the coordinate accuracy of these points (accuracy of the GPS used to calculate the flood extend marks is of approximately 5 m); B) the hydraulic coherence algorithm is based on the law stating that hydraulic energy decreases from upstream to downstream. Under the assumption of low flow velocity, which is acceptable in the Alzette floodplain, this hydraulic law can be simplified into a decrease of water level in the flow direction.

10. Page 3230: the results obtained with the first approach show that calibrating all the parameters of the coupled model in one go using the SAR images is not feasible.

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Thus we decided to focus on the use of the SAR-derived flood information to assess the saturation status of the basin, i.e. we used the water levels estimated using the SAR images to calibrate only the stormflow coefficient. We consider the latter to be the only time varying parameter that can be sequentially estimated via remote sensing techniques. However, to do so it was first necessary to calibrate the other (constant) parameters, and this was possible since we demonstrated in this section that they are not event-dependent. Thus Section 5.3 is important because it represents a justification of the methodology and thus represents a prerequisite to the next step of the methodology.

12. Page 3232, line 4: the term “global” is used in order to distinguish this first evaluation from the “local” evaluation, described at line 17. The term “global” means that the evaluation of the stormflow coefficient has been performed over the entire river reach, on the contrary the term “local” means that the evaluation has been performed cross section by cross section. However, the term “global” will be replaced with “average” in order to avoid misunderstandings and make the meaning clearer.

13. Page 3232, lines 20-23: we consider that the uncertainties related to the estimation of the water levels using SAR imagery prevent us from obtaining a well identifiable value of the stormflow coefficient. These uncertainties stem from 3 main sources: the image processing (i.e. the choice of the radiometric threshold values), the georeferencing and the spatial resolution of the SAR image. Thus, we recognize that the term “noise” is not proper in this context because the uncertainties are not due to SAR noise but to the above-mentioned errors. Another source of uncertainty worth mentioning is the resolution and accuracy of the digital elevation model.

14. Page 3233, lines 9-10: within these lines we refer to the “mean uncertainty” introduced in Sec. 5.1. As stated in the discussion about the “all-at-once” calibration scheme (Sec. 5.2), the SAR-derived flood information at hand does not allow by itself unambiguously calibrating a multitude of model parame-

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ters because the above-mentioned “mean uncertainty” is too high. Two alternatives for reducing this phenomenon that is generally termed equifinality (Beven and Binley, 1992) could be the use of complementary field-recorded data sets (see Hostache et al., 2007) or additional SAR images (if available).

References:

Hostache, R., Schumann, G., Puech, C., Matgen, P., Hoffmann, L. and Pfister, L.: Water level estimation and reduction of hydraulic model calibration uncertainty using satellite SAR images of flood, BiogeoSAR, Bari, Italy, 25-28 September, 2007.

Beven, K. and Binley, A.: The future of distributed models: model calibration and uncertainty prediction, Hydrol. Process., 6, 279-298, 1992.

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