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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Assimilation of satellite data to optimize large scale hydrological model parameters: a case study for the SWOT mission" *by* V. Pedinotti et al.

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REVIEW 3

-Abstract p. 4478 l. 13-15: Please rephrase "might have locally signi?cant errors". The problems of parameter estimation occur across all scales and these errors rather "typically" occur.

Text corrected.

p. 4478 l. 18: replace "so that" with "and This line was removed as asked by reviewer 2. p. 4479 l. 1: please replace "leads" by "led"

Corrected in the text.

p. 4479 l. 4: I would recommend removing: "despite potential problems related to equi?nality" as this is vague and no particular problem with equi?nality were identi?ed in the study.

Corrected in the text.

p. 4479 l.6-9: "prediction" see general comments

Replaced by "simulation"

-Introduction p. 4479 l. 14: "such" is not appropriate here since no impact studies are mentioned previously.

Corrected in the text.

p. 4479 l. 15: I suggest you replace "over and under" by "above and below"

Corrected in the text.

p. 4479 l. 16-19: Please rephrase. This sentence is a bit confusing/long.

Replaced by "At regional or global scales, realistic representation of major surface hydrologic and hydrodynamic processes is very challenging and requires the use of computationally efficient, easily parameterized, comparatively simple and physically based routing methodologies"

p. 4479 l. 20: insert "the" before "huge"

Corrected in the text. p. 4479 l. 23: replace "but also" by "and"

Corrected in the text.

p. 4480 l. 10: Please simplify the sentence; the verb does not match the structure of the sentence. I suggest something like: "However, hydrologically complex areas such as wetlands or floodplains are better represented as three dimensional processes and

cannot be adequately. . ."

Replaced by " Yet, more hydrologically complex areas, such as wetlands and floodplains are three-spatial-dimension processes, cannot be adequately resolved using one-spatial-dimension observation"

p. 4480 l. 12-17: The link between these sentences should be made clearer. Perhaps specify that you are writing about different types of surface water monitoring?

" Hydrological models require information about continental water dynamics and storage variations above and below the surface for calibration and evaluation of the simulated water budget. To this end, diverse types of monitoring data are needed. In situ discharge data, for example, give 1-spatial-dimension information which quantifies water fluxes in a specific river channel, but do not give any direct information about runoff or lateral inflow. Yet, hydrologically complex areas, such as wetlands and floodplains which are three-spatial-dimension processes, cannot be adequately resolved using one-spatial-dimension observations (Alsdorf et al., 2007). Spatially distributed observations are required, such as those provided by satellites which give 2-dimensional information about surface water dynamics. Recently, efforts have been made to build global maps of floodplains variability and extent, providing an additional metric for CHSs evaluation (Papa et al., 2010). Nadir altimetry has also constituted a valuable progress for the monitoring of surface water dynamics and elevation (TOPEX-POSEIDON, ENVISAT, JASON 1 and 2; Baup et al., 2007; Santos Da Silva et al., 2012). " p. 4480 l. 25: Replace "concerning" by "For"

Corrected in the text.

p. 4480 l. 29: Remove "thus"

Corrected in the text.

p. 4481 l. 2: "geomorphologies"

Referee 2 suggested to remove those lines.

p. 4482 l. 8: replace "he" by "they"

Corrected in the text.

p. 4482 l. 12: typo "qmodeling"

Corrected.

p. 4482 l. 17: Input data such as precipitation should be included in the list as it tends to be one of the major sources of uncertainty.

Corrected.

p. 4483 l. 5-7: Please specify what type of data was used to evaluate the model and whether the model was calibrated.

'The model parameters were estimated using geomorphologic relationships to characterize the river characteristics. The modelling evaluation showed that the model was able to reasonably reproduce the major hydrologic and hydrodynamic processes. The model outputs were compared to in-situ discharge as well as satellite derived flood extent, total continental water storage changes and river height changes.' (added in the text)

p. 4483 l. 10-11: Consider merging the two sentences.

Corrected.

p. 4483 l. 17: "spatially distribute" awkward, please rephrase

Replaced by "Such data can potentially be used to estimate spatial parameters..."

p. 4483 l. 18-20: The results sensitivity analysis would be relevant here, especially in order to justify the stated objective of improving Manning"s coef?cient in the next paragraph.

Added :" These tests have shown that the model was sensitive to modifications of some key river parameters (river height and depth as well as Manning coefficient) and that a

good estimation of those parameters was required to optimize the simulation errors. "

-Study domain and model description p. 4484 l. 24: replace "thus" with "and"

Corrected.

p. 4485 l. 23: missing "resolution" at the end of the sentence?

Corrected.

p. 4487 l. 9: replace "this" with "the ?"

Corrected.

p. 4487 l. 22: "could be considered" is not strong enough in my opinion, the other effects are very important and "should be considered" would be more appropriate

Corrected.

p. 4487 l. 25-27: please provide references.

References added :"Pavelski and Smith, 2008; Yamazaki et al., 2014; Durand et al., 2010"

-Satellite observations p. 4489 l.5-8: I recommend removing "Indeed, here" and merging the two sentences: "It is assumed that the state of the system as well as the error statistics of the model and observations are known which will not be the case. . ."

Corrected.

p. 4489 l.8: remove "also"

Corrected.

p. 4489 l.9: reorder words: "since it allows for the quantification . . . modeling before launch"

Corrected.

p. 4489 l.11: typo: "in" -> "is"

Corrected

p. 4489 l.11: remove "indeed"

Corrected.

p. 4489 l.18-20: Missing verb. Perhaps "The . . . results are generated . . ."

The verb here is "to result from". The sentence explains that the background simulation is obtained from a different simulation in which the Manning coefficient was perturbed.

p. 4489 l.23: "and/by assimilating" rather than ", assimilating"

Corrected.

p. 4490 l.5: I think that ", in addition to" should simply be "and" if I understand the sentence correctly

Corrected.

p. 4490 l.9: The problem of water level/surface elevation/depth will be present for all applications using real data, not only real time. More discussion should be included on the impact of neglecting this.

Added : "Thus, for DA applications in real conditions, the direct comparison between SWOT and ISBA-TRIP water levels will not be straightforward and will need further investigation. For example, the model and the observations could be compared in terms of water elevation anomalies (relative to a reference which would be representative of a pluri-annual averaged water elevation). However, in the framework of an OSSE, the same model is used to generate the apriori and observed water levels and this issue can be evaded. "

p. 4490 l.12: Is this out of the scope of an OSSE or simply of this study?

The framework of the OSSE allows to evade this issue as direct comparison between

apriori and observed WL can be done. The sentence was modified to make a clearer point.

p. 4490 l.20: "earth"s rotational speed"

Corrected.

p. 4491 l.7: repetition, replace with: "investigated within the DA framework"

Corrected.

-Data assimilation schemes p. 4491 l.19: remove "indeed" and commas

Corrected.

p. 4491 l.25: remove "indeed". "Hydrodynamic models" cannot be the subject here, "modelers" could.

Corrected.

p. 4492 l.6: I think there are more problems than just a scale issue. How accurate is this linear relation to width? I think it is important to clearly acknowledge that the initial value of the roughness used would be very uncertain in a real case (especially for an uncalibrated model).

Replaced by : "These geomorphologic relationships are used to obtain the spatially distributed Manning coefficient which provides a 'global' fit or best estimate. However, the accuracy of these relations can be very uncertain due to the significant heterogeneity of the river and land properties, especially in uncalibrated models"

p. 4492 l.15-18: I do not understand the relevance of the variability of the correction of the coefficient in the context of this study: since the SWOT observations are generated using a constant "true" Manning, the assimilation-estimated Manning would have no reason to bene?t from this. What was the reason for the choice of the 2-day time window?

A longer assimilation window requires a larger computational and storage capacity than available for this study. As the principal scope of this work is to present and assess the DA methodology, it was decided to use a simple configuration with an assimilation window of two days. Since this study was performed, the computational capacity was improved and the impact of the window's length was investigated. A DA simulation was done with a 22 day assimilation window and showed a quicker and better convergence of the Manning coefficient. This will be the subject of a future article which will also discuss the impact of considering other sources of model uncertainties and non gaussian errors. In real conditions, it might be relevant to investigate the possible time variability of the Manning coefficient especially in areas where flooding events usually occur.

p. 4493 l.12: Is 20% error Manning"s realistic considering typical variations between streams?

The authors are not sure to understand the question but this 20% error is issued from the sensitivity tests performed in Pedinotti et al. (2012) and Decharme et al. (2011). According to these studies, 20% constitutes a realistic (or assumed) range of error on this parameter.

-Results p. 4496 l.5: an absolute relative error should be used in order to carry out averaging.

This is correct and the absolute relative error is actually what was calculated to compute the average. The expression of the calculation is wrong. This was corrected in the text.

p. 4497 l.15: typo? "differs"

Corrected.

p. 4497 l.25: Is there any proof for the physical link between the width and the in?uence of the roughness? I can think of two other possibilities: - the hypothesis of linear relation between width and roughness means that the 20% std will lead to a larger

absolute error on the roughness for wider rivers - it is not necessarily related to width as any errors (occurring or corrected) upstream will have an impact on the downstream portion of the river as well (and rivers just happen to typically be wider downstream)

The sentence was replaced by :"The improvement is larger for stations that are located downstream of the river, possibly because of the cumulated corrections upstream of these stations. Moreover, the hypothesis of linear relation between width and roughness means that the 20% sandard deviation will lead to a larger absolute error on the roughness for wider rivers."

p. 4498 l.14: Please include some discussion of why the impact on flow is smaller than for levels. Shouldn"t this be expected since the Manning"s roughness is in fact updated through level measurements?

This is indeed expected since the Manning' roughness is updated through level measurements. The improvement of discharge can be seen as a secondary effect of the improvement of the Manning coefficient, although the discharge-Manning or discharge-level relationships are non linear.

p. 4498 l.15: I disagree that a "seasonal variability" is seen for the assimilation results, rather it appears that the open loop run is closer to the "truth" during the dry months leaving little room for improvement (this is more or less what is then written on line 20 regarding sensitivity to Manning"s roughness, but the separation of this in 2 paragraphs is confusing)

The sentence about seasonal variability was removed.

p. 4498 l.19: It is unclear what you mean by "noisy", is this the same 20-day "noise" from the level observations?

Yes, it is the same noise than observed for water levels and this precision was added in the text.

p. 4499 l.13: Please rephrase to avoid using the word "results" 3 times

Corrected.

p. 4500 l.19: list what you mean by "continental reservoirs" here to avoid confusion.

Replaced by :"regional to large scale continental reservoirs including river, groundwater, aquifers and floodplains"

p. 4501 l.2: I agree that there is typically a lack of data for monitoring of these storages. However, I think it should be pointed out that the physical representativeness of the modeled values is not guaranteed, specifically because of the lack of monitoring data.

This comment is relevant and was added to the text. The physical representativeness of the modeled values is not guaranteed, specifically because of the lack of monitoring data. Here, the values have simply been bounded to be within a reasonable range (based on rivers similar to the Niger and the scale of TRIP).

-Discussion

Considering that the assimilation corrects the Manning's number I recommend discussing the improvement on this parameter before the impact on levels.

Corrected.

p.4502 l.9: "degradation of the error estimates": please explain what you mean. Isn"t the discussion here about improving these estimates? The fact that they are no longer Gaussian is not a degradation. Or do I misunderstand your meaning?

The "error estimates" refers to the relative errors that are calculated for the evaluation of the assimilation. The introduction of non gaussian observation errors in the assimilation method would require the change of the assimilation filter since the EKF makes the hypothesis of gaussian errors. The sentence was changed to :"However, their introduction in the system is not obvious and the use of a different assimilation filter due to the aforementionned Gaussian issue."

p.4503 l.8 : what would be the impact of assimilation windows of different lengths?

As said previously, an ongoing study is investigating the impact of the assimilation window's length on the assimilation performance. Preliminary results showed that a longer assimilation window improves the performance of the model which is expected because for each correction, there is more information available about the water dynamics in space and time. This will be the subject of a future article.

p.4503 l.17-20 : Is this not a repetition of the discussion from p.4503? This paragraph would fit better after the discussion of the Gaussian observation error and other sources (f.ex. precipitation etc.).

Corrected

-Conclusions I think the conclusion would benefit from having some information removed. For example it is unnecessary to repeat why Manning"s number was the chosen parameter (p4503 l. 24-p.4604 l.4)

The conclusion was shortened as advised by referee 3Âă: 'This study presents a simple method for assimilating SWOT virtual water level into a large-scale coupled land-surface hydrology model (TRIP-ISBA) in order to improve estimates of the required global hydrological model input parameters. In this case, the assimilation is used for the correction of a single parameter which is the Manning coefficient. To accomplish this, an Observing System Simulation Experiment (OSSE) was performed, using virtual SWOT observations of water levels. Two orbits, with different subcycles but with the same 22 days repeat period, have been considered to generate the observations (1-day and 3-day subcycles), each one providing a specific spatial and temporal coverage of the domain. Uncertainties on the estimation of the Manning coefficient are assumed to be the only sources of modeling errors. The Extended Kalman Filter (EKF) algorithm was applied every 2 days (the length of the assimilation window) to compute an optimal Manning coefficient (analysis). The Manning coefficient globally converged for both orbital subcycles to the same average value, the convergence being faster for the 3-day subcycle orbit. The method leads to a global reduction of 40% of the Manning

coefficient error over the river. This correction significantly improved the water levels (the error has been reduced by 30% for the river) and, to a lesser extent, discharge (7% of reduction of the error which can be significant for the Niger river in terms of water resources considering that its mean annual discharge is $6000m^{3}.s^{-1}$). Moreover, the biggest improvements were observed downstream of the river (Lokoja), which is a valuable result for climate applications which require estimation of the discharge at large rivers mouths.

This method gives a promising perspective for global scale applications, and it could be extended to other large basins. However, several relatively simple hypotheses have been made, and these should be addressed and refined in future studies. The context of the OSSE allows the evaluation of the model but does not guarantee the physical representativeness of the corrected values obtained in this study. Moreover, other sources of uncertainties should be assumed for the assimilation, such as rainfall errors and/or river bankfull depth. Modeling errors such as those from the ISBA land surface parameterisation should be considered, such as that pertaining to runoff. It was also considered in this work that observation and modeling errors were not correlated in space and time which might not be realistic. The use of more realistic errors simulated by Lion (2012) in the framework of the SWOT mission pre launch investigatiions will be considered in future studies.

Another perspective consists in the application of this method to other TRIP parameters, or several parameters at a time. Correction of ISBA parameters, such as those controlling sub-grid runoff for example, is also planned but must be considered carefully as the impact on the river is less direct. Before the satellite launch, the AirSWOT airborne campaign will provide SWOT-like datasets of water level, which will enable studies using a more realistic SWOT DA application, instead of the Observing Simulation System experiment presented here. Even if this airborne campaign will not cover the Niger basin, it will potentially provide a better observation error model. Yet, using more complex observations and model errors might require a modification of the as-

similation scheme to overcome extremely strigent EKF filter asumptions of Gaussian unbiased errors. Possible assimilation techniques to test are the Ensemble Kalman Filter or the particle filter.'

p.4505 l.10: "Another perspective: : :": the organization here is confusing as the previous sentence is about results and not perspectives. The conclusion should be reorganized so that this follows the suggestion of further work with different error models, and so that the first part of this paragraph directly follows the assertion that the assimilation experiment provided good results (somewhere around p.4504 l.17).

Corrected

p.4505 l.21: "the/run" typo? -Figures Fig.4: typo in legend "input" Fig. 8, 13 & 18: missing y axis labels Fig.10: y axis should be unitless Fig.11: appears to be missing two locations Fig. 14: Please correct numbering

All corrected

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