Hydrol. Earth Syst. Sci. Discuss., 7, C5122–C5129, 2011
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Interactive comment on "Combining satellite radar altimetry, SAR surface soil moisture and GRACE total storage changes for model calibration and validation in a large ungauged catchment" *by* C. Milzow et al.

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Received and published: 22 February 2011

We thank the reviewer for his detailed review of our manuscript and his recommendations. We think that especially the recommendation of an automatic calibration will improve our manuscript.

REVIEWER'S GENERAL COMMENTS

1) Qualitative vs. quantitative approach

Following the suggestion of the reviewer we are performing an automatic calibration of the model. By doing so, we resolve many of the weak points that the reviewer has identified. The subjective judgment involved for a manual calibration is avoided. The different observational datasets are also rigorously combined because we apply a multi-objective calibration that tries to minimize the difference between all observational data and their respective simulation. Because of the non-linearity of our model we apply a global search algorithm.

2) Manuscript structure and data description in the introduction

We think that a detailed description of the remotely sensed datasets that we use is useful because some of these datasets (gravity, soil surface moisture and altimetry) are not commonly applied in hydrological modeling. Reviewer 3 is even asking for the description of additional datasets. We will improve by adding short statements on where the data we apply have already been used by other researchers.

There has been very little research published on the Okavango catchment in the past (a lot, though, on the downstream Okavango Delta). We will emphasize this and present few more existing studies on the catchment hydrology and land use.

REVIEWER'S SPECIFIC COMMENTS

1) Bias identification and usage of the term "bias"

Our use of the term "bias" was partly incorrect and we will remedy to this. In the

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abstract we will replace “but support bias identification in the precipitation data” with “but support the identification of periods with over- respectively underestimations of the precipitation input”. The term “bias” would, without further specification, imply that the entire length of the considered time series is affected by it.

In section 4.3 we will replace “that the unknown bias is constant over time” with “that the conceptual differences introduce biases that are constant over time”

In the results sections we will replace “The over-prediction of discharge in 2008 is most likely due to a bias in the precipitation product” with “The over-prediction of discharge in 2008 is most likely due to an overestimation of the precipitation product for that year”.

2) Precipitation aggregation and HRU/subbasin size

The precipitation data are aggregated to the subbasin resolution by averaging all values of precipitation data grid cells within each subbasin shape. A weighted averaged is used that accounts for precipitation data grids cells located only partially within a subbasin. In SWAT, precipitation inputs are defined at the subbasin scale.

Our subbasins cover areas of 49312, 12782, 31837, 19766, 14223, 37174 and 4338 km^2. The pecipitation grids have cells of approximately 64 (FEWS), 2500 (TRMM) and 22500 (ECMWF) km^2. Only the last subbasin is significantly smaller than the grid cell of the coarsest precipitation product. This last subbasin (the most south-eastern one) has a very dry climate and contributes virtually no runoff to the river.

The spatial or temporal resolution of the products does not seem to be correlated to the 2001-2009 average precipitation over the catchment (Figure 2a of

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the initial manuscript).

There are presently no in-situ precipitation gauges in the catchment for a validation and bias identification of the precipitation products. If such gauges would exist, their data would be assimilated to the precipitation products, making a validation use impossible. Also, the observed difference between the products would likely be strongly reduced with the input of gauged data. We have therefore opted for a validation of the present products using historical gauged rainfall and runoff data (Figure 2b of the initial manuscript). The historical annual rainfall to runoff ratios are compared with the ratios of present annual mean runoff and annual mean precipitation as given by the three available products. FEWS-Net is closest to the historical data in this analysis and we therefore select it as “most trustable” precipitation input. Our approach assumes that the historical rainfall data are not biased.

3) Aggregation of soil surface moisture (SSM) data

The 1 km resolution SSM data are aggregated to the subbasin resolution and to the catchment. We show only the comparison at the catchment scale because the comparison at the subbasin scale didn’t reveal any other findings than those presented at the catchment scale.

4) Automatic calibration

As described above, we will integrate the results of an automatic calibration into the revised manuscript.

5) Bias

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As noted above we will clarify our use of the term “bias”. We used historical rainfall data to identify the less biased precipitation product. We then conduct our main analyses and the calibration with the identified product (FEWS-Net).

6) Goodness of fit measures

We are already presenting values of the Nash Sutcliffe model efficiency (NSE) for simulated and observed discharge at Andara (using FEWS-Net precipitation) in the results section. We will add the NSE values for the simulations with scaled (same long term mean as FEWS data) TRMM and ECMWF precipitation. The automatic calibration will also introduce a series of goodness of fit measures.

REVIEWER’S COMMENTS ON DETAILS

- Data combination (title, abstract, conclusions)

Through the automatic, multi-objective calibration the data will be combined in an objective way.

-Acronym SAR (abstract): Synthetic aperture radar, will be written in full at first appearance

- Model application for agricultural development scenarios (p.9125, l.11)

This point is also noted by reviewer 3. The goals of the work presented in the manuscript and the goals of the overall project will be more clearly differentiated in the revised manuscript. See the response to reviewer 3 (point 2) for details.

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- Gauged catchment (p.9126, l.13)

We will change our terminology from “ungauged” to “poorly gauged” throughout the manuscript. See also the reply to reviewer 1 concerning data availability.

-Acronym SCS (p.9129, l.9): Soil Conservation Service, will be written in full at first appearance

-Data for Hargreave’s formula (p. 9129, l.15):

Input data to the ET_0 calculation with Hargreave’s formula will be given in the revised manuscript (maximum and minimum daily temperature, incoming extraterrestrial solar radiation).

-Model resolution (p.9130: l.6-10)

The model setup counts 86 HRUs with size ranging from 23 to 12029 km^2 and a median at 970 km^2. The water balance calculations are performed at the HRU level.

- split sample validation (section 5)

As noted by Ǩlemes (1986) in his widely accepted article on model validation techniques, given that our model is developed to evaluate the impact of future land use change, a proper validation requires a “differential split-sample test". In such a test the sample (period with available input data and gauged stream flow) is split in two periods that differ in their land use. Since in our case two gauged periods with different land use are not available, a validation of the SWAT model together with our parameter set for the Okavango catchment

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and our application is strictly speaking not possible. A simple split-sample test would allow the validation of our model and parameter set for e.g. completing interrupted time series of discharge with complete time series of meteorological data. Since this is not our purpose we prefer to use the full time series for calibration. By doing so, we improve the calibration potential and let aside a validation that would be of little relevance for our study.

Still according to Ǩlemes (1986), the SWAT model itself (but not our particular parameter set) can be validated for the purpose of assessing the impact of land use change by using a gauged "substitute basin" in which land use change has occurred during the gauged period. Catchments fulfilling these criteria are unfortunately very rare. The study by Alansi et al. (2009) is an example of a differential split-sampling test. The validation is successful but land use changes are not very large between the calibration and validation periods. Heuvelmans et al. (2004) address the problem of land use change by exchanging calibrated model parameters of different catchments with different land uses. The authors conclude that "the transfer of parameter estimates between catchments with different environmental conditions [...] may be problematic". However their study catchments differ not only in land use properties but also in slope and soil type.

Realizing the difficulty of a meaningful validation, we will remove "validation" from the title and briefly explain the notions stated above in the revised manuscript.

- Periods for annual means (caption of figure 2)

Both periods (August to July and November to October) cover exactly 12 months and thus allow for annual means to be taken. We will clarify by writing the periods and the "to" out as done here. The two periods are shifted

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because the high flows at the catchment outlet are shifted relative to the rainy season in the catchment.

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