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Hydrology and Earth System Sciences Discussions

HESSD

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Interactive Comment

Interactive comment on "Water balance modelling in a semi-arid environment with limited in-situ data: remote sensing coupled with satellite gravimetry, Lake Manyara, East African Rift, Tanzania" *by* D. Deus et al.

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Reply to Reviewer 2-C4953-2011

We present here our answers to reviewer #2. We are grateful to the reviewer to have raised inconsistencies and shortcoming in our manuscript. We have amended the manuscript and hope it has improved. Nonetheless, we disagree on the use of GRACE data. We, as other authors using GRACE-TWS, follow the guidelines of NASA for the use of their data. They explicitly state that the grid has a resolution of 1°, which is about 100 km in the region of interest. Additionally, even is the lakes of interest are smaller than the optimum resolution doesn't mean that the use of GRACE-TWS is not valid. Lakes are the hydrogeological "response" to effects that largely extent their physical boundaries. Finally, we did not use GRACE-TWS to model the lake changes. We simply state that GRACE-TWS data remarkably follow our model output and THEREFORE imply/infer that GRACE-TWS data could be well suited to monitor relatively small lakes. We have modified the text to make that clear and avoid further misunderstandings.

Reviewer comment 1:

GRACE data. The resolution of GRACE time-variable gravity data (greater than about 150 000 km2) is at least one order of magnitude coarser than the study area (about 450 and 18 700 km2 for the Lake Manyara surface area and the catchment area, respectively). The authors use GRACE data of the GRACE Tellus website. Besides of filtering with a Gaussian smoother of 300km radius, the basic GRACE spherical harmonic coefficients are considered only up to degree and order 60 in these data. This roughly corresponds to a wavelength of about 660 km or a pixel size of about 330x330km (110000 km2). Any smaller-scale feature cannot be resolved in these data. Thus, this product does not have a specific information content for the study area of interest here which is at least one order of magnitude smaller (or even two orders of magnitude as in the present manuscript if only the lake surface area is considered). The results may at best give evidence for the fact that the study area shows similar dynamics to a larger scale region in its surroundings. The conclusion that GRACE data may be useful for smaller lakes and basins (page 8763) is not valid.

Answer:

First of all we would like to point out clearly that we used global Total Water Storage land mass grid data in units of equivalent water thickness derived from GRACE gravity

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field. The spatial sampling of the data is 1 degree (Berker et al., 2010; Swenson and Wahr, 2006; Swenson and Wahr, 2009). The GRACE data have been scaled based on a numerical hydrologic model to behave as if they had a 1-degree spatial resolution when we apply the scaling coefficients. Therefore, GRACE land mass grid total water storage column dataset used in this study has a spatial resolution of 1 degree which is about 100km (10000 km2) and the size of the study area is 18700 km2. Based on this fact there is no any spatial scale mismatch between the dataset and the study area. With reference to the results presented and discussed on page 8760-8762 we are convinced that it is possible to use GRACE derived total water storage to identify large scale features. We stand by our conclusions on page 1763 that GRACE total water storage dataset may be useful for smaller lakes and basins.

Reviewer comment 2:

What is the 'true rainfall' reference that leads the authors to the statement that TRMM and GPCP underestimate precipitation in the catchment (page 8743, line 10)? How can they derive from the few station data they have throughout the study area a basin average value that is comparable to TRMM resolution?

Answer:

We considered rain gauge station rainfall data value as true rainfall value. So based on our comparison using four precipitation data sets we found that TRMM and GPCP rainfall values were below observed rain values. For comparison we extracted all corresponding TRMM and GPCP rainfall values for every rain gauge station. We are aware that an extrapolation from four stations to the entire catchment area could be insufficient. But, the stations used cover different areas of the basin and at different altitudes. We are quite confident that they are representative of the area. Additionally, these 4 stations are probably 4 more that most arid regions in the world would contain. This paper is aimed to provide suitable remote sensing approaches to environmental monitoring, not to validate available datasets. .

Reviewer comment 3:

The authors use MODIS-based land surface temperature (page 8744). This is very probably not the quantity required by the model as input for the evapotranspiration equation (which is air temperature for the Penman-Montheith approach), nor is it directly comparable to in-situ temperature data (fig. 5) which probably are air temperatures as well (although not exactly explained in the manuscript).

Answer:

We have modified the manuscript to make it clearer which input data were used. We argue that temperature estimates based on LST are suitable as we show a net correlation between in-situ air temperature and LST. We used both in-situ air temperature and MODIS LST to force two separate models. The results produced using the two models are quite similar (Fig. 1a,b). We have stated this in the modified text.

Reviewer comment 4:

The time resolution of the modeling approach is not clear. On page 8752, line 3, the authors state a monthly time step, other instances give evidence of a daily time step (e.g. page 8750, requirements for ET calculations with daily resolution). In particular in view of significantly varying energy fluxes between daytime and night and the corresponding non-linear ET response, using mean daily values may not be adequate for the Penman-Monteith approach.

Answer:

We carried out our final simulation on monthly time step. We agree that there are some typing errors on page 8751 about the time resolution used. This has been modified. The Penman-Monteith approach is widely used with daily data in very many hydrological studies and models. Also the Crop-ET guideline of the FAO is suggesting the use of Penman-Monteith with daily mean values. Therefore, we think that the use of the Penman-Monteith formula with mean values is an adequate way to estimate potential

ET.

Reviewer comment 5:

Figure 9 and page 8753. Model validation for evapotranspiration (ET). Of which type are the observed ET data? ET is generally difficult to measure, how can it be compared to model results? What exactly are the model and station data used for this comparison? How can it be argued that they are comparable in terms of, e.g., spatial scale, land cover type?

Answer:

We amended the manuscript to make clear that we used observed evaporation from ET pans for validation. We compared observed evaporation and simulated actual evapotranspiration at a single point/pixel. We are aware that pan ET cannot be directly be compared against ET from vegetated land surfaces. Here one would need a Lysimeter which is not available in the catchment. Anyway, we found out that both ET data show similar patterns and magnitude. In areas where in-situ data are scarce we have to adapt. Conventional methods, such as the ones used in Europe and USA, are not applicable in emerging countries.

Reviewer comment 6:

What is the difference between Fig. 11 and Fig. 16?

Answer:

As it is indicated in the figure descriptions Fig. 11 represents the catchment water balance parameters for the entire catchment while Fig. 16 shows the lake water balance of lake Manyara only.

Reviewer comment 7:

Given the lake change bars in Fig.15, Lake Manyara should experience a steadily declining water volume as negative values predominate (even for year 2007). How do

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the data in this figure relate to results shown in Fig. 18? Lake volume changes do not seem to be consistent in terms of magnitude between the two figures.

Answer:

Fig. 15 presents the lake volume changes neglecting the inflow from the catchment while Fig. 18 shows the lake water balance variations including such inflow. However we decided to remove figure 15 to avoid misunderstandings.

Reviewer comment 8: Extending my comment 7), how can a predominantly positive lake water balance as given in Fig. 17 explain the steady decrease of water volume in the lake?

Answer:

Fig. 17 presents the catchment water balance as a weighted combination of P-ET and P-E curves and not lake water balance as asked in the question. Lakes with a large catchment basin area relative to the lake surface area reflect a water balance more closely linked to the value of precipitation minus evapotranspiration such that the lake water balance is driven by a weighted combination of P-ET and P-E (Cardille et al., 2004).

Reviewer comment 9:

From a statistical point of view, it does not seem to be valid to draw a linear regression for the heterogeneous distribution of Figure 19.

Answer:

Point taken, we modified the text accordingly. Our interest was to show the correlation between the two dataset. We removed Fig. 19 from our presentation to avoid repetition simply because the correlation value is also indicated in Fig. 18b (Fig. 14b in the modified manuscript).

References

Cardille, J., Coe., M. T., and Vano., J.: Impacts of climate variation and catchment area on water balance and lake hydrologic type in groundwater-dominated systems: A generic lake model., Earth Interactions, 8, 1-24., 2004. Becker, M., LLovel, W., Cazenave, A., Güntner, A., and Cretaux, J.: Recent hydrological behavior of the East African great lakes region inferred from GRACE, satellite altimetry and rainfall observations., Comptes Rendus Geoscience, 342, 223-233, ISSN 1631-0713, doi: 1610.1016/j.crte.2009.1612.1010., Doi:10.1016/j.crte.2009.12.010., 2010. Swenson, S., and Wahr, J.: Post-processing removal of correlated errors in GRACE data., Geophysical Research Letters, 33, L08402. doi:08410.01029/02005GL025285., 2006. Swenson, S. C., and Wahr, J.: Monitoring the water balance of Lake Victoria, East Africa, from space, Journal of Hydrology, 370, 163-176, ISSN 0022-1694, doi: 0010.1016/j.jhydrol.2009.0003.0008., 2009.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 8, 8737, 2011.

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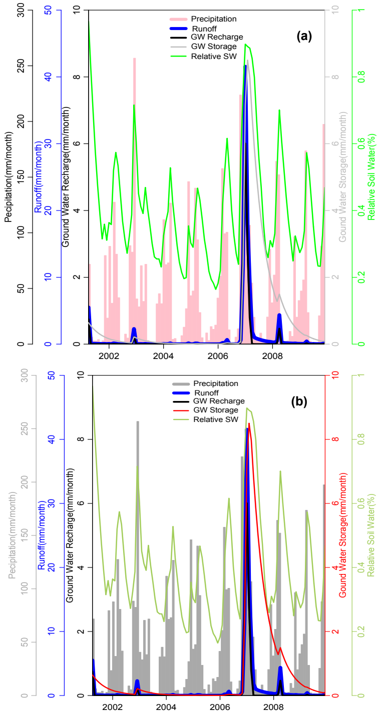

Figure 1: Model result based on (a) MODIS LST and (b) in-situ air temperature

Fig. 1.

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