

Response to Reviewer's comments on submission to Earth Syst. Dynam. Discuss., 4, 355-392, 2013 (doi:10.5194/esdd-4-355-2013)

Note: textual remarks, inconsistencies and minor errors have been updated in the new text wherever applicable. References refer to those used in the manuscript.

We wish to thank the Anonymous Referee #1 for his/her constructive comments and insightful suggestions on our paper. They helped us to substantially improve the quality of the manuscript. Our detailed responses to the comments of the Referee #1 are presented below.

Response to comments raised by the Anonymous Referee #1 (reviewer's comment in italics, changed text between quotation marks):

This study presents the implementation of a global water demand model into a global hydrological model to simulate water withdrawal and consumptive water use from surface water and groundwater resources. In my view, there is quite some overlap with the previous work of the authors, but the global modelling of water allocation from groundwater and surface water separately is a contribution. Overall the paper is well-written, but I think it would benefit by:

RC1. More interpretation (in discussion section) of the advantages of integrating the water use model in a water balance model compared to previous approaches.

A1. As pointed out by the Referee, Section 5 (Discussion and conclusions) was rather short. We have expanded the discussion regarding the advantages of our integrated framework compared to previous approaches.

RC2. Further explanations of methodology and assumptions made, in particular with regard to allocation of groundwater and surface water resources and calculation of return flows. It would also be good to show the sensitivity of trends in groundwater and surface water withdrawal to these assumptions.

A2. As suggested by the Referee, we have added the explanations and discussion about our water allocation scheme (surface water, groundwater) and the calculation of return flows, and the assumptions therein in Section 2.6 (Water allocation and return flow) and Section 5 (Discussion and conclusions). The discussion about the sensitivity to these assumptions has also been included in Section 5 (Discussion and conclusions).

RC3. In addition, further explanation of the new irrigation scheme is needed. Please explain why these algorithms were used, and to what extent this approach results in more realistic estimates of irrigation water demand compared to the previous approach.

A3. We have added further explanations of our new irrigation scheme in Section 2.3 (Irrigation water requirement) and discussion about the advantages of the new irrigation scheme in Section 5 (Discussion and conclusions).

RC4. I would recommend adding more country specific results which are discussed in the text but are not yet presented. For example, Fig 1 is interesting but does not show any results for individual countries that are discussed on P368/L16-19. I would

suggest to modify this figure (or add a figure/table) to show the country specific results that you discuss in the text.

A4. To improve the clarity, we have modified Figure 1 (now individual figure for each climate forcing with summary statistics). We have also added a table listing individual countries that are discussed in Section 4.1 (Accuracy of simulated irrigation water requirement (IWR)).

Response to specific comments:

SC1. P357/L20-27: Please note that H08, MATSIRO and VIC have already been applied on a higher spatial resolution (0.5 deg) and refer to recent studies that applied these models on a global level on higher resolution).

A5. We have referred to more recent studies for the three model and changed a spatial resolution to 0.5 degree.

SC2. I would recommend merging section “2.1 Water balance” and “2.2 Snow accumulation and melt” and excluding the “degree day algorithm”, because this is not a new feature of your integrated model. I think you may also assume that the degree day approach is well known.

A6. We agree that merging Section 2.1 and 2.2 would make easier to read. We have merged the two sections in our revised manuscript.

SC3. “2.3 Irrigation water requirement”: please explain why these algorithms were used to calculate irrigation water requirement and how this affects your results compared to the previous method used.

A7. We have added further explanations of our new irrigation scheme in Section 2.3 (Irrigation water requirement) and discussion about the advantages of the new scheme compared to previous approaches in Section 5 (Discussion and conclusions).

SC4. “2.4 Other sectoral water demands” P263/L24-25: Can you justify your assumption that daily industrial/energy water demand is kept constant over the year? This seems unrealistic to me and also inconsistent with calculations of water demands for other sectors (in with seasonal (daily-time step) variations included).

A8. This is a good point. As noted by the Referee, in reality, we expect that industrial water demand would also fluctuate over the year (the seasonal amplitude may not be large). For domestic water demand, we have found country statistics for seasonal demands and made a function to reproduce this trend (please refer to Wada et al., 2011b). However, due to limited available data, we were not able to obtain country statistics of monthly industrial water demand and to identify the seasonal trends. Therefore, we have kept industrial water demand constant following the study of Hanasaki et al. (2008a,b). We have added explanations to clarify this point as a limitation in Section 2.4 (Other sectoral water demands).

SC5. “2.6 Water allocation and return flow”: A motivation and further explanations of the assumptions made with regard to allocation of groundwater and surface water resources is needed. How realistic is the assumption that you allocate groundwater predominantly to meet the water demand with remaining water demand met from surface water (except in case of reservoirs) on a worldwide level? I can imagine that in some parts of the world this assumption is realistic and valid (e.g. river basins in

India) but not in all regions. Please include a motivation and show the overall impact of this assumption on your results.

A9. We concur this is an important point. As suggested by the Referee, we have added further explanations and discussion about our water allocation scheme (surface water, groundwater) and the calculation of return flows, and the uncertainties therein. The discussion about the sensitivity to our assumptions (of water allocation) has also been included in Section 5 (Discussion and conclusions).

SC6. “2.6 Water allocation and return flow”: Explanation of calculation of return flow is missing.

A10. We have added explanations of calculation of return flow in Section 2.6 (Water allocation and return flow).

SC7. “2.6 Water allocation and return flow”: For which years did you use country desalination water withdrawal data? Please also include a full link to the desalination water withdrawal data used from WRI Earthtrends and explain how you combined this data with FAO AQUASTAT.

A11. We used available country statistics of desalination water withdrawal for the period 1960-2010 from the two data sources. The data was obtained primarily from the FAO AQUASTAT database, but was supplemented by the WRI EarthTrends where applicable. The data is given in 5-year interval and we linearly interpolated the data to obtain annual values. We have added detailed explanations about the calculation of desalinated water withdrawal and the data sources.

SC8. “4 Result” P368/L3: Please explain how simulated TWS anomalies were calculated and how you compared this with GRACE.

A12. TWS was calculated from the sum of simulated snow, surface water, soil water and groundwater storage. The TWS anomalies were computed over the overlapping period of 2003-2010 with the GRACE data. We have added explanations of the calculation of simulated TWS and the TWS anomalies in Section 4 (Results).

SC9. “4.3 Regional trends of surface water and groundwater withdrawal and consumption”: I am wondering to what extent the rate of change in groundwater and surface water use is affected by the assumptions that you made with regard to allocation of groundwater and surface water? I think it would be good to reflect on this and show the sensitivity of estimated trends in groundwater and surface water to the assumptions you made.

A13. We concur this is an important point. The discussion about the sensitivity to our assumptions (of water allocation) has been included in Section 5 (Discussion and conclusions).

SC10. “5 Discussion and conclusion”: I would suggest to discuss in more detail the advantages of integrating the water use model in a water balance model compared to previous approaches (because this was defined as the overall goal of this study).

A14. As suggested by the Referee, we have expanded the discussion regarding the advantages of our integrated framework compared to previous approaches.

SC11. P375/L4-5 “Nevertheless, our simulated....., respectively”: You should add that this is presented for a selection of basins which are heavily affected by human impacts (this was not yet shown on a global level).

A15. We have revised the sentence and have specified the selected basins (also the limitation of our TWS assessment).

Technical corrections

-P369/L22 include “.” after “Western USA”

This has been corrected.

-Fig 2: It would be interesting to show these plots also for more regions (e.g. Asia).

Due to limited data availability, we were not able to obtain data for more regions such as Asia (would be very interesting though). Figure 2.a includes Asian countries but this is only for country totals rather than state/province values.

-Fig 3: More explanation is needed of how simulated and observed trends are presented in this figure. I would suggest creating plots with simulated and reported trends over time for different countries in separated figure panels.

As suggested by the Referee, we have recreated Figure 3 (now individual figure for each country/region with summary statistics). We have also added explanations of the new figure.

-Fig 4/5: Please increase the size of the figure panels to increase the visibility of numbers and trends presented.

We have revised Figure 4 and 5 to increase the visibility.