Hydrol. Earth Syst. Sci. Discuss., 12, C1773–C1778, 2015
www.hydrol-earth-syst-sci-discuss.net/12/C1773/2015/

Hydrology and Earth System Sciences
Discussions
Open Access

Interactive comment on "GlobWat – a global water balance model to assess water use in irrigated agriculture" *by* J. Hoogeveen et al.

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Received and published: 27 May 2015

We thank the anonymous referees for their constructive review of our paper. We will address the comments from both referees below:

Anonymous Referee #1, major point of criticism 1, structure of the paper. The current structure of the paper was chosen to describe the development of a new, Open Source, global model that could be parameterized by freely available global datasets, and that would be as much as possible consistent, in terms of generating comparable data, with the statistical data as available FAO's AQUASTAT. The objective of the paper is the description of the model and eventually a description of the accuracy of the model. Therefore, the equations were left in the main text (and not put in an Annex, even

though this was discussed among the authors), and the validation, against independent sources, is considered a result. The results from GlobWat have been discussed in other publications (FAO: World agriculture: towards 2030/2050, FAO: World agriculture: towards 2050/2080) and are not the focus of the current paper. With regard to the example that it is hard to understand that no results per crop are shown, this is because the cropping patterns on irrigated land are designed in a detailed way to obtain the most accurate results to be compared with data available in AQUASTAT. In AQUASTAT, no water withdrawal data per crop is provided so this would be beyond the scope of the objective of the paper. However, it is not difficult to obtain results per crop, and if it adds to the interest of the paper we should do that.

Anonymous Referee #1, major point of criticism 2, literature review. We are aware of the many improvements and adjustments in other models, but could not find papers describing the results of the improved model on a global scale. We will look into this further.

Anonymous Referee #1, major point of criticism 3, information used in calibration. Indeed, we should describe better that the objective of the paper is to create a model that is complementary to the statistical data as available in AQUASTAT. However, we consider it one of the strong points of the article that per country irrigation statistics are being calculated by combining modeled crop water requirements and water withdrawal statistics. We are not aware of reliable global data regarding irrigation efficiencies, nor do we think that simulating irrigation efficiencies would improve the results obtained. With regard to the assumption that there is always enough water available to assure that crops under irrigation never suffer water stress, we are of course aware that in reality this is often not the case. However, we are not aware of more reliable alternatives. Assuming full supply irrigation is a transparent and more defendable assumption than applying a fixed coefficient of under irrigation since; in general, over-irrigation is still a more common practice than under irrigation.

Anonymous Referee #2, general impression. Including more agricultural details with regard to rainfed crops would indeed be an improvement for next versions of the model. The current model was designed to calculate water use by irrigated crops. The model is called GlobWat since the model design is similar to FAO's CropWat , but rather than CropWat's focus on the irrigation water requirements on field level GlobWat has a global focus. Calling the model GlobAgWat would ruin the similarity between both names. In addition, a Global Water Balance model developed by FAO has by definition a focus on agriculture. It is a misconception that the calibration and validation has been done on the same data. Calibration was carried out on the basis of country statistics as available in AQUASTAT. Validation has been done on river discharges available in the Global River Discharge Database which is completely independent from the AQUASTAT database. It is not completely clear either why it would be better to validate on the vertical water balance. Calibration on rainfall is difficult since it is an input in the model, calibration on soil moisture is also difficult since there are no large global datasets that describe soil moisture availability in the root zone over large areas. Calibration on evaporation would be the best option, but there are few datasets that measure evaporation over large areas and over a long time interval to be comparable to the global average evaporation. The best option would be to compare evaporation modelled by GlobWat with evaporation assessed through remote sensing. However, also over here it may be difficult to find an appropriate dataset. With regard to the assumption that there is always enough water available to assure that crops under irrigation never suffer water stress, please see also our reply to Anonymous Referee #1, major point of criticism 3. Referee # 2 suggests calculating crop stress from irrigated / irrigable areas, or from available upstream horizontal water inflow (Qin). It is not completely clear to us what is meant with irrigable areas. However, in many areas, especially in moderate climates, the irrigable area –if that is meant to be equal to Area Equipped for Irrigation - is much larger than the actually irrigated areas. In these climates, the total irrigable area is only irrigated under drought conditions. When there is no drought, no irrigation is practiced. In other climates, irrigation is practiced when a variety of conditions, beside water supply, are met, including economic viability, labour availability, etc. With regard

to comparing water requirements with available inflow, this can be done, but, due to the scale of the model, it occurs only rarely that the evaporative demand of irrigated crops is higher than the amount of inflow. In the case where this happens, we often see drawdown of groundwater levels or the use of fossil groundwater. So while it is true that in practice there is not enough renewable water available to satisfy crop demand, it is very difficult to model how much water is really used.

Anonymous Referee #2, major remarks. On the abstract and introduction, the comments can be accommodated. The statement that "agriculture accounts for 70% of water withdrawals" comes straight from AQUASTAT. We will add this reference. Equation 1 has indeed Eincr-irr on both sides of the equal sign. This is consistent with figure 1. Adding the irrigation efficiency would be indeed elegant, and we need to consider this, but strictly speaking it would not be consistent with the model formulation, because irrigation efficiencies are not being calculated in the model. The irrigation efficiencies are calculated by comparing Eincr-irr with water withdrawn as available in AQUASTAT. The Thornthwaite Mather procedure published by Thornthwaite and Mather (1955, 1957) is one of the simplest procedures to calculate water balances for the root zone. It explains how evaporation depends on changes in soil moisture. The soil moisture component has not been introduced before section 3 and therefore we consider it relevant to leave this section. Page 808 eq 11. We would be grateful if Anonymous Referee #2 could provide us with the references of better soil data since this is indeed considered the weakest point in the model. Salts are indeed not taken into consideration. It would be a major effort to include it in a global model, especially since there are to our knowledge no reliable global datasets on soil salinity. Page 808 line 10, parameterization of the soil characteristics is indeed considered very difficult, and it are the most uncertain variables in the model. We are not aware however that other methodologies (based on ksat for example) will yield much better results. Calculating recharge on the basis of ksat will probably give too much emphasis on the soil map, and the link with a map with groundwater characteristics will be gone. We should add some discussion about this. Page 812 line 12. All equations in section 8 refer to the vertical water balance.

Equation 22 refers to the excess water on a gridcell. If the balance over the open water gridcell is negative, the gridcell does not contribute additional water to the water body. This does not mean, however, that in the horizontal water balance no outflow is generated. In section 9 is explained that the outflow over the whole water body depends on the amount of water stored (the river sub-basin storage in equation 31 and 32). What will happen in dry seasons is that while the vertical water balance does not contribute to additional storage in the subbasin, the outflow of the subbasin will be reduced. Page 814 line 8. More discussion will be added. Page 814 line 24. The difference between crop water requirements and irrigation requirements includes the water requirements to maintain a layer of water on paddy fields for weed control. This may need more explanation. Calibration has been done on country statistics on Internal Renewable Water Resources, and Ground Water Recharge, both from AQUASTAT. Validation has been done on river discharges (from different datasets, see earlier). If this is not clear enough it should be elaborated. If the evaporation datasets are available we could add a comparison of modeled evaporation with evaporation derived from Remote Sensing.

Anonymous Referee #2, minor remarks. Page 802 line 25: We will follow AQUASTAT definitions Page 803 line 9: Yes Page 805 line 5: The lag time for the horizontal water balance depends on the size of the sub-basin considered. We should explain that better. Page 805 line 12: I don't think a word is missing we will re-word the sentence. Page 805 line 22: OK Page 806 line19: OK Page 807 line 12: More elaboration on the choice for CRU CL 2.0 can be given. It has mainly to do to have one base climate data set as input for precipitation and reference evapotranspiration that describes an average situation to compare outcomes with average AQUASTAT data. Page 810 line 15 – 25: We will see if this whole section can be moved forward. Page 812, more discussion can be given on open water evaporation. Page 815, eq. 34: Water withdrawals from agriculture are based on AQUASTAT country statistics. They are compared with incremental evaporation aggregated by country. The unit of analysis is therefore the country and not the river basin. Page 817 line 19: The unit of specific discharge is indeed mm per year this can be clarified. Page 818 line 6: Agreed. Page 818 line 25:

Correct, this should be table 7.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 12, 801, 2015.