Hydrol. Earth Syst. Sci. Discuss.,
doi:10.5194/hess-2017-112-SC2, 2017

Hydrology and Earth System Sciences
Discussions
Open Access

Interactive comment on "HESS Opinions: A Planetary Boundary on Freshwater Use is Misleading" *by* Maik Heistermann

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Received and published: 22 March 2017

In his opinion paper, Dr. Heistermann raises concerns about the concept of Planetary Boundaries on Freshwater, which was published in Rockström (2009) and revised in Steffen et al. (2015). The concept suggests that a variable (here: freshwater withdrawal), which exceeds a certain value (here: 4000km^3/year on the global and a predefined percentage of the mean monthly river flow on the catchment scale), leads to a substantial regime shift, which could have feedbacks on the planetary scale.

I do understand that it might sound intriguing to provide simple numbers, with which we can measure and describe the state and availability of freshwater resources on different spatial scales. However, as already suggested by Dr. Heistermann, the hydrological cycle and its regional up to global scale feedbacks are far more complex.

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Discussion paper

In Steffen et. al. (2015), thresholds for low-flow (25%), intermediate-flow (30%), and high-flow months (55%) are presented, together with an uncertainty range of 30%. The findings are based on modeled runoff from the global LPJmL-model, which was run with a spatial resolution of 0.5°x0.5°, driven by monthly precipitation data from GPCC and CRU cloudiness and temperature. However, no validation or performance measures, which are the "bread and butter" in any hydrological study, are shown. I do understand that an extensive model like LPJmL, which simulates the full ecosystem, cannot be validated like e.g. a dedicated catchment-scale hydrological model. But if modeled runoff is used for deriving any meaningful quantity, I think that some sort of validation or uncertainty analysis (e.g. through ensemble runs) is essential.

While these are concerns on the conceptual level, I would like to add several quantitative issues to the discussion. Even if there would be something like a Planetary Boundary on freshwater, we neither have the knowledge nor the data to provide *reliable* estimates on the availability or withdrawal of freshwater resources on the *global scale* as well as impacts of regional freshwater shortcomings on the greater water cycle. The concept of basin- and global-scale boundaries, however, would require detailed and extensive information about the major hydrological variables, their dynamics, and their interdependencies on different spatial and temporal scales.

Since several years, we have to face a decline in the availability of station data for the major hydrological variables river discharge and precipitation. Especially lesser developed countries lack of reliable observational data. This leaves many regions around the Earth completely unobserved. Unfortunately, this holds true in particular for arid or semi-arid regions, where good knowledge on the availability of freshwater resources is vital. While there are projects and initiatives which try to give reliable estimates on the major hydrological variables in data-sparse regions (e.g. the Predictions in Ungauged Basins (PUB) initiative), the derived quantities are still highly uncertain. In such dry environments, I agree that an upper limit of freshwater withdrawal might be of real use. But I assume that such thresholds have to be seen in the context of the short-term to seasonal regional water management and not, as suggested by the concept of Planetary Boundaries, as a measure for the potential of substantial regime shifts, which could have feedbacks on the planetary scale.

In the past years, several papers have been published, in which issues of the declining availability of station data and imbalances in the catchment-scale water budgets are addressed (e.g. Lorenz and Kunstmann, 2012; Lorenz et al., 2014). As suggested by Steffen et al (2015), runoff is a key variable for the concept of basin-scale boundaries on freshwater. However, while there is good data coverage especially in European or North American watersheds, many rivers in Africa, South America, or Asia are either ungauged or show significant data gaps in their discharge data. Of course, satellite based approaches (e.g. from satellite altimetry) are promising alternatives but even these methods require at least legacy runoff observations for validation or calibration. Global hydrological models are able to provide runoff estimates even for completely ungauged regions. However, as already mentioned, it is difficult (or even impossible) to measure the performance and reliability when we have no benchmark data.

For many regions, the concept of Planetary Boundaries is therefore facing a fundamental question. How can decide if freshwater use exceeds a certain threshold when we do not even have reliable and up-to-date discharge observations?

The closure of the water budgets, on the other hand, is of major importance for analyzing the availability and recharge of freshwater resources. On the basin scale, precipitation minus actual evapotranspiration is the dominant source of freshwater. There are various publications which address significant uncertainties in both global precipitation (e.g. Ghene et al., 2016, Lorenz and Kunstmann, 2012, Lorenz et al., 2014) and evapotranspiration (e.g. Müller et al., 2013) data. In Lorenz et al. (2014), 90 combinations of current state-of-the-art data sources for precipitation, evapotranspiration, runoff, and water storage changes have been analyzed over approx. 100 catchments worldwide. It was concluded that over the vast majority of study regions, the water budget imbalance (i.e. the residual of precipitation minus evapotranspiration minus runoff minus water storage changes) is more than 25% of the mean annual runoff (see Fig. 1). One can expect even larger imbalances on the monthly time-scale. It is therefore highly questionable if our current data sources are able to give reliable and consistent estimates on the amount of water which enters and leaves a watershed *on the global scale*.

It could further be concluded that there is no global best (or most reliable) dataset. Due to the climatic and hydrological heterogeneity of river basins worldwide and the consequential non-transferability of model performance, one has to deal with highly variable uncertainty levels for different regions. This, of course, holds also true for a global model like LJPmL.

I understand that all these issues can be sealed out when using non-validated runoff estimates from a single model. But it has to be accepted that there are significant inconsistencies even in our most advanced hydrometeorological data sources for the major water cycle variables. These add up to even bigger uncertainties and residuals when trying to analyze and close the water budgets on the basin up to the global scale. But reliable estimates for the water in- and output into and from a region, respectively, are essential if we want to measure and analyze the availability of freshwater resources. As one does not have this information, it is currently not possible to give any meaningful numbers about boundaries on freshwater use on the global scale.

In conclusion, besides the conceptual shortcomings, which were addressed by Dr. Heistermann, the concept of Planetary Boundaries on Freshwater must be questioned due to insufficient data quality and quantity.

The discussion shows once again that many other scientific communities are not aware of the difficulties and obstacles when working with hydrometeorological information. It is our duty, however, to emphasize the strengths and weaknesses of our most advanced hydrometeorological models, satellite sensors and observation data to communities beyond the hydrological sciences.

References:

- Dai, A., and K. E. Trenberth (2002), Estimates of Freshwater Discharge from Continents: Latitudinal and Seasonal Variations, *J. Hydrometeor*, **3**, 660–687, doi: 10.1175/1525-7541(2002)003<0660:EOFDFC>2.0.CO;2
- Gehne, M., T. Hamill, G. Kiladis, and K. Trenberth, 2016: Comparison of Global Precipitation Estimates across a Range of Temporal and Spatial Scales. *J. Climate*, **29**, 7773–7795, doi: 10.1175/JCLI-D-15-0618.1
- Lorenz, C. and H. Kunstmann, 2012: The Hydrological Cycle in Three State-of-the-Art Reanalyses: Intercomparison and Performance Analysis. **J. Hydrometeor.**, **13**, 1397–1420, doi: 10.1175/JHM-D-11-088.1
- Lorenz, C., H. Kunstmann, B. Devaraju, M. Tourian, N. Sneeuw, and J. Riegger, 2014: Large-Scale Runoff from Landmasses: A Global Assessment of the Closure of the Hydrological and Atmospheric Water Balances. *J. Hydrometeor.*, **15**, 2111–2139, doi: 10.1175/JHM-D-13-0157.1
- Mueller, B. et al., 2013: Benchmark products for land evapotranspiration: LandFlux-EVAL multi-data set synthesis, *Hydrol. Earth Syst. Sci.*, **17**, 3707–3720, doi: 10.5194/hess-17-3707-2013
- Rockström, J., W. Steffen, K. Noone et al., 2009: A safe operating space for humanity, *Nature*, **461**, 472-475, doi: 10.1038/461472a
- Steffen, W., K. Richardson, J. Rockström, et al., 2015: Planetary boundaries: Guiding human development on a changing planet, *Science*, **347**, doi: 10.1126/science.1259855

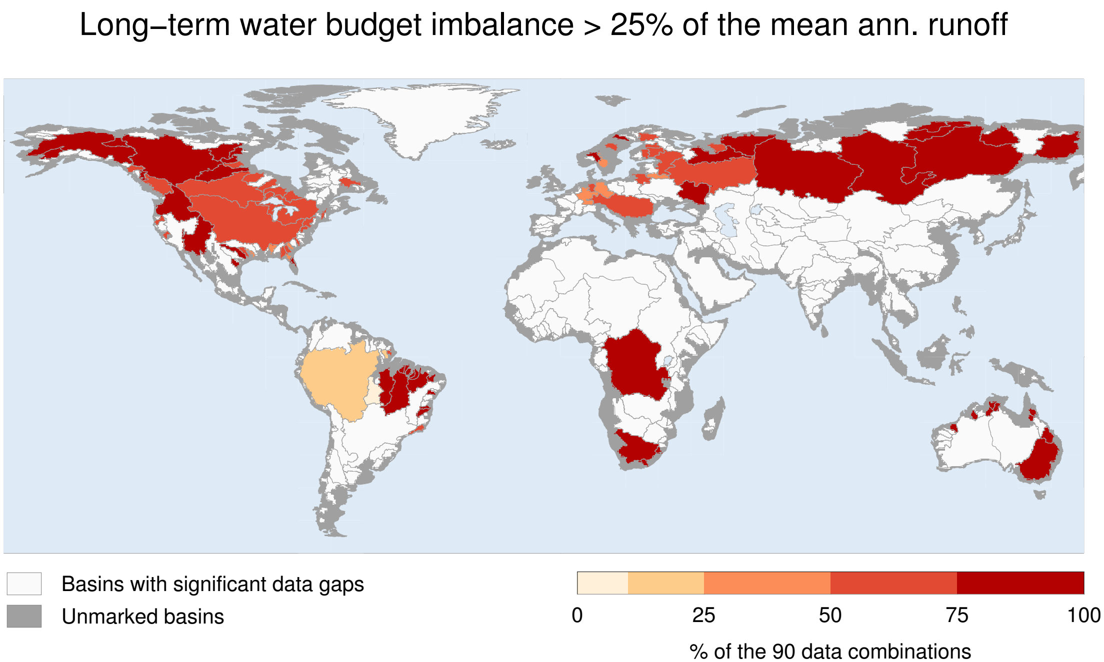

Fig. 1. Percentage of data combinations where the water budget imbalance exceeds 25% of the mean annual runoff during the period 2003 to 2010.