

Author responses to Anonymous Referee Comments for

“Hydroclimatic regimes: A distributed water-balance framework for hydrologic assessment and classification”

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(Specific revisions, made in response to comments, are given in blue type.)

Review #1

General Comments:

This manuscript presents new metrics of hydrological regime and classification, compensating for classic ones such as local runoff and aridity index. The authors proposed three metrics (total water availability, green-blue index, and hydrological-unit evapotranspiration ratio) and applied them to the conterminous United States including a wide area of arid lands. They declared that these metrics characterize hydrological regimes in arid lands in more hydrologically consistent manner. This manuscript demonstrates their concept rather than some research results. I agree with their conclusion, only if these new metrics are used in conjunction with classic ones (Table 2), which are simple and can be more easily useful. The three metrics (TWA, GBI, and et/p) require evaluation of landscape fluxes (Lin and Lout) and so intensive measurements or hydrological models. The manuscript was well prepared; it even includes the glossary of terms. The new metrics were well presented by using two different types of hydrological models; a continental water-balance one and a transient watershed one. They would be used not only for hydrological studies but also for water management, considering the difference between green and blue waters. I conclude that the manuscript is acceptable after minor revision.

Response:

Thank you for your comments.

Specific Comments

Comment 1. Page 2937 Line 15 From the viewpoint of provisional service, the original definitions of green (ET) and blue water (Lout) by Falkenmark and Rockström (2004, 2006, 2010) look still valuable. Just a comment.

Response to Comment 1:

We agree that the original Falkenmark and Rockström definition of green water remains relevant, especially for analysis of catchments. We are simply proposing to place it in a broader spatial context.

In response to your comment, we added the following sentence to the end of Section 2.2:

“In summary, our re-interpretation of green-blue water terminology attempts to place the original definitions of Falkenmark and Rockström (2004, 2006, 2010) into a more general, open-system

spatial context, whereby both types of inflow to a hydrologic unit (landscape inflows and precipitation) are available for partition into blue and green outflows.”

Comment 2. Page 2941 Line 9 Please provide your reason or a reference for the assumption “the river corridor is 30% of the total hydrologic unit area”.

Response to Comment 2:

The reason for choosing the 30% value is stated on Line 11 (2 lines further down), as follows:

“The percentages used in the calculations were determined by subjective [*trial-and-error*] calibration of the model to measured streamflow in arid-region rivers that are known to lose water due to ground- and surface-water evapotranspiration in the downstream direction.”

To improve clarity, we have inserted the phrase “*trial-and-error*” to the Line 11 sentence, as shown above.

Comment 3. Page 2962 Figure 1e Please use different symbols for catchments (a-d). They are confusing with figure identifiers (a-f) especially in the caption.

Response to Comment 3:

Thanks for this helpful comment. In response, we have re-labeled catchments (a-d) as “(1-4)”, to avoid any confusion with Figures 1a, b, c, d, and e. We have made this change throughout the text, tables, Figures 1c and 1e, and the figure graphics, and figure captions.

Review #2.

Comment [1]. This work follows the extensive calls by a wide range of people for new strategies to hydrological science in line with the needs of a changing and increasingly impacted world (Wagener et al., 2010, WRR). One important issue is the presence or absence of data. It might be nice for the authors to discuss the data needs for their approach in the conclusions section since it will help people understand how transferrable these ideas are to other regions of the world. Most dry regions of the world are in developing countries where data is much more sparse than in the US.

Response to Comment 1:

Thank you for this very useful comment.

In response, we have added a new section to the Discussion section of the paper (Section 5.4, “Data Requirements, Data Availability, and Future Research Directions”), which addresses the present limitations of global-scale data, as well as the growing availability of new global datasets and modeling tools. We also specifically acknowledge the key point that the world’s drylands tend to have sparse data—which makes the question of global datasets very important to one of the main points of this paper (ie, that drylands have been neglected by hydrologists.)

Comment [2]. The study presented only includes 4 figures and is rather brief on the insights provided. Recent studies that aimed at understanding variability in time had problems to decipher differences in controls on variability (e.g. Sawicz et al., 2014, HESS). I would very much like to know how the classification presented has changed over the decades analysed? I think that the long-term average is less interesting. Given that places are weak sources or sinks, have they changed in character with time? Where are the limits of current data in understanding this variability?

Response to Comment 2

We accept your point—that the study is rather brief in describing insights provided by the new approach with regard to *continental-scale* temporal variation (seasonal, inter-annual, or decadal) in the new indicators across the U.S. This is for two reasons.

First, as previously noted, the study is primarily intended as a theoretical contribution, providing a re-interpretation of the widely used green-blue water paradigm in a fully general (as opposed to strictly catchment) version of the landscape water balance. The examples are given mainly to illustrate the conceptual framework. At the continental scale, we chose to focus on the very large spatial variation in regimes in the USA.

Second, there are serious data limitations associated with any attempt to do spatially *and* temporally distributed analysis, at a continental scale, simultaneously. This is because temporal variation in the blue boundary fluxes of each hydrologic unit (Lout, Lin) depend not only on climate forcing (P and ET, which would be obtainable on a time-varying basis), but on the storage properties of each hydrologic unit—about which we claim no knowledge in this initial, proof-of-concept demonstration.

[However, in response to your comment, we have added a new paragraph to Section 5.4 \(see paragraph 2\) that addresses the above issues. .](#)

Comment [3]. What is the opportunity for using these indices for projecting into the future? Are there projections of both the climate and the water demand (or the economic and population growth) that could be used to estimate these indicators into the next decades?

Response to Comment 3:

Thanks for this comment. Yes, hydroclimatic regimes could be simulated for future conditions of climate and human water use, with projections from (a) downscaled Global Climate Models, and (b) models of future human water use (constrained by historic data). Our entire approach is based on the terrestrial water balance equation (Section 2, Equation 1), which contains terms relevant to future climate (P, ET) and human water use (Hin, Hout).

[In response to your comment, we have added 2 sentences to the end of paragraph 1 in Section 5.4. These sentences address these specific comments.](#)

Comment [4]. How would you bring in other datasets, e.g. about groundwater?

Response to Comment 4.

In response to your comment, we have added a third paragraph to Section 5.4 that specifically discusses the differentiation of groundwater and surface-water flow components of landscape flow, and how groundwater can be incorporated into our framework.

Comment [5]. What is missing from the manuscript right now is a discussion about how these new indicators and the results are more informative for water management. The discussion of the results is a bit brief and it does not sufficiently link into water management. The authors would make a stronger case if they would really state what this new classification means for understanding and managing water resources. The results are described, but could be interpreted more.

Response to Comment 5.

Thanks very much for this comment. We completely agree.

In response, we have added a new section on water management (Section 5.3) to the paper. (This new section was drawn from an earlier version of the Online Supplement.)

In accord with this change, we have updated the title of the paper to:

Hydroclimatic regimes: A distributed water-balance framework for hydrologic assessment, classification, and management.

Thanks very much for your helpful and insightful comments on our paper!