Spatio-temporal assessment of annual water-balance model for Upper Ganga Basin By Shukla et al.

This study estimates the water yield for the Upper Ganga basin using variations of the Budyko model that relates aridity index (ratio of long term potential evapotranspiration to precipitation) to evaporation ratio (ratio of long term actual evapotranspiration to precipitation). Several versions of a parameterized form of the Budyko curve, developed over the past years, are used to estimate long term streamflow for the basin. It is also assessed whether the inclusion of spatial variability of basin properties improves predictive skill. Though the study does not make any new contributions, it has the potential to contribute to understanding hydrology of this particular basin. However, in its present form it has major drawbacks:

1. Literature review: The study overlooks a significant body of literature in streamflow modeling in the region. Studies are available both at the scale of entire India, the Ganga basin as well as finer scales. In addition, the premise of the study is poorly developed and developments related to Budyko's theory are improperly explained. In fact, the work by Donohue et al. (2012) is cited but equations from InVEST's online documentation are instead used. It is not straightforward to connect the equations in the manuscript with Donohue et al. (2012) formulations. Overall, the introduction needs connection to a wider literature base, along with better exposition of developments in Budyko theory.
2. Methods: The methods rely on previously developed relationships between Budyko parameter and observable catchment properties. However, some of these relationships, such as those in Donohue et al. 2012 were developed for Australia. Similarly, Xu et al. (2013) report that the global model could explain only 53% of observed variation of Budyko's parameter in their dataset. The large basin model worked well but is the Upper Ganga basin large enough in comparison to the 32 basins used in Xu et al. (2013)?
3. Climate data: The resolution of climate data used to compute fine scale variables is of concern. The introduction stresses on a stronger control of precipitation (and potential evapotranspiration) on runoff estimates, as compared to Budyko's parameter, but the analysis works with coarse climatic data. Though precipitation and temperature data were downscaled to the resolution of land use data (by a statistical technique that is not described well.), the effect of elevation on these variables was neglected (for example lapse rate was not accounted for in temperature estimates). As the basin has significant elevation variations, this may lead to biases in water yield estimates.
4. Validation: For the validation catchment, 32% of observed discharge is removed as it is assumed to be snowmelt. But snow melt still counts within the hydrological budget of the region as it is contributed by precipitation falling as snow, which is being used in the Budyko model. If the melt contribution was from long term glacier melts that contribute water to the region in addition to precipitation falling as rain or snow, one may remove it. Even that will be challenging at annual time scales if the basin has significant storage. Unless the distinction between glacier and snow melt is made, and some reasoning as to why Budyko's approach can be applied at annual time steps, it will be hard to justify this reduction. There is also the issue of claiming predictive skill over an entire basin by looking at performance at a single sub-basin in a single year. Note that most approaches based on the Budyko's curve must work with long term data as even at annual time scales, catchment's water storage

changes may be significant and the Budyko model may be invalid (Donohue et al. 2007). The discussion should reflect the limitations of this approach.

5. Interpretation of results: For some reason, as we move from strategy A to E, catchment water yield steadily increases, or, ET decreases. This indicates a systematic change in the Budyko parameter as we go from simpler to more complex relationships requiring more data. Why would the Budyko parameter scale in this manner? This also seems to be in contradiction of the result by Choudhary (1999) who showed that as larger areas are used in a lumped form, Budyo's parameter changes such that actual evapotranspiration reduces. See also the discussion in Donohue et al. (2007). Given the limited data for validation, it is important to physically interpret the results instead of focusing on which method is the best.

Minor Comment

Structure: The paper can be re-structured to improve clarity. Sections 2 and 4 have overlapping items, while 'data' generally goes better with 'Study area'.

References

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