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Hydrology and Earth System Sciences Discussions

Interactive comment on "Controls on hydrologic similarity: role of nearby gauged catchments for prediction at an ungauged catchment" *by* S. Patil and M. Stieglitz

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Author Response to Referee #1:

We thank Referee #1 for reviewing our manuscript. Below we address the questions raised by the referee:

RC = Referee comment AC = Author comment

1) RC: My main concern is on the model used in this study, which is a simple interpolation model of daily flow values. The implicit assumption made by the authors is

that the success of the model results from a hydrological similarity between the donor and the receiver catchments. This, I think is rather plausible but the contrary is not true: two very hydrologically similar catchments in terms of hydrological processes but under different climate forcings will yield very different daily flow simulations.

AC: First, we would like to clarify that, as pointed out by Referee #2, the streamflow estimation method presented in this study is a variant of the drainage-area ratio method (Hirsch, 1979; Wiche et al., 1989; Emerson and Dressler, 2002). We regret that this method was not referred to and cited in the original version of the manuscript, but we will rectify that in the modified manuscript. The original drainage-area ratio method involves streamflow transfer from only 1 donor catchment. We wanted to implement a streamflow transfer approach that incorporates multiple donor catchments. As shown in our results (Fig 2 in the paper), considering multiple donor catchments (vs. single donor) significantly improves predictability at an ungauged catchment.

Secondly, regarding identification of similarity between donor and receiver catchments, our method is based on the spatial proximity approach. The spatial proximity approach inherently assumes that catchments located close to each other are more likely to be hydrologically similar than those that are located far away from each other. This might not always be the case. Nonetheless, in spite of this limitation, the spatial proximity approach is widely used and numerous PUB (prediction at ungauged basins) methods are based on this approach (e.g., Skoien and Bloschl, 2007; Archfield and Vogel, 2010; Andréassian et al., 2011). Moreover, some recent studies have shown that spatial proximity is by far the most reliable surrogate metric for ascribing hydrologic similarity (in the absence of streamflow data, which is the case with ungauged catchments) (Merz and Bloschl, 2004; Oudin et al., 2008; Zhang and Chiew, 2009).

In this paper, our goal was to specifically test whether the spatial proximity approach to identify streamflow similarity is applicable across a wide range of conditions. Continental US provides a perfect setting to test this problem due to the large spatial variability in climate and physiographic features within that country. Our results show that the

spatial proximity approach does not work everywhere, which in itself is a novel result that has not been shown before (atleast in the context of US catchments). Overcoming the above stated limitation will require development of an entirely new conceptual approach to PUB, which is certainly out of the scope of our study.

2) RC: The failure of the runoff-runoff model may stem from two causes: (1) different daily inputs (even a 1-day lag in precipitation might cause great damages on the NSE efficiency) and (2) different hydrological behaviours.

AC: We would first like to mention that our model is not a rainfall-runoff model; it is a streamflow interpolation method that does not use precipitation data as input.

We also do not think that a small lag in precipitation input can cause great damages on NSE. We have used 19 years of daily data on 756 catchments ranging in size from 30 – 5000 sq km. Moreover, the streamgage density of the US catchments is much less than that in many European countries. Therefore, it is virtually impossible to find nearby catchments in our data that will have identical daily precipitation over the 19 years, and lags are inevitable. Nonetheless, we still find distinct geographic patterns of high NSE values within the continental US. If precipitation-lag was such a big problem, our results would have never shown 40% of the 756 catchments having NSE > 0.7.

Andréassian et al. (2011) (mentioned by the referee) tried to explicitly incorporate a lag parameter in their streamflow interpolation model. However, Andréassian et al. found that the lag parameter was near zero at a daily time-scale (Table 2 in their paper). Precipitation lag can play an important role when interpolating streamflows at hourly time-scale (as shown by Andréassian et al., 2011), but our paper is concerned only with the daily time-scale.

3) RC: The modelling framework precludes from finding those catchments that are hydrologically similar but not spatially close.

AC: This is certainly by design, and is a well-recognized limitation of the overall spa-

tial proximity based similarity approach, not of our framework alone. All the methods referred to by the referee in his suggestions (Skoien and Bloschl, 2007; Archfield and Vogel, 2010; Andréassian et al., 2011) are also spatial proximity based (i.e., they only consider nearest neighbors) and have this same limitation. Regardless of this limitation, the fact is that the spatial proximity is a widely used surrogate metric for ascribing hydrologic similarity. Therefore, a study like ours that explores the wider applicability of spatial proximity approach is definitely valuable.

An alternative to spatial proximity approach is the physical proximity approach, where donor catchments are identified based on similarity in physiographic attributes (and can be far away from the receiver catchment). However, we have limited ourselves to exploring the spatial proximity approach alone and comparing these two approaches was certainly beyond the scope of our study.

Our paper contends that if we assume that nearby catchments are hydrologically similar so that daily streamflows can be transferred among them, does that assumption hold true everywhere? In that context, the method implemented in our paper is entirely valid. In the modified manuscript, we will provide a detailed discussion outlining the caveats and limitations of the overall spatial proximity approach. However, we would like to reiterate that these limitations are not exclusive to our modeling framework.

4) RC: My suggestions to the authors on the paper would be to choose among two different paths: 1. Stick to the problem of prediction in ungauged basins and propose a more appropriate runoff-runoff model structure. The authors could refer to existing models (see e.g. Skoien et Bloschl, 2007; Archfield et Vogel, 2010; or more recently Andréassian et al., 2011) 2. Consider hydrological similarity through the correspondence of some hydrologic signatures (for instance those that are used in the paper), those flow statistics being much less influenced by climate forcings compared with daily flow values. The authors could refer to numerous recent studies on this issue (e.g. Sawicz et al., 2011).

AC: Regarding suggestion 1: Conceptually, our method is same as the methods used in papers suggested by the referee, i.e., all the methods (including ours) are based on the spatial proximity approach. Specifically, choose N nearest neighbors and assign appropriate weighting scheme to transfer streamflow to ungauged catchment. The only difference is in the mathematical formulation. Therefore, we do not understand how the referee's previous concerns (which basically highlight a conceptual limitation of the spatial proximity approach) will be addressed by using methods from Skoien and Bloschl (2007), Archfield and Vogel (2010) or Andréassian et al. (2011).

We also disagree with the notion that hydrologic similarity is somehow disconnected from the prediction in ungauged basins question. Hydrologic similarity is certainly a prerequisite condition for transferring information from gauged to ungauged catchments. Therefore, the two problems cannot be considered in isolation.

Regarding suggestion 2: We were specifically interested in prediction of daily streamflow at ungauged catchments (as stated in the title of our paper). Therefore, by definition, the hydrologic signatures used by Sawicz et al. (2011) would not be available at an ungauged catchment. As a result, we have to resort to surrogate metrics (we use spatial proximity) to identify similarity and transfer streamflows to ungauged catchments.

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