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Interactive comment on "A comparison between parameter regionalization and model calibration with flow duration curves for prediction in ungauged catchments" *by* D. Kim et al.

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Dear Dr. Qamar:

We greatly appreciate your interest and comments in our manuscript. We believe that revising our manuscript based on the referee 3's constructive review will improve the manuscript. Your comments will be considered as well in revision. Our main revision will mainly include follows points:

(1) We will include more literatures about prediction in ungauged catchments in introduction. Additional literatures will be about FDC regionalization and signature-based calibration methods. We will also introduce the decade-long project of the IAHS in

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Prediction in Ungauged Basins (Blöschl et al., 2014).

(2) We will restructure the manuscript from gauged to ungauged catchments. We will first show results and discussion about predictive performance and uncertainty at gauged catchment of both hydrograph- and FDC-based calibrations. Then, we will move to compare and discuss the parameter regionalization and calibration with regional FDCs.

(3) We will provide actual FDC-based calibration in combination with three flow signatures at gauged catchments. This will be more interesting to readers.

Once again, we thank for your contribution, and please find our response as per your comment below.

The manuscript “A comparison between parameter regionalization and model calibration with flow duration curves for prediction in ungauged catchments” compares parameter regionalization techniques with FDC-based model calibration. My specific comments are listed below;

1. A number of studies have already been conducted regarding the comparison parametric and non-parametric methods for the regionalization of FDCs. Some of the studies are listed below; Ganora D, Claps P, Laio F, Viglione A. 2009. An approach to estimate non-parametric flow duration curves in ungauged basins. Water Resour Res. 45. doi:10.1029/2008WR007472 Qamar MU, Azmat M, Cheema MJM, Shahid MA, Khushnood RA, Ahmad S (2016) Model swapping: a comparative performance signature for the prediction of flow duration curves in ungauged basins. J Hydrol 541:1030–1041. http://dx.doi.org/10.1016/j.jhydrol.2016.08.012 The authors are advised to go through these studies in order to familiarize themselves with the latest developments in the field of PUB. They further have to defend how their study is different from the already executed comparative studies? Frankly, I don’t see much innovation, here.

-> We will provide more studies on FDC regionalization and signature-based calibration as recommended by the referee 3. We would consider the proposed references in revision. In our knowledge, the FDC-based model calibration has been barely evaluated against conventional parameter regionalization. Given numerous methods for runoff prediction in ungauged catchments, comparative studies can significantly contribute to selecting proper methods for hydrologic applications (e.g. Zhang et al., 2015; Parajka et al., 2013) in our opinion. The objective of this study is not to propose a novel approach.

2. The authors used dataset from 2007-2015 for model calibration and validation phases. Such dataset is not enough to hunch the flow trends. In such case, the modeling technique can be considered suitable for a particular time phase but cannot be generalized due to inadequate data length. Since the results generated by the proposed model for the entire study area are tested by using a LOOCV procedure. One solution to increase the data length is to consider one station as ungauged, removing it from the whole database and estimating FDC for that station with the proposed approach.

-> As explained, quality of streamflow data before 2007 was a critical reason for only using a relatively short period. In fact, data-length for calibration is a controversial topic. Several studies (e.g. Seibert and Beven, 2009) indicated that a few runoff measurements can contain much of the information content of continuous runoff time series. Since droughts and floods were all experienced in South Korea during 2011-2015, we could assume the calibrated parameter sets can relatively well reflect the hydrologic responses. For your information, we provide here the time series plots of spatially averaged SPI6, SPEI6, and SEDI6 during 1974-2015 in South Korea. SEDI is a recently proposed drought index based only on evapotranspiration (Kim and Rhee, 2016) And, I do not clearly understand why leaving out one catchment can extend the data length. The LOOCV is to evaluate performance of methods in the ungauged cases.

3. Line 15 reads, “Though combining a temperature index snowmelt model with GR4J can be an alternative approach, it increases the number of parameters and thus model

uncertainty". How can increase of parameters make the technique uncertain? Increasing parameters increase complexity but it always betters efficiency. A thorough explanation is needed for this claim.

-> GR4J conceptualizes catchment response to rainfall using 4 parameters. If we add any parameter for snowmelt process, it can affect the existing parameters. Interactions between the parameter of snowmelt and the other parameters can happen when calibrating against a hydrograph. Thus, uncertainty to determine parameters will be increased, and the equi-finality problem will become severe.

4. The periods and range of streamflow data (2007-2015) and climatic data (1973-2015) are not overlapping? Will it not be problematic? Moreover how was the range of climatic data used in calibration and validation phases of the model?

-> They are overlapping during the period of streamflow data (2007-2015). I do not understand intention of this comment exactly. As explained, a two-year warm-up period is used. For example, when simulating runoff for 2011-2015, we simulated streamflow for 2009-2015, but evaluated for 2011-2015 only.

5. The equitation (4) seems to be generated by multivariate regression analysis. The authors never explained its generation, which is inevitable. How effective was this rescaling?

-> No. It is just a multiplication of annual precipitation and drainage area. Annual precipitation (mm yr-1) is rescaled by the drainage area (km2) for having a unit of streamflow (m3 s-1).

6. Equation 6 should be eliminated as it is already discussed above (equation 2). Moreover the performances indices need to increased. I suggest including mean absolute error and root mean square error.

-> We will consider unifying similar criteria in revision. Strictly speaking, equation 2 and 6 are different. The performance indicators will be reselected based on previous studies in revision.

7. Why only five nearest neighbors were used? Why not, say, 8 or 10 or 12? There has to be a reason for that. The authors are suggested to go through the following paper and study Figure 9 in detail in which Samaniego and Kumar (2010) selected nearest neighbors by observing the error generated by different number of neighbors.

Samaniego, L., A. Bárdossy, and R. Kumar (2010), Streamflow prediction in ungauged catchments using copula-based dissimilarity measures, Water Resour. Res., 46, W02506, doi:10.1029/2008WR007695.

-> This was because GR4J showed rapidly decreasing performance with increasing neighbors in Oudin et al. (2008). Five catchments are for consistency with FDC regionalization. We will address this more clearly in revision.

8. The authors never discussed the complications involved in the implementation of each method. The discussion section should also compare the simplicity of each method in terms of implementation.

-> As replied, we will restructure the manuscript, and provide more comprehensive discussion in revision.

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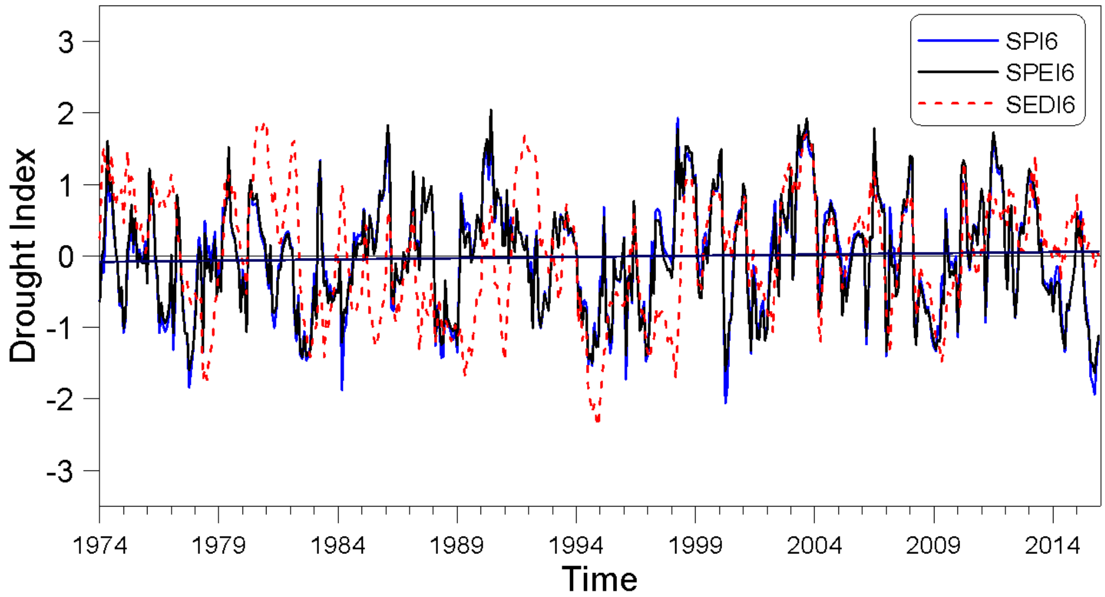

Fig. 1. Drought indices during 1974-2015 in South Korea

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