

## ***Interactive comment on “Annual Characterization of Regional Hydrological Drought using Auxiliary Information under Global Warming Scenario” by Zulfiqar Ali et al.***

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This study proposed an improved method to calculate regional hydrological drought indices by incorporating auxiliary information, i.e., temperature, which is important to investigate hydrological extremes under global warming. However, the intro, results and discussion can be improved. I do have several concerns that should have been addressed before it can be considered for publication. 1. The authors used a new method to calculate hydrological drought index using temperature (LWSDI). LWSDI is not just a drought index, only when LWSDI is smaller than a threshold, it can be used for drought identification. Most importantly, the authors failed to demonstrate the improved

C1

LWSDI is more appropriate than SPI/SPEI (or other hydrological drought indices) in investigating hydrological drought event. Although there are good relationships between LWSDI and SPEI/SPEI, it is not convinced to prove LWSDI is better than the existing drought indices.

Authors Response: In the present work, we mainly focused on the improvement of time series data of precipitation records. The procedure of LWSDI is the same as of SPI and SPEI. However, LWSDI used improved time series data. The improvement of data is based on equation 1. In this equation, we used temperature as an auxiliary variable. Here, the Equation 1 is derived from sampling estimators. It is well-known method of statistics. Therefore, it's obvious that the better quality of data will produce better inference. Reference: Tarima, S., & Pavlov, D. (2006). Using auxiliary information in statistical function estimation. *ESAIM: Probability and Statistics*, 10, 11-23. Cochran, W. G. (2007). *Sampling techniques*. John Wiley & Sons.

2. The first two sentences of the ABSRACT and INTRODUCTION are the same. Please rewrite. Response: Thank you reviewer. In revised version of the manuscript, we have now rephrased the sentences accordingly. 3. Line 23-33: The authors failed to explain the relationships among different types of droughts. “Hydrological drought occurs when dry weather patterns outweigh other climate conditions”. This sentence is rather difficult to understand. Generally, hydrological drought is considered as the water shortage in surface/subsurface water during a certain period. The LWSDI is estimated by precipitation and temperature, which might be a kind of meteorological drought index. Response: This comment is related to the reviewer 2 comments. There we replied as, “In literature, there is too much confusion between the time scales and the definitions of drought such as meteorological, agricultural and hydrological (Bazrafshan et al., 2014). However, many authors have considered that the twelve-month time scale is suitable for defining hydrological drought (Svoboda et al., 2012). In the present work, a statistical methodology is adopted to improve time series data of precipitation. On the same manners of SPI, the proposed data is further used to compute drought

C2

indices. The output of the proposed method of data is compatible to compare SPI-12 and SPEI-12. Therefore, we called LWSDI as a hydrological Index, because it gives monthly numerical standardized values at 12-month time scale. References: Bazrafshan, J., Hejabi, S., & Rahimi, J. (2014). Drought monitoring using the multivariate standardized precipitation index (MSPI). *Water resources management*, 28(4), 1045-1060. Svoboda, M., Hayes, M., & Wood, D. (2012). *Standardized precipitation index user guide*. World Meteorological Organization Geneva, Switzerland." However, the sentence has now converted into a short paragraph which covers some definitions of droughts and literature about time scales.

4. Page 4 Line 40: 'various survey indicate that there is a positive correlation between rain and temperature. . .'. But in following, the authors indicate there are negative correlations between them (Rajeevan et al., 1998). It seems the method proposed by this study only can be used when there is a positive relationship between precipitation and temptation. Therefore, I strongly recommend the authors to give the relationship between them in the manuscript. Response: In casestudy experimentation, the correlation between precipitation and temperature is positive. For the revised paper, we have now prepared a table of correlation between precipitation and temperature. In addition, the significance of the correlation is tested by T-test. 5. Before selecting the appropriate probability distributions, I suggest the authors pay more attention to check whether the precipitation time series are stationary before statistical modelling. Response: We have now acknowledged by reviewer suggestions. We will make reanalysis accordingly. 6. The results and discussion are rather poor. The title of this study is "annual characterization. . .". The authors only show the statistics of the employed methods, but don't state the annual characterization of hydrological drought in Pakistan. There might be a severe drought in the study area during the study period, it would be better to identify and characterize these droughts, and compare with the other drought indices. Response: We will increase the quality of the result and discussion section. In addition, the grammar will be corrected from the native English speaker. The word annual characterization is used for the 12-month

C3

time scale. In the revised version, we will focus on the 12-time scale. In addition, the categorical analysis will be performed for analyzing and comparing drought indices.

Please also note the supplement to this comment:

<https://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2018-373/nhess-2018-373-AC2-supplement.pdf>

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C4