Closure to "Meteorological Drought Quantification with Standardized Precipitation Anomaly Index for the Regions with Strongly Seasonal and Periodic Precipitation" by Kironmala Chanda and Rajib Maity

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At the outset, the writers would like to thank Javad Bazrafshan (discusser) for writing a discussion on the original paper. The original paper proposes a new method for meteorological drought quantification, named as standardized precipitation anomaly index (SPAI), which is applicable for periodic (seasonal) and nonperiodic precipitation series. Thus, SPAI is shown to be more general, and standardized precipitation index (SPI) is a special case of it. The discusser has mentioned some issues which, the writers feel, have resulted because of some misinterpretations of the working principle of SPAI. These issues, though already discussed in the original paper, are further clarified point by point in this closure.

1. First of all, the writers would like to state that Eq. (1) in the original paper is not related to the SPAI computation in any manner. It simply represents the expression of a mixed probability distribution. Thus, the discusser has wrongly referred to Eq. (1) while discussing the anomaly calculation in the SPAI methodology. Per Eq. (5) in the original paper, anomaly is calculated by deduction of the monthwise means from the respective precipitation values. The expression is reproduced as

$$y_{ij} = (x_{ij} - \bar{x}_j) \tag{1}$$

where y_{ij} = precipitation anomaly for the ith year and jth time step of the year; x_{ij} = precipitation for the ith year and jth time step of the year; and $\bar{x}_j$ = long-term mean precipitation of the jth time step of the year.

The discusser wrongly equates the standard deviation of the entire anomaly series (S_y) with the standard deviation of the raw precipitation series (S_x) in the equation shown in Eq. (4) of the discussion paper. The variable $\bar{x}_j$ is the long-term mean precipitation of the jth time step of the year and is not the same as $\bar{x}$ (which is the long-term mean precipitation of the entire raw precipitation series). Thus, $S_y \neq S_x$. This can be shown as

$$\begin{aligned} S_y &= \frac{\sum_{i=1}^{n}\sum_{j=1}^{m}(x_{ij} - \bar{x}_j - 0)^2}{n \times m - 1} \\ &= \frac{\sum_{i=1}^{n}\sum_{j=1}^{m}(x_{ij} - \bar{x}_j)^2}{n \times m - 1} \neq S_x \end{aligned} \tag{2}$$

This may be checked directly using actual data. For example, for the monthly precipitation series of Gangetic West Bengal (GWB), India, which has been used in the original paper, the standard deviation of the entire raw precipitation series is $S_x = 138.9$ mm, whereas the standard deviation of the entire anomaly series is $S_y = 65.3$ mm.

Thus, the proof shown by the discusser does not hold, and the conclusion that "SPAI (like the SPI) can be calculated using the statistical parameters obtained from the raw precipitation data rather than the anomaly series" is wrong.

Further, while attempting to prove the aforementioned statement/conclusion of the discussion paper, the discusser assumes that precipitation anomalies follow the normal distribution, which is not necessarily true. In fact, it has been found in another paper that t-location scale distribution is a suitable parametric distribution that can describe the anomaly series for Indian precipitation (Chanda and Maity 2016).

2. The design of SPAI is such that a given anomaly value in both low and high precipitation months will produce an identical SPAI value. This is because a single probability distribution is fitted to all the anomaly values rather than 12 monthwise distributions used in case of SPI. It has been demonstrated that this property makes it easier to interpret SPAI values than SPI values. The value of the SPAI is sufficient to indicate whether water stress is faced by the community or not, whereas for SPI, a combination of the index value and the climatology of the location for that particular month when it occurs is required to understand the water stress faced by the society.

In Fig. 2(a) in the original paper, the minimum value of January SPAI observed during the study period in Gangetic West Bengal, India is −0.15 (corresponding to a precipitation of zero), and the maximum value of the same is 1.37 (corresponding to a precipitation of 108 mm). If the precipitation in January is even larger, say 150 mm (which is 12 times the mean value of 12.16 mm), then an appropriately large SPAI value (1.68) will obviously result. On the drier side, it is not possible to get any rainfall lower than zero. Thus, it is only natural that the severity of precipitation deficits would potentially be less than the severity of precipitation surpluses in dry months because there is a physical limit to the maximum negative anomaly possible (the mean rainfall of the month), whereas there is theoretically no limit to the maximum positive anomaly. This fact must not confused as a shortcoming of SPAI methodology; rather, the SPAI quantifies the deficit and surplus in a manner relevent to the society in a monsoon-dominated climatology where lack of rainfall in dry months is not at all harmful for the society.

The discusser states that "the severity of precipitation deficits would potentially be less than the severity of precipitation surpluses in dry months." However, this is not true in general. In a region which receives low rainfall throughout the year, such as the arid regions of the middle east, a lack of precipitation in a certain month will of course produce large negative SPAI values indicating serious implications for the society. This can be demonstrated with data generated for 30 years having very low monthly mean rainfall values of 10.34, 7.84, 7.13, 10.58, 11.51, 13.23, 15.19, 13.34, 11.47, 9.53, 9.93, and 8.90 mm, respectively. In this low rainfall climatic regime, for a particular January month, if there is no rainfall, then the corresponding SPAI value is obtained as −2.77 indicating very severe drought. Similarly, if the January rainfall is 20.67 mm, then the SPAI value is 2.39 which adequately reflects the large surplus. Thus, in this case, severity of precipitation deficits would not be less than the severity of precipitation surpluses unlike those in dry months of monsoon-dominated regions. This reinforces the fact that SPAI is able to quantify the deficit and surplus in a manner relevent to an arid climatological regime as well.

3. The discusser agrued that SPAI eliminates the occurrence of droughts in dry season because the values of negative anomalies are too small in those months. The discusser also states that if the occurrence of droughts in dry seasons is not important, then it might be better to quantify droughts through SPAI only in the high precipitation season such as a monsoon-dominated season studied in the discussed paper. However, the writers would like to state that in the original paper, the SPAI is shown to be a generalized approach that is applicable for both periodic and nonperiodic precipitation patterns throughout the year. It can be explained with examples of (1) a monsoon-dominated region receiving high precipitation during monsoon months, and (2) a nonmonsoon-dominated region receiving low rainfall throughout the year.

   Gangetic West Bengal, India, is a monsoon-dominated region with strongly seasonal periodic precipitation. January is a traditionally dry month in GWB with a mean precipitation of approximately 12 mm, so lack of precipitation in January is obviously not reflected as a large negative SPAI. However, if there is lack of precipitation in a traditionally wet month (say July, with a mean precipitation of approximately 329 mm), then a large negative SPAI is obtained indicating cause for concern for the society. This is discussed in details in the section "Potential of the Proposed SPAI in Monsoon-Dominated Climatology" in the original paper.

   For the example of a nonmonsoon-dominated region, the demonstration with synthetic data set, explained in Point 2 before, may be referred. The demonstration appropriately indicates the usefulness of SPAI throughout the year in arid regions. It must be appreciated that rainfall deficit in a traditionally dry month of monsoon-dominated region is not significant to the society. However, the same when occurring in a region with perenially low rainfall is very much significant. Both these situations are appropriately taken care of by the SPAI. Thus, SPAI can be used to quantify droughts throughout the year in all kinds of climate.

References

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