EGU2020-454: Investigating the divergence between Standardized Precipitation Index (SPI) and Standardized Precipitation Evapotranspiration Index (SPEI) in defining droughts over different climatic zones of India

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Background and Objectives

- A considerable uncertainty prevails in drought evaluation, when compared to other natural hazards owing to the significant shift in the trends of meteorological variables, induced by the changing climate (Hayes et al., 2005; Intergovernmental Panel on Climate Change (IPCC), 2012; Nam et al., 2015).

- While the annual rainfall in the higher latitudes has increased (Dore, 2005; Trenberth, 2011), the land precipitation in lower latitude regions has reduced (Mote, 2003; Knowles et al., 2006).

- Furthermore, a global increase is observed in the minimum, maximum, and nighttime temperature, along with the intensity, frequency, and duration of heatwaves and dry spells (Alexander et al., 2006; Perkins et al., 2012).

- Drought quantification is carried out with the help of various unbiased indices, which encompass the historical characteristics of these long-term meteorological variables (Palmer, 1965; Mckee et al., 1993; Vincente-Serrano et al., 2010). Thus, insights pertaining to climate variability can also be perceived in the divergence of drought likelihood as described by prominent meteorological indicators.

Objectives:

- To analyze the evolutionary characteristics of meteorological droughts in India.

- To evaluate the divergence in the drought likelihood defined by commonly used drought indices.

Study Area and Data Sets

- Study area: Indian subcontinent (7.5°N to 37.5°N and 67.5°E to 97.5°E) (Fig. 1)

- Daily gridded precipitation (0.25° × 0.25°) and maximum/minimum temperature (1° × 1°) data from Indian Meteorological Department (IMD).

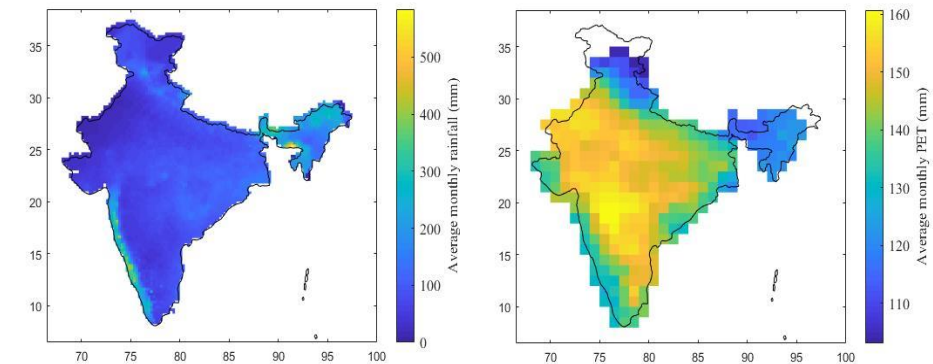- Duration: 63 years (January 1951 to December 2013)

Figure 1. Spatial variation of long-term average monthly rainfall and Potential Evapotranspiration (PET) from January 1951 to December 2013 in India

Methodology	**Results and Discussion**

Evolution of meteorological droughts in India:

- Evaluation of Standardized Precipitation Index (SPI) and the Standardized Precipitation Evapotranspiration Index (SPEI), following the steps developed by Mckee et al. in 1993 and Vincente Serrano et al., in 2010, respectively.

- Evaluation of the Drought Hazard Index (DHI) (Maccioni et al., 2015), by amalgamating important physical drought characteristics like maximum drought magnitude, maximum drought duration and maximum drought frequency. DHI is estimated for both SPI and SPEI.

- Analysis of long-term trend in the meteorological variables of average annual precipitation and average annual temperature utilising the Mann Kendall test (Mann, 1945; Kendall, 1975). The magnitude of slope was evaluated using the Sen's Slope method (Sen, 1968).

Evolution in the divergence of drought likelihood:

- Quantification of the normalized divergence in the percentage area under drought, as defined by SPI and SPEI, in different climate zones of India.

- Utilising the Multidimensional Ensemble Empirical Mode Decomposition (MEEMD, Wu et al., 2009), the residue difference for the moving average correlation between SPI and SPEI, precipitation (P), potential evapotranspiration (PET) and net precipitation (D), was evaluated.

Evolution of meteorological drought in India:

- The decadal variation of DHI by SPI (Figure 2a) and SPEI (Figure 2b) reveals that drought hazard has magnified over India for the past sixty-three years.

- Decades of 1961 to 1970, 1971 to 1980 and 2001 to 2013 showcase the highest drought hazard.

- The north-western states of India like Gujarat, Rajasthan, Uttar Pradesh, Punjab, Haryana and the southern states of Tamil Nadu, Andhra Pradesh and Telangana are most prone to drought episodes.
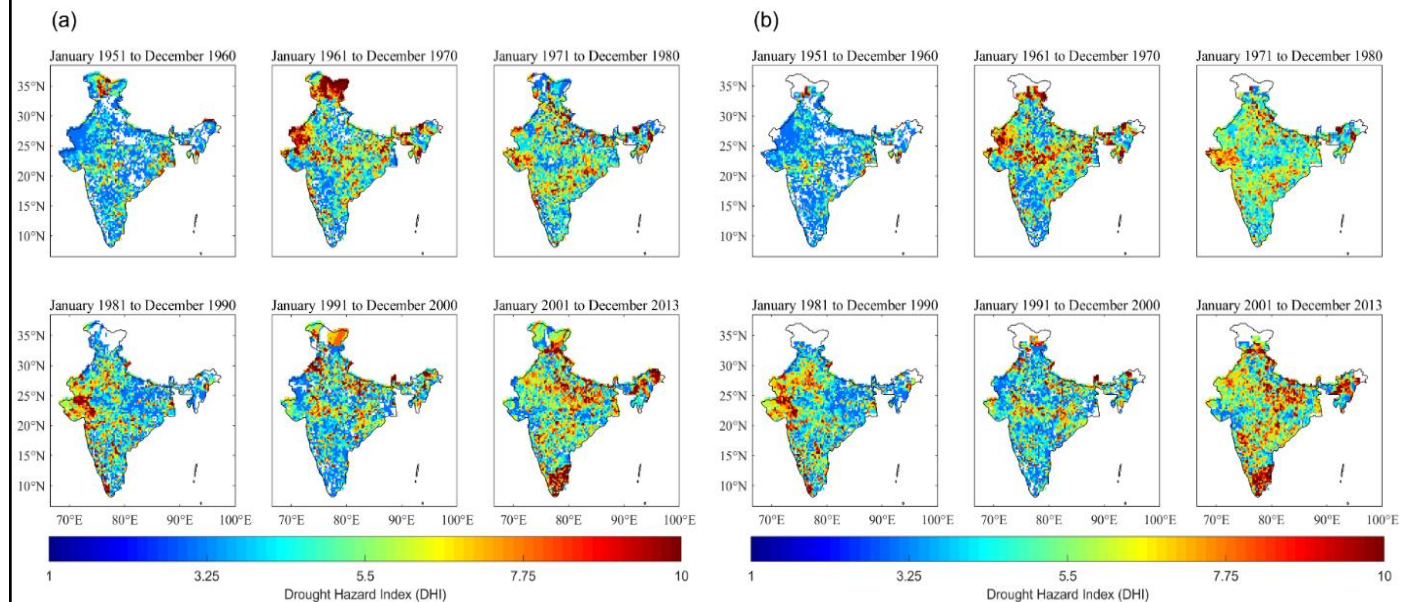

Figure 2. (a) Decadal variation of DHI as represented by SPI_{12} (b) Decadal variation of DHI as indicated by $SPEI_{12}$

Results and Discussion

- The late 1970s mark the breakpoint of the increasing divergence between SPI and SPEI, the latter describing a higher drought hazard (Figure 3).
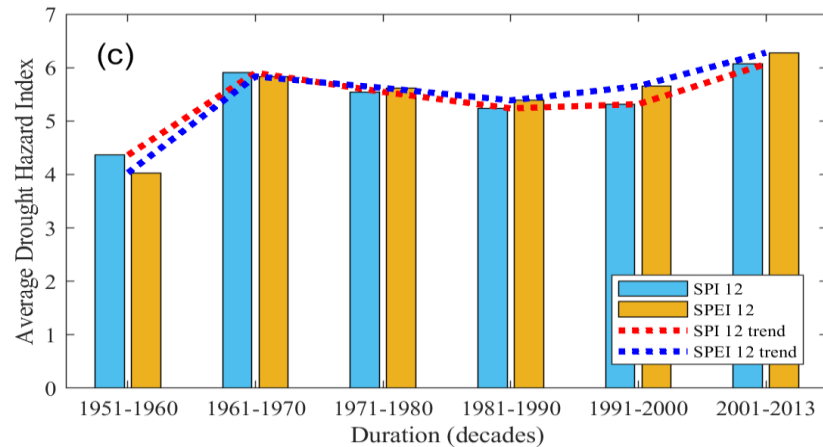

Figure 3. Temporal variation of DHI as indicated by SPI_{12} and $SPEI_{12}$

Trend analysis:

- The trends exhibited by the climate variables, explain the temporal divergence shown by SPI and SPEI. While the annual precipitation series exhibits a falling trend of -1.519 (Figure 4a), the average yearly temperature series (Figure 4b) can be divided into three realizations based on different trend behaviour:

  - falling for the 1951 to 1975 period,
  - no trend for the 1976 to 1990 period, and
  - rising for the 1991 to 2013 period (Figure 4c).

- The year 1978 forms the breakpoint (based on slope change from negative to positive) of increasing divergence, which is also highlighted in prior results.
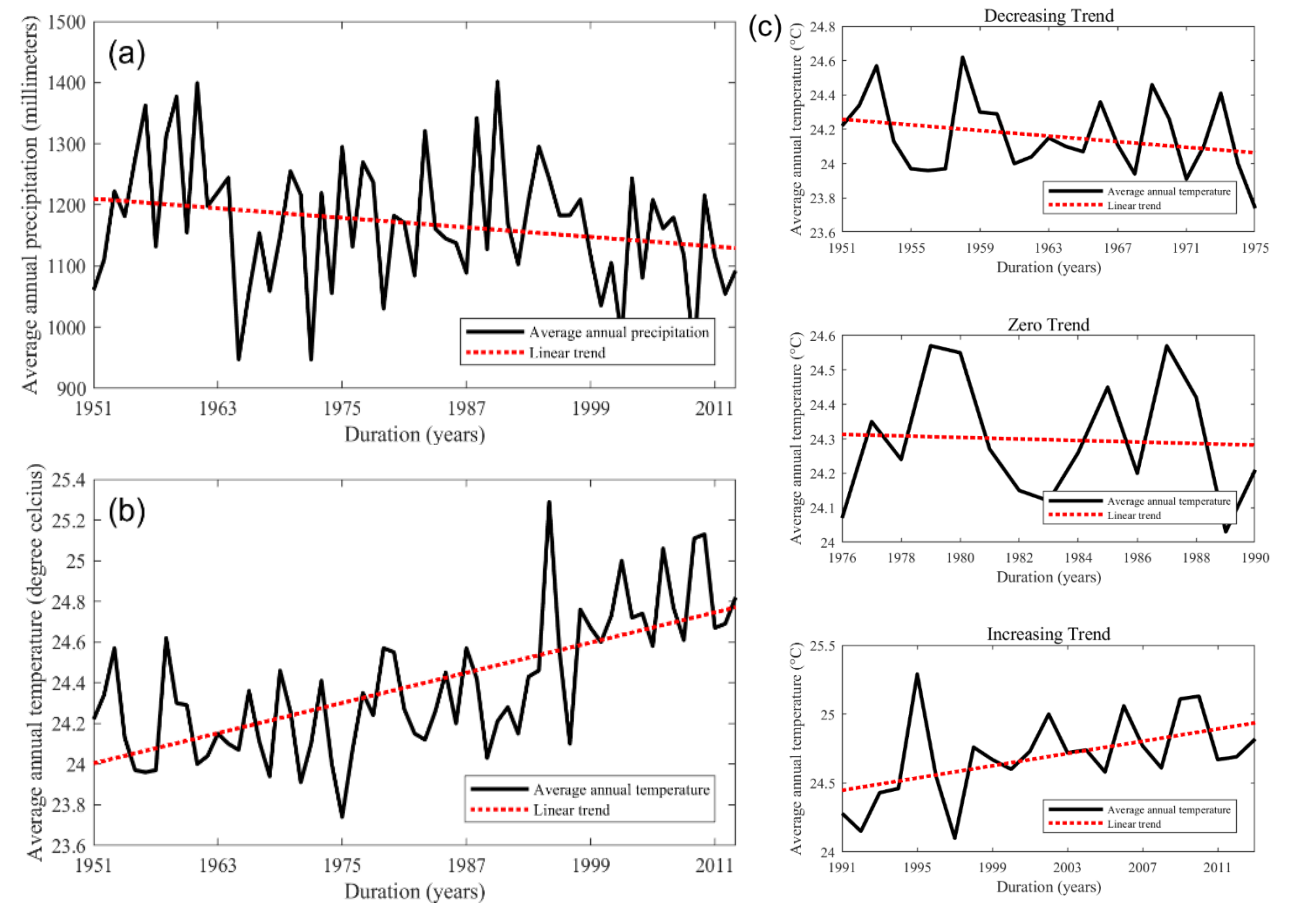

Figure 4. (a) Linear trend in the variation of average annual precipitation series from 1951 to 2013 (b) Linear trend in the variation of yearly average temperature series from 1951 to 2013 (c) Division of yearly temperature trend into three segments: (i) falling (ii) no trend (iii) rising

Results and Discussion

Divergence in the drought likelihood

- India is divided into six climatic zones (Tropical monsoon, tropical wet and dry, hot desert, semi arid, humid subtropical and subtropical highland), and the normalized divergence in the evolution percent drought area represented by SPI and SPEI is evaluated for each climate zone.

- The dominance of SPI and SPEI is synonymous to the negative and positive divergence values, respectively. A decrease in the divergence between SPI and SPEI is observed for the arid and the semi-arid zones, while enhancement is detected in the tropical monsoon and the tropical wet and dry climate zones (Figure 5).
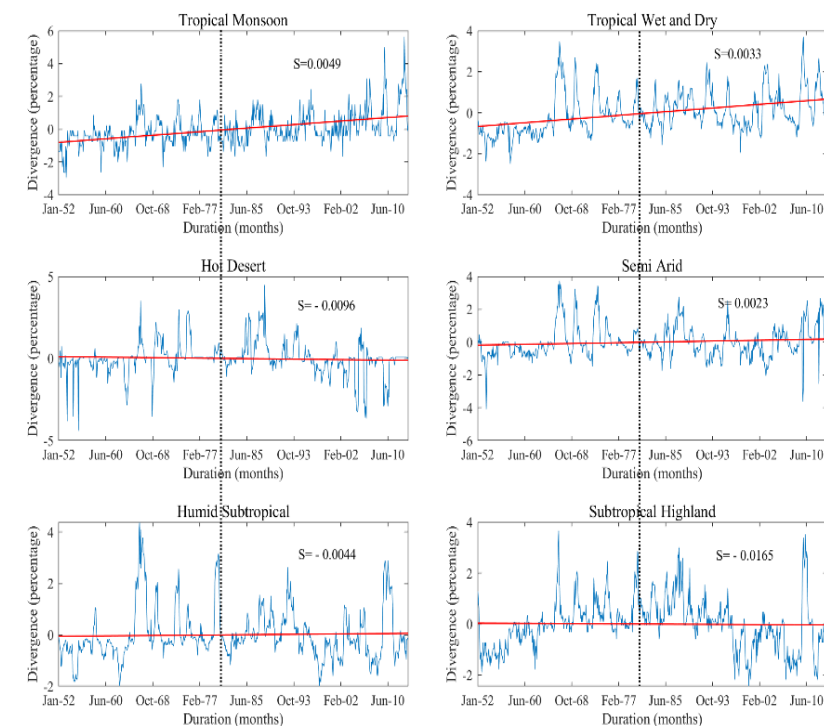
Figure 5. Normalized divergence in the percentage area under drought by SPI and SPEI in different climate zones of India

- The possible reasons behind the divergence behaviour observed in Figure 5 are explored by analysing the MEEMD trend in the moving average correlation series of SPI and SPEI (Figure 6).

- The moving average correlation series is created by taking a 20-year window and a 1-year lag-time. Patches of an increasing trend, describing higher correlation are noticed in the north-western and central portions of India. Thus, a tendency of reducing divergence in the arid and semi-arid zones of India can be inferred.
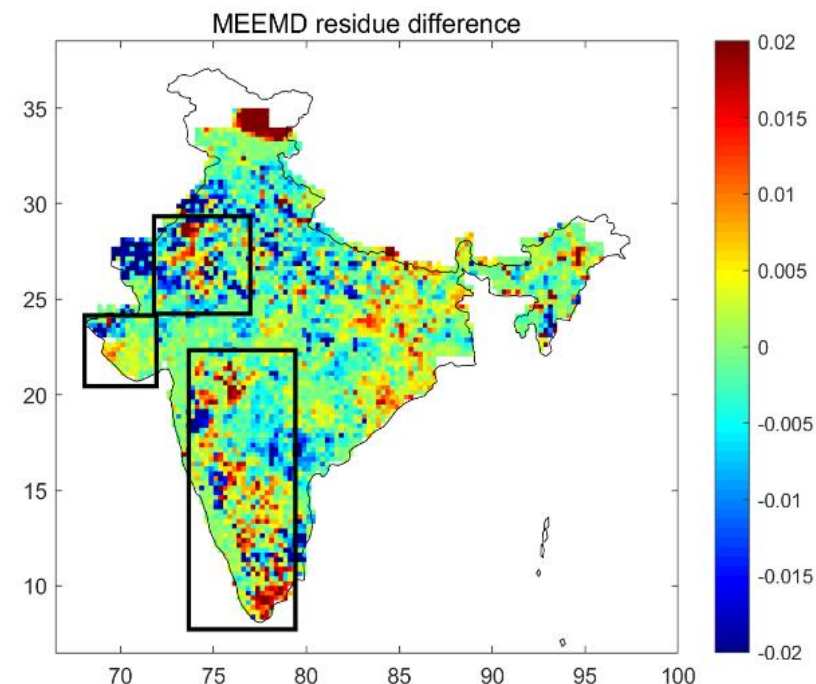
Figure 6. MEEMD trend in the moving average correlation between SPI and SPEI.

Results and Discussion

- The reasons behind the reduction of divergence in the arid and semi-arid regions were explored using the MEEMD analysis of the driver variables *(P, PET, P-PET)*.

- Spatial variation of MEEMD residue reveals that in general, while monthly precipitation has increased in the western parts of India and has reduced in the eastern regions (Figure 7a), PET has diminished in north-western India and has increased in the southern and eastern India (Figure 7b). The spatial variation of the trend in the monthly water balance (P-PET) reveals that while the regions of the Western Ghats and Northeastern hills are experiencing a water-deficit, the northwestern part of India has an enhanced water balance (Figure 7c).
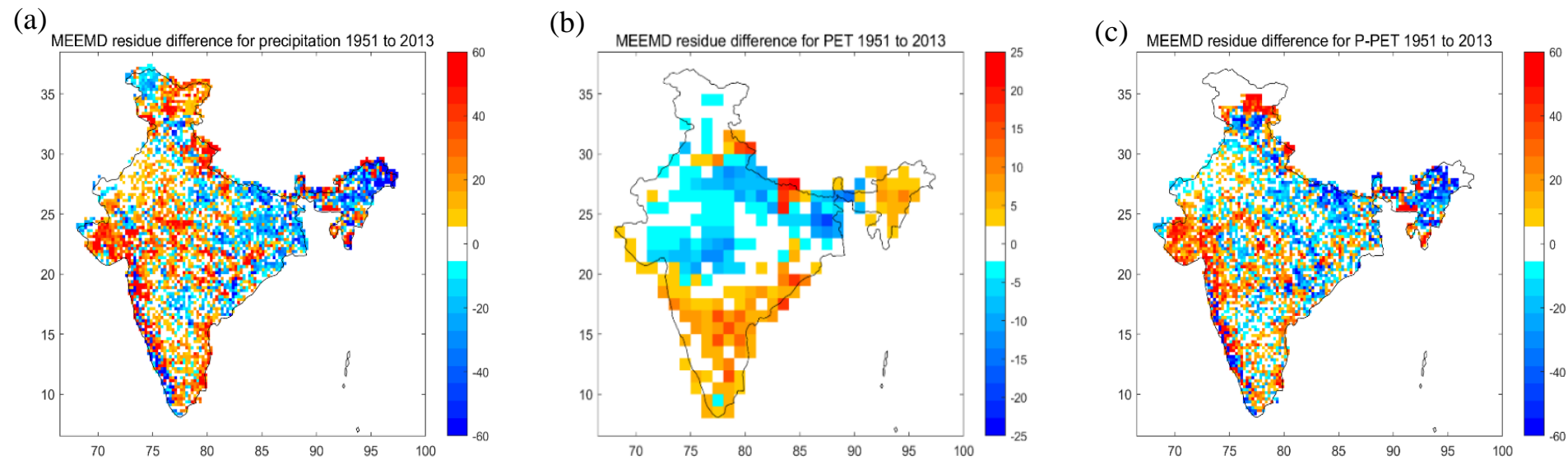

Figure 7. (a) MEEMD trend in (a) Precipitation, (b) PET and (c) water balance (P-PET).

Conclusions

- The overall meteorological drought hazard has magnified over India in the past few decades, especially since the 1970s.

- A strong regional divergence exists in India. The North-western and South-central parts of India are most prone to the occurrence of droughts.

- A strong disagreement exists in the definition of drought likelihood by SPI and SPEI in the wet climatic zones of India observed in the Western Ghats and the North-Eastern regions.

- A reduced divergence exists in the dry regions of Rajasthan and Deccan Plateau.

- The divergence behaviours aligns with evolution of wet climatic zones of India as dry and the drier climatic zones of India as wet.

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