Projection of Indian Monsoon Sparse Zone shift under Climate Change

Vasundhara Barde[1], U.C. Mohanty*[1], P. Sinha[1], M.M. Nageswararao[2], Dev Niyogi[3]

1School of Earth, Ocean, and Climate Sciences, Indian Institute of Technology Bhubaneswar, India
2CPAESS, UCAR at NOAA/NWS/NCEP/EMC, College Park, Maryland-20740, USA
3Department of Geological Sciences, Jackson School of Geosciences, and Department of Civil, Architectural, and Environmental Engineering, Cockrell School of Engineering, The University of Texas at Austin, Austin, TX, USA.
*ucmohanty@iitbbs.ac.in

Introduction

The spatiotemporal variability of the Indian summer monsoon (ISM) is of interest both from a societal perspective as well as a scientific endeavor. Recent studies indicate the potential for weakened Indian monsoonal rainfall. The Indian region has yet to experience an "excess monsoon" year in the 21st century. On the other hand, several "deficit monsoon" years have been witnessed (e.g., 2002, 2004, 2009, and 2013). Thus, understanding how the monsoon variability interplays with drought potential is of growing relevance. For such an assessment, this study defines a zone with less seasonal rainfall than the long-term average (116 years) as a 'Monsoon Sparse Zone (MSZ)'. It is found that the region experiences more drought events where MSZ persists thus highlighting that the MSZ is one of the preconditions for the initiation and persistence of the drought.

Objectives

- To identify the major drought prone area i.e MSZ and track the shifting of it by using drought indices.
- To provide the future projection for drought prone areas in India by using CORDEX-SA Regional climate models simulations.

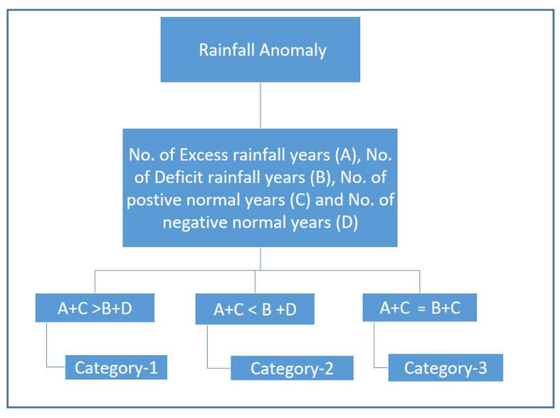
Data & Methodology

Data used :

- India Meteorological Department (IMD) daily rainfall (0.25˚×0.25˚), 1901-2016, IMD temperature (1˚×1˚), 1971-2020
- National Oceanic and Atmospheric Administration (NOAA_ERSST_V4) 2.5˚×2.5˚, 1901-2016
- Coordinated Regional Climate Down-scaling experiment-South Asia, (CORDEX-SA) regional climate models, 1971-2100

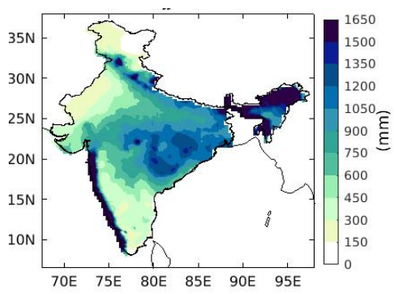
Methods used:

Standardized Precipitation Index, Bias correction method, Contiguous Drought Area (CDA) and Spatial tracking (S-track) method

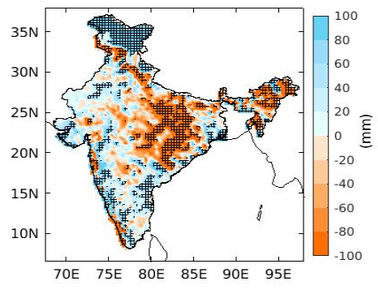


Results & Discussion

Climatology of Indian Summer Monsoon rainfall

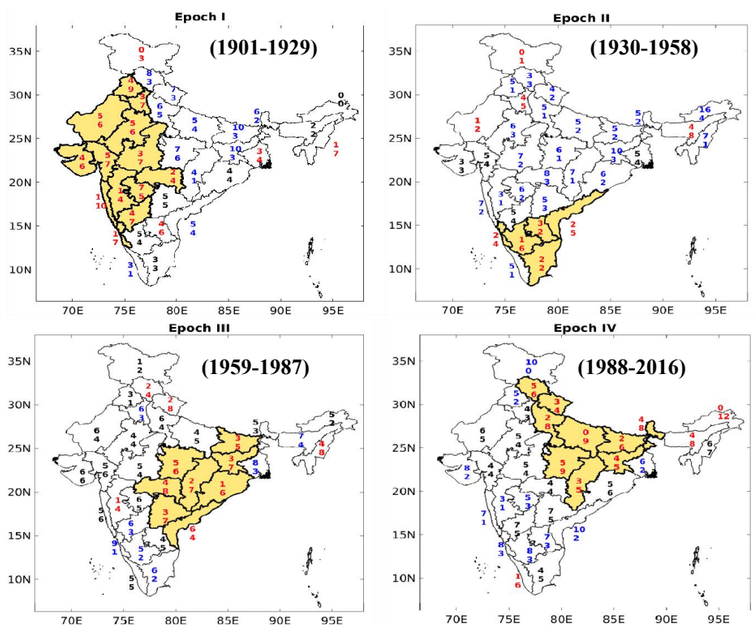


Difference of mean rainfall (P2-P1)



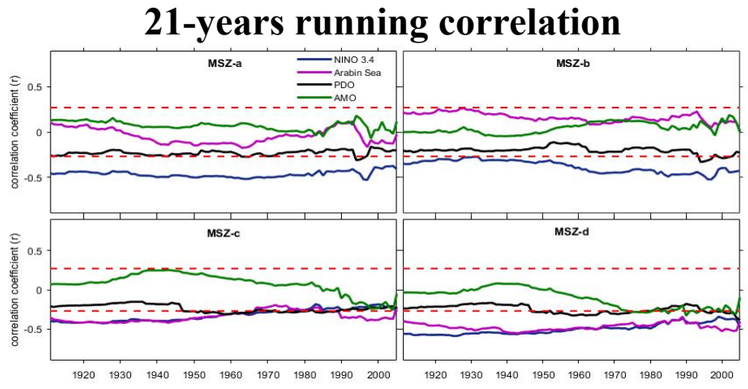
P1: 1901 to 1958 and P2: 1959 to 2016; hatched region shows the significant values for 95% confidence level

Counter-clock wise shifting of MSZ

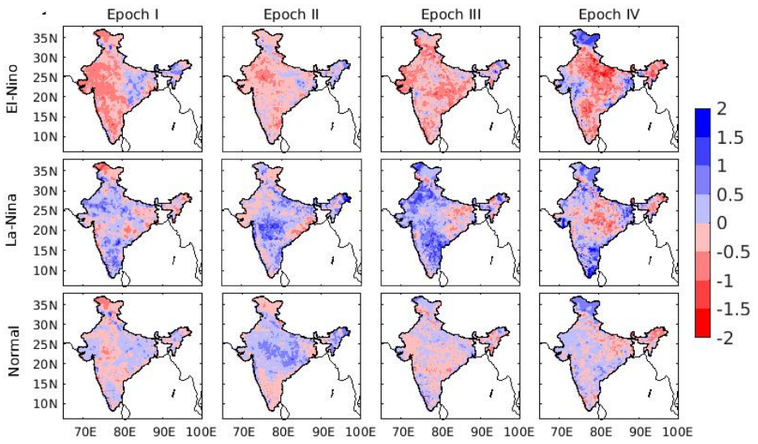


The MSZ shift is insensitive to Epochal time selection (23, 24 years, also for wet/dry Epoch episode of Indian summer monsoon)

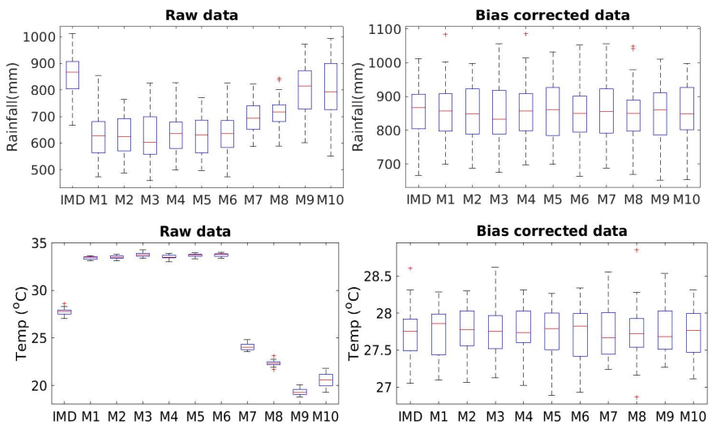
21-years running correlation



SPI during El Niño-Southern Oscillation (ENSO)

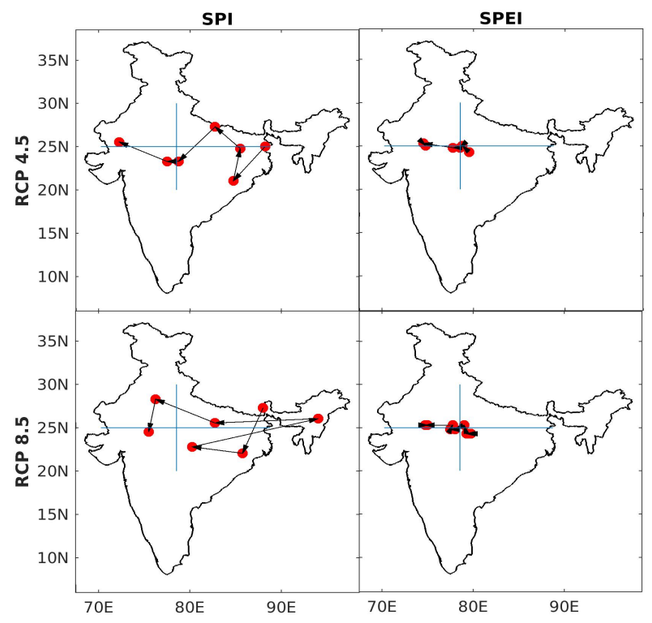


Equidistant quantile mapping (EDQM) bias correction for 2006 to 2020 period



M1 (ACCESS-CSIRO-CCAM), M2 (GFDL-CM3-CSIRO-CCAM), M3 (CNRM-CM5-CSIRO-CCAM), M4 (COSMO_CLM), M5 (CCSM4-CSIRO-CCAM), M6 (GFDL-ESM2M-IITM-RegCM4), M7 (ICHEC-EC-EARTH-SMHI-RCA4), M8 (LMDz-IITM-RecCM4), M9 (MPI-ESM-LR-CSIRO-CCAM), and M10 (NorESM1-M-CSIRO-CCAM).

The Decade wise (2006-2099) future projection of MSZ



Earlier studies also showed that in the future, drought frequently occurs in north-west India (Zhai et al. 2020; Shrestha et al. 2020).

Summary/Conclusion

- The MSZ hotspots show a counter-clockwise transition from west to north-central India through the peninsular region from one epoch to another.
- The results were tested for the duration of the epochs considered, and it is found that the MSZ shifting is insensitive to epochal time selection.
- The SST at Pacific decadal oscillation (PDO) and Niño-3.4 shows significant negative correlation with MSZ locals.
- The statistical analysis of the CORDEX data indicates that the MSZ will continue the counter-clockwise march over India. The MSZ location is likely to be shifted over to northwest India through central India in the future.
- This shift is of concern as it indicates that the region that is seeing continued growth in the population and has increased agricultural intensification could lead to cascading impacts. This finding related to the potential shift in MSZ would need to be considered for food and water security across India and indeed the wider monsoon region.

Acknowledgements & References

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- Barde, V., Sinha, P., Mohanty, U. C., Zhang, X., & Niyogi, D. (2021). Counter-clockwise epochal shift of the Indian Monsoon Sparse Zone. Atmospheric Research, 263, 105806.
- Shrestha, A., Rahaman, M. M., Kalra, A., Jogineedi, R., & Maheshwari, P. (2020). Climatological drought forecasting using bias corrected CMIP6 climate data: A case study for India. Forecasting, 2(2), 59-84.
- Zhai, J., Mondal, S. K., Fischer, T., Wang, Y., Su, B., Huang, J., ... & Uddin, M. J. (2020). Future drought characteristics through a multi-model ensemble from CMIP6 over South Asia. Atmospheric Research, 246, 105111.

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IMD, MoES, NEW DELHI, INDIA