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Drought Assessment over India using RCMs with Standardized Precipitation Evapotranspiration Index

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November 23, 2022

Abstract

Regional Climate Models (RCMs) work at finer resolution over a limited region and are presumed to perform better at regional scales. RCMs need thorough evaluation before being used for any climate change impact assessment study due to the biases associated with the observed data. While few studies used RCM outputs for understanding the spatio-temporal variability of precipitation and temperature over India, application of RCMs in drought assessment has been overlooked. Here, the study aims to perform drought analysis using RCMs over India with Standardized Precipitation Evapotranspiration Index (SPEI) as the drought index. About 10 RCMs from the Coordinated Regional Climate Downscaling Experiment program (CORDEX) have been considered in the analysis. To remove the systematic biases, a Quantile based bias correction method has been used. The study evaluated the performance of bias-corrected RCMs to simulate rainfall over India for each grid using the statistical measures such as correlation and Nash-Sutcliffe Efficiency coefficients. The monthly precipitation for all over India was best represented by the experiment LMDz-IITMRegCM4 (Regional Climatic Model version 4). Based on the performance evaluation in the study, ICHEC-EC-EARTH-SMHI-RCA4 and MPI-CSC-REMO2009 were used along with LMDz-IITMRegCM4 for drought assessment over India. The results reveal that for West and North-East zones, the drought frequencies and intensities increase for the periods of 2001-2050 and 2051-2100 with Representative Concentration Pathways (RCP) 4.5 for all three considered RCMs. All over India, the average drought intensities were observed to be increasing for ICHEC-EC-EARTH-SMHI-RCA4 and LMDz-IITMRegCM4 while there is no change for MPI-CSC-REMO2009.

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AGU 100 ADVANCING EARTH AND SPACE SCIENCE | FALL MEETING Washington, D.C. | 10-14 Dec 2018

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Introduction

- More intense droughts and increased precipitation variability lead to increased stresses to water and agriculture (IPCC AR5 WG2 Ch26 Exec. Summary).
- Around 93% of farmers of India cultivate nearly 55% of arable land (FAO).
- Regional Climate Models (RCMs) work at finer resolution over a limited region and are presumed to perform better at regional scales.
- Application of RCMs in drought assessment has been overlooked in the Indian context.

Our Research

- **Objective :** To evaluate the performance of RCMs in simulating the historical and future drought characteristics over India with Standardized Precipitation Evapotranspiration Index (SPEI) as the drought index. The study investigated the performance of 10 CORDEX RCMs in reproducing the monthly mean variability for the period of 1951-2014 through India Meteorological Department (IMD) gridded data sets at 0.25 X 0.25 degree resolution.

Study Area & Data

- This study covers main land region of India with a spatial domain of 6.5°N to 38.5°N and 66.5°E to 100°E.
- Gridded observed daily precipitation, minimum and maximum temperature datasets for India were obtained from IMD for a common time period of 1951-2014.
- RCM data of 10 RCMs for South-East Asia are obtained at daily scale for precipitation, minimum and maximum temperature.
- All the data sets are brought to a common resolution of 0.25° using bilinear interpolation and converted to monthly scale.
- Some parts of Jammu & Kashmir and North-East hills were left out from analysis due to inconsistent data.

Methodology

- The RCM data of precipitation and temperatures were bias corrected using **Equidistant Quantile mapping method** (Li et. al 2009).
- The performance of RCMs is evaluated using N-S (Nash–Sutcliffe model efficiency coefficient) for each grid point individually after the bias correction. The study selected 3 best performing RCMs for the drought analysis.
- The PET is estimated based on Hargreaves model. P(Precipitation) and PET(Potential evapotranspiration) are first aggregated at 12 month scale:

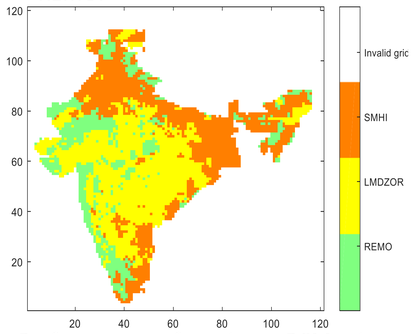
$$P_i^k = \sum_{i-k+1}^{i} P_i \qquad PET_i^k = \sum_{i-k+1}^{i} PET_i \qquad D_i^{12} = P_i^{12} - PET_i^{12}$$

Where P_i^k and PET_i^{12} are the k month scale (k =12) aggregated P and PET in month i. Then, D_i^{12} is the 12 month scale residual water available, in month, i.

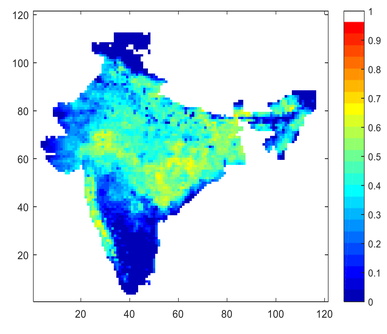
- The structure of SPEI (Vicente-Serrano et al., 2010) is adopted with the modification of (Stagge et al., 2015) to produce the standardized drought index based on GEV(Generalized Extreme Value) distribution to fit D_i^{12} time series.

Performance of RCMs

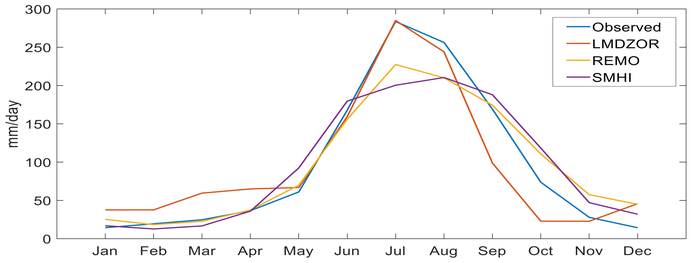
- The monthly precipitation for all over India was best represented by the experiments LMDz-IITMRegCM4.
- Based on the performance evaluation in the study, ICHEC-EC-EARTH-SMHI-RCA4 and MPI-CSC-REMO2009 were also used for drought analysis.
- Poor performance of RCMs in simulating precipitation over Jammu and Kashmir, North-East hills and south zones. Therefore, these zones were excluded from the drought analysis.
- Based on the comparison of performance of RCMs with IMD data sets, the LMDZOR has been identified as best performing RCM over central and some parts of North zone while SMHI performance is good over North-East and parts of North-zone. The extreme rainfall in the western-ghats is best represent by REMO.



Performance of various RCMs in simulating the observed rainfall after bias correction for each grid point over India



N-S values computed for the best RCM after bias-correction for each grid point all over India

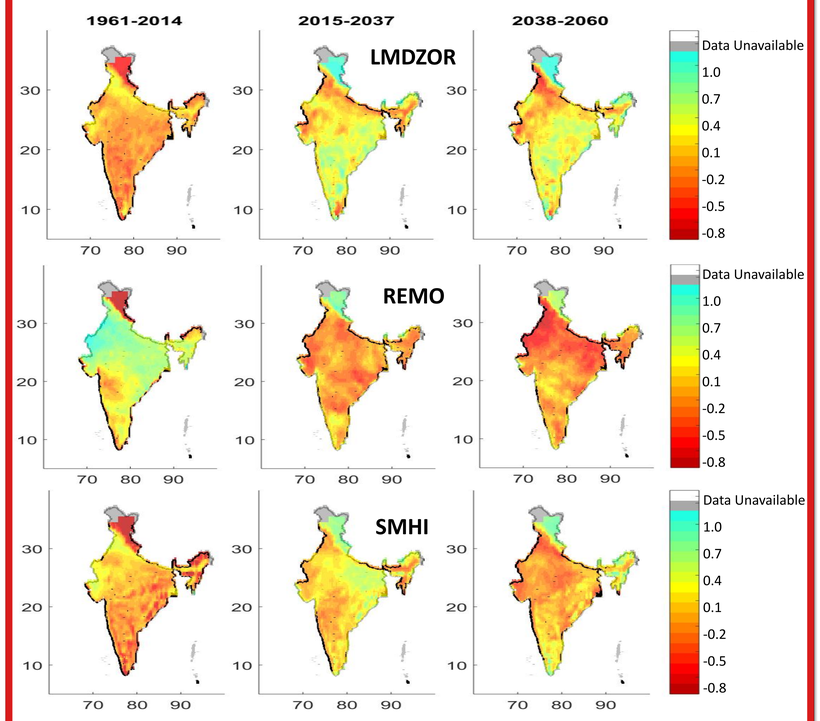


Comparison of monthly spatial averaged rainfall over India for observed and CORDEX datasets

Zone	ACCESS	CCSM4	CNRM	COSMO	GFDL	LMDZOR	MPI	NorESM	REMO	SMHI
Central	32.88	23.67	9.06	14	27.09	67.35	38.2	28.23	47.72	19.1
North	22.16	24.85	21.57	34.58	11.84	44.9	34.35	22.74	11.14	57.09
North-East	6.83	4.56	2.28	44.65	2.05	13.44	3.42	4.1	6.38	55.81
West	18.64	18.95	17.82	3.3	20.39	20.39	32.54	9.27	16.17	2.47
South	0	0	0	8.81	0	9.28	0.3	0	8.65	4.25
NE hills	3.2	0.8	4	27.2	0.8	10.4	14.4	0.8	15.2	32.8
Jammu & K	3.57	12.64	13.74	7.14	12.09	0	14.56	16.48	2.47	8.24
India	17.9	16.3	11.5	17.89	34.01	34.01	25.47	15.57	21.32	23.59

Comparison of performance of various CORDEX models in terms of percentage area in each meteorological zone of India with (N-S>0.4) (Best Coverage is shown in red)

Results/Discussions



Variations in SPEI values (drought intensities) over India for three time slices 1961-2014, 2015-2037 and 2038-2060 with CORDEX datasets

Conclusions

- The performance of RCMs in simulating the Indian climatology is satisfactory for North, Central, North-East and West zones. However the simulations are not reliable for South, North-East hills and Jammu & Kashmir.
- LMDZOR, REMO and SMHI RCMs performed best in simulating the rainfall for India
- For West and North-East zones, the drought frequencies increase for the periods of 2001-2050 and 2051-2100 for all three considered RCMs.
- All over India, the drought intensities were observed to be constantly increasing for all the RCMs considered.

References & Acknowledgments

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Acknowledgements: The research work presented here is funded by Science and Engineering Research Board (SERB), Department of Science and Technology, Government of India through Start-up Grant for Young Scientists (YSS) Project no. YSS/2015/002111.

CSIRO: Commonwealth Scientific and Industrial Research Organization, **GFDL**: Geophysical Fluid Dynamic Laboratory, **CNRM**: Canadian Climate Centre, Gatineau, Canada, **COSMO**: Consortium for Small-scale Modeling, **MPI**: Max Planck Institute for Meteorology, Germany , **SMHI**: Swedish Meteorological and Hydrological Institute, **LMDZ**: Laboratoire de Me´te´orologie Dynamique Zoomed version, **ACCESS:** Australian Community Climate and Earth-System Simulator, **CCSM4:** Community Climate System Model, **NorESM**: Norwegian Earth System Model, **REMO**: Regional Climate Model