Evaluation of Brazil's Extreme Precipitation Climate Indices and Future Changes

Regina Risso*

*Corresponding Author**

Regina Risso
Green Land,
Deapartment of Environment, Brazil
E-mail: Climatolres@journal.com

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Commentary

Extreme occurrences frequently result in significant economic and societal losses, particularly in weaker nations like Brazil. Because device policies of adaptation and mitigation to climate change typically take into account the outcomes of the most recent generation of ESMs, it is crucial to understand whether the evolution of Earth System Models (ESMs) from Coupled Model Intercomparison Project (CMIP) improves the representation of extreme events and investigating their future change. In this study, a subset of 40 ESMs from CMIP3, CMIP5, and CMIP6 are evaluated for their performance in simulating eight extreme precipitation climate indices over Brazil between 1981 and 2000. Additionally, their projected changes for the intermediate (2046-2065) and long-term (2081–20100) are estimated under the worst-case scenario for each CMIP generation. Results show that the most difficult precipitation index is CDD. whereas the most effective ones were PRCPTOT and R20mm. According to model results, CMIP3 has the best skill for Northeast Brazil, CMIP5 has the best skill for Center-West, and CMIP6 has the best skill for North, Southeast, and South regions. As a result, at least for Brazil, there was no discernible improvement in the representation of precipitation climate extremes across the entire country. In addition, reproducing the observed trends is challenging for all models across CMIP generations. This suggests that CMIP models still require improvement. The climate projections show a consensus signal among the majority of precipitation climate extremes and CMIP generations, which increases their reliability despite the relatively poor performance in the historical climate. Overall, the projected extreme precipitation events to be more severe, frequent, and protracted in all Brazilian regions, with the central northern portion of Brazil and the southern sector expected to experience more pronounced changes in heavy rainfall and severe droughts. the improvement in the simulation of precipitation extremes cannot be achieved by simply increasing spatial resolution. Because the most recent IPCC reports typically take into account the results of the most recent generation of ESMs, investigations examining whether the evolution of CMIP models improves the depiction of the current climate are crucial.

In this way, using the simulations and climate projections of the ESMs from the CMIP and the extreme climate indices advised by the ETCCDI is a great tool to investigate extreme precipitation climate events and their projected changes, especially for Brazil that needs to advance in studies on climate modelling with the objective of improving knowledge about climate change and its impacts across the entire country. This dearth of studies is even confirmed the improvement in the simulation of precipitation extremes cannot be achieved by simply increasing spatial resolution. Because the most recent IPCC reports typically take into account the results of the most recent generation of ESMs, investigations examining whether the evolution of CMIP models improves the depiction of the current climate are crucial.

Being aware that Brazil, particularly in its tropical region, is extremely sensitive to climate changes. Demonstrated that the Amazon basin and Northeast Brazil could experience temperature increases of more than 4°C by the end of the twenty-first century. In the far future, Northeast Brazil is expected to have an increase of up to 15% in the proportion of dry days and a rise of up to 100% in the proportion of days with heavy rainfall (2076–2100). As a result, this study has two main goals

1. Assess how well a subset of ESMs from CMIP3, CMIP5, and CMIP6 perform in representing extreme precipitation climate indices during the historical period in Brazil take into account the ongoing need for more in-depth information on the future climate in South America.
2. Take into account the lack of studies assessing whether the evolution of the ESMs from CMIP3 to CMIP6 improves the representation of extreme climate Brazil is the study country which has a population of more than 214 million people and a total area of about 8.516 000 km2. The Amazon rainforest, the densestly populated dry land region in the world, the Semiarid region in Northeast Brazil, one of the largest wetlands on earth (the Pantanal region), and the fifth largest watershed in the world are all significant physical features and natural resources of the nation. Brazil's precipitation pattern is modified by numerous atmospheric systems because of its huge geographical extent. In Brazil's five macroregions, North (NT), Northeast (NE), Center-West (CW), Southeast (SE), and South (S), these atmospheric conditions provide wet and dry seasons at various periods throughout the year (ST). However, the majority of Brazil is generally characterised by a monsoon climate, with the wet (dry) season predominating during the austral summer and autumn (winter and spring), primarily linked to the meteorological systems of the South Atlantic Convergence Zone (SACZ) and Intertropical Convergence Zone (ITCZ).

For this study, the eight ETCCDI-defined extreme precipitation climate indices total wet-day precipitation (PRCPTOT), very wet day (R95p), maximum 1-day precipitation (RX1day), maximum 5-day precipitation (RX5day), simple daily intensity (SDII), number of heavy precipitation days (R20mm), Consecutive Dry Days (CDD), and Consecutive Wet Days were chosen (CWD). The calculated indices, which were selected because they represent the main extreme events that primarily affect the study area, allowed for the assessment of the intensity (PRCPTOT, R95p, RX1day, RX5day, and SDII), frequency (R20mm), and duration (CDD and CWD), of extreme precipitation climate events. Additionally, these indices have been extensively utilised to research observed and modelled climate variability worldwide.

The chosen extreme precipitation climate indices have been computed on an annual basis to reduce the inter-annual extreme precipitation variability across Brazilian regions and to take into account that annual scale extreme climate indices have greater significance. Observational database Xavier et al. contributed the observational dataset that this study utilised (2016). The database was created using the inverse distance weighting interpolation method, which was applied to 3625 rain gauges and 735 weather stations covering the entire Brazilian territory, providing data with a spatial resolution of 0.25° 0.25° for the 1980–2016 period. The database contains daily precipitation information. There are numerous other data sources in the literature, (2016), that could be used to evaluate method used to collect data from 3625 rain gauges and 735 weather stations across the entirety of Brazil from 1980 to 2016 with a spatial resolution of 0.25°.

There are a number of other data sources in the literature that could be used to assess the effectiveness of the ESMs across CMIP generations, including the Global Meteorological Forcing Dataset (GMFD) Multi-Source Weighted-Ensemble Precipitation (MSWEP) , Climate Hazards Group InfraRed. However, some research revealed that the Xavier database offered a better representation of the rainfall in Brazil. , mostly as a result of quality control, the amount of station networks being developed, and the omission of reanalysis product and satellite rainfall estimation. Additionally, this dataset has already been applied in a number of ways in Brazil, such as the analysis of extreme drought episodes.

A study was initially conducted to determine which "families" of models are present from CMIP3 to CMIP6 and have data available on a daily scale in order to construct the extreme climate indices. This study revealed that there are seven families of models that satisfy the aforementioned requirements: the Center National de Recherches Meteorologiques (CNRM), Institute of Atmospheric Physics (FGOALS), Geophysical Fluid Dynamics Laboratory (GFDL), Institute Pierre-Simon Laplace (IPSL), Atmosphere and Ocean Research Institute (MIROC), Max Planck Institute for Meteorology (MPI), and Meteorological Research Institute (MRI). All of the available model sets were chosen after determining which model families were present in every CMIP version. At this stage, 40 models were found. The next stage was choosing the years of study after choosing the models. It was discovered that each version of the ESMs included in CMIP3 (1961-2000), CMIP5 (1850-2005), and CMIP6 (1850-2014) have a different historical time frame available. Therefore, it was decided to choose a period suitable with the three versions because one of the study's goals is specifically to determine whether the evolution of the CMIP models has improved the depiction of extreme rainfall events. The era 1961–2000 was one of the options after using this condition. However, the 1980–2016 observational dataset is accessible. As a result, the years 1981 to 2000 were chosen as the time frame for the historical climate analysis. In order to comprehend how future extreme rainfall events might behave, 2046-2065 (the mid-century future) and 2081-2100 were two time slices that were taken into consideration (far future). The sets of ESMs used in CMIP3, CMIP5, and CMIP6 were used to project the climate for the entire 21st century while taking into account various prescribed forcing agents and various hypotheses regarding, among other things, population growth, economic development, the energy model, and globalisation. As notedby direct comparison of the CMIP generations scenarios is thus not a simple task (2013b). However, the most likely climatic scenario for the future is the following given the current trends in greenhouse gas emissions, which recently reached 421 ppm - 50% above preindustrial levels - and negative environmental decision-making by many countries, including Brazil.

The most gloomy climate scenario is what is most likely to occur in the future. For CMIP3, CMIP5, and CMIP6, respectively, the SRES A2, RCP8.5, and SSP5-8.5 scenarios will be taken into consideration for analysing the climate projections. According to the SRES A2 emission scenario, there will be about 850 ppm of CO2 in the atmosphere in 2100.The RCP8.5 predicts that by the end of the century, the radiative forcing will be approximately 8.5 Wm2 (compared to preindustrial conditions) and the equivalent CO2 concentrations will be approximately 1370 ppm. The possibility for future growth powered by fossil fuels is the final characteristic of the SSP5-8.5. The spatial resolutions of the ESMs range from around 1-4°of latitude/ longitude Nevertheless, for the purposes of comparison, all datasets (observation using a first-order conservative remapping technique, to a common 1.0° grid. We conducted single-member simulations and one or two model-run experiments. As this study suggests a first-order comparison of the extreme precipitation climate indices for Brazil over the three CMIP generations, additional work utilising numerous ensembles can be done to look into these potential discrepancies in results.

Finally, we evaluate whether employing Multi-Model Ensembles (MMEs) may improve the depiction of extreme precipitation climate indices in addition to assessing the extreme climate indices by each model separately. A popular method for reducing the wide spread exhibited in individual model results is to calculate the ensemble mean. To that end, we calculated the average of each index across the CMIP generation (CMIP3, CMIP5, and CMIP6) models, and we treated those results separately. The five Brazilian macroregions and Brazil as a whole were the subjects of all analyses. To account for its variety in climate extremes, the subdivision was carried out.

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