Comparison of Different Bias Correction Schemes Based on Quantile Delta Mapping in the Perspective of Frequency Analysis of Precipitation Indices Over Karachi and Hyderabad Under Climate Change Scenario

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ABSTRACT

This research examines the analysis of frequency of precipitation indices two major cities of Pakistan namely Hyderabad and Karachi. These indices include maximum daily amount of precipitation (R1day), maximum 5-day cumulative amount of precipitation (R5day) and consecutive dry days (CDD). Three bias correction schemes based on quantile delta mapping (QDM)are considered to remove the biases of precipitation dataset. First scheme is monthly based correction (MC), second is annual based correction (AC) and third is peak correction based on annual raw data (PCRAW). Two global climate model (GCM) outputs of precipitation as modelled data from CMIP6 and observed data from APHRODITE are utilized for the analysis. Firstly, four statistical frequency distributions namely: generalized extreme value (GEV), Gumbel (GB), Log-Pearson Type III (LP3), and Lognormal (LOGN) distributions are applied. It is found that LP3 distribution is a good choice for the study area. Secondly, three bias-correction schemes are compared at two cities and suggested that PCRAW performed best based on bias correction for frequency analysis. Lastly, based on two GCMs, the research demonstrated an ensemble forecast of future extreme indices with return period of 200 years and proposed an overall increasing trend of all precipitation indices at both cities. Moreover, the outcome of this study may contribute to understand the impacts of climate change on precipitation.

Keywords: Precipitation indices, Bias correction, QDM, GCMs, CMIP6.

INTRODUCTION

Pakistan is a sensitive region to weather-related hazards, such as: waterlogging, aridity and high-temperature events. The primary source of precipitation is monsoon season, a natural phenomenon that results in intense floods in this region. In recent decades, high resolution GCMs have been applied to understand fine scale global climate scenarios. These GCMs are especially useful for Southeast Asia region as the climate of this region is dominated by monsoon. Outputs from these models exhibit consistent deviations for different causes. Thus, method of bias correction is used before its application for effective study. Bias of a GCM is described as the deviation between a modeled environmental data and the related actual weather data. Cannon applied quantile-based bias correction on hydrological extreme measures. They used generalized extreme value distribution (GEV) for frequency analysis with return period of 20 years. Their research on different advanced intense hydrological indicators failed to meet the criteria for more probability distributions. Moreover, multiple factors including: urbanization, transportation, agriculture and infrastructure in Pakistan have affected some of the devastating extreme precipitation events in recent past decades. Therefore, prediction about future precipitation extremes is essential to examine environmental change with empirical evidence. This study presents the results of Quantile Delta Mapping (QDM), as QDM provides bias-correction of future model

climate data by including the changes in all quantiles appearing between the reference and historical model data.

OBJECTIVES

The study aims to:

1. Computation of precipitation indices frequencies under changing climate conditions for Karachi and Hyderabad.
2. Comparison of the performance of four frequency distributions: GEV, GB, LP3 and LOGN.
3. Application and assessment of three schemes based on QDM for correction of biases: MC, AC, and PCRAW.
4. Identification of the most reliable combination of frequency distribution and bias-correction scheme to project future precipitation indices with least error.

METHODOLOGY

The QDM algorithm is employed in this study to mitigate biases from modeled historical and projected data of precipitation on daily basis, extracted from two GCMs: MIROC6 (r1i1p1f1) and EC–Earth3–Veg–LR under SSP585. By finding the difference in quantiles (Δ) between the historical and projected datasets, QDM adjust the observed distributions and generate bias-corrected projections. The process is repeated for each bias-correction scheme (MC, AC, and PCRAW) to evaluate their relative effectiveness. Precipitation extreme indices are selected as suggested by the Expert Team on Climate Change Detection and Indices (ETCCDI) framework and analysis focuses on events of return periods: 10, 25, 50, 100, and 200 years. Kolmogorov-Smirnov (K-S) test was used to check suitability of probability fitting. Mean absolute percentage error (MAPE) was used to test accuracy of frequency distributions.

CONCLUSION

LP3 notably performed well as compare to other three probability distributions by K-S test and owing to the stable minimum values of MAPEs for two cities. For GEV, the mean value of the averaged MAPEs over all indices and GCM model is 15.4%, for GB is 11.1%, for LP3 is least value 0.87% and for LOGN is 9.33%. Overall, while all four distributions generally produced acceptable projections, the GEV distribution may be less suitable than the others due to deviations in its projected values and Gumbel and Lognormal distributions give less accurate fitting in comparison to distributions of three parameters. Among the bias-correction schemes, PCRAW achieved the best accuracy, with nearly-zero MAPE for R1day and R5day and approximately 3 % for CDD. Its strong performance can be attributed to the limited annual peak samples, which allow precise quantile mapping between historical and modeled data. The MC ranked second, with an average MAPE of 6.1 %, followed by AC at 9.97%. While, MC effectively represented seasonal variability, it tended to slightly over-project precipitation indices. AC provided consistent but less accurate results. The outcomes highlight the growing risk of intense precipitation and prolonged dry spells under climate change, emphasizing the need for climate-resilient water management and agricultural adaptation strategies.

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