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# Temperature Projections from GCMs Using Quantile Remapping Method

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**Abstract**

General Circulation Models (GCMs) represent the state art of models for simulations of global climate which takes in to changes in circulation patterns through mathematical and Numerical models. The Globalization and rapid Industrialization coupled with change in land use land cover, is altering the CO2 content in the atmosphere ultimately increasing the temperature. The present study deals with projections of temperature across Indian land region using Quantile remapping method from CMIP5 suite under RCP 8.5 scenario. Bias occurs in the GCM model outputs due to various reasons such as incomplete understanding of geophysical processes, subsequent parameterization, assumptions, methods of solutions in the GCM leads to bias in GCM simulated variables. In the present study 10 GCM are used and the Multi model average (MMA) indicate increase in surface temperature, minimum and maximum temperature for future time windows (2020s, 2050s and 2080s). Our study highlights the usefulness of the climate models for future management of temperature.

**Keywords:** GCMs, Bias Correction method Multimodel Average (MMA)

## INTRODUCTION

GCMs are widely used for weather forecasting, understanding of the climate system, and projecting climate change for future. These computationally intensive numerical models are based on the integration of variety of fluid dynamical, chemical, and biological equations [IPCC, 1]. Climate is measured by assessing the patterns of variation in temperature, humidity, atmospheric pressure, wind, precipitation, atmospheric particle count and other meteorological variables in a given region over elongated time periods nearly for 30 years or so [1]. GCMs exhibit significant skill in simulation of global climate at huge spatial scale. GCMs are at present are the most realistic tools for simulation of climate system to rising greenhouse gas concentration. They are, however, incapable to stand for local sub-grid scale features and dynamics [2, 3]. GCMs are skillful in simulations of climate related variables rather than hydro meteorological variables [4]. However, due to partial understanding of complete geophysics behind the climate system, the outputs from GCMS exhibit systematic error (bias) with that of observed data [3, 5]. Therefore this systematic/logical bias needs to be corrected using various bias correction methods viz. Nested bias corrections method, Quantile remapping method, Multiplicative shift technique, Regression technique, Principal component regression technique [6,7]. Here, we employ quantile based transformation method of Li et al [5].

## DATA AND METHODOLOGY

IMD (India Meteorological Department) has provided the observed surface, minimum and maximum temperature at $1^0$ spatial resolutions. Here, we use 10 GCMs from CMIP5 suite for analysis and future projections of temperature under 8.5 RCP scenario.

**Table 1.** GCMs used in the present study from CMIP5

| Model Centre | Model | Institution |
|---|---|---|
| CMCC | CMCC-CESM | Euro-Mediterranean Center on Climate Change |
| CNRM | CNRM-CM5 | National Meteorological Research Centre |
| CSIRO | ACCESS-1 | Commonwealth Scientific and Industrial Research Organisation, Australia |
| INM | INM-CM4 | Institute for Numerical Mathematics |
| IPSL | IPSL-CM5B-LR | Institute Pierre-Simon Laplace |
| MIROC | MIROC-ESM | Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute |
| MPI | MPI-ESM-MR | Max Planck Institute for Meteorology (MPI-M) |
| MRI | MRI-ESM1 | Meteorological Research Institute |
| NCC | NorESM1-M | Norwegian Climate Centre |
| NIMR | HadGEM2-AO | National Institute of Meteorological Research, Korea |

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## METHODOLOGY

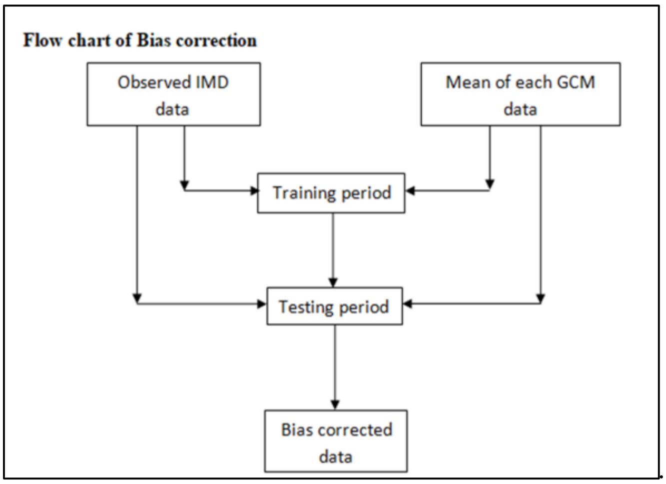


**Figure 1:** Flow chart for Bias correction method

The Fig 1 shows the broad outline of the bias correction method suggested by Li et al [5]. GCMs data is extracted to Indian portion. After the extraction of required period, GCMs data is interpolated to that of observations. Here, we notice the GCMs original data do not match with observed IMD temperature data. Hence, Bias correction is performed on the GCM simulated data.

The methodology used in the present study is described below:

Li et al. (2010) method is basically a quartile based remapping method where cumulative distribution functions are fitted to the observed, training and testing data of GCM. The methodology includes the following steps:

1).The observed as well as GCM (XGCM) simulated data, first Cumulative Distribution Functions (CDFs) are fitted to them.

2). GCMs testing period is used to generate new series by making use of GCM train parameters. By finding the difference between new data and test data, climate change signal is obtained.

3). for future/ testing, corresponding to a CDF value, the change is added to GCM test data with observed parameters. For further details refer to Li et al [5] method.

## RESULTS AND DISCUSSIONS

The methodology is applied to GCM simulated data with 1969-1984 as training and 1985- 2000 as testing data. All the plots are presented for testing data. The gridded observed temperature data is obtained from India Meteorological Department (IMD). (Fig 2).

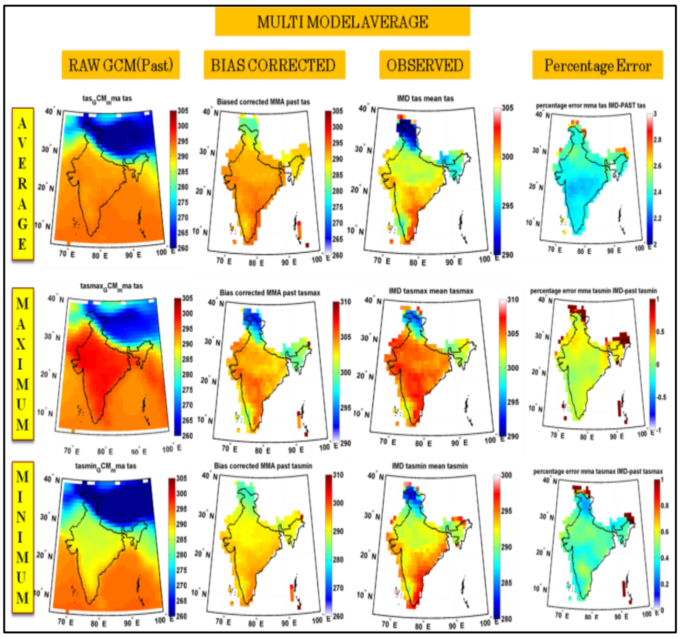


**Figure 2:** Shows the Multimodel average of original/raw, bias corrected, observed, percentage error for simulated data. (Units are in $^{0}$K).

We find from Fig 2 that the percentage errors lies around 4-5% at most of nodes and hence present Bias correction method performs very well. It has captured the spatial variability also well.

## FUTURE PROJECTIONS RESULTS (RCP 8.5 SCENARIO)

The future changes in temperature are carried out for 90 years (2011-2100). These changes are performed in three time scales of 30year time period (2011-2040, 2041-2070, 2071-2100). The changes in temperature are performed with respect to base bias period (1986-2005). There is rise in temperature in central, south, north east of India. The western India do not show significant rise in average temperature.

Average temperature is increases from 2011-2040 to 2071-2100. Minimum and maximum temperatures also show some increase in temperature in three time periods. In 2011-2040 the average temperature is about 298 $^{0}$K in north India and 302 $^{0}$K in south India and Gujarat, Rajasthan regions. In 2041-2070 the average temperature is increased about 2 to 3 $^{0}$K compared to 2011-2040. In 2071-2100 average temperature increases drastically. In all three time periods minimum temperature shows high value about 300 $^{0}$K in coastal regions. Maximum temperature shows high values about 306 to 310 $^{0}$K in middle Indian regions.

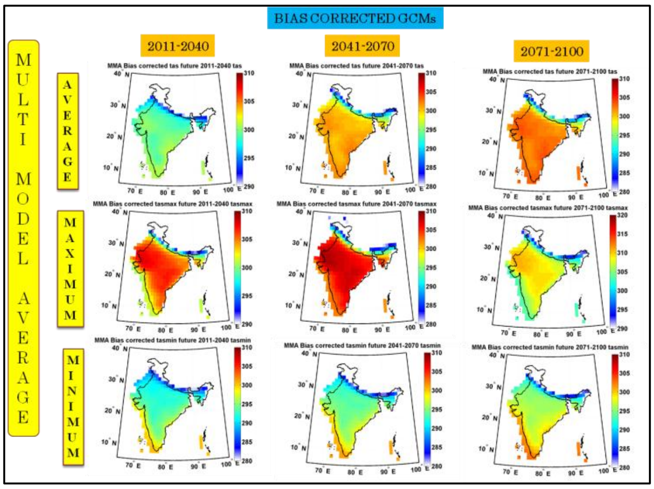


**Figure 3:** Shows the Bias corrected temperature distribution of Indian region for different time windows 2020s, 2050s and 2080s.

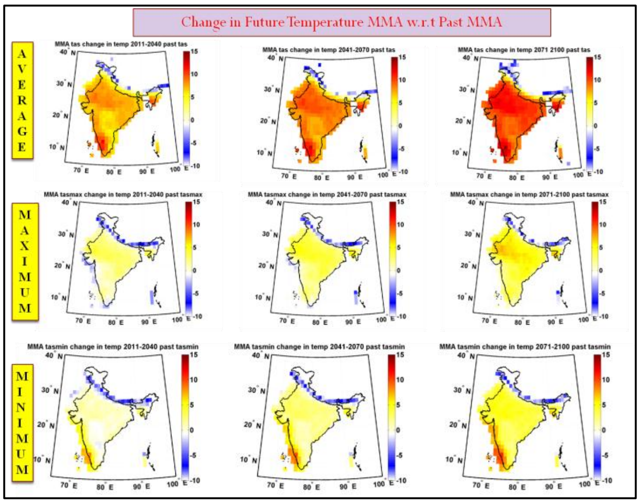


**Figure 4:** Shows the changes in temperature distribution with respect to historical period (1986-2005).

The fig 4 is an important finding from our research study. Bias corrected future temperatures show increase in temperature with respect to the historical temperatures. Average temperature is increasing in future. Minimum and maximum temperatures are not changing 2011-2040, but increasing up to $5^0$C in 2041-2070 and 2071-2100.

## CONCLUSIONS

The objective of the study is to examine the performance of bias correction on climate models and the estimation of daily temperature projections of India for the future period up to 2100.

The major findings of the present work are as follows:

- The multi model average of all the bias corrected GCMs has better result.
- The future projection for the years (2011-2040, 2041-2070, 2071-2100) indicates that the average temperature is increasing in all three future time scales (2011-2040, 2041-2070, 2071-2100).
- The change in maximum and minimum temperature for the future period 2011-2040 does not show significant change from historical period.
- The changes in maximum and minimum temperature for the future period 2041-2070 and 2071-2100 shows increase in temperature up to $5^0$C in most regions of India with respect to historical period. This needs to be thoroughly examined using various regional models for reliability studies.

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