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# Future Temperature Projections for India for climate change studies

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**Abstract**: *Climate change impacts are usually assessed by making use of General Circulation Models (GCMs) which simulate large scale climate variables accounting Green House Gases (GHGs) and aerosols. The Globalization due to rapid industrial growth, change in land use land cover, may alter or modify the CO2 in the atmosphere ultimately raising the atmospheric temperatures near the surface of the earth. An attempt is made in the present study to analyze from General climate models (GCMs) simulated temperature of data for daily mean, maximum and minimum temperature on the Indian region due to the effect of anthropogenic activities for the future time slice (2010-2040) known as 2020s. The Coupled Model Intercomparison Project 5 (CMIP5) simulated GCM (MIROC, CCCma, MRI) data is used for the present work. Incomplete understanding of geophysical processes and subsequent parameterization, assumptions, methods of solutions in the development of a GCM leads to bias in GCM simulated variables. In the present study, quantile based remapping method [Li et al 2010] has been used for bias removal. The study reveals that using the Multi model average (MMA) there is an increase in surface temperature and reduction in minimum temperature maximum temperature for future. Our study highlights usefulness of the present model for temperature projections and management for future.*

**Keywords:** *Bias correction, General Circulation Models, temperature*

## I. Introduction

Global average temperatures have been rising, and human activities have changed the composition of the atmosphere significantly and the climate will continue to change [IPCC, 2007]. Changes in the Earth's climate system throughout geologic time can be linked to changes in the components of the climate system. Global climate changes will likely result in impacts that affect water utilities and their operations, such as changes in temperature and precipitation. This is a result of warmer temperatures intensifying and accelerating the hydrological cycle, leading to an increase in evaporation that causes an increase in total annual precipitation. As temperatures increase, evaporation increases, resulting in droughts and floods. 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 long periods of time [IPCC, 2007]. General or global circulation models (GCMs) simulate the Earth's climate via mathematical equations that describe atmospheric, oceanic, and biotic processes, interactions, and feedbacks. Climate models use quantitative methods to simulate the interactions of the atmosphere, oceans, land surface, and ice. They are currently the most credible tools available for simulating the response of the global climate system to increasing greenhouse gas concentrations, and to provide estimates of climate variables (e.g. air temperature, precipitation, wind speed, pressure etc.) on a global scale. GCMs demonstrate a significant skill at the continental and hemispheric spatial scales and incorporate a large proportion of the complexity of the global system; they are, however, inherently unable to represent local sub-grid scale features and dynamics [Wilby and Wigley, 1996]. This limitation led GCMs model outputs not to use the directly for impact assessment studies. The accuracy of GCM model outputs increases with climate related variables rather than hydro meteorological variables [Wilby et al 2004]. Therefore the GCMs are good in simulating temperature due to incomplete knowledge of complete geophysical processes behind the climate system, led to systematic error with that of observed temperature data [Salvi et al 2011]. Therefore this systematic 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 [Acharya et al 2012; Johnson and Sharma, 2012; Li et al 2010. The present study the quantile based remapping method suggested by Li et al [2010] has been adopted.

## II. Bias Correction Method

Bias represents the systematic deviations of GCM simulated model outputs with respect to observed data. This happens due to incomplete knowledge of the processes governing the climate system due to various reasons namely limited understanding of the climate, parameterizations, assumptions led to systematic deviations of GCM model outputs [Shashikanth et al 2013]. The bias removal is the first step in the climate study and it depends on the quality of the observed data. As mentioned, we have used Bias correction method proposed by Li et al [2010] method, which is known as quantile transformation method, based on cumulative distribution functions of observed training and testing data (Fig. 1). The methodology is briefly discussed in the following steps.

**(A) Bias correction for training data (Observed data is available for the same period)**

Requirement of Data (1) Observed temperature for training period (2) GCM simulated temperature time series for the same grid for training period.

**Steps**

(1) Fit the Gamma probability distribution for both observed and GCM train time series data of temperature. Let the distribution parameters for the observed time series be A1 obs and A2 obs. Similarly let the parameters for the GCM train series be B1GCM and B2GCM.

(2) Compute the CDF for both the time series using corresponding parameters. Let the CDF for observed time series be CDF observed and CDF for GCM simulated time series be CDFGCM.

(3) Using $CDF_{GCM}$ and parameters of observed data A1 obs and A2 obs, obtain the corrected time series of temperature. This is procedure simply replaces the GCM simulated value by an observed value whose quantile values are equal.

**(B) Bias correction for future data (Observed data is not available for future period)**

Requirement of Data: (1) GCM simulated temperature time series data for future (to be corrected; observed data is not available for this period) (2) GCM simulated temperature time series for the same grid for training period (observed data is available of this training period) (3) Observed temperature time series at the same node for training period.

**Steps**

(1) Fit the same Gamma probability distribution for all the time series. Let the distribution parameters be A1obs and A2obs. Similarly let the parameters for the GCM simulated time series for training be B1GCM_train and B2GCM_train and the parameters for the future time series (testing period) be B1GCM_test and B2GCM_test.

(2) Compute the CDFs for all the three time series using their respective parameters. Let the CDF for observed time series be CDF observed and CDF for GCM simulated series for training period be CDF $_{GCM\_train}$ and CDF for GCM simulated time series for future (testing) period be $CDF_{GCM\_test}$.

(3) Generate a time series using the CDF $_{GCM\_test}$ and parameters B1GCM_train and B2GCM_train. Subtract these time series values from the GCM simulated time series for future (testing) period. This difference can be treated as the climate change. This step is essential because future time series cannot be directly corrected using past observed data [Li et al 2010].

(4) Using $CDF_{GCM\_test}$ and the parameters Aobs1 and A2obs, get the new time series and add the difference calculated in the previous step to this time series. This is the bias corrected time series for future.

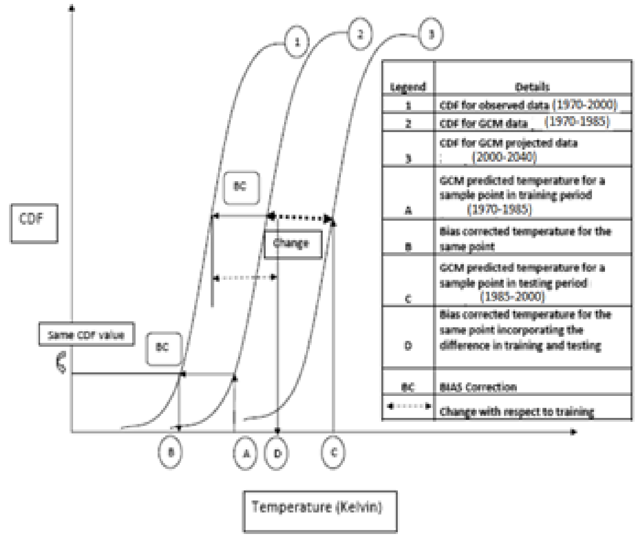


**Fig 1: Bias Correction methodology [Li et al Method, 2010]**

## III. Results and Discussions

Bias corrected Li et al (2010) methodology applied to GCMs simulation data to obtain the model data for the training and testing period data for the work 1970 – 1985 and 1986 -2000 respectively.

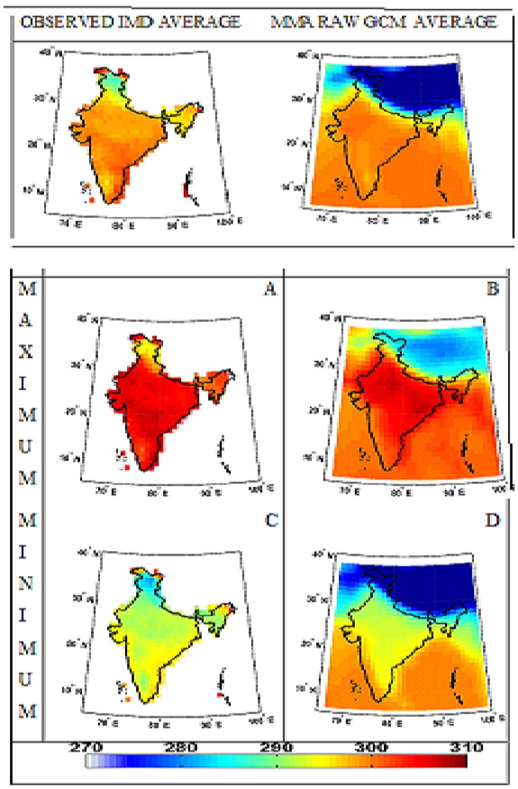


**Fig 2: Shows the Raw simulated temperature data from GCMs with respect to observed data. The science behind occurrence temperature has reasonably simulated by GCMs, however, has some bias. Units in $^{0}$K**

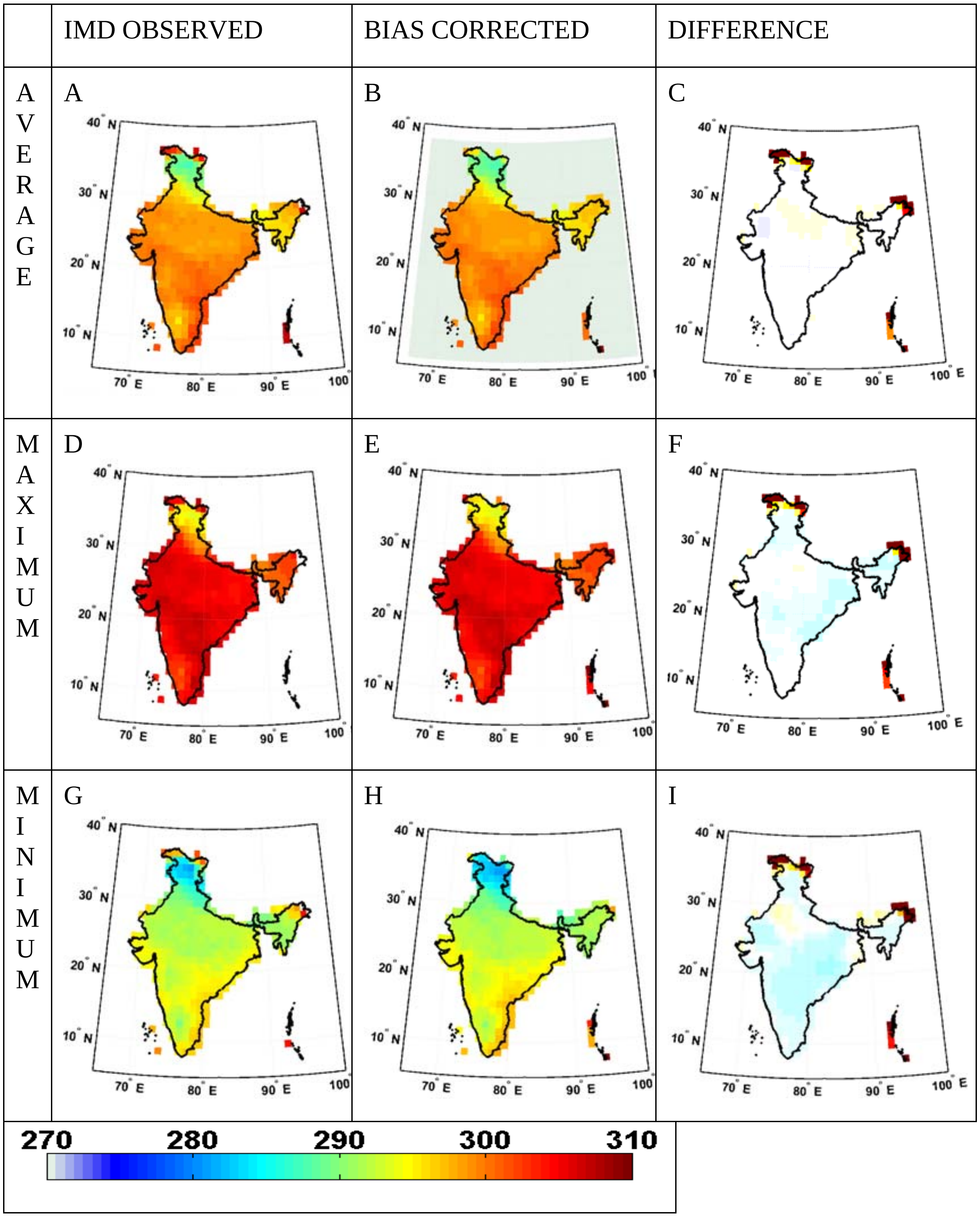


**Fig 3; Shows the observed and Bias corrected temperature (multimodel average) simulated data for average, maximum and minimum temperature for validation period [1986-2000]. Units $^{0}$K**



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**Future Projections Results (RCP 4.5 Scenario)**

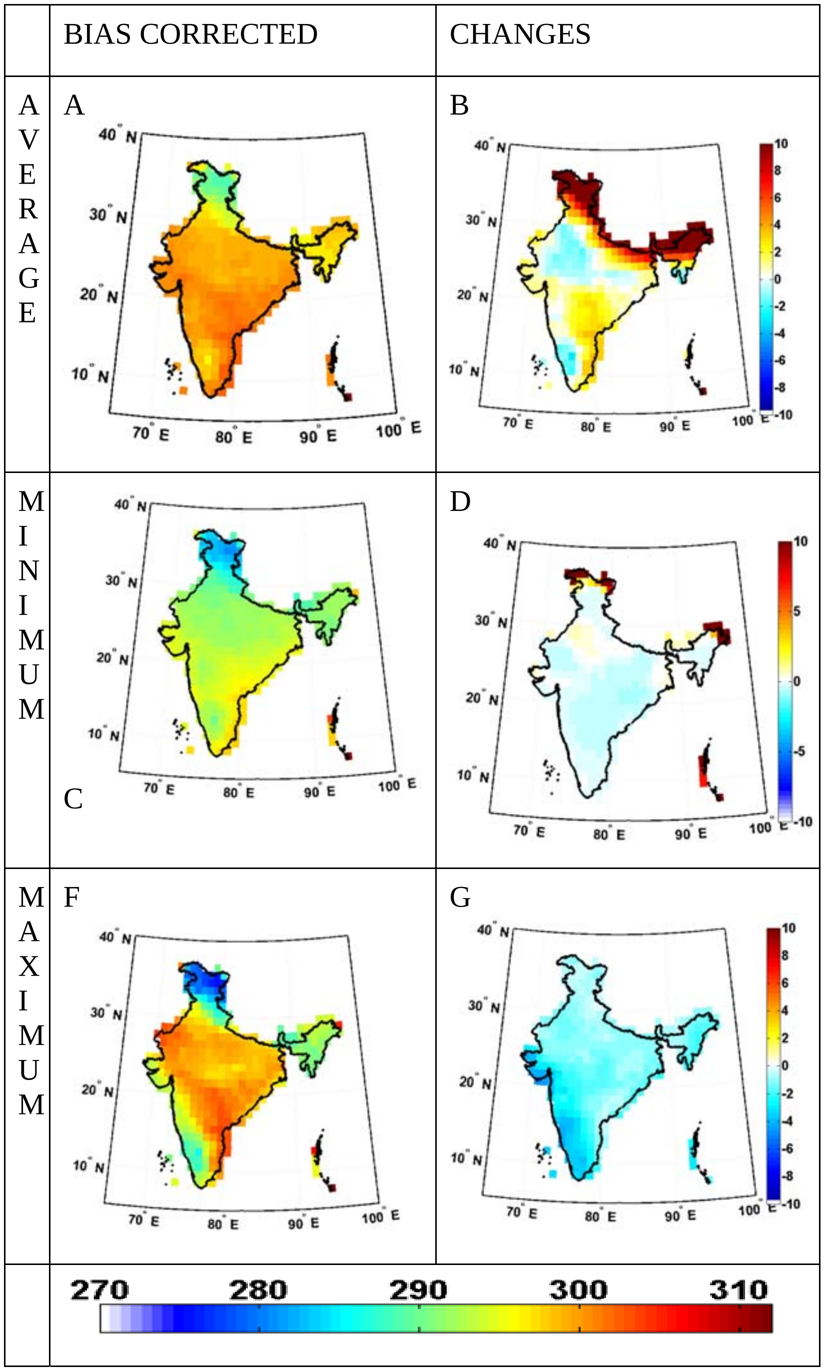


**Fig 4: Shows bias corrected MMA and Changes in temperature for visual interpretation.**



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After establishing the model, the raw simulations are bias corrected using the methodology as proposed in the earlier sections.

The future changes in temperature are carried out for 30 years the (2010-2040).the changes in temperature are performed with respect to base bias period (1986-2000).

There is rise in average temperature in central, south, north east of India. The western India do not show significant rise in average temperature. The minimum temperature further decreases in the most of the regions in India. Similarly the maximum temperature for future decreases in most of the regions of India as well.

## IV. CONCLUSIONS

The objective of the study is on India's temperature for historical and future data. The Climate models temperature data for the historical period from 1970 to 2000 and future 2010 to 2040 from CMIP5 is downloaded. Due to in complete knowledge about the geographical processes governing the climate system, the assumptions on models of GCMs which results difference in estimate of observed and simulated data. This difference is known as bias. For the present study bias corrections technique proposed by Li et al (2010) is used. The method by Li et al (2010) used quantile remapping method and for validation period results shows that the method indeed comes close to a realistic projections.

## V. ACKNOWLEDGMENT

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