Statistical Downscaling of Maximum Temperature in Hoshangabad District of India

Ankit Balvanshi, H.L. Tiwari, Mayank Gupta, Akhilesh Sharma

Abstract*: The Global Climate ModelsCanESM2 and CGCM3 were utilised to downscale the maximum temperature for Hoshangabad district of Madhya Pradesh, India. The area of study comprises to be of 6704 km^2. The predictors employed for CanESM2 were ncepmslpgl, ncepp500gl, ncepp850gl and ncepmslpas, ncepp500gl, ncepp850gl were the predictors fixed for CGCM3. The total duration of the study was from the years 1979 – 2001. The two GCMs, CGCM3 and CanESM2 were checked for their capability in downscaling the maximum temperature climatic parameter. The GCM outputs were evaluated on Nash Sutcliffe Efficiency (NSE) and coefficient of determination (r^2) criterias. The period of calibration was taken to be 1979-1995 and 1996-2001 was chosen as the period of validation. GCM CanESM2 obtained NSE of 0.77, 0.75 and r^2 of 0.79, 0.79 during the periods of calibration and validation respectively. It was concluded that CanESM2 model is found comparatively more suitable for downscaling of maximum temperature for Hoshangabad region. The GCM can be further employed to generate the future scenario of maximum temperature in the region.

***Keywords*: Global Climate Model, CGCM3, CanESM2, NSE, r^2.**

I. INTRODUCTION

The I.P.C.C. (Intergovernmental Panel on Climate Change) is the principle body that defines the climate change. According to the IPCC, any change in climate parameters that can be found using the various statistical tests or by change in properties is known as Climate Change.This change can be due to natural variability or due to human activity. The definition of climate change given by IPCC is different from the definition given by UNFCC. UNFCC defines climate change as the change in climatic parameters that can be due to direct or indirect human activities which changes the global atmosphere composition[1]. The downscaling technique plays a dynamic role for the estimation and prediction of the climate change. This technique is also used for the calculation of irrigation demand. [2] used the HADCM3 scenario file for the estimation of CWR of crops in Baroda district in Gujarat.

[3] conducted a study to downscale rainfall and temperature from GCMs. The single site data of study area situated in Indira Sagar canal command area of M.P. (Madhya Pradesh), India wasgiven input to downscaling model. The region lies between 74° 46' - 76° 29' E long. & 21° 46' - 22° 19' north lat.The total area encompassed of around 3550 km². The GCM used for the study was Had CM3. The results showed that the model is efficient in downscaling of precipitation and temperature climatic parameters.The future results during years 2010-2099, estimated araise in total average annual rainfall and annual average temperature for station. [4] researched to find out the Future changes in precipitation, temperature and ET0 in the central India by LS SVM (least square support vector machine). The climate model HadCM3 was employed in the study.The area of study was chosen to be Betul, Raisen and Hoshangabad districts having total area about 12,290 km^2. It was found that there is increase in the future rainfall, temperatures and ET0. [5]worked to project the min. temp. using the Canadian GCM for the Raipur region in India.The downscaling tool was SDSM which employs the statistical downscaling technique to downscale the climatic parameter. The projected min temp. was for future periods FP-1 (2020–2035), FP-2 (2046–2064), and FP-3 (2081–2100). It was concluded that the model was efficient in the downscaling of the minimum temperature of the Raipur region.

II. STUDY AREA

Hoshangabad is a district located on the southern banks of Narmada river. The physical location of the area lies at 22.75°N latitudes 77.72° E longitudes (figure 1).

Revised Manuscript Received on September 25, 2020.

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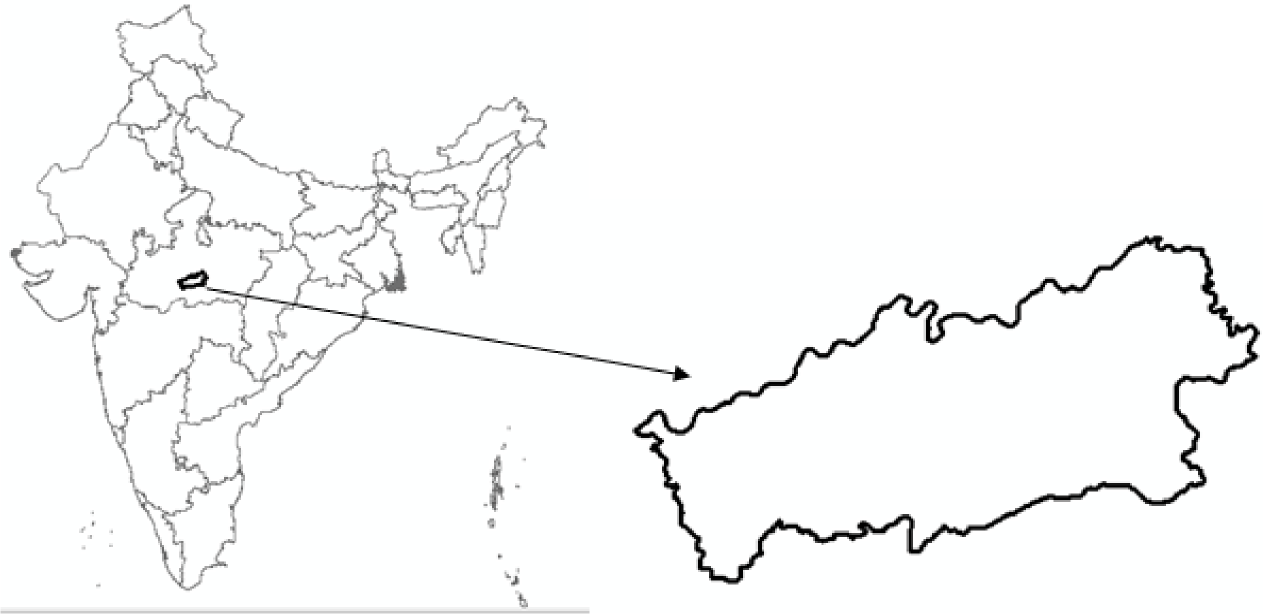

Figure 1Location of Hoshangabad Region, India

Average precipitation in Hoshangabad:
The average annual rainfall of the study regions is 1340 mm.The months from June to September contributes to the highest receiving months of the rainfall in this region.
AverageTemperature in Hoshangabad:
The annual average temperature of this region goes to nearly 19^0 C as minimum temperature& 40^0 C as maximum temperature.
Soil Present in Hoshangabad:
The region comprises of mostly black cotton soil. The texture of the soil varies from heavy to light soil. The hydrologic soil group is C and D that implies high runoff capacity of the soil in the region.

III. WORKING PROCEDURE

Statistical Downscaling Technique (SDSM):

- The relationship between historic and current atmospheric variables is established.
- After the establishment of relation between historic and current variables, the future scenario generation starts.
- This downscaling method creates area specific climate scenarios whereas the RCMs lack behind because of their limitation of area size which is upto 20-50 kms [6, 7, 8, 9 and 10].
- The historical maximum temperature data was taken for the period from 1979-2001. This data was utilized for the downscaling of the GCM CGCM3 and CanESM2.

The working procedure of statistical downscaling model is depicted ahead in figure 2.

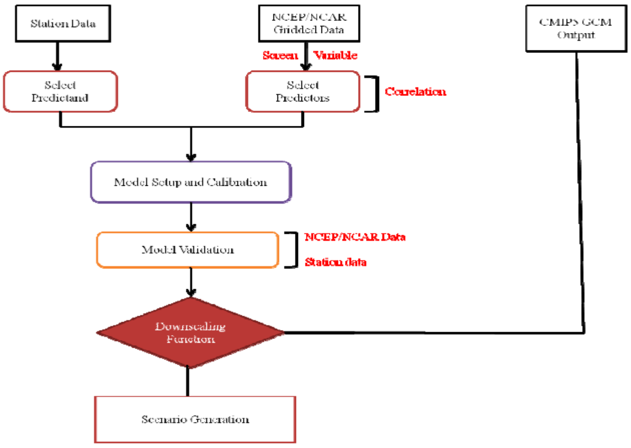

Figure 2Working Steps of Model

Processes involved

1. Controlling the quality of data input
2. Downscaling of climate variables (Screening)
3. Calibration of Model
4. Current climate data generation
5. Future Scenario generation [8].

Evaluation of models

(i) Coefficient of Determination, r^2

$$r^2 = \left(\frac{\sum_{i=1}^{n} (O_i - \bar{O})(P_i - \bar{P})}{\sqrt{\sum_{i=1}^{n} (O_i - \bar{O})^2} \sqrt{\sum_{i=1}^{n} (P_i - \bar{P})^2}} \right)^2$$

Where, O is observed value
P is predicted value
O .

The range of this evaluation parameter lies between 0 and 1 which describes how much of the observed dispersion is explained by the prediction. A value of zero means no correlation at all while a value of 1 means that the distribution of the prediction is equal to that of the observation. A model which steadily over predicts or under-predicts all the time will give outcome as good r^2.

(ii) Nash Sutcliffe Efficiency

The efficiency E or η was proposed by Nash and Sutcliffe in the year 1970. It is defined as 'one minus the sum of the absolute squared differences between the calculated and observed values normalized by the variance of the observed values' during the period of study. Mathematically the formula is expressed as:

$$E = 1 - \frac{\sum_1^n (O_i - P_i)^2}{\sum_1^n (O_i - \bar{O})^2}$$

Where, O_i is the observed data,

P_i is the modeled data,

$\bar{O}$ is the mean of the observed data.

IV. RESULTS AND DISCUSSIONS

The statistical downscaling technique was employed for the downscaling of the GCM CanESM2 and CGCM3 climate model. The period during 1979 to 1995 was chosen as calibration years and 1996 to 2001 was considered as validation years. The results were evaluated with the accuracy criterias NSE and R^2. The NSE for the maximum temperature during years 1979-95 for CGCM3 and CanESM2 was found to be (0.75 & 0.77) and during years 1996-2001 was found to be (0.74 & 0.75) respectively. The R^2 for the maximum temperature during years 1979-95 for CGCM3 and CanESM2 was found to be (0.75 & 0.77) and during years 1996-2001 was found to be (0.74 & 0.75) respectively.

Results on the basis of Coefficient of Determination

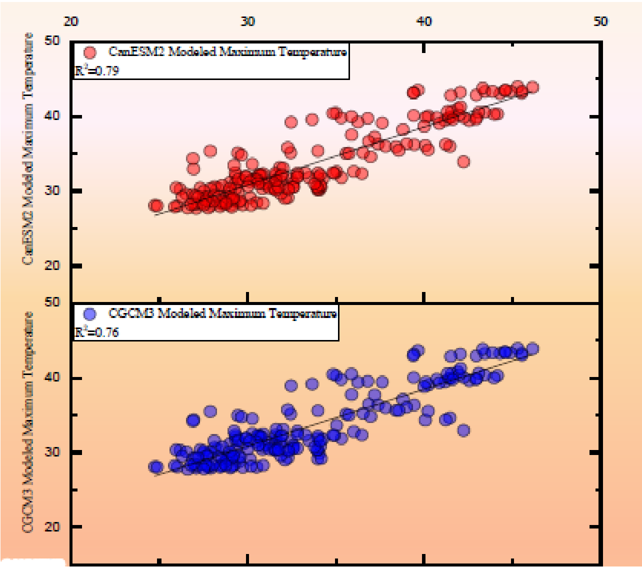

Figure 3 Coefficient of determination chart during calibration period

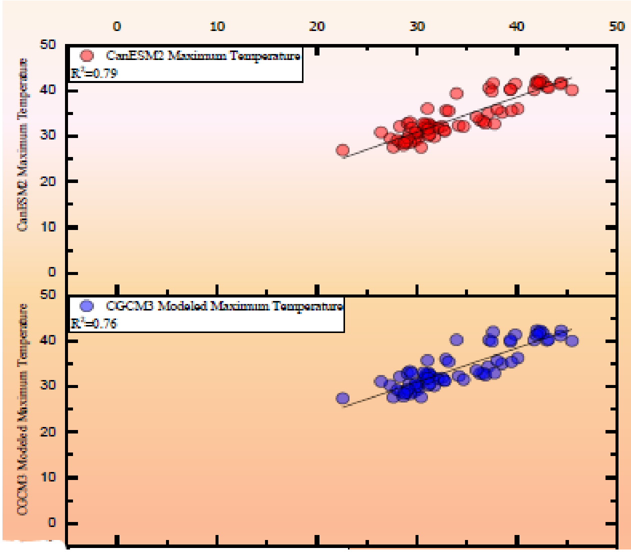

Figure 3 Coefficient of determination chart during validation period

Table 1 NSE and R^2 Results of GCMs

Parameter	Performance Criteria	CGCM3		CanESM2	
		Cali.	Vali.	Cali.	Vali.
Max Temperature	N.S.E.	0.75	0.74	0.77	0.75
	R^2	0.76	0.76	0.79	0.79

V.CONCLUSIONS

The climate models CanESM2 and CGCM3 were utilised for the downscaling of the climatic parameter maximum temperature. The accuracy of the downscaled result was tested using the Nash Sutcliffe Efficiency (NSE) and coefficient of determination (r^2) criterias.The NSE of CanESM2 obtained a higher NSE values of 0.77 & 0.75 and r^2 values of 0.79, 0.79 respectively during calibration and validation. In comparison with CanESM2, CGCM3 climate model obtained less accuracy values (Table 1). It was concluded that CanESM2 climate model ismore appropriate for statistical downscaling of climatic parameter in the study area. CanESM2 Global Climate Model can be used ahead for the generation of the future climate under different scenarios.

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