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FUTURE PREDICTION AND TREND ANALYSIS OF TEMPERATURE OF HARYANA

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ABSTRACT

General circulation models are hybrid mathematical model used for climate change impact studies. It works on a coarser scale and downscaling is necessary for climate change impact at regional scale. Monthly temperature in Haryana is downscaled in this study. In this study the future monthly temperature in Haryana is downscaled using outputs of CGCM3 for A2 emission scenario. The data for the base period of 30 years (1971-2000) and for the future period of 100 years (2001-2100) has been downscaled. Standrised data set of temperature from Indian metereological department(IMD) Pune has been taken as observed and a relationship is generated between predictand and predictors of Canadian coupled global climate model (CGCM3) and the generated relationship are then used for downscaling temperature for future period. The correlation coefficient shows relationship between observed and predicted data. From the prediction it has been observed that temperature rise in winter season is more than summer season. It has been observed from the predicted temperature (2001-2100) both for maximum as well as minimum, rise in temperature is less during summer and more during winter. The rise in monthly temperature for both maximum and minimum is approximately in the range of 1-3 degree Celsius during summer whereas rise in monthly temperature both for maximum and minimum rises upto 5 degree Celsius during winter at the end of century which is within the range as Projected by Intergovernmental Panel on Climate Change (IPCC) that the earth's average temperature will rise 1.4–5.8 degrees Celsius during this century.

Keywords: *GCM; Climate Change, CGCM3, IMD, Downscaling.*

INTRODUCTION

India is Developing nation, with fastest growing Economy based on Agriculture. Haryana is an agriculture based state as 85% of major land used for agriculture. Agriculture is very vulnerable to Climate Change. Hence the impact of climate change on Agriculture will also impact the Economy. It is necessary to study the pattern of temperature and its variability for assessing the impact of climate change on various surface processes i.e. hydrology, agriculture, forestry, water resources management (Anandhi et al, 2008, 2009). The GCM models are very advance mathematical model which are widely used for Climate change Impact studies. A general circulation model (also known as a global climate model, both labels are abbreviated as GCM) uses the same equations of motion as a numerical weather prediction (NWP) model, but the purpose is to numerically simulate changes in climate as a result of slow changes in physical parameters (such as the greenhouse gas concentration) or some boundary conditions (such as the solar constant) (*B. Geerts and E. Linacre). (http://www.das.uwyo.edu/~geerts/cwx/notes/chap12/nwp_gcm.html)*

There are numbers of GCMs available for different emission scenario. In this study Canadian coupled global climate model (CGCM3) has been used. It works on a coarser scale with a 3.75 degree grid cell size for atmospheric horizontal resolution. Hence downscaling is necessary to obtain local-scale surface variable from global-scale atmospheric variables that are provided by GCMs

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STUDY AREA

The state of Haryana is situated in the northern part of India, it is surrounded by Uttar Pradesh (UP) in the east, Punjab in the west, Uttarakhand, Himachal Pradesh in the north and Delhi, Rajasthan in the south. The Yamuna river defines its eastern border with Uttarakhand and Uttar Pradesh. Haryana is an agriculture state in northern India. It is located in between 27°39' to 30°35' N latitude and 74°28' and 77°36' E longitude. The altitude of Haryana varies between 200 metres to 1200 metres above sea level.

Data Used

There are three sources of data

1. IMD gridded Maximum and Minimum Temperature (1° x 1°) spatial resolution from 1971-2000 (30 years) are collected from National Climate Centre IMD, Pune.
2. GCM outputs of Canadian centre for environmental prediction model CGCM3.1 are obtained from http://www.cccma.ec.gc.ca for the base period of 1971-2000(30 years) and for the future period of 2001-2100 (100 years) under A2 scenario.

METHODOLOGY

In this study a relationship is derived in between observed data and predicted data of maximum temperature using multiple linear regressions. This involves various processes:

Screening of downscaling predictor variables

Identifying empirical relationships between gird predictors (such as mean sea level pressure) and single site Predictands (such as station precipitation) is central to all statistical downscaling methods. The main purpose of the screen variables operation is to assist the user in the selection of appropriate downscaling predictor variables. (Wilby et al., 2000) proposed that there are three main factors constraining the choice of predictors: (1) whether the predictors were reliably simulated by the GCM; (2) how readily available the GCM output data; and (3) the correlation strength with the surface variables of interest.

Re-gridding and standardization

The data extracted from GCM are re-gridded to IMD grid. Re-gridding is often needed because the grid spacing or co-ordinate system is GCM do not correspond to the grid-spacing and co-ordinate system of the Observed data. CGCM3.1 model has a coarser resolution of 3.75 latitudes by 3.75 longitudes. The re-gridding is done using linear/bilinear interpolation. Standardisation is widely used prior to downscaling to reduce systematic biases in the mean and variance of GCM predictors relative to observations (or re-analysis data). The procedure typically involves subtraction of the mean and division by standard deviation of the predictor for a predefined baseline period.

$$Z = \frac{x - \mu}{\sigma} \qquad (1)$$

x = variable

μ = mean of the population

σ = standard deviation of the population

Principal component analysis

Principal component analysis (PCA) involves a mathematical procedure that transforms a number of (possibly) correlated variables into a (smaller) number of uncorrelated variables called *principal components*. The first principal component accounts for as much of the variability in the data as possible, and each succeeding component accounts for as much of the remaining variability as possible. The objective of Principal component analysis (PCA) is to discover or to reduce the dimensionality of the data set and to identify new meaningful underlying variables. The principal component of 97% variability extracted and original values are transformed into new set of values called principal components.

Multiple linear regressions

Multiple linear regressions is a generalization of linear regression by considering more than one independent variable, and a specific case of general linear models formed by restricting the number of dependent variables to one. The basic model for linear regression is

$$Y_i = \beta_0 + \beta_1 z_{i1} + \beta_2 z_{i2} + \cdots + \beta_r z_{ir} + \varepsilon_i, i = 1, \ldots, n, \qquad (2)$$

In the formula above we consider *n* observations of one dependent variable and *p* independent variables. Thus, Y_i is the i^{th} observation of the dependent variable, Z_{ij} is i^{th} observation of the r^{th} independent variable, $r = 1, 2, ..., p$. The values β_r represent parameters to be estimated, and ε_i is the i^{th} independent identically distributed normal error.

RESULTS AND DISCUSSION

For the temperature analysis, monthly mean observed temperature data for the period of 30 years (1971-2000) has been collected and for the same period climate variables from the GCM are also collected. GCM climate variables for the period of 100 years (2001-2100) are also collected for future predictions.

The Statistical downscaling includes developing quantitative relationships between local surface variables (predictands) and large-scale atmospheric variables (predictors). For selecting the potential predictors, a correlation is checked among the predictand and predictors. The probable predictor selected for downscaling having correlation above 0.78 is mslp, temp2, temp925, zg500, zg850, Ua500, shum. The scatter plots are also prepared to see the relationship of predictand with GCM predictors .

After the standardization of predictor's data set, the principal component analysis (PCA) is carried out to extract the principal components upto 97% cumulative from above mentioned variables. First three eign values (F1, F2, F3) considered for the further investigation since its come upto 97% cumulative. Table 1 shows the details of eign values for maximum and minimum temperature. Then taking predictand as dependent variable and predictors as independent variable, a multiple linear regression is carried out and the regression coefficient is determined. The prediction has been carried out using regression coefficient as well as PCA obtained from the GCM data set. The R^2 obtained from the observed and of downscaled temperature data set is shown in the Table 2.

Table 1: Cumulative % of variables after PCA

	F1	F2	F3	F4	F5	F6	F7
Maximum Temperature							
Eigenvalue	5.925	0.654	0.342	0.060	0.017	0.001	0.000
Variability (%)	84.642	9.340	4.883	0.860	0.249	0.020	0.006
Cumulative %	84.642	93.983	98.866	99.726	99.974	99.994	100.000
Minimum Temperature							
Eigenvalue	6.622	0.661	0.551	0.088	0.059	0.017	0.001
Variability (%)	82.779	8.265	6.884	1.105	0.739	0.208	0.016
Cumulative %	82.779	91.044	97.929	99.034	99.772	99.980	99.997

Table 2: R^2 coefficients obtained for Calibration and Validation period

Maximum Temperature		Minimum Temperature	
R^2 (Calibration)	R^2 (Validation)	R^2 (Calibration)	R^2 (Validation)
0.902	0.899	0.973	0.967

Maximum temperature analysis

From the observed data set, it is found that the hottest month in the Haryana state is May having average monthly temperature above 40° C and coolest month is January having average monthly temperature approximately 20° C. It is predicted that during the 2041-2070 the average temperature of Haryana will rise in-between 0.1 to 0.9° C. The variation of temperature rise will vary with the Region, Topography, Geology, Urbanisation, Agriculture practice and other factors.

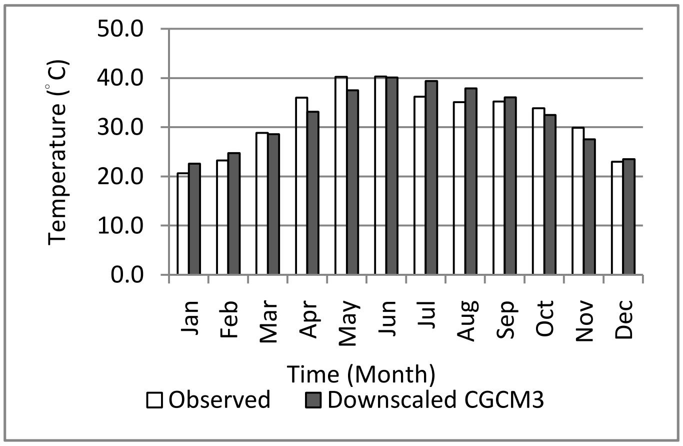

Fig. 1: Observed and Downscaled monthly mean maximum temperature for the base line period (1971-2000)

It has been observed from the study, that the month of March have maximum rise in temperature. There is also fall in temperature predicted between 0.2-1.1° C. The fall in temperature is observed in the monsoon and post monsoon period this may be due to cooling effect of rainfall during monsoon period.

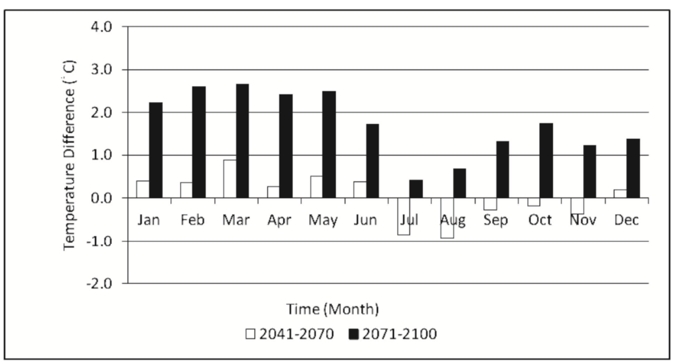

Fig. 2: Change in monthly maximum temperature between baseline period and future for CGCM3 A2

During the 2041-2070, there is an increased rise in the temperature and there are only few month in which fall in temperature is predicted. The rise in temperature varies in-between 0.1-2.3° C. The maximum rise in the temperature of 2.3° C is predicted in the month of April & May in the south-western part of Haryana touching boarder of Rajasthan. From the most of the results shows that the maximum rise in temperature is in the month of March and May & in some region April and February is also observed.

The least temperature rise is predicted in the month of June to august. The north-eastern part of the Haryana show least temperature rise. This may be due to region touching the border of Himachal Pradesh which is a hilly region.

Minimum temperature analysis

It has been observed from the results, that the month of July is warmest having average minimum temperature around 27° C and coolest month is January having average minimum temperature around 6° C.

It is predicted that during the 2041-2070, the average minimum temperature of Haryana will rise in-between 0.2 to 1.0° C as shown in figure 3. There is also fall in temperature predicted in-between 0.1-1.1° C. There is a fall in temperature is also observed in the month of monsoon and post monsoon period (July-Nov).

During the 2071-2100, the rise in the temperature increases. In some months there is a fall in minimum monthly average temperature is predicted in the western & southern part of the Haryana.

The rise in temperature varies in-between 0.1-2.7° C. The maximum rise in temperature of 2.7° C is predicted overall in the month of March. The least temperature rise is predicted in the month of June & July.

It has been observed that the in future the rise in minimum temperature is more than the maximum temperature. It has been also observed from the predicted temperature form 2001-2100, that the rise in both maximum and minimum temperature during the winter season is more than in summer season.

CONCLUSION

It has been observed from the predicted maximum monthly temperature, that rise in maximum temperature varies between 0.1-2.3° C in 2071-2100 where as the rise in minimum temperature varies between 0.1-2.7° C. Hence, it is concluded that the rise in minimum temperature is more than the maximum temperature. Hence in future, the night will be warmer.

It has been observed from the predicted temperature (2001-2100) both for maximum as well as minimum, that the rise in temperature is less during summer and more during winter. The rise in monthly temperature for both maximum and minimum is approximately upto 1° -3° C during summer whereas rise in monthly temperature both for maximum and minimum rises upto 5° C during winter at the end of century which is within the range as Projected by IPCC (Intergovernmental Panel on Climate Change) that the earth's average temperature will rise 1.4°–5.8° C during this century.

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