ASSESING PREDICTABILITY OF PRECIS REGIONAL CLIMATE MODEL FOR DOWNSCALING OF CLIMATE CHANGE SCENARIOS

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ABSTRACT:

The Tamil Nadu Agricultural University by arrangement with Hadley centre, UK Met Office, UK received the PRECIS model and the required GCM boundary data for driving it to make impact studies over Tamil Nadu. Towards achieving this, a study was carried out during 2008-09 at Agro Climate Research Centre, Tamil Nadu Agricultural University, Coimbatore to assess the predictability of PRECIS Regional Climate Model for downscaling of climate change scenarios. The PRECIS was run with boundary data of HadCM3Q0 A1B scenario from 1960 up to 2098 continuously. However, 28 years of data alone selectively post processed for seven selected locations for verification. The future prediction indicates a definite increase in maximum and minimum temperature over years and the likely increase for 2098 against 1968 could be 2.4 to 3.4ºC for maximum and 3.1 to 4.0ºC for minimum temperature. However, such a definite trend was not noticed in respect of rainfall in the locations studied. The predictions were verified with the observations for temperature and rainfall and the results are favourable for the use of PRECIS for downscaling.

1. INTRODUCTION

1.1 Global Climate Models

Global climate models also known as General Circulation Models (GCMs) are the most complex of climate models, since they attempt to represent the main components of the climate systems in three dimensions. The GCMs are computer driven models, which use differential equations based on basic laws of Physics, Fluid motion and Chemistry. It works with a horizontal resolution between 150 and 600 km with 10-20 vertical layers in atmosphere overland and 30 layers over ocean. The GCMs normally used are atmospheric GCMs (AGCM), oceanic GCMs (OGCM) and atmosphere-ocean coupled GCMs (AOGCM). As per Intergovernmental Panel on Climate Change (IPCC), there are about 23 GCMs available from various countries with varying reliabilities. These GCMs lack accuracy due to their insufficient spatial and temporal resolution (Wilby and Wigley, 2002) and hence they lack in simulation of atmospheric features influencing regional climate. Thus emphasize the need for using Regional Climate model (RCM) for downscaling to get finer scale features.

1.2 Downscaling

Downscaling is the process of bringing the values of GCMs into a fine scale by running a regional climate model (RCM). RCMs use the boundary data of GCMs as their input that is it gets coarse climate information from GCMs and works on a spatial resolution of 50km or less. The runs are restricted to a limited area and the models use more accurate representation of many surface features such as complex mountain topographies and coastlines. It also allows small islands and peninsula to be represented realistically. One such RCM is PRECIS developed by (UK Met office's) Hadley centre.

1.3 PRECIS (Providing Regional Climates for Impact Studies)

PRECIS is an atmospheric and land surface model of high resolution and limited area, which is locatable over any part of the globe. It has a horizontal resolution of 0.44° (~50km) or 0.22° (~25km) and 19 levels in the vertical. Dynamic flow, the atmospheric sulphur cycle, clouds and precipitation, radiative process, the land surface and the deep soil are the processes formulated in PRECIS.

PRECIS is forced at its lateral boundaries by the simulations of a global climate models *viz*., HadCM3, HadRM3, ECHAM. The output of PRECIS is post processed and used for various impact studies. The weather variables derived can be used to find out the expressions of each of them by working out deviations, depicting as charts or graphs and can also be used to drive other models to understand the impact.

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The PRECIS was run with boundary data of HadCM3Q0 A1B scenario from 1960 up to 2098 continuously. However, 28 years of data alone selectively post processed for seven selected locations for verification.

2. MATERIALS AND METHODS

2.1 Domain Selection

The Tamil Nadu state has boundaries at 08° 05' N to 13° 35' N and 76° 15' E to 80° 20'E and hence a domain was fixed with sufficient buffer zone. The horizontal resolution of 0.22° x 0.22° or 25 km x 25 km was selected out of two resolutions available in PRECIS with 43 EW points and 49 NS points along with buffer grids as depicted in the Fig 1. The coordinates of rotated pole was 257.85° longitude and 79.01° latitude. The rotated pole co-ordinates require regrid procedure built in with the software and is described later in this chapter including the removal of 8 grid buffer zone. The entire state of Tamil Nadu was covered in 221 full grids and another 43 half grids on its borders. The grid layout is depicted in the Fig. 2.

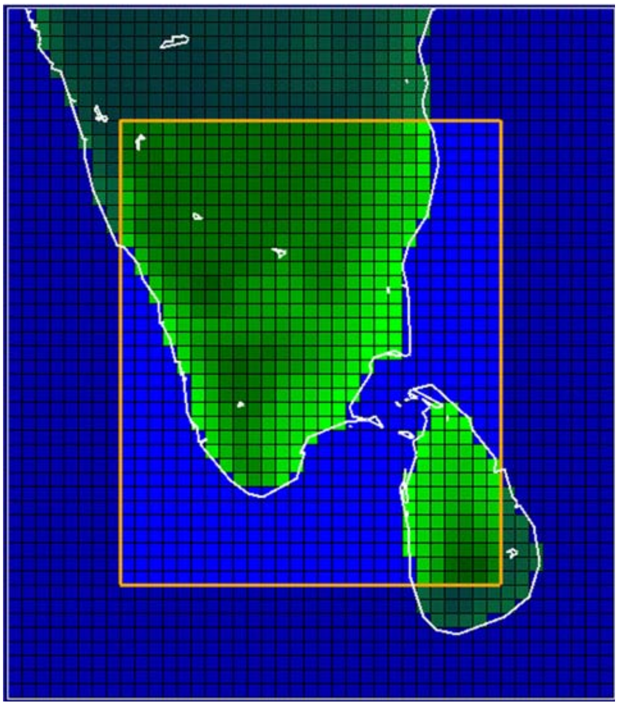

Figure 1. Domain with Buffer Grids

2.2 Scenario Selection

HadCM3Q is a version of the Hadley Centre's third generation coupled ocean-atmosphere general circulation model. This model is different from the standard HadCM3 model in that it uses flux adjustments to ensure that the SSTs remain close to climatological values during a control period, while allowing sea surface temperature (SST) to vary from natural variability and from atmospheric forcing such as increasing CO_2 and it includes an atmospheric sulphur cycle. The external forcing is from the SRES A1B emissions scenario. The sea-surface boundary conditions are taken directly from the ocean component of HadCM3Q.

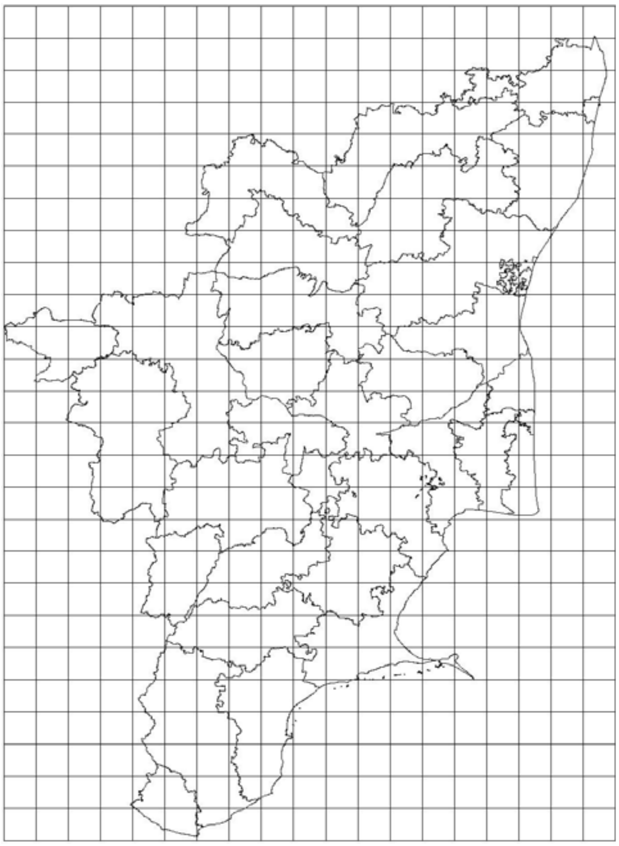

Figure 2. Grid Layout of Tamil Nadu

2.3. Statistical Analysis of Climate Data

The data retrieved for control years viz., 1978, 1979, 1988, 1989, 1998, 1999 were used to pick data for their 7 grids in each of the Agro Climatic Zone (ACZ). Only point data of place, which were close to the grid of PRECIS, were used for statistical analysis. The details of locations selected in each ACZ are given below.

Name of ACZ	Location	Co-ordinates	PRECIS Coordinate
North Eastern Zone	Tirupattur	12.48°N 78.56°E	12.56°N 78.54°E
North Western Zone	Salem	11.65°N 78.10°E	11.68°N 78.10°E
Western zone	Coimbatore	11.00°N 76.97°E	11.02°N 77.00°E
Cauvery Delta Zone	Adhirama pattinam	10.33°N 79.38°E	10.36°N 79.42°E
Southern zone	Kovilpatti	9.20°N 77.88°E	9.26°N 77.88°E
High Rainfall Zone	Kanya kumari	8.08°N 77.50°E	8.16°N 77.44°E
Hilly zone	Ooty	11.40°N 76.73°E	11.46°N 76.78°E

2.4 Rainfall Analysis

The rainfall being discrete variable, a daily contingency table was formed as below for further analysis using methodology described by Wilks, 2006.

Observed	Predicted	
	No Rain	Rain
No Rain	Z (NN)	F (NY)
Rain	M (YN)	H (YY)

Where Z = No. of correct negatives

F – No. of False Alarms (predicted but not observed)

M = No. of misses (observed but not predicted), and

H = No. of Hits (predicted and observed).

2.4.1 Ratio Score or Hit Score: It is the ratio of correct forecasts to the total number of forecasts. It varies from 0 to 1 with 1 indicating perfect forecast. The score was expressed as percentage indicating the higher the best.

$$\text{ACC} = \frac{CorrectForecast}{TotalForecast} = \frac{H+Z}{N}$$

$$\frac{H+Z}{N} = \frac{YY+N}{(YY+NN+YN+NY)} X100$$

where (N = Z+F+M+H)

2.5 Temperature Analysis

The maximum and minimum temperate being continues variable the monthly means were compared with that of observed data using RMSE.

2.5.1 Root mean square error (RMSE): The root mean square error is calculated using the following formula.

$$RMSE = \left[\frac{1}{n}\sum(fi - oi)^2\right]^{1/2}$$

Where

fi = forecast value
f = mean forecast value.
oi = observed value
o = mean observed value and
n = total number of observations / forecast

3. RESULTS AND DISCUSSION

The results of present study revealed that the trend analysis of the agro-climatic zone wise selected locations indicated that there was marked increase in both maximum and minimum temperature. The rate of increase in maximum temperature is more during northeast monsoon season than other seasons and the increase ranged from 2.4 to 3.4°C (Table 1). The mean of the locations studied under the HadCM3Q A1B scenario indicated that the maximum temperature likely to increase by 3°C by 2098 in Tamil Nadu. The maximum and minimum temperature predicted for Tamil Nadu indicates a progressive increase towards west from the east coast (Fig 3 & 4). The trend of increase in minimum temperature was on higher side than that of maximum temperature. The rate of increase of minimum temperature had no seasonal effect and Tamil Nadu is likely to record 3.1°C to 4.0°C more during 2098 over the year 1968 (Table 2).

The root mean square error estimated for observed maximum and minimum temperature was with in limits indicating the usability of PRECIS for downscaling (Table 3 & 4).

Statistical verification of predicted temperature with observed indicated better skill for maximum temperature than for minimum temperature.

Year	Coimbatore	Kanya kumari	Ooty	Salem	Adhiram Pattinam	Tirupattu r	Kovil patti	Mean
1968	32.2	28.8	25.9	34.8	34.8	33.5	35.0	32.1
1978	31.6	28.0	24.6	34.3	34.3	32.8	34.4	31.4
1988	31.6	28.8	26.0	34.0	33.7	32.4	34.6	31.6
1998	32.6	28.9	26.0	34.9	35.0	33.3	34.9	32.2
2008	32.4	28.9	26.1	34.9	35.2	33.6	35.0	32.3
2018	32.3	28.7	25.7	34.7	34.5	33.1	34.7	32.0
2028	34.1	30.2	27.1	36.1	36.5	34.4	36.7	33.6
2038	32.9	29.6	26.6	35.6	35.5	34.3	35.9	32.9
2048	34.3	30.1	27.6	36.5	36.9	35.0	36.8	33.9
2058	33.0	29.6	26.2	35.9	35.9	34.2	35.9	33.0
2068	33.5	30.2	27.8	36.7	36.7	35.5	37.0	33.9
2078	35.6	31.8	28.8	38.4	38.1	36.9	38.2	35.4
2088	35.4	31.2	28.7	37.8	37.8	36.3	37.8	35.0
2098	35.2	31.8	28.3	37.8	38.3	36.4	38.2	35.1
2098-1968	3.0	3.0	2.4	3.0	3.4	2.9	3.2	3.0

Table 1: Annual Mean Maximum Temperature (°C) Over the Years for Selected Location

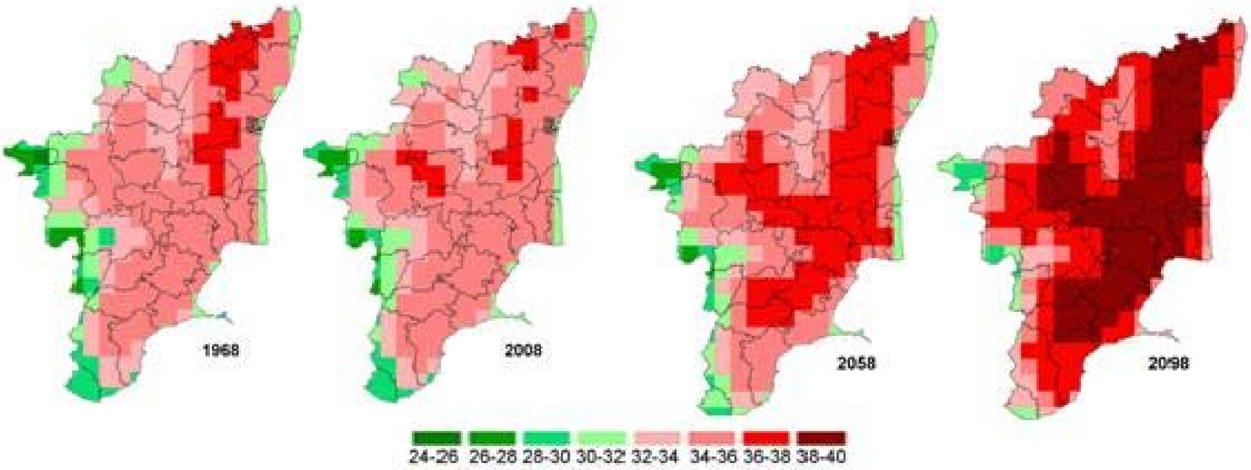

Figure 3. Spatial Pattern of Mean Maximum Temperature

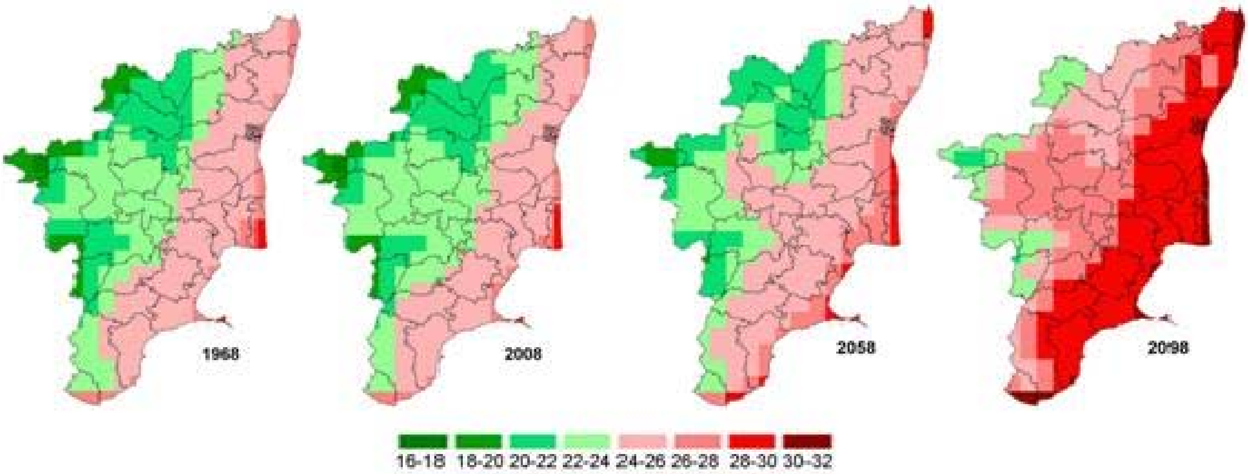

Figure 4 Spatial Pattern of Mean Minimum Temperature

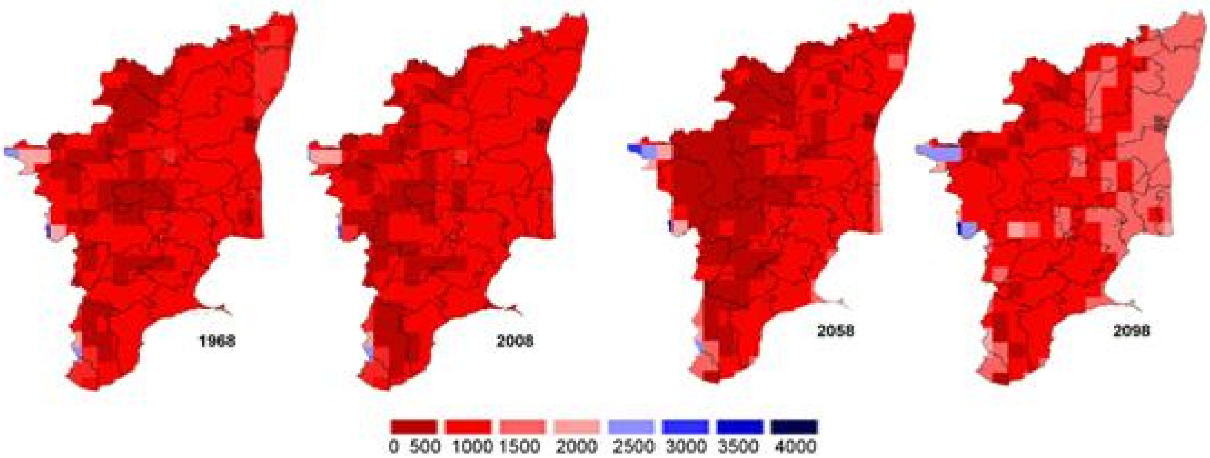

Figure 5. Spatial Pattern of Annual Rainfall

Year	Coimba tore	Kanya kumari	Ooty	Salem	Adhiram Pattinam	Tiru Pattur	Kovil patti	Mean
1968	21.3	26.9	17.5	22.3	25.7	20.8	24.3	22.7
1978	20.6	26.2	16.9	21.2	24.5	19.7	23.3	21.8
1988	20.6	26.5	17.0	21.0	24.7	19.4	23.5	21.8
1998	20.7	26.5	17.1	21.0	24.8	19.6	23.6	21.9
2008	21.7	27.1	18.0	22.4	25.9	20.7	24.5	22.9
2018	21.3	26.8	17.7	22.0	25.5	20.6	24.2	22.6
2028	22.6	28.1	18.6	23.5	27.2	21.7	25.7	23.9
2038	22.4	27.9	18.6	23.1	26.8	21.4	25.4	23.7
2048	22.6	28.0	18.7	23.3	27.0	21.5	25.8	23.8
2058	22.4	27.8	18.7	23.2	26.5	21.6	25.5	23.7
2068	22.9	28.4	19.2	23.7	27.2	22.1	26.1	24.2
2078	24.7	29.8	20.6	25.8	29.4	24.2	27.8	26.0
2088	24.1	29.3	20.2	25.1	28.8	23.5	27.2	25.5
2098	25.0	30.0	21.1	26.1	29.6	24.6	28.3	26.4
2098-1968	3.7	3.1	3.6	3.8	3.9	3.8	4.0	3.7

Table 2: Annual Mean Minimum Temperature (^{o}C) Over the Years for Selected Location

Year	Coim batore	Kanya kumari	Ooty	Salem	Adhiram pattinam	Tiru pattur	Kovilpatti
1978	6.07	4.91	5.94	3.97	8.07	6.32	1.52
1979	4.74	3.15	7.94	5.35	8.98	4.18	1.77
1988	4.92	2.97	8.12	4.82	7.75	3.82	2.99
1989	4.57	4.2	8.31	4.92	6.97	4.73	2.42
1998	4.97	4.75	8.45	4.83	7.66	5.29	2.01
1999	5.17	3.86	9.43	5.54	6.46	5.01	2.01

Table 3: Root Mean Square Error (RMSE) Estimated for Maximum Temperature

Year	Coimbatore	Kanya Kumari	Ooty	Salem	Adhiram Pattinam	Tirupattur	Kovilpatti
1978	3.65	2.51	7.92	4.24	2.37	4.98	0.75
1979	3.50	2.62	7.01	4.10	2.45	4.77	1.31
1988	4.37	2.62	7.18	5.44	3.09	6.16	2.68
1989	4.00	2.90	8.17	4.82	3.04	5.42	2.77
1998	4.69	2.56	6.54	5.48	3.02	6.01	1.02
1999	3.91	2.82	7.49	4.58	2.65	5.26	2.28

Table 4: Root Mean Square Error (RMSE) Estimated for Minimum Temperature

Year	Coimbatore	Kanya Kumari	Ooty	Salem	Adhiram Pattinam	Tirupattur	Kovilpatti
1968	598.9	660.3	1835.0	525.0	783.0	450.0	632.3
1978	512.7	402.6	1776.3	619.8	723.5	424.4	490.1
1988	508.2	476.7	1616.5	486.4	683.0	334.7	490.1
1998	494.7	395.0	1540.6	498.3	611.6	439.7	491.9
2008	571.0	534.4	1545.0	601.3	827.4	478.8	585.4
2018	495.5	464.6	1535.5	645.9	905.2	544.8	713.8
2028	420.4	410.1	1698.5	525.4	663.7	477.7	480.1
2038	567.7	643.1	1864.4	631.9	786.7	458.6	540.9
2048	352.2	472.5	1253.0	554.8	724.8	430.6	412.2
2058	413.6	326.2	1750.3	515.0	911.9	343.2	492.1
2068	457.0	710.4	1753.6	534.6	646.3	316.5	462.7
2078	704.0	508.8	1938.6	404.1	721.6	278.7	502.5
2088	446.6	349.4	1690.5	584.2	724.8	461.4	584.7
2098	743.6	473.9	2442.5	709.4	1062.5	539.3	693.0

Table 5: Total Annual Rainfall (mm) Over the Years for Selected Location

The precipitation prediction had no definite trend but, during 2098 peak rainfall was predicted for five of the seven locations studied (Table 5). Spatial pattern of rainfall indicates that north eastern parts of Tamil Nadu is likely to receive more rainfall in future years compared to that of earlier years (Fig 5).

The ratio score used in respect of rainfall indicated higher skill in non rainy season than rainy season. The skill in rainfall prediction also varies with locations as point data sets are used for verification.

CONCLUSION

The scenario presented in this paper includes more detailed regional information (25 km × 25 km), and are very useful for impact assessments in various sectors. This paper includes only the basic aspects of the simulation results and the regional model output contains a large number of additional parameters while the scenarios presented in this study are indicative of the expected range of rainfall and temperature changes, it must be noted that the quantitative estimates still have large uncertainties associated with them. The results of present study revealed that PRECIS regional climate model can be successfully used as a tool to downscale climate change scenario with higher resolution.

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