Validation of Extreme Climatic Events as Inferred From Hadley Center Regional Climate Model Version 2.0 at Local Level in Central India

C N Tripathi and K K Singh

ABSTRACT

A validation exercise was performed to test the ability of the Hadley Center Regional Climate Model Version 2.0 in simulating the features of observed extreme climatic at six selected locations in Central India. Extreme events considered for the evaluation were extreme hot conditions, extreme cold conditions, extreme rainfall and rainy days. Extreme hot conditions (on the basis of maximum temperature being more than certain threshold, depending upon the general occurrence of high temperature at particular locations) extreme cold conditions (on the basis of minimum temperature being less than certain threshold value, depending upon the general occurrence of lower minimum temperature at particular location) were compared with the corresponding observed climatology. No of rainy days (On the basis of a day having rainfall more than certain threshold, depending upon the location, and extreme rainfall conditions (on the basis of rainfall being more than certain threshold depending upon the location) in simulated and observed climatology were also compared. Results indicate that the occurrence of extreme hot conditions are much more frequent in simulated climate than that of observed climate at almost all the locations in Central India. Frequencies of occurrence of observed extreme cold conditions was overestimated for some locations and underestimated for other locations in Central India. Therefore it seems from above comparison that the occurrence of extreme cold condition in observed climate is not adequately represented by simulated climate in Central India. The frequencies of occurrence of extreme rainfall conditions are much less frequent in simulated climate than that of observed climate at almost all the locations in Central India Number of rainy days in observed climate are overestimated in simulated climate at almost all the locations of Central India. Therefore regional simulation perform very poorly in simulating extreme climatic events and can not be used for realistic impact assessment at local level in India.

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Key words: Regional, Local, Extreme, Hot, Cold

1. Introduction

Regional climate trends and extreme events during the last century due to global warming and climatic changes have greatly influenced public perceptions of climate variability and change. Today, many climate research institutions all over the world are pursuing research programs and projects for better understanding of the present day climate and the future climate change through modeling and other approaches. As a result many Global and regional climate models are now available and are being improved further - in their resolution as well as in their parameterization scheme. Now the improved understanding of the effect of the aerosols in addition to the greenhouse gases on the climate are also being taken into account. On a global scale, a number of climate models (developed by different scientific groups in the world) have shown considerable improvements in simulating the present day climate. However, the regional climates by these global models lack the finer scale details and therefore these models may perform poorly in model validation on regional scale. In order to overcome these limitations high-resolution

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Regional Climate Models (RCMs) are now being developed which are driven at its boundaries by the output derived from a GCM. RCM is a limited area high-resolution climate model that is embedded in a coarse resolution GCM over the area of interest. At the lateral boundaries, either two-way or one-way interacting nesting can be employed. The two-way nesting technique allows the interaction of the regional and global climate models iteratively and therefore requires simultaneous integration of the two models. In the one way nesting techniques the initial and lateral boundary conditions needed to run the regional model are provided by the output of the GCM simulation. Regional climate models attempt to capture regional details in surface climatic characteristics as forced by regional details such as topography, lakes, coastline and land use distribution (Leung et al 2006). Giorgi et al., (2001) has proposed more systematic and wider applications of RCMs to adequately assess their performances and uncertainties in producing the regional climate information.

Many regional climate simulation are available which are now being used for impact assessment and planning. However most impact assessment models which are used to simulate the impact of climate change and variability require reliable weather data at a higher spatial resolution

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of the order of 50 kms by 50 kms or even more and at daily temporal resolution. It is therefore necessary to evaluate the climate Simulation by Regional Climate Models at daily and sub daily temporal resolution and at local level. A number of attempts have been made in the past to demonstrate the capability of regional climate models embedded in General Circulation model in simulation the Indian Climatology (Jones et al., 1995; Bhaskaran et al., 1996; Vernakar et al., 1999; Lal ,M 2000; Dash et al., 2006; Mukhopadhyay et al., 2010, Bhate et al., 2012). However none of these attempts were applied to test the daily simulation of climate at a very high resolution of 50 KM by 50 KM spatial resolution which is very important in view of many agricultural and hydrological impact models use weather data at such higher resolution only. In an earlier study Tripathi and Singh., 20013 have studied the validity of regional simulation for mean climate over Indian subcontinent. Present study attempts to test a regional climate simulation by Hadley Center, UK, regional climate model version 2 (HadRM2) in simulating the extreme climatic events at 50 KM by 50 KM spatial resolution and daily time scale for some locations in central India. Details methodology and data used are discussed in the following section

2. Materials and Methods

2.1. Hadley Center Regional Climate Model Version 2 (HadRM2)

The RCM (HadRM2) is a high-resolution limited area atmospheric model driven at its lateral and sea surface boundaries by output obtained from HadCM2 integration. The formulation of HadRM2 is identical to the atmospheric component of HadCM2(Jones et al., 1995; Bhaskaran et al., 1996). Apart from details concerning diffusion and filtering, both models use 19 hybrid coordinate vertical levels and regular latitude-longitude horizontal grids. The grid spacing in HadCM2 is 2.5° X 3.75° and 0.44° X 0.44° in HadRM2 which is kept quasi-regular over the region of interest by shifting the coordinate pole. The time steps are 30 and 5 minutes respectively. General details of the RCM formulation and the one-way nesting technique may be found in Jones et al., 1995, whilst Bhaskaran et al., 1996 provide specific information on the RCM set up for the Indian monsoon region. Though higher resolution regional climate models are now available now, but the availability of simulated climate data for all the region of India is limited by cumbersome exercise and computer power required. Therefore at first stage of we have used the climate data as simulated by Hadley Center Regional Climate Model Version 2 (HadRM2)

2.2. Validating the Simulated Extreme Climatic Events

2.2.1. Simulated Climatic Data

Control and anomaly GCM climate simulation had each been carried out for 21 years by Hadley Center of climate research UK. CO2 is held constant in the control simulation at present day values. The anomaly integration (GHG) has CO2 increasing by 1% per year (compound) and is initialized after 50 years of increasing CO2 concentrations, in the year 2040. The nested RCM simulations were integrated over the same periods with the first year disregarded. The data generated in these transient experiments were obtained from "Hadley Center for Climate Prediction" U.K. at a resolution of 0.44° X 0.44° latitude by longitude grid points for whole India. The daily weather data on maximum and minimum temperature and rainfall for six locations located in Central India were obtained by taking weighted mean of values of respective weather parameter at four nearest grid points surrounding these locations (Table 1).

2.2.2. Observed Weather Data:

For comparing the statistical properties of the simulated climatic data with the corresponding observed data the daily observed weather data on maximum and minimum temperature and rainfall for 19 years (15 years for some of the locations) for the period 1980-1999 (1985-1999 for some of the locations) in central India have also been collected from India Meteorological Department Pune, for six selected locations in Central India as shown in Table 1.

Table 1: Co-ordinates and Weather Data Period for Selected Locations in Central India

S.No.	Stations (Region)	Data Period	Latitude	Longitude
1	Akola	1985-98	20.70	77.03
2.	Gwalior	1980-96	26.15	78.14
3	Indore	1980-98	22.72	75.80
4	Jabalpur	1980-98	23.15	79.97
5	Raipur	1980-98	21.27	81.60
6	Parbhani	1985-98	19.27	76.78

2.2.4. Comparison of Extreme Events in Observed and Simulated Climate

Extreme climatic events considered for evaluation were extreme hot events, extreme cold events, Extreme rainfall and rainy days. Extensive statistical analyses were performed to test the ability of the HadRM2 in simulating the features of extreme events of observed climatology for six selected locations in Central India. Extreme hot conditions (on the basis of maximum temperature being more than certain threshold, depending upon the general occurrence of high temperature at particular locations) extreme cold conditions (on the basis of minimum temperature being less than certain threshold value, temperature at particular location) were compared with the corresponding observed climatology. No of rainy days (On the basis of a day having rainfall more than certain threshold, depending upon the location, and extreme depending upon the general occurrence of lower minimum

rainfall conditions (on the basis of rainfall being more than certain threshold depending upon the location) in simulated and observed climatology were also compared

3. Results and Discussion

3.1. Observed and Simulated Extreme Hot Conditions

Comparison of extreme hot conditions in observed and simulated climatic data for six selected locations in central India are shown in Fig. 1. The threshold for the maximum temperature to be characterized as extreme hot conditions is location dependent and has been chosen on the basis of general occurrence of higher temperature at that location. Results indicate that the occurrence of extreme hot conditions are much more frequent in simulated climate than that of observed climate at almost all the locations in Central India except for Akola and Parbhani where occurrence of extreme hot conditions is slightly less frequent in simulated climate than that in observed climate.

Therefore it seems from above comparison that the frequencies of occurrence of extreme hot conditions in observed climate is not adequately represented by simulated climate in Central India

3.2. Observed and Simulated Extreme Cold Conditions

Comparison of extreme cold conditions in observed and simulated climatic data for six selected locations in Central India is shown in Fig. 2. The threshold for the minimum temperature to be characterized as extreme cold conditions is location dependent and has been chosen on the basis of general occurrence of lower minimum temperature at that location. These comparisons indicate that simulated climate is underestimating the frequencies of occurrence of extreme cold conditions as compared to that in observed climate at Akola, Indore and Parbhani where as it is overestimating the frequencies of occurrence of observed extreme cold events at Gwalior Jabalpur and Raipur by large margin.

Therefore it seems from above comparison that the occurrence of extreme cold condition in observed climate is not adequately represented by simulated climate in Central India. Attempts to compare the rainfall in observed and simulated climate have been discussed in next section.

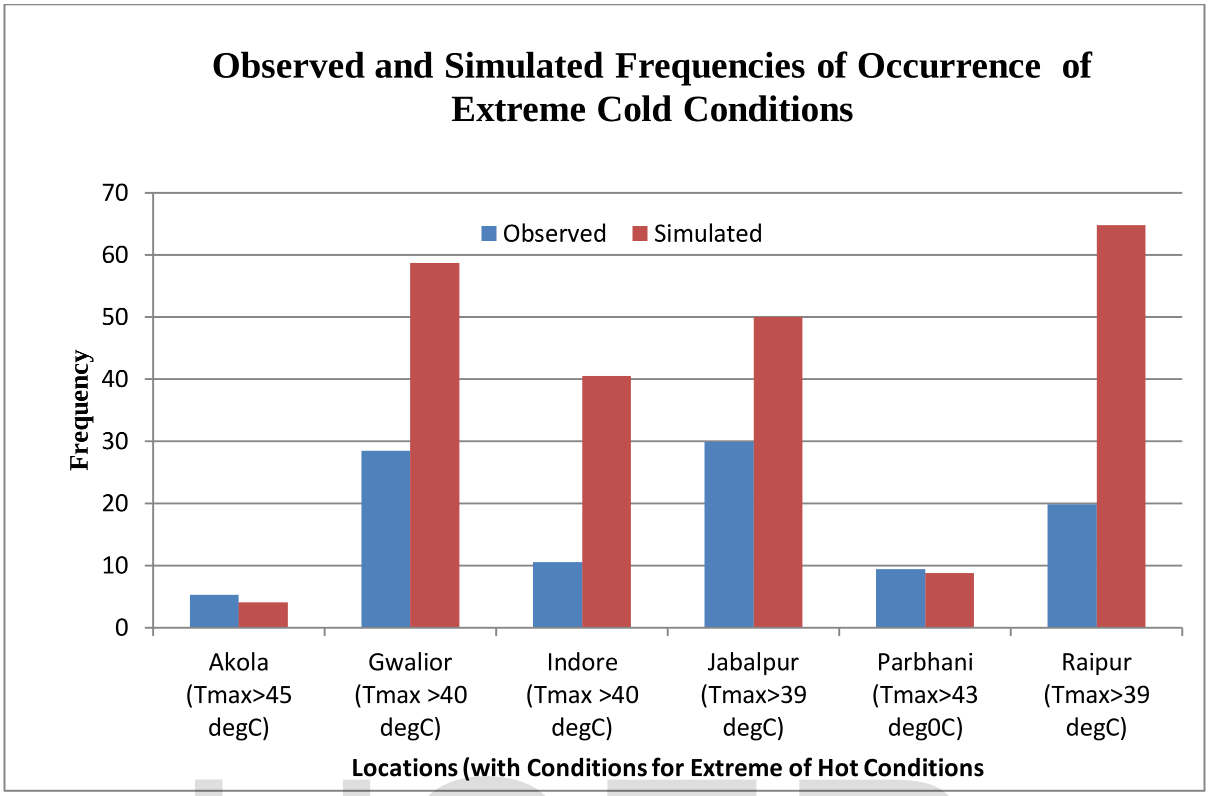

Fig. 1: Observed and Simulated Distribution of Extreme Hot Conditions at Different Locations in Central India

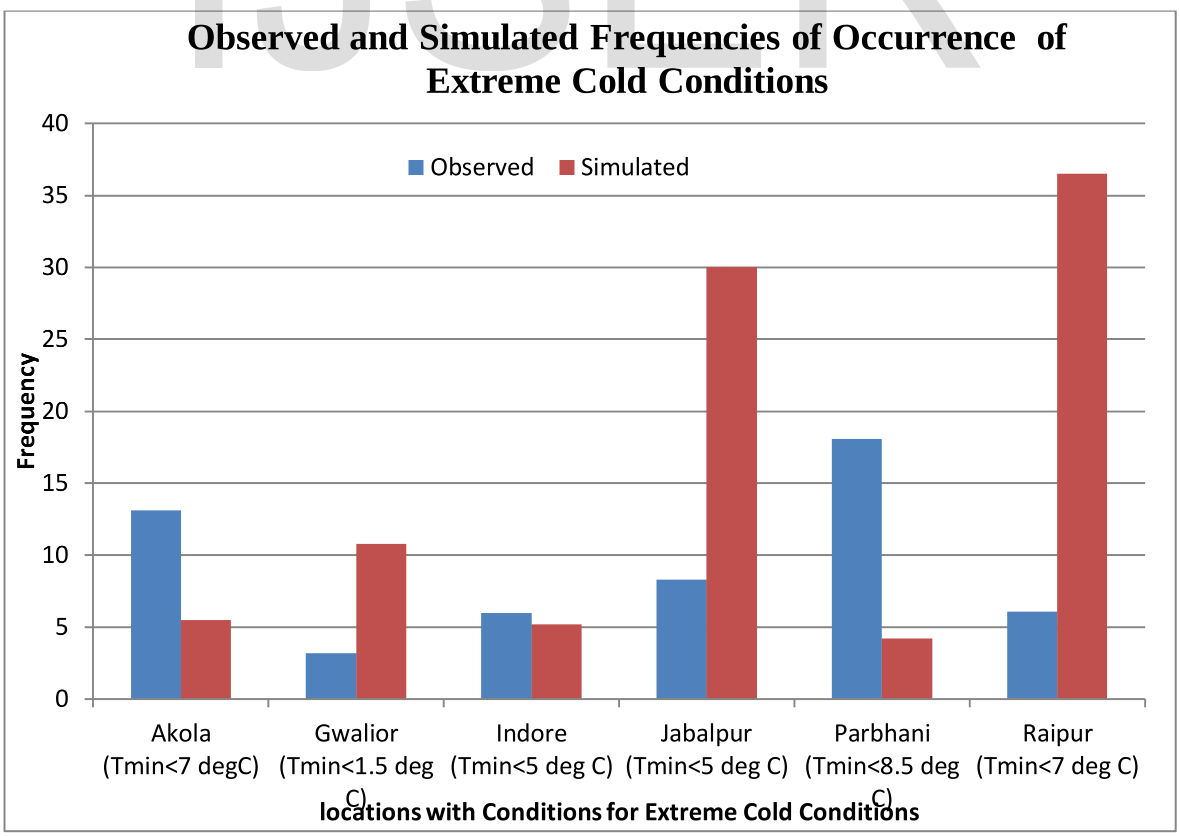

Fig. 2: Observed and Simulated Distribution of Extreme Cold Condition at Different Locations in Central India

3.3 Observed and Simulated Extreme Rainfall and Number of Rainy Days

Comparison between observed and simulated extreme rainfall and number of rainy days for six locations situated in six different geographic regions of India are shown in Fig 3 and Fig 4 respectively. The threshold for the rainfall to be characterized as extreme rainfall conditions is location dependent and has been chosen on the basis of general occurrence of higher rainfall events at that location. Similarly the threshold for the minimum rainfall in a day to be characterized as rainy day is also location dependent. These comparisons indicate that the frequency of occurrence of extreme rainfall conditions are much less frequent in simulated climate than that of observed climate at almost all the locations in Central India except at Akola where simulated extreme rainfall conditions is marginally higher in simulated climate than that in observed climate. The comparison of number of rainy days indicate that the Number of rainy days in observed climate are overestimated in simulated climate at almost all the locations of Central India except at Indore where rainy days are underestimated in simulated climate.

Therefore it seems from above comparison that the characteristics of observed extreme rainfall are also not well simulated by HadRM2.

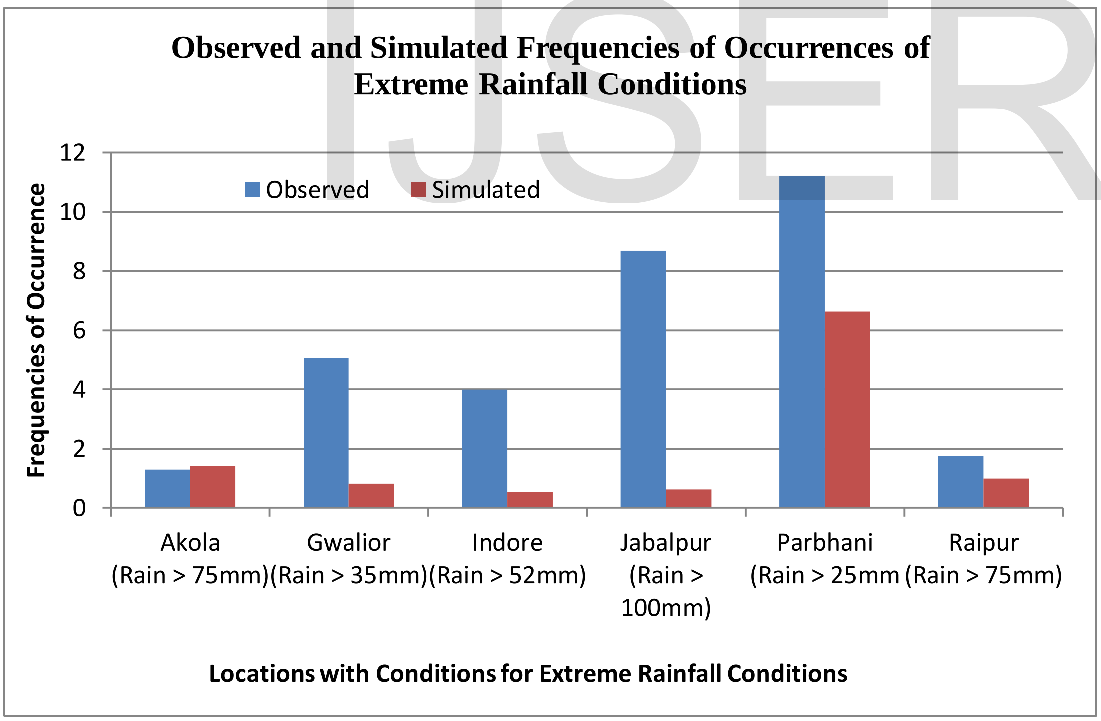

Fig. 3: Observed and Simulated Distribution of Extreme Rainfall Condition at Different Locations in Central India

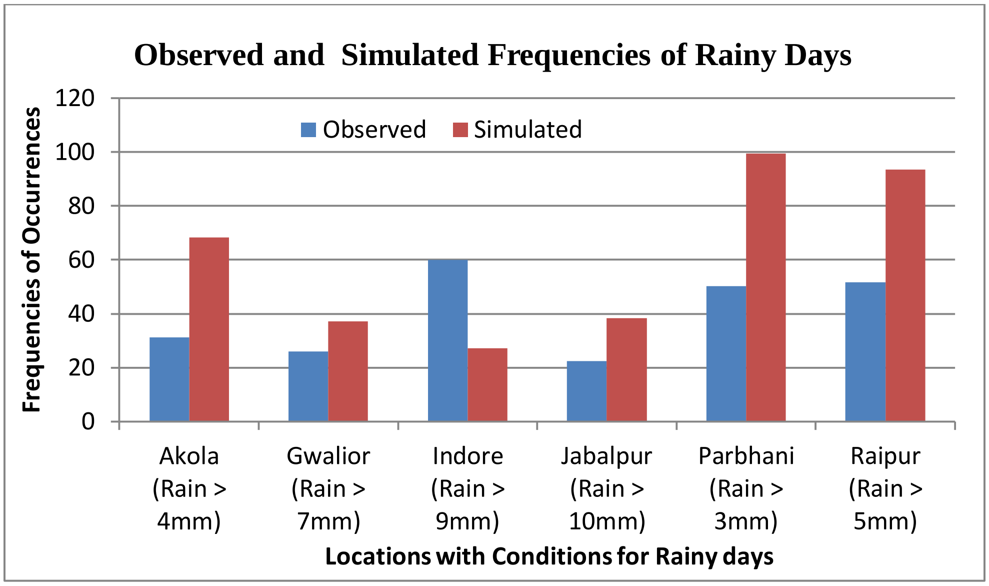

Fig. 4: Observed and Simulated Distribution of Number of Rainy Days at Different Locations of Central India

4. Conclusions

The occurrence of extreme hot conditions are much more frequent in simulated climate than that of observed climate at almost all the locations in Central India. Frequencies of occurrence of observed extreme cold conditions was overestimated for some locations and underestimated for other locations in Central India. Therefore it seems from above comparison that the occurrence of extreme cold condition in observed climate is not adequately represented by simulated climate in Central India. The frequencies of occurrence of extreme rainfall conditions are much less frequent in simulated climate than that of observed climate at almost all the locations in Central India Number of rainy days in observed climate are overestimated in simulated climate at almost all the locations of Central India. Therefore regional simulation perform very poorly in simulating extreme climatic events and none of the observed extreme climatic events are adequately represented in simulated climate Therefore it is imperative that understanding and predictions of regional climate variations and change be improved and placed on a firm scientific foundation for proper policy planning at local level in Central India.

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