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ON IMPLICATIONS OF REGIONAL CLIMATE SIMULATION FOR EXPLORING CLIMATE RESILIENT TECHNOLOGIES IN AGRICULTURAL SECTOR: A CASE STUDY

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Abstract: Climate change that has occurred during past decades and expected to occur in future will impact agriculture adversely and therefore adaptation strategies are urgently needed to assist in minimizing such climate impacts. Crop growth models which are used to explore and evaluate crop adaptive responses to climatic fluctuations require daily weather data on maximum temperature, minimum temperature, rainfall at local level along with various other information. To fulfil these requirements, several regional climate models (RCM) are being developed by different modelling group in the world to simulate the various climatic parameters at daily and sub daily scale and at a spatial resolution of 50 KM by 50 KM or more in different part of world. However there is considerable uncertainties in RCM simulated mean and variability of present and future climatology. This paper presents a statistical comparison of observed and RCM simulated mean and variability of maximum temperature, minimum temperature, and rainfall at five selected location in East India namely Barrackpore, Bhubneshwar, Faizabad, Pusa and Ranchi. Result indicate that the simulated climate is not able to replicate the mean and variability of maximum temperature, minimum temperature and rainfall at any of the selected location. Significant over and under estimation of both mean and variability of these climatic parameters is simulated by the RCM in consideration. Therefore while applying such regional climate simulation in crop simulation model to explore adaptation option may lead to the risk of maladaptation which implies negative consequences either in the long term that needs more attention. Suitable techniques must be applied to remove the biases and uncertainties in climate simulation, before such simulation can be applied to explore climate resilient adaptation options.

Keywords: Climate Resilient, Agricultural Sector

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INTRODUCTION

IPCC fifth assessment report (2013) predicts that the global surface temperature increase by the end of the 21st century is likely to exceed 1.5 °C relative to the 1850 to 1900 period for most scenarios, and is likely to exceed 2.0 °C for many scenarios. The global water cycle will change, with increases in disparity between wet and dry regions, as well as wet and dry seasons, with some regional exceptions. Timing of wet and dry seasons may also be altered. Increased precipitation is likely to be unevenly distributed over the globe. Change in frequencies and intensities of extreme weather events and precipitation pattern have been reported in different part of world (IPCC 2013). The report also detailed the range of forecasts for warming, and climate impacts with different emission scenarios. Compared to the previous report, the lower bounds for the sensitivity of the climate system to emissions were slightly lowered, though the projections for global mean temperature rise (compared to pre-industrial levels) by 2100 exceeded 1.5 °C in all scenarios (McGrath, Matt 2013).

Changes in climate will have profound implications for agriculture as the crop production is largely dependent on climatic parameters during the growing season. There are many studies reported in literature aimed at assessing the impact on agriculture and suggesting various adaptation measures in India and elsewhere. A loss of 10–40% crop production is predicted in India by the end of this century (Aggarwal, P. K., 2008). Climate change is projected to decline the yields of several major crops in India if no measures are taken (Kumar et al., 2011). Crop growth models and decision support systems are being used now a days as an effective tools for assessing and exploring the adaptive technologies under changing climate conditions. Crop simulation models used to evaluate crop responses to climatic fluctuations require daily weather data on maximum temperature, minimum temperature, rainfall at local level along with various other information. Therefore climate change information at regional and local level and at daily and sub daily temporal scale is required for impact assessment on agriculture. Such need for providing reliable climate change information has enforced many climate research institutions all over the world to develop research programs and projects for better understanding of the present day climate and its future change through modelling and other approaches. Regional climate models (RCMs) attempt to capture regional details in surface climatic characteristics as forced by regional details such as topography, lakes, coastline and land use distribution (Artale V et al., 2010; Qian et al., 2010; Diro et al., 2012; Giorgi et al., 2012). Many regional climate models are now available which simulate the various climatic parameters at daily and sub daily scale and at a spatial resolution of 50 KM by 50 KM or more in different part of world (Ratnam et al., 2009; Im et al, 2010; Torma et al., 2011; Bhate et al., 2011). 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. However in order to evaluate the degree of confidence on agricultural impact of projected change in climate it is necessary to evaluate the performance of simulated present climate with regard to replicating the nature of observed climate. Since the changes in mean, variability and extremes of climate are increasingly being recognized as having serious implications for agriculture, it becomes necessary to examine the nature of changes in the characteristics of mean, variability and extremes of climatic parameters in simulated climate as observed in the past. It is also necessary to study the changes in the nature of mean and extreme climatic event in the future for the development of appropriate adaptation policies.

A number of attempts have been made in recent years to examine the trends of extremes climatic events at different spatial and temporal resolutions in different part of world (Wehner et al., 2010; Xiaoming et al., 2010; Chen, Cheng-Ta and Knutson, T., 2012; Wehner, 2013). Few studies have analyzed the nature of changes in extreme weather events as observed in India in the past (Kothawale and Rupa Kumar., 2005; Goswami et al., 2006; Kothawale et al., 2010; Dash et al, 2011; Singh and Patwardhan., 2012). Detail review on the nature and occurrence of extreme weather events in India is given in De et al., (2005). A number of attempts have also been made in to demonstrate the capability of regional climate models in simulating 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 or at local level which is very important in view of many agricultural impact models using weather data at such higher resolution only. Year to year deviations in the weather and occurrence of climatic anomalies / extremes in respect of four seasons in India are Cold wave, Heat wave, Heavy rain etc. Therefore evaluation of simulated present climate on simulating these aspects of weather and climate anomalies becomes necessary in order to place any confidence in its future projection and impacts. In India presently PRECIS model as developed by Hadley center UK is being used to simulate climate information in various emission scenarios at daily and sub daily scale at very high spatial resolution. In addition to PRECIS, the simulated data available from Hadley Ccentre Regional Climate model version 2.0 have also been used for impact assessment in agriculture and other sector. Present study is attempted with the aim to explore the uncertainty in the nature of mean, variability and extremes of maximum and minimum temperature, rainfall and rainy days in simulated climate as compared to that in observed climate at local level in East India. Study gives some inference on the degree of confidence which may be placed on future projection of mean, variability and extremes of these climatic parameters and therefore on impact assessment using such climatic simulations. Possibility of negative impact of adaptation measures which are implemented without considering the nature of uncertainty in the simulated climate and importance of climate resilience techniques is also discussed herewith.

MATERIALS AND METHODS

Observed Weather Data

Depending upon the observed weather data availability five locations in East India were chosen for the study. Daily data on observed maximum temperature, minimum temperature and rainfall for the duration as shown in Table 1 were collected for five selected location in East India from India Meteorological Data Pune. Attempts were made to collect these observed daily weather data for the duration similar to that of simulated climate at all the location for fair comparison with simulated data. However for some of the locations data on lesser duration were available as shown in Table 1.

Table 1: Selected Weather Stations in East India

S.No.	Stations	Data Period	Latitude	Longitude
1.	Barrackpore	1985-98	22.46	**88.24**
2.	Bhubneshwar	1980-98	20.25	**85.87**
3.	Faizabad	1982-98	26.79	**81.60**
4.	Pusa	1980-98	25.98	**85.67**
5.	**Ranchi**	**1980-98**	**23.42**	**85.33**

Simulated Climatic Data

Simulated daily climatic data by Hadley Center Climate Model version 2.0 (Jones et al., 1995; Bhaskaran et al., 1996) for control and anomaly climate at a resolution of 0.44° X 0.44° latitude by longitude grid points for whole India were obtained from Hadley Center of climate research UK. The daily weather data on maximum and minimum temperature and rainfall for Five selected locations in East India were obtained by taking weighted mean of values of respective weather parameter at four nearest grid points surrounding these locations. These data for control/present daily data were taken for 19 years (centered at 1990s) and future/anomaly were centered at (2050's).

Exploring Mean, Variability and Extreme Climatic Conditions in Simulated and Observed Climate

Mean and standard deviation of daily maximum temperature and minimum temperature were calculated for both simulated and observed climate from the daily data at all the selected locations. Mean and standard deviation of annual rainfall were also calculated for both simulated and observed climate from the daily data at all the selected locations. Implications of these simulation for impact assessment and adaptation in agricultural sector is discussed herewith.

RESULTS AND DISCUSSIONS

Mean and Variability of Daily Maximum Temperature

Mean and standard deviations of simulated daily maximum temperature were compared with corresponding mean and standard deviation of observed climate as shown in Figure 1 at all the selected locations of East India. Mean of daily maximum temperature in observed climate is overestimated by simulated climate at all the selected locations in East India except at Bhubaneshwar where it is underestimated by simulated climate. Degree of overestimation is different at different locations. Variability of daily maximum temperature in observed climate as indicated by standard deviation in Figure 1 is also overestimated by simulated climate at all the selected locations in East India except at Bhubaneshwar where it is underestimated in simulated climate. Degree of overestimation in variability by simulated climate is different at different locations in East India.

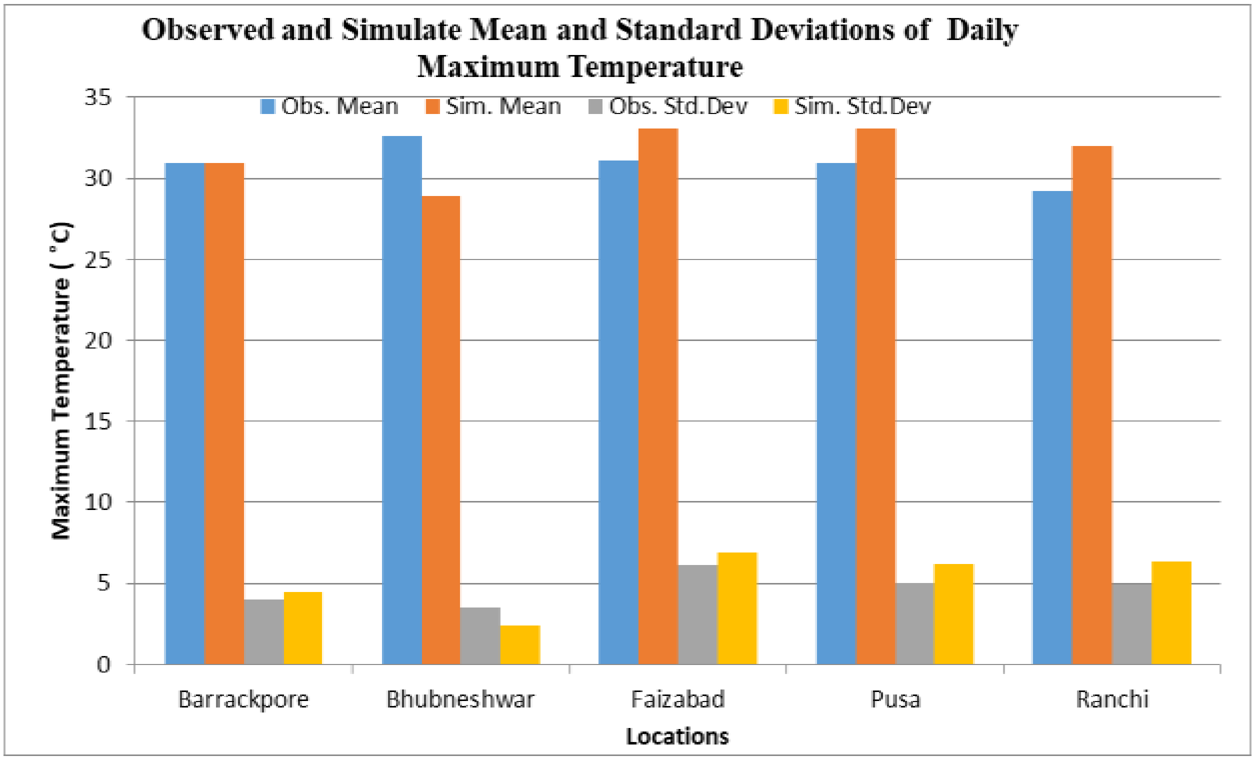

Figure 1: Observed and Simulated Mean and Standard Deviation of Daily Maximum Temperature at Different Locations in East India

Mean and Variability of Daily Minimum Temperature

Comparison of mean and standard deviations of minimum temperature in observed and simulated climate at different locations of East India is shown in Figure 2. Mean of daily minimum temperature in observed climate is overestimated at Bhubaneshwar, Pusa and Ranchi where as it is underestimated at Barrackpore and Faizabad. Variability in observed daily minimum temperature is overestimated at Barrackpore, Faizabad and Ranchi whereas it underestimated at other location in East India.

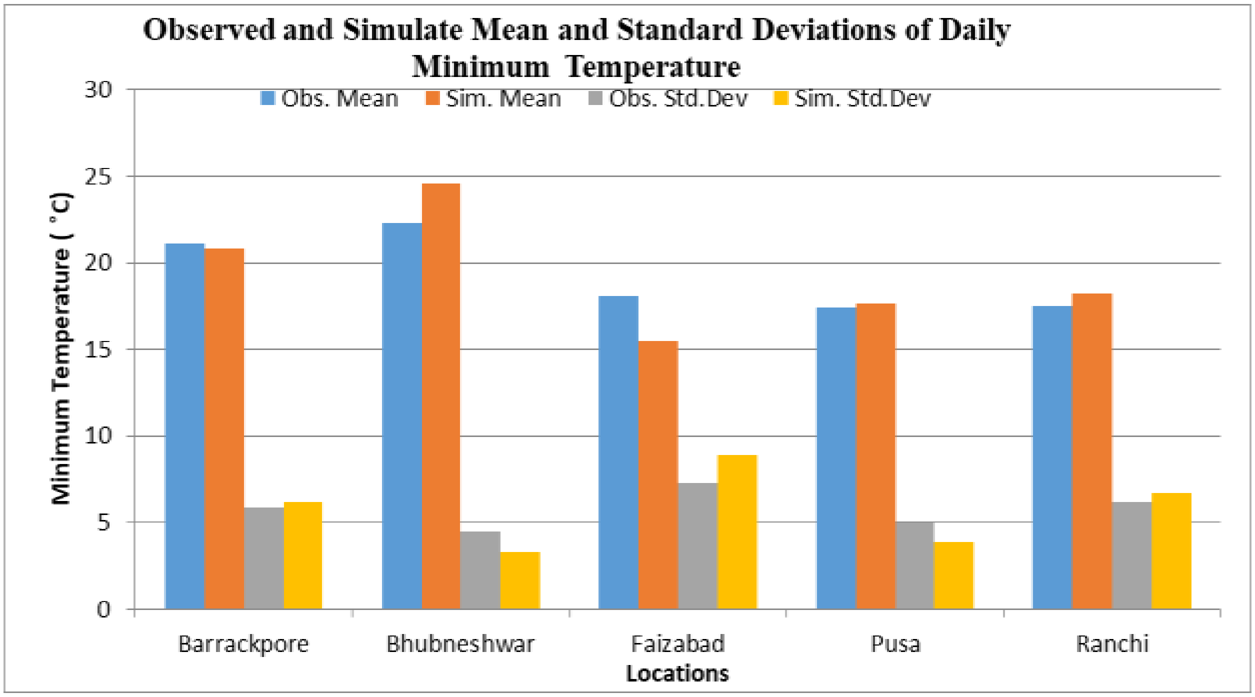

Figure 2: Observed and Simulated Mean and Standard Deviation of Daily Minimum Temperature at Different Locations in East India

Mean and Variability of Annual Rainfall

Comparison of mean and standard deviations of annual rainfall in observed and simulated climate at different locations of East India is shown in Figure 3. Mean of annual rainfall in observed climate is underestimated by simulated climate at most of the selected locations in East India except at Bhubaneshwar where it is overestimated in simulated climate. Similar spatial trend in comparison of observed and simulated variability in annual rainfall was found.

Thus there is considerable uncertainties in model simulation results which may result from pathways of radiative forcing to climate models, downscaled climate projections, impact estimates and finally to recommendations for appropriate adaptation responses.

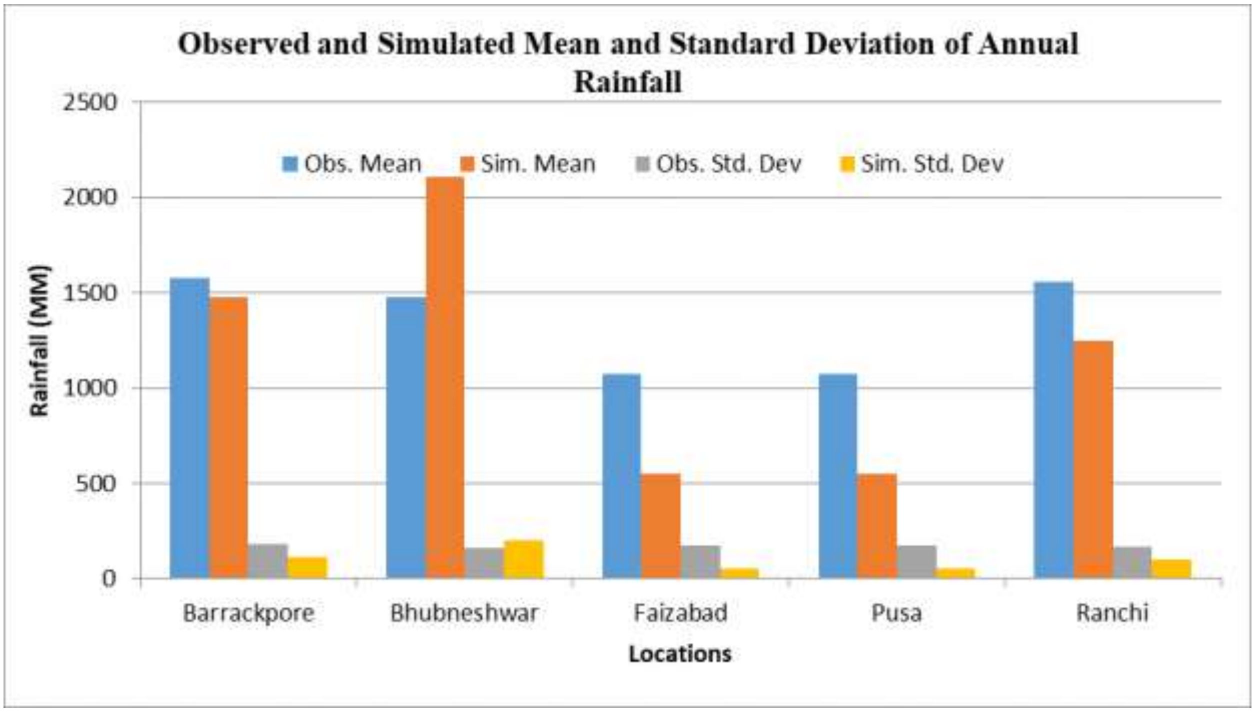

Figure 3: Observed and Simulated Mean and Standard Deviation of Annual Rainfall at Different Locations in East India

Implications of Simulated Climate Data for Agricultural Impact Assessment and Exploring Adaptation Technologies

There is emerging consensus that agriculture is vulnerable to climate change and that adaptation strategies are urgently needed to assist in minimizing climate impacts (Rosenzweig et al., 2013). While a significant body of research exists to assess the adoption of innovations (Rogers, 2003) and conservation practices in agriculture, research seeks to understand what drives climate change adaptation and mitigation practices among farmers (Barnes and Toma, 2012, Arbuckle et al., 2013a, Arbuckle et al., 2013b and Wood et al., 2014). A major challenge is that climate change adaptation strategies and farmer responses will vary across regions (Berry et al., 2006) based on agro-ecological contexts, socio-economic factors (Adger et al., 2009), climatic impacts, and existing infrastructure and capacity. To address food security, adaptation and mitigation simultaneously the FAO (2013) has developed the concept of Climate Smart Agriculture (CSA). Climate Smart Agriculture has gained considerable attention, especially in developing countries, due to its potential to increase food security and farming system resilience while decreasing greenhouse gas emissions (FAO, 2013). Crop Simulation Models are useful decision-support tool for adaptation planning in agriculture as field experiments and trials consume lot of time and money. Models may be applied to explore particular options of climate adaptation according to their environmental and socio-economic impacts (Tripathi and Singh 2013 b; Tripathi et al., 2013 c). However these model usually require reliable climate data on daily temporal scale to be applied for exploring adoptive options under changed climatic conditions. Present study and also the study by Tripathi et al., (2013) indicate that the Regional Climate Models are not reasonably good in simulating the present and future climate scenarios and therefore a very less confidence can be placed on implication of these simulation for impact assessment and exploring adaptation technologies in agricultural sector. Better understanding of future climate change and variability may help farmers to implement both short and long term climate resilient adaptation response. The application of regional climate simulation for impact assessment and exploring future adaptation technologies in future may lead to miss information and maladaptation practices. Suitable bias correction and uncertainty removal methods will have to be applied before applying such simulation for impact and adaptation studies in order to make food systems more efficient and climate resilient, at every scale from the farm to the global level. Future research supporting climate change adaptation efforts should thus be based on integrated assessments of risk and vulnerabilities (considering climate variability and uncertainty).

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