

Future change in the frequency of warm and cold spells durations over Pakistan simulated by the PRECIS regional climate model



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Abstract : The prospect of climate change caused by anthropogenic activities has generated a variety of research focusing on investigating the past climate and predicting the climate of the future using different climate models. Climate indices are valuable to evaluate the potential impact of climate change on our activities, agriculture and economy and they are also useful to monitor the climate change on a global basis. The objective of this work is to present a study of the model simulated future variations in the frequency of warm and cold spells duration over Pakistan. Analysis of future change was done on the basis of a running 30 years simulations with PRECIS regional climate model at a horizontal resolution of 50 km driven by lateral boundary conditions from GCM HadAM3P. Validation was done by comparing baseline simulated climatology with observed station and CRU data. The frequency of warm and cold spells and percentile changes was then calculated for future period to assess potential future changes in the characteristics of these extreme temperature changes as a consequence of the greenhouse warming. Simulation show that the increase in warm spells is particularly visible for Pakistan.

1. Introduction

Although many of climate change scenario studies are devoted to their impact on mean climate description, changes in climate variability and extremes of weather and climate events have received increase attention in the last few years (IPCC, Houghton et al., 2001). In this work Regional Climate Model (RCM) simulation experiment is used to see the future variations in the climate indices of temperature such as frequency of warm and cold spell duration, TXx, TXn, TNx, TNn as well as percentile based extreme future change. This study is centered over Pakistan region which is a region having several climatic aspects. Daily output data from RCM is used to analyzed temperature extremes over Pakistan. The results show significant changes in temperature extremes.

2. Experimental Design

The model used in this experiment is PRECIS which is a Regional Climate Model of Hadley Centre UK. The horizontal resolution for the simulation is taken to be 0.44° (-50 km) with the domain covering South Asia from 5° to 50° North and 55° to 100° East. The model was driven by input data of HadAM3P model which is a high resolution (150 km) atmospheric part of HadCM3 GCM. The A2 scenario data was downscaled in this simulation for two periods comprising 1961-90 in base line and 2071-2100 in future.

3. Methodology and Validation

To validate and compare downscaled data with observed data (CRU) model output is first regridded to regular lat / lon grids (dx=dy=50km) to make comparison possible. In time series analysis for validation, station data from all the available stations over Pakistan is used. This is done by first averaging all the station data into one time series and is then compared with the simulated one. Fig.1 is showing root mean square error (RMSE) of precipitation and temperature over Pakistan. The error is some what greater in northern areas as compared to the remaining part of Pakistan. This is because of the very complex topography of northern areas.

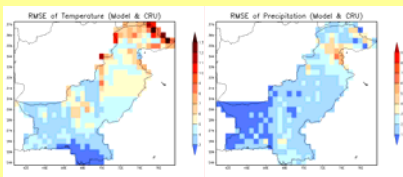


Fig.1 RMSE (1961-90) of model for temperature and precipitation over Pakistan (compared with CRU).

The scatter plots of monthly temperature and precipitation is shown in Fig. 2. The model performance (as compared with CRU) in simulating temperature is pretty better than the precipitation.

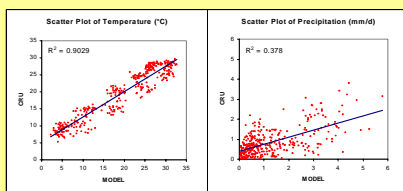


Fig.2 Scatter plots for temperature and precipitation over Pakistan.

8. Seasonal Percentile Based Changes

As a measure of intensity for extreme summer and winter temperature conditions, the 90th percentile of maximum temperature (T⁹⁰_{max}) and 10th percentile of minimum temperature (T¹⁰_{min}) (Folland et al., 1999) of the daily data corresponding to both seasons for 30 years modelled period (30 x 90=2700 data at each model point) have been computed and are spatially analyzed in fig. 8a,b. These are essential to describe timescale appropriate for variability description and societally sensitive extremes (Jones et al., 1999). The change in T⁹⁰_{max} temperature is higher in winter than summer whereas in the case of T¹⁰_{min}, the change is higher in summer. Change in lower threshold that is T¹⁰_{min} is higher in summer specially over south western parts of Pakistan showing the daily minimum temperature will become more warmer. For minimum temperature upper threshold T⁹⁰_{min}, the northern areas shows higher change.

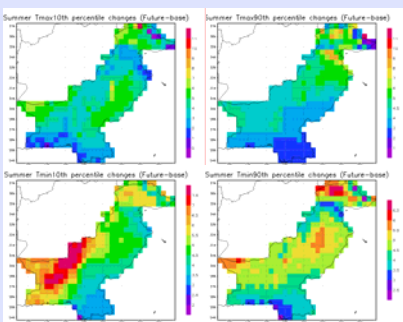


Fig.8a Change in Tmax 10th, Tmax 90th, Tmin 10th and Tmin 90th percentiles for summer temperature.

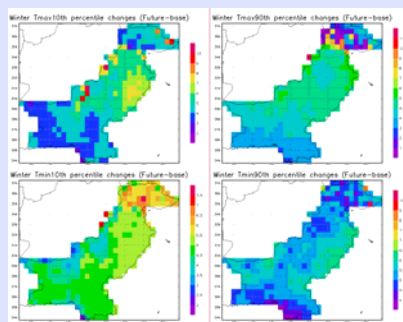


Fig.8b Change in Tmax 10th, Tmax 90th, Tmin 10th and Tmin 90th percentiles for winter temperature.

4. Validation contd.

To validate model performance with station data, probability distribution function of both station (Stations averaged over Pakistan) and model daily data is shown in the fig. 3 which is showing a good agreement of downscaling performance over Pakistan, with slight change in distribution spread which is acceptable.

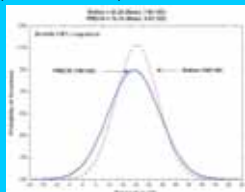


Fig.3 Pdf's comparison of Model with station data.

Various numerical statistical measures are calculated on the annual and seasonal basis to depict the model performance over Pakistan. In table.1, less bias and more accuracy is observed for temperature and precipitation is well simulated on the annual basis.

	PRECIPITATION		
	CORR	RMSE (mm/d)	% diff (mm/d)
Annual	0.61	1.02	49.89
Summer	0.15	2.83	107.10
Winter	0.10	2.02	-20.17
	TEMPERATURE		
	CORR	RMSE (°C)	Diff (°C)
Annual	0.95	3.30	-0.32
Summer	0.29	2.11	0.10
Winter	0.15	7.95	-1.73

Table.1 Validation measures (Correlation, RMSE and Bias).

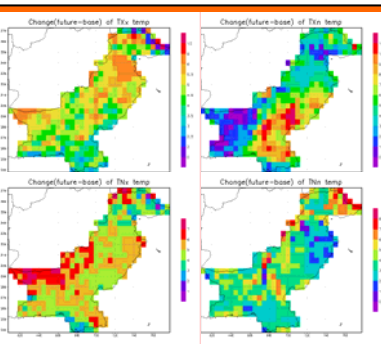


Fig.4 Maximum (max, min) and Minimum (max, min) temperature changes.

5. Change in Temperature Indices

Projected future changes in highest and lowest temperature in daily maximum and minimum temperatures throughout the 30-year scenario relative to control run (1961-90) are analyzed to see potential change in highest and lowest ends of maximum and minimum temperature (as shown in fig. 4). Maximum temperature shows a future change of 4 - 8 °C for its highest (max, TXx) value and having rise of about 10°C over southern Pakistan. The change is somewhat less in remaining part for its lowest (min, TXn) value. Change in highest daily minimum temperature (TNx) relative to base period shows an increase of 7°C over south western part whereas 3 - 5 °C rise is observed over other parts of country. For lowest minimum temperature (TNn) on the average 4°C is depicted for whole region. This shows that the maximum and minimum temperature have risen over this region which is also depicted in fig. 6.

6. Analysis of WSDI and CSDI

Changes in trend of warm and cold spell duration indices (WSDI, CSDI) are calculated for model daily data by using RCLIMdex software (As in fig. 5). The projected warm spells over Pakistan seems to be increasing whereas the cold spells having decreasing trend.

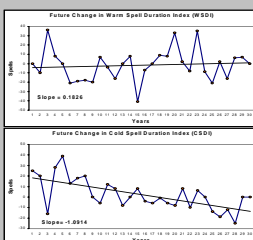


Fig.5 Warm and Cold spell duration changes between A2 and control run.

7. Change in Temperature Extremes

A rise in mean would not necessarily lead to rise in extreme temperature events. If the change in mean, however, was related to a shift in the distribution then this could have a major impact on society and ecosystems.

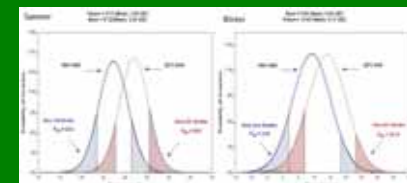


Fig.6 Seasonal change in temperature extremes.

Fig. 6 shows future shift in mean, 90th and 10th percentiles values for both seasons which is according to future warming. The over all shape of the distribution is not changed for both seasons in future. Change in minimum temperature is widely spread on many parts over the region as compared to the maximum temperature change as shown in fig. 7.

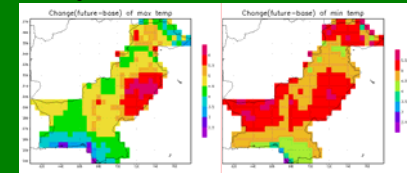


Fig.7 Annual change in minimum and maximum temperature.

9. Conclusion

1. The comparison of model output with observed climatology in base period shows that the downscaled data can be used for analyzing future changes. However model biases are more over northern areas of Pakistan.
2. Almost all of the temperature indices show significant changes over the region.
3. Trend in temperature indices reflect an increase in both maximum and minimum temperature.
4. There is a much larger percentage of land area showing significant change in minimum temperature (5 °C) than maximum temperature.
5. Percentile based spatial change shows that the daily minimum temperature will become more warmer as compare to the increase of daily maximum temperature in summer whereas in winter the change in maximum threshold temperature is high.
6. The occurrence of annual cold spells trend significantly decrease while for warm spells there is slight increase. The decreasing trend in the cold spells is greater in magnitude.