

Regional climate assessment of precipitation and temperature in Southern Punjab (Pakistan) using SimCLIM climate model for different temporal scales

Asad Amin¹ · Wajid Nasim^{1,2,3} · Muhammad Mubeen¹ · Saleem Sarwar⁴ · Peter Urich⁵ · Ashfaq Ahmad⁶ · Aftab Wajid⁶ · Tasneem Khaliq⁶ · Fahd Rasul⁶ · Hafiz Mohkum Hammad¹ · Muhammad Ishaq Asif Rehmani⁷ · Hussani Mubarak^{8,9,10} · Nosheen Mirza^{8,9,10} · Abdul Wahid¹¹ · Shakeel Ahamd¹² · Shah Fahad¹³ · Abid Ullah¹⁴ · Mohammad Nauman Khan¹³ · Asif Ameen¹⁵ · Amanullah¹⁶ · Babar Shahzad¹⁷ · Shah Saud¹⁸ · Hesham Alharby¹⁹ · Syed Tahir Ata-Ul-Karim²⁰ · Muhammad Adnan²¹ · Faisal Islam²² · Qazi Shoaib Ali²³

Received: 26 May 2016 / Accepted: 3 October 2016 / Published online: 17 October 2016
© Springer-Verlag Wien 2016

Abstract Unbalanced climate during the last decades has created spatially alarming and destructive situations in the world.

Anomalies in temperature and precipitation enhance the risks for crop production in large agricultural region (especially the

✉ Wajid Nasim
wajidnasim@ciitvehari.edu.pk

✉ Shah Fahad
shah_fahad80@yahoo.com

¹ Department of Environmental Sciences, COMSATS Institute of Information Technology (CIIT), Vehari 61100, Pakistan

² CIHEAM-Institute Agronomique Mediterranee de Montpellier (IAMM), 34090 Montpellier, France

³ CSIRO Sustainable Ecosystem, National Agricultural Research Flagship, Toowoomba, QLD 4350, Australia

⁴ SMEC Consultancy Services, Lahore 54660, Pakistan

⁵ CLIMsystems, Flagstaff Hamilton 3210, New Zealand

⁶ Agro-Climatology Laboratory, Department of Agronomy, University of Agriculture, Faisalabad 38040, Pakistan

⁷ Department of Agronomy, Faculty of Agricultural Sciences, Ghazi University, Dera Ghazi Khan, Pakistan

⁸ Department of Environmental Sciences, COMSATS Institute of Information Technology, Abbottabad 22060, Pakistan

⁹ National Engineering Research Center for Control and Treatment of Heavy Metal Pollution, Changsha 410083, China

¹⁰ Department of Environmental Engineering, School of Metallurgy and Environment, Central South University, Changsha, Hunan 410083, China

¹¹ Department of Environmental Sciences, Bahauddin Zakariya University, Multan, Pakistan

¹² Department of Agronomy, Bahauddin Zakariya University, Multan, Pakistan

¹³ College of Plant Science and Technology, Huazhong Agricultural University, Wuhan, Hubei 430070, People's Republic of China

¹⁴ National Key Laboratory of Crop Genetic Improvement, Huazhong Agricultural University, Wuhan, Hubei 430070, People's Republic of China

¹⁵ College of Agronomy and Biotechnology, China Agricultural University, Beijing 100193, China

¹⁶ Department of Agronomy, Faculty of Crop Production, The University of Agriculture, Peshawar 25130, Pakistan

¹⁷ Agricultural University, Faisalabad 38000, Pakistan

¹⁸ Department of Horticulture, Northeast Agricultural University, Harbin 150030, China

¹⁹ Department of Biological Sciences, Faculty of Science, King Abdulaziz University, Jeddah 21589, Saudi Arabia

²⁰ National Engineering and Technology Center for Information Agriculture, Nanjing Agricultural University, 1 Weigang Road, Nanjing, Jiangsu 210095, People's Republic of China

²¹ Department of Agriculture, University of Swabi, Swabi, Pakistan

²² Institute of Crop Science and Zhejiang Key Laboratory of Crop Germplasm, Zhejiang University, Hangzhou 310058, China

²³ College of Horticulture and Forestry Sciences, Huazhong Agricultural University, Wuhan, Hubei 430070, People's Republic of China

Southern Punjab) of Pakistan. Detailed analysis of historic weather data (1980–2011) record helped in creating baseline data to compare with model projection (SimCLIM) for regional level. Ensemble of 40 GCMs used for climatic projections with greenhouse gas (GHG) representative concentration pathways (RCP-4.5, 6.0, 8.5) was selected on the baseline comparison and used for 2025 and 2050 climate projection. Precipitation projected by ensemble and regional weather observatory at baseline showed highly unpredictable nature while both temperature extremes showed 95 % confidence level on a monthly projection. Percentage change in precipitation projected by model with RCP-4.5, RCP-6.0, and RCP-8.5 showed uncertainty 3.3 to 5.6 %, 2.9 to 5.2 %, and 3.6 to 7.9 % for 2025 and 2050, respectively. Percentage change of minimum temperature from base temperature showed that 5.1, 4.7, and 5.8 % for 2025 and 9.0, 8.1, and 12.0 % increase for projection year 2050 with RCP-4.5, 6.0, and 8.5 and maximum temperature 2.7, 2.5, and 3.0 % for 2025 and 4.7, 4.4, and 6.4 % for 2050 will be increased with RCP-4.5, 6.0, and 8.5, respectively. Uneven increase in precipitation and asymmetric increase in temperature extremes in future would also increase the risk associated with management of climatic uncertainties. Future climate projection will enable us for better risk management decisions.

1 Introduction

Anthropogenic rise in greenhouse concentrations is causing significant anomalies in climate at global and regional scales (IPCC 2014). Global circulation model (GCM) predictions have warned about frequency and severity of these changes in future (Wilby et al. 2002; Nasim et al. 2016a) and their profound biological, societal, and environmental impacts (Easterling et al. 2000; Patz et al. 2005; Rosenzweig et al. 2008; Hautier et al. 2015; Hertel 2016; Nasim et al. 2016b). These impacts are largely felt as the changes in the risks of extreme events, maximum and minimum temperature variations, and precipitations have caused floods (Porter et al. 2014). So, climatic predictions should be used for the future adaptations on the risks of climatic extremes and changes in their rate of occurrence and strength over time. Pakistan is not exempted from these events. In this context, in Pakistan, these events can be tackled by integrated models and tools. Climate change adaptation assessments are essential that can help to link the gap between the management and technology in order to reduce these risks. The information of spatial scale used as a base to investigate the impact of changing climate on various sectors in our society can also affect the magnitude and sometimes even the sign of the potential change and corresponding impacts (Kueppers et al. 2005; Amin et al. 2015). Many scientists have proposed different changes for the implementation of climate modeling (Kravitz et al. 2013). One of the most

effective approaches for the climate modeling recommended by Intergovernmental Panel on Climate Change (IPCC) is global climate models (GCMs) in representative greenhouse gas concentration pathway RCPs (IPCC 2014).

Spatial resolution of global climate models is still insufficient to adequately describe many regional climate processes. In order to determine better estimates for regional climate parameters, high-resolution regional climate models (RCMs) are frequently used (Warrick 2009). This approach has been comprehensively employed in recent European research projects also including an ensemble approach, by designing series of coordinated experiments using multiple models to pursue different research questions (Bao et al. 2015; Christensen et al. 2008). RCM has higher resolution for the specific regions of the globe than a GCM which have resolutions 100 to 300 km for all over the globe (Katzav and Parker 2015). RCMs were used within global model to access more specific simulations for a particular region or location (Warrick 2009).

SimCLIM is an integrated model and tool used to examine the impacts and adaptations to climate change and extreme climatic events. Different tools of SimCLIM are used for the spatiotemporal analysis of spatial and site time series analyses. Basic feature of the SimCLIM is to deal with risk-based climate impact assessment by its greenhouse gas (GHG) concentration pathways generator and extreme event analyzer. In SimCLIM Pakistan data set, estimates of the return periods for predicted extreme events (e.g., precipitation, maximum, minimum, and mean temperature) can be used to assess the current and future climate scenarios of climate change (Yin et al. 2013). This study was conducted to present and utilize features of the climate projection-integrated SimCLIM system for the assessment of site-specific climatic events (precipitation, minimum, and maximum temperature) and to study the variation associated with different time scales. Different features of the SimCLIM can be used to perform the site-specific climate analysis of maximum, minimum temperature, and precipitation (Bao et al. 2015). The objective of this study was to assess the past climate changes and compute the projected changes in productive agro-climatic region Southern Punjab, Pakistan, for the years 2025 and 2050 using regional and global climate models. In view of these changes, vulnerabilities of region may be assessed and suitable coping mechanism adaptation strategies be proposed.

2 Data and methodology

2.1 Study area and data

Climatologically, most parts of Pakistan are arid to semi-arid with significant spatiotemporal variability in climatic parameters like precipitation, maximum, and minimum temperature. More than half (59 %) of the annual rainfall is due to monsoon

rains, a dominant hydro-meteorological resource for Pakistan. The Southern Punjab is mostly dominated by the arid climate. The study area focuses on Southern Punjab, Pakistan, roughly centered on Multan, as shown in Fig. 3. Climatic data set for the last 32 years (1980–2011) was used to analyze base line data with SimCLIM base line projections. Graphs were drawn for precipitation, maximum, and minimum values for current climatic variations in the country assessed by Multan weather observatory. Monthly temperature extremes (maximum and minimum temperature for whole year) and precipitation monthly averages were analyzed.

2.2 Important tools of SimCLIM systems

An open framework modeling software SimCLIM can be used to study the impacts and adaptation strategies to climate change and climatic extremities (Warrick et al. 2012). CLIMFACTS was the basic origin of SimCLIM from New Zealand (Warrick 2009), with different other countries and regions of the world (for example, it also develops a data pack for Pakistan initially for mean, minimum, maximum temperature, and precipitation for climatic projections for specific region). SimCLIM 2013 is a computer-based modeling system for examining the spatiotemporal variability in climatic conditions and their impacts. It is a customized geographical information system (GIS) which includes tools for the spatial analysis of climate variability and change and associated impacts on various social-economic sectors. Its “open-framework” feature allows the user to customize the model for their own geographical area and spatial resolution and to attach climate impact models. It has functionality to combine models and different data patterns. It has a top down approach to deal with global, regional, and local models, and we can manipulate data for the study of impacts on human health, agricultural, and natural resource management for that specific region (Yin et al. 2013). SimCLIM system was developed to describe the baseline climate; examine present climate variations and extreme events, risk, and adaptation assessment of present and future; create scenarios and project impacts of climate and sea level change; conduct sensitivity analyses; examine risks and uncertainties; and facilitate integrated impact analyses.

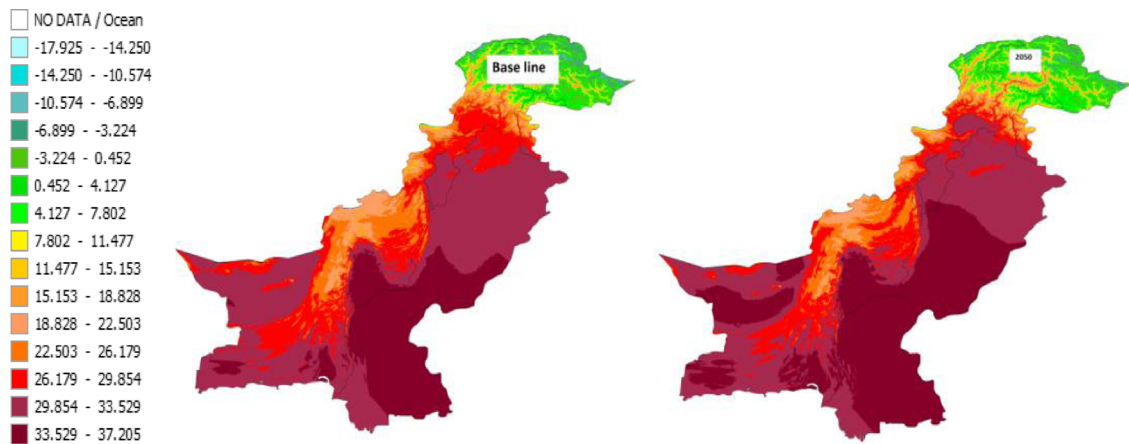
User-friendly applications of SimCLIM have more facility to customize the system for their specific goals. At the basic scale, SimCLIM contains scenario generator which were developed by pattern scaling methods (Warrick 2009) that deals with different patterns of climate change from complex GCMs which show time variant projections of global climate change. These variations are used to perturb the time series data to develop the climate scenarios for different sites or time scales as shown in Fig. 1. SimCLIM 2013 follows the fifth assessment report (AR5) of IPCC (IPCC 2014). SimCLIM provides the facility to select the GCM patterns for the development of suitable global projections (AR5) of sensitivity values and future

climatic variations and thus for the assessments of uncertainties caused by future GHG emissions and systematic modeling (Yin et al. 2013; Warrick 2009). SimCLIM has the capacity to develop “ensemble” patterns by the combined effect of user-selected GCM output, in which we can find median, lower, and upper percentiles as output. Extreme event analyzer is a useful tool for the extreme event assessment. With the help of this tool, we can observe the extreme values like extreme daily precipitation, mean temperature year by year observed from the data. Site-specific climate scenarios are used to plot with normalized GCM values which show the fitness of data as shown in Fig. 2. Site-specific climate change data from local observatory are used to compare historic time scale data with SimCLIM by using ensemble for precipitation, maximum, and minimum temperature (Fig. 2).

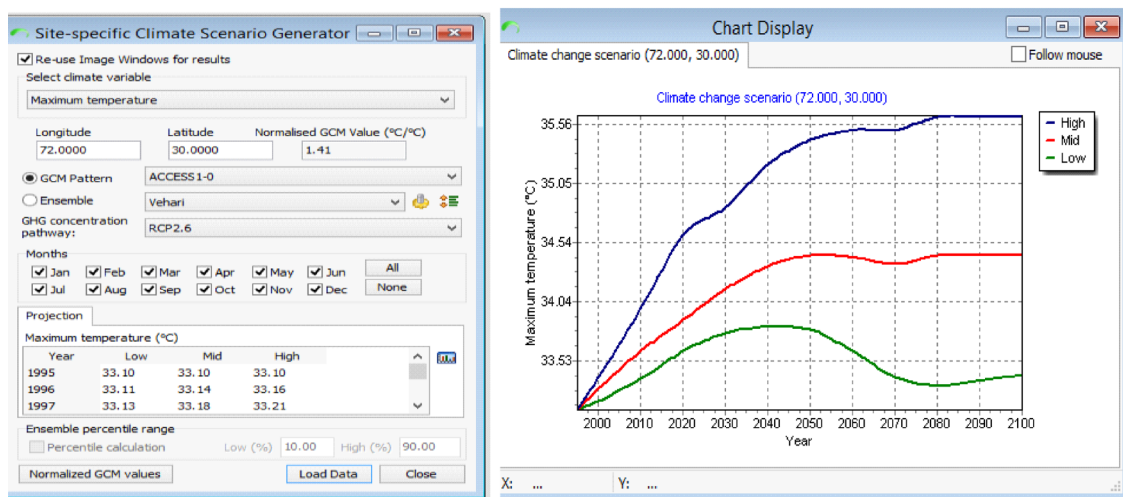
2.3 Selection of climate model

To project the future climate for local or regional scale is important to select suitable GCMs (Pierce et al. 2009; Bao et al. 2015). For a specific site, average of 40 GCMs (ensemble) should be used for suitable projections as single GCM projection has very limited scope (Hulme et al. 2000). GCM evolutions are accepted for specific site, and if these projected the current climate accurately, then these will project the accurate future climate (Coquard et al. 2004). According to this perspective, any climate change scenario consisted on single GHG emission rate and/or role of individual GCM output is ineffective for climate modeling purposes, because it cannot effectively provide the information associated with its projection, while other study claims that selection of proper GCM should be based on quality of predicted regional climate (Pierce et al. 2009). The future climate change is quite uncertain. One important aspect in climate modeling is to deal with uncertainty range in policy planning processes and decision making. In this study, to project the climate risks in future GHG emission rates and climate sensitivity, a combination of different GHG-RCPs and climate variations is used to characterize the future climate change scenario with the associated uncertainty range.

RCP4.5 with low-climate sensitivity, RCP6.0 with mid-climate sensitivity, represents a middle range future global change scenario, which was used as an indicator of the median projection of the future global change, while RCP8.5 with high-climate sensitivity was used as an indicator of the corresponding low and high bound of the uncertainty range. Another uncertainty associated with climate projections is the variation in GCM predictions. To account for such an uncertainty in climate risk assessment, different GCMs were combined by a pattern scaling method to build a model ensemble. The mean value of the models for climate variables is normally used to predict the middle conditions, as that mean value often matches better with observed climate than any individual GCM (Reichler and Kim 2008). However, in this



Spatial pattern, Time-slice analysis e.g. Maximum temperature change for the Pakistan Region



Time-series projections for Southern Punjab, Pakistan

Fig. 1 Spatial and site timeseries projections produced by SimCLIM scenario generator

study, the 50 percentile of the GCM model ensemble was used in order to prevent the influence of huge outliers in some GCM simulation on the final change values.

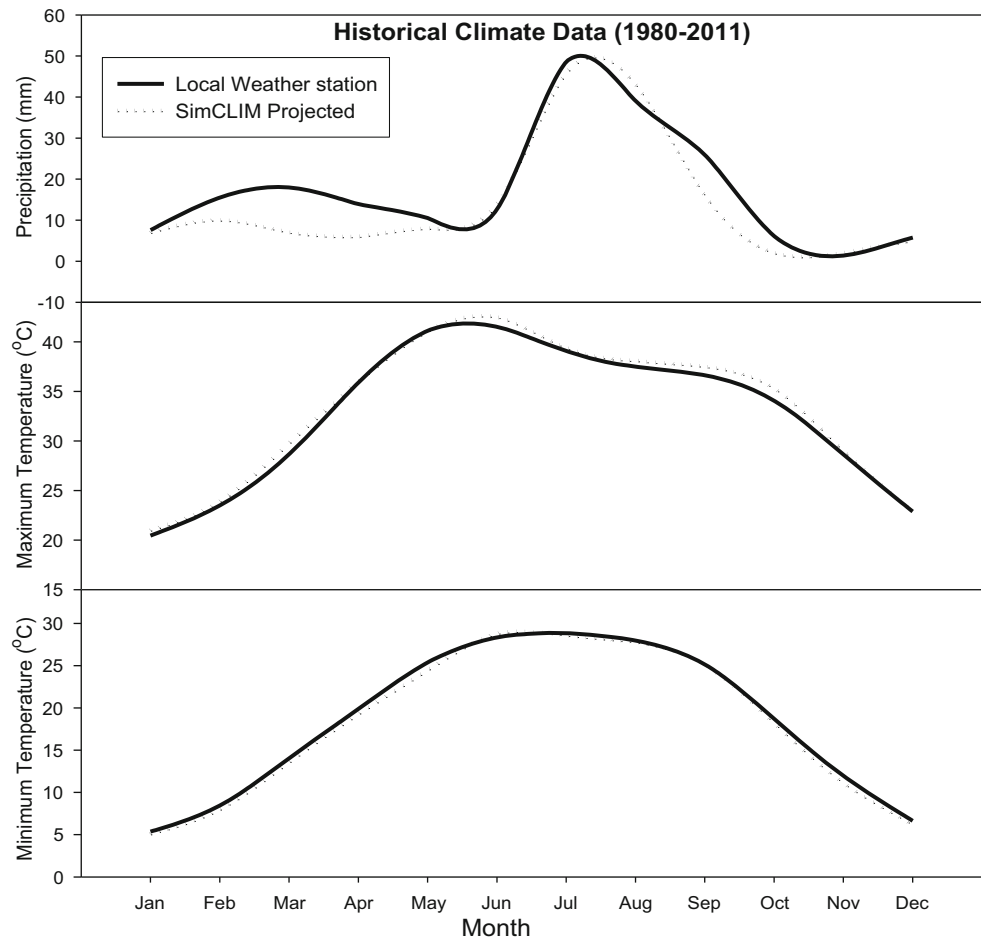
To find out the localized projections, 40 GCM (ensemble) was selected from SimCLIM. The monthly observed precipitation, maximum, and minimum temperature data were used as baseline data of Pakistan. IPCC has claimed on the basis of analysis of observe data, which global temperature is increasing (IPCC 2007, 2013, 2014). The analysis of 31-year data (1980–2011) of Southern Punjab, Pakistan, also shows increasing trend to support this IPCC statement as, in general terms, the local data indicates that annual maximum and minimum temperatures have been increasing across Pakistan as shown in Fig. 1. IPCC (2013) has studied that increase in temperature is caused by increasing GHG emissions in the atmosphere. Occurrence of the hot days in number is increasing, but cold days are decreasing, with associated shifts in annual and seasonal means and extremes.

Annual maximum, minimum temperature, and precipitation for the base climate (1980–2011) study area by using ensemble of 40 GCMs are shown in Fig. 2. Details of the observed maximum, minimum, and precipitation data and their future change projections for the study area are discussed below: the mean annual rainfall is 205.0 mm, July and August are the wettest months with 49.0 and 39.0 mm whereas November and December are the driest months with rainfall of 1.4 and 5.8 mm, respectively. The median scenario change projection indicates that the annual rainfall change in the area will likely be small, with an average increase across the area of 4.0 to 6.7 % by 2025 to 2050, respectively, as shown in Table 1.

2.4 The context and approach

Problems of climatic variations are widespread in Pakistan and have been particularly acute during the present decade with prolonged periods of high rainfall. Future climate with

Fig. 2 Timescale evaluation for historical climatic data (1980–2011) between local weather station (Multan) data and SimCLIM projected data (using 40 GCM ensemble) for Southern Pujnab, Pakistan



the projected higher temperatures (Cheema et al. 2012; Sheikh et al. 2015; Maida and Rasul 2011) and decreased annual precipitation have worsened the situation for many areas of Pakistan. Southern Punjab is one such area, in this particular area; a promising retort for this fatal crisis encourages the climate adaptation and mitigation strategies by using future

climate broadcasting applications (Abbas et al. 2013; Shirazi et al. 2006). While justifying this assumption that climate projection applications are the sole source for future adaptation and mitigation policies (as may be the case for the other regions of the world), future climate projection application (SimCLIM) is used here to study an exploratory assessment of the adequacy of climatic projections under present climatic variability and future climate risks (Bao et al. 2015). These risks are studied by its occurrence during the whole year for specific site and time scale. The analyses are carried out for Southern Punjab, using its historical data of observed precipitation, minimum, and maximum temperature, which are used with future conditions to perturb by a scenario of climate change. Analyses results of this study are configured spatially to provide risk map for present and future climatic conditions.

Table 1 Mean monthly rainfall of Southern Punjab for baseline, 2025 year and 2050 year using median scenario

Month	Rainfall(mm)		
	Baseline	2025	2050
Jan	7.59	7.24	6.98
Feb	15.53	15.18	14.92
Mar	17.99	17.26	16.71
Apr	13.89	13.45	13.12
May	10.52	11.02	11.4
Jun	12.62	13.55	14.24
Jul	48.6	51.4	53.49
Aug	39	40.62	41.83
Sep	25.96	28.75	30.84
Oct	6.1	6.96	7.6
Nov	1.35	1.51	1.64
Dec	5.77	5.84	5.89

3 Results and discussion

3.1 Baseline parameters

In order to summarize climate response behavior, 40-model ensemble (median) was used to predict the climate change for 2025

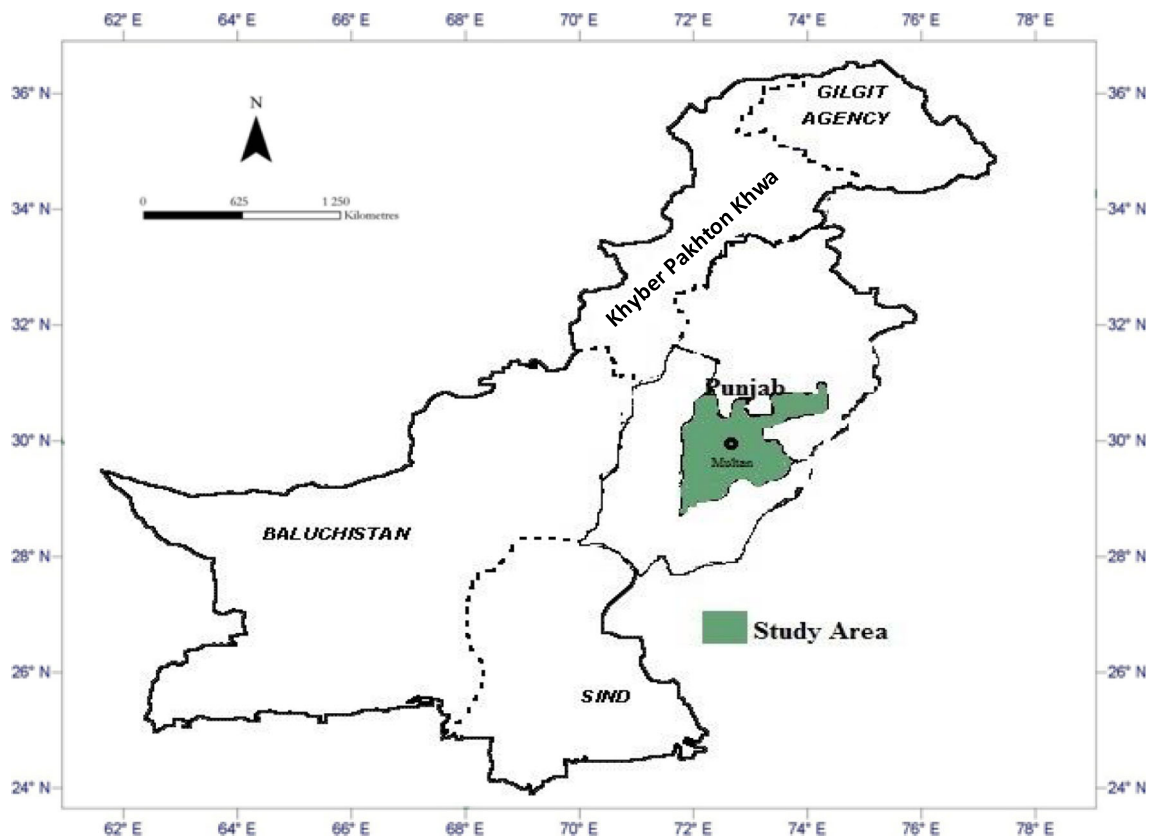


Fig. 3 Study area focuses on local weather station of Southern Punjab, Pakistan

and 2050 by SimCLIM. Data set of Multan Meteorological Station from Punjab, Pakistan, consisting of monthly averages of total precipitation, daily maximum (T_{max}), and minimum (T_{min}) temperatures for the baseline period (1980–2011) was used to compare with SimCLIM base line climate data (temperature and precipitation) trends. While discussing the variations between the observed baseline data and projected data by SimCLIM, monthly precipitation showed large variation

between both grids, but in case of maximum and minimum monthly temperature, both projection years showed almost similar readings. In terms of annual average maximum and minimum temperature for observed and model projected values (32.5–33.0 °C) and (18.4–18.0 °C), respectively, and annual average precipitation showed more difference across both grids. While comparing the monthly variation for both years from February to May variations in precipitation was high, but for

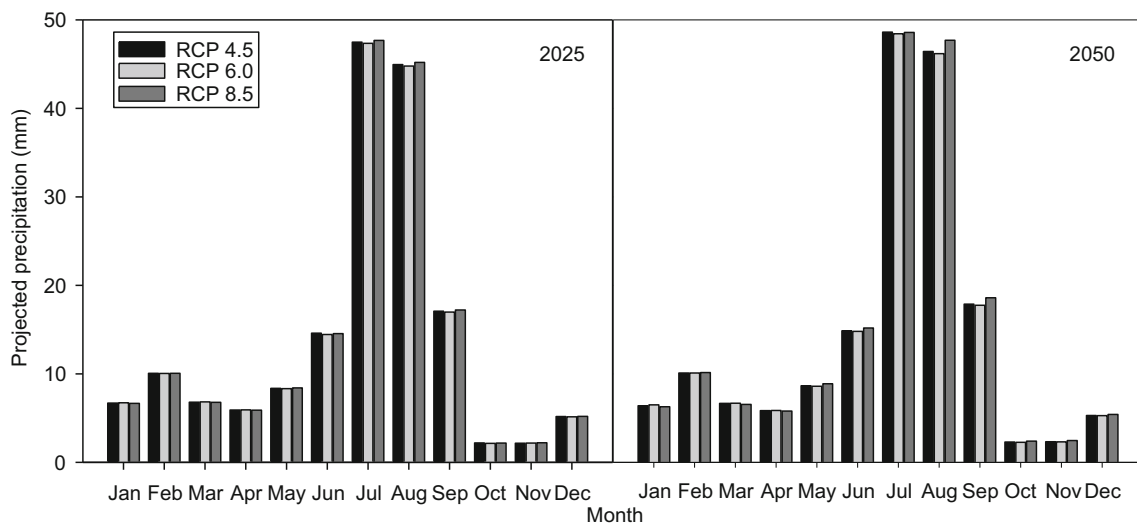


Fig. 4 Projected precipitation for 2025 and 2050 by using (ensemble) 40 GCMs with RCP-4.5, 6.0, and 8.5 for Southern Punjab, Pakistan

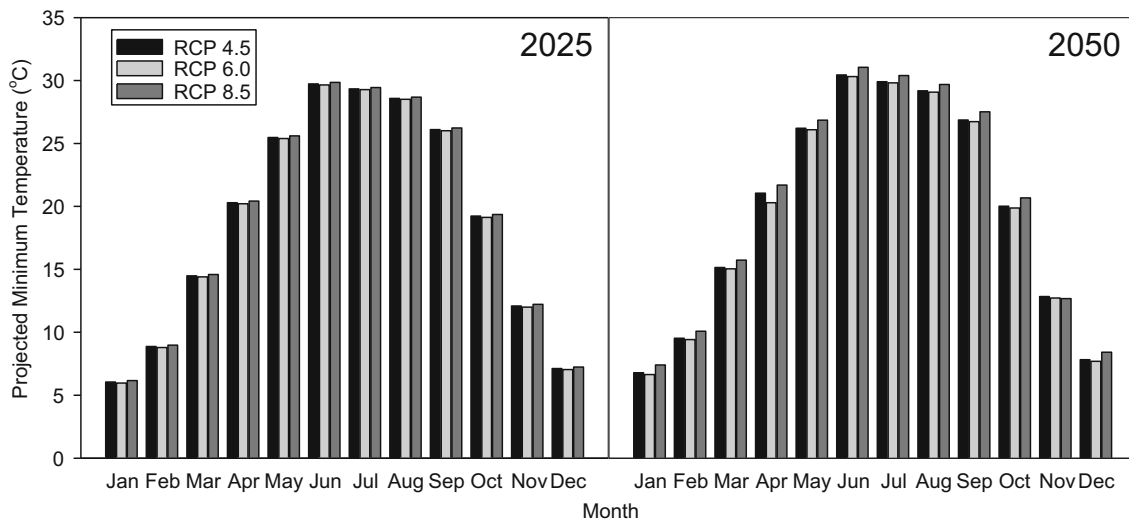


Fig. 5 Projected monthly averages of daily minimum temperature for 2025 and 2050 by using (ensemble) 40 GCMs with RCP-4.5, 6.0, and 8.5 for Southern Punjab, Pakistan

remaining months, values were closed but in some months even decreased slightly. In this way, the overall pattern is one of the moderate increases in rainfall for the middle months of the year; total annual rainfall showed around 205.0 mm for observed baseline data and 166.0 mm for SimCLIM data. The highest recorded precipitation was 48.6–46.0 mm in July and the lowest was 1.3–2.0 mm in November for observed and SimCLIM projected data, respectively. This means that the level of rainfall is highly unpredictable and can vary greatly from year to year.

While discussing the average monthly maximum and minimum temperature of baseline year observed and SimCLIM data was 32.5–33.0 and 18.4–18.0 °C, respectively, month wise average maximum and minimum temperature observed and SimCLIM projected have quite close values. High temperature was observed for the month of June (41.5–42.5 °C) and minimum temperature’s value for July (28.8–28.6 °C) for observed

and SimCLIM projected data, respectively. These results show validity and closeness between the observed climate data and SimCLIM projected data and verify the ability of SimCLIM for future time scale climate prediction. Figure 2 shows maximum and minimum temperature model projection for baseline statistically significant trends at a 95 % confidence level on a monthly projection with regional weather location observation. Maps shown in Fig. 1 represent the spatial distribution of baseline trends and projected data. Many researchers used such technique for finding variability in climate on diversified time scale (Sohail and Burke 2013) (Fig. 3).

3.2 Projection of precipitation for 2025 and 2050

In Fig. 4, trends for precipitation on all time scales are shown. Precipitation showed the increasing trends for all month of the

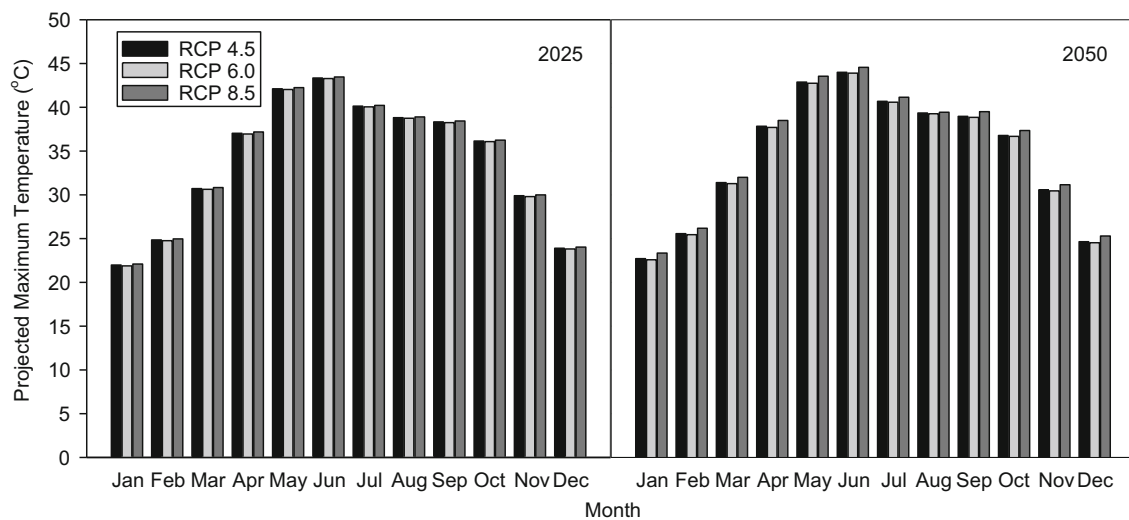


Fig. 6 Projected monthly averages of daily maximum temperature for 2025 and 2050 by using (ensemble) 40 GCMs with RCP-4.5, 6.0, and 8.5 for Southern Punjab, Pakistan

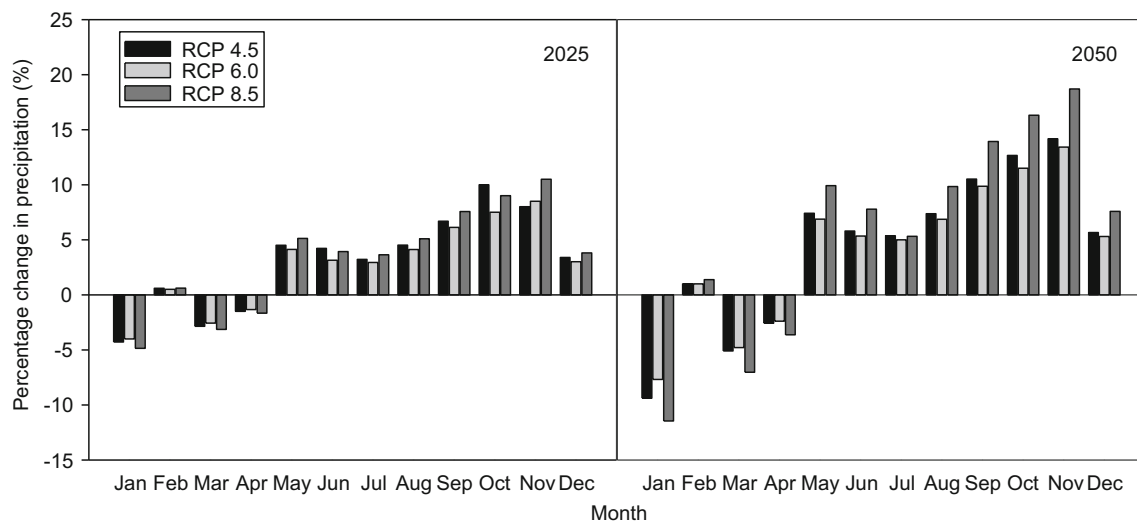


Fig. 7 Percentage change in precipitation from baseline (1980–2011) for 2025 and 2050 by using (ensemble) 40 GCMs with RCP-4.5, 6.0, and 8.5 for Southern Punjab, Pakistan

year except (January, March, and April) for 2025 and 2050. In contrast, January, March, and April were characterized by having a decrease in precipitation for both projection years. High precipitation increase was observed in August (1.8 to 3.8 mm) for 2025 and 2050, respectively. Increased precipitation was observed for 2025 and 2050 from the baseline. The 110 years of mean temperature and precipitation data (1901–2010) of Pakistan reveal an increasing trend of about 106.0 mm in precipitation (Sohail and Burke 2013). High percentage change was observed for months (September, October, and November), and low percentage change (July and December) was observed as compared to other months for 2025 and 2050.

Precipitation projections (Fig. 4) for both years showed slight annual increases through 2025 to 2050. Projections also showed increasing variability between different years 2025 to 2050 (3.2 to 6.0 %), respectively. Projections through to 2025

showed a leveling off and possibly a slight decline in rainfall relative to 2050 levels. Changes of precipitation have been observed since the beginning of the twentieth century which amounted to about 2 % increase over the land area of the globe (Sohail and Burke 2013). Similar study conducted in North America revealed the positive trends in the precipitation extreme indices (Griffiths and Bradley 2007; Abbas et al. 2013). The overall increase in average precipitation for future projections while discussing the inter RCP variability (IPCC Fifth Assessment Report AR5) with present climate situations. RCPs were used to estimate the high, medium, and low climatic uncertainty range for projected years (IPCC 2014). Global temperature will increase by 1.8–4.0 °C with an overall average increase of 2.8 °C in temperature (IPCC 2007). Historical data analysis in different studies showed that climatic extremes for most of the areas of the globe (e.g., Peterson and Vose 1997;

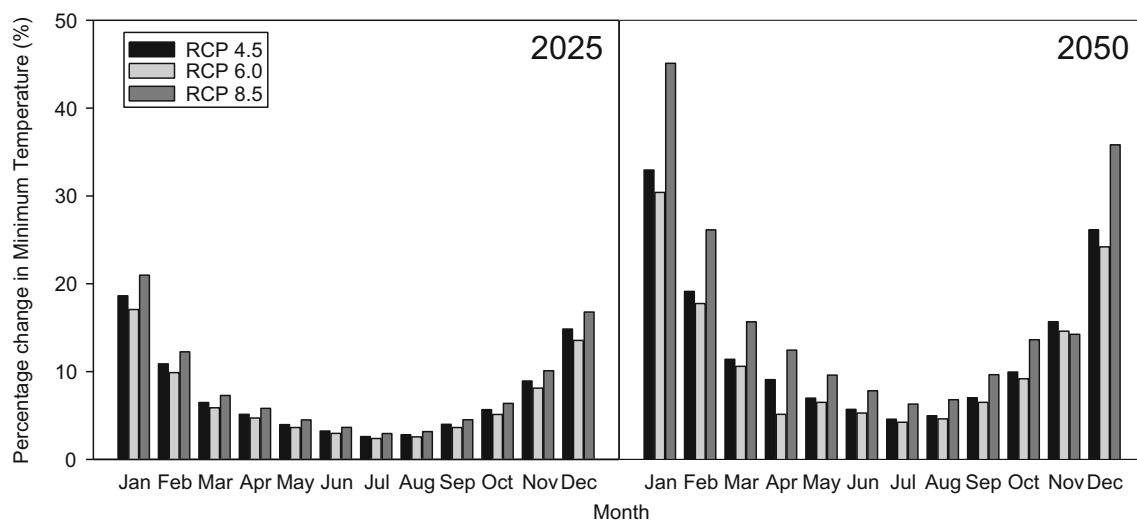


Fig. 8 Percentage change in monthly average minimum temperature from baseline (1980–2011) for 2025 and 2050 by using (ensemble) 40 GCMs with RCP-4.5, 6.0, and 8.5 for Southern Punjab, Pakistan

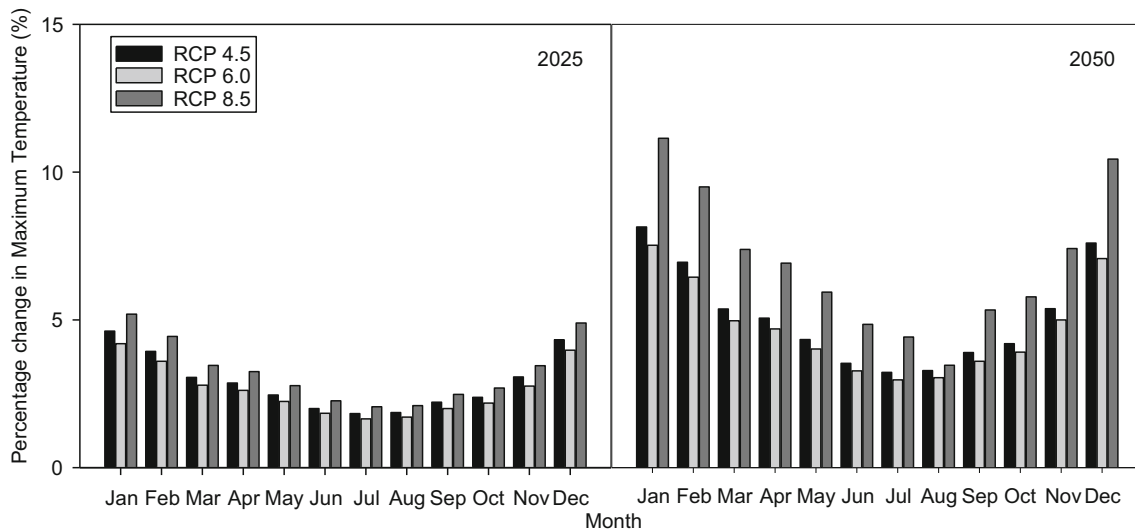


Fig. 9 Percentage change in monthly average maximum temperature from baseline (1980–2011) for 2025 and 2050 by using (ensemble) 40 GCMs with RCP-4.5, 6.0, and 8.5 for Southern Punjab, Pakistan

New et al. 2001; Hansen et al. 2001; Marengo et al. 2009; Safeeq et al. 2012; Abbas et al. 2013; Abbas et al. 2013). According to Fig. 7, the RCP-4.5 showed 3.3–5.6 %, RCP-6.0 predicted 2.9 to 5.2 %, and the RCP-8.5 uncertainty predicted 3.6 to 7.9 % for 2025 and 2050, respectively.

3.3 Projection of minimum temperature for 2025 and 2050

Minimum temperatures are projected to continue to increase. Both projected years 2025 and 2050 showed almost identical projected temperature change over the future for all RCPs. For model projection year 2025, a temperature change of 0.9, 0.8, and 1.0 °C for RCP-4.5, 6.0, and 8.5, respectively, and continued substantial deviation around the mean are clearly identifiable. For the future temperature projection for 2050, showed variation almost doubles then 2025. For 2050, minimum temperature showed variation for different RCPs. High variation showed by RCP-8.5 for both projection years shown in Fig. 5. The projected temperature change reaches 1.0 to 2.2 °C for 2025 to 2050, respectively. This is higher than the 2 °C limit that the IPCC has identified as the point beyond which ecological systems (and human systems by extension) may become severely disrupted (IPCC 2014). While discussing (Fig. 8), the percentage change of minimum temperature from base temperature showed 5.1, 4.7, and 5.8 % for 2025 and 9.0, 8.1, and, 12.0 % for projection year 2050 with RCP-4.5, 6.0, and 8.5, respectively.

3.4 Projection of maximum temperature for 2025 and 2050

Figure 6 shows the variation of monthly projected maximum temperature by using 40 GCM ensemble in SimCLIM

climatic variability downscaling utility. Maximum temperature showed 2.7, 2.5, and 3.0 % change for 2025 and 4.7, 4.4, and 6.4 % change for 2050 from baseline temperature for RCP-4.5, 6.0, and 8.5, respectively (Figs. 7 and 8). Different climate models for Asian regions showed a temperature increase 0.5–2 °C by 2030 and 1–7 °C by 2070 (IPCC 2007). Similar trends in projection showed increasing trend in maximum temperature for future as predicted by previous studies (Jones and Moberg 2003). Temperature ranges are more rapidly raising in the arid or semi arid regions of India, western China, and northern Pakistan (Zahid and Rasul 2011; IPCC 2013). While discussing (Fig. 9), the average yearly maximum temperature 0.9, 0.8, and 1.0 °C for 2025 and 1.6, 1.5, and 2.1 °C for 2050 will be increased with RCP-4.5, 6.0, and 8.5, respectively.

4 Conclusions

The approach appears to offer an effective method of portraying model behavior under changing climate, as well as numerous advantages for analyzing, comparing, and presenting results from multi-model ensemble simulations. In spite of the simplified assumptions required for undertaking multiple simulations, some clear tendencies emerged from this analysis. Percentage change in precipitation projected by model with RCP-4.5 showed 3.3–5.6 %, RCP-6.0 predicted 2.9 to 5.2 %, and the RCP-8.5 uncertainty predicted 3.6 to 7.9 % for 2025 and 2050. Percentage change of minimum temperature from base temperature showed 5.1, 4.7, and 5.8 % for 2025 and 9.0, 8.1, and 12.0 % increase for projection year 2050 with RCP-4.5, 6.0, and 8.5. Maximum temperature 2.7, 2.5, and 3.0 % for 2025 and 4.7, 4.4, and 6.4 % for 2050

will be increased with RCP-4.5, 6.0, and 8.5, respectively. These uncertainties show that Southern Punjab, Pakistan, is exposed to major risks related to climate change comprising rise in maximum and minimum temperature and large variation in precipitation near future. Model projection enables us for sustainable management of climatic risk.

Acknowledgments The corresponding author (Wajid NASIM) is highly thankful to Government of Australia, for Endeavor Research Award/Fellowship (No. 4915_2015) for The Commonwealth Scientific and Industrial Research Organization (CSIRO), Sustainable Agriculture, National Research Flagship, Toowoomba-QLD 4350, Australia. Moreover, first author is grateful to the International Global Change Institute (IGCI) Hamilton, New Zealand for providing software (SimCLIM 2013), for providing required climatic dataset for future projections with respect to Southern Punjab, Pakistan. Furthermore, co-authors (Wajid NASIM and Shakeel AHMAD) are thankful to Higher Education Commission (HEC), Pakistan, for partial funding.

References

- Abbas F, Ahmad A, Safeeq M, Ali A, Saleem F, Hammad HM, Farhad W (2013) Changes in precipitation extremes over arid to semi-arid and sub-humid Punjab, Pakistan. *Theor Appl Climatol* 15:1–23
- Amin A, Mubeen M, Hammad HM, Nasim W (2015) Climate Smart Agriculture—a solution for sustainable future. *Agric Res Commun* 2:13–21
- Bao Y, Hoogenboom G, McClendon R, Urich P (2015) Soybean production in 2025 and 2050 in the southeastern USA based on the SimCLIM and the CSM-CROPGRO-soybean models. *Clim Res* 63:73–89
- Cheema SB, Rasul G, Ali G, Kazmi DH (2012) A comparison of minimum temperature trends with model projections. *Pak J Meteor* 8:39–52
- Christensen JH, Boberg F, Christensen OB, Lucas-Picher P (2008) On the need for bias correction of regional climate change projections of temperature and precipitation. *Geophys Res Lett* 35:L20709
- Coquard J, Duffy PB, Taylor KE, Iorio JP (2004) Present and future surface climate in the western USA as simulated by 15 global climate models. *Clim Dyn* 23:455–472
- Easterling DR, Meehl GA, Parmesan C, Changnon SA, Karl TR, Mearns LO (2000) Climate extremes: observations, modeling, and impacts. *Science* 289:2068–2074
- Griffiths ML, Bradley RS (2007) Variations of twentieth century temperature and precipitation extreme indicators in the Northeast United States. *J Clim* 20:5401–5417
- Hansen J, Ruedy R, Sato M, Imhoff M, Lawrence W, Easterling D, Peterson T, Karl T (2001) A closer look at United States and global surface temperature change. *J Geophys Res* 106:23947–23963
- Hautier Y, Tilman D, Isbell F, Seabloom EW, Borer ET, Reich PB (2015) Anthropogenic environmental changes affect ecosystem stability via biodiversity. *Science* 348:336–340
- Hertel TW (2016) Food security under climate change. *Nature Clim Change* 6:10–13
- Hulme M, Wigley TML, Barrow EM, Raper SCB, Centella A, Smith S, Chipanshi AC (2000) Using a climate scenario generator for vulnerability and adaptation assessment: MAGICC and SCENGEN Version 2.4 workbook. Climatic Research Unit, Norwich
- IPCC (2007) Asia in climate change, impacts, adaptation and vulnerability contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, pp. 469–506
- IPCC (2013) Climate change: the physical science basis. Contribution of working group I to the fifth assessment report of the intergovernmental panel on climate change. In: Stocker TF, Qin D, Plattner GK, Tignor M, Allen SK, Boschung J, Nauels A, Xia Y, Bex V, Midgley PM (eds). Cambridge University Press, Cambridge and New York, p. 1535
- IPCC (2014) Climate change: impacts, adaptation, and vulnerability, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge and New York, pp. 1–32
- Jones PD, Moberg A (2003) Hemispheric and large-scale surface air temperature variations: an extensive revision and an update to 2001. *J Clim* 16:206–223
- Katzav J, Parker WS (2015) The future of climate modeling. *Clim Chang* 132:475–487
- Kravitz B, Caldeira K, Boucher O, Robock A, Rasch PJ, Alterskjær K, Karam DB, Cole JN, Curry CL, Haywood JM, Irvine PJ (2013) Climate model response from the geo engineering model inter comparison project (GeoMIP). *Journal of Geophysical Research: Atmospheres* 118:8320–8332
- Kueppers LM, Snyder MA, Sloan LC, Zavaleta ES, Fulfrost B (2005) Modeled regional climate change and California endemic oak ranges. *Proc Natl Acad Sci* 102:16281–16286
- Maida Z, Rasul G (2011) Frequency of extreme temperature and precipitation events in Pakistan 1965–2009. *Sci Int (Lahore)* 23:313–319
- Marengo JA, Jones R, Alves LM, Valverde MC (2009) Future change of temperature and precipitation extremes in South America as derived from the PRECIS regional climate modeling system. *Int J Climatol* 29:2241–2255
- Nasim W, Belhouchette H, Tariq M, Fahad S, Hammad HM, Mubeen M, Munis MFH, Chaudhary HJ, Khan I, Mahmood F, Abbas F, Rasul F, Nadeem M, Bajwa AA, Ullah N, Alghabari F, Saud S (2016a) Correlation studies on nitrogen for sunflower crop across the agroclimatic variability. *Environ Sci Pollut Res* 23(4):3658–3670
- Nasim W, Belhouchette H, Ahmad A, Rahman MH, Jabran K, Ullah K, Fahad S, Shakeel M, Hoogenboom G (2016b) Modelling climate change impacts and adaptation strategies for sunflower in Punjab-Pakistan. *Outlook on Agriculture* 45(1):39–45
- New M, Todd M, Hulme M, Jones P (2001) Precipitation measurements and trends in the twentieth century. *Int J Climatol* 21:1889–1922
- Patz JA, Campbell-Lendrum D, Holloway T, Foley JA (2005) Impact of regional climate change on human health. *Nature* 438:310–317
- Peterson TC, Vose RS (1997) An overview of the global historical climatology network temperature database. *Bull Am Meteorol Soc* 78:2837–2849
- Pierce DW, Barnett TP, Santer BD, Gleckler PJ (2009) Selecting global climate models for regional climate change studies. *Proc Natl Acad Sci* 106:8441–8446
- Porter JR, Xie L, Challinor AJ, Cochrane K, Howden SM, Iqbal MM, Lobell DB, Travasso MI (2014) Food security and food production systems. In: Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL (eds) *Climate change 2014: impacts, adaptation, and vulnerability. Part a: global and Sectoral aspects. Contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change*. Cambridge University Press, Cambridge and New York, pp. 485–533
- Reichler T, Kim J (2008) How well do coupled models simulate today's climate. *Bull Am Meteorol Soc* 89:303–311
- Rosenzweig C, Karoly D, Vicarelli M, Neofotis P, Wu Q, Casassa G, Menzel A, Root TL, Estrella N, Seguin B, Tryjanowski P, Liu C, Rawlins S, Imeson A (2008) Attributing physical and biological impacts to anthropogenic climate change. *Nature* 453:353–357

- Safeeq M, Mair A, Fares A (2012) Temporal and spatial trends in air temperature on the island of Oahu, Hawaii. *Int J Climatol* 33(13): 2816–2835
- Sheikh MM, Manzoor N, Ashraf J, Adnan M, Collins D, Hameed S, Manton MJ, Ahmed AU, Baidya SK, Borgaonkar HP, Islam N, Jaya singh earachchi D, Kothawale DR, Premalal KHMS, Revadekar JV, Shrestha ML (2015) Trends in extreme daily rainfall and temperature indices over South Asia. *Int J Climatol* 35:1625–1637
- Shirazi SA, Zahid F, Bokhari MH (2006) Impact of spatio-temporal trends and anomalies of surface air temperature over Punjab. *Geograph Pap* 1:22–32
- Sohail MG, Burke F (2013) Climate change and precipitation in Pakistan a meteorological Prospect. *Int J Econ Environ Geol* 4:10–15
- Warrick RA (2009) Using SimCLIM for modelling the impacts of climate extremes in a changing climate: a preliminary case study of household water harvesting in Southeast Queensland. 18th World IMACS/MODSIM Congress, Cairns, Australia, pp 2583–2589
- Warrick R, Ashford G, Kouwenhoven P, Li Y, Urich P, Ye W (2012) Spatial risk-based assessments for climate adaptation using the SimCLIM modeling system: a case study of domestic rainwater harvesting as the sole source of water. *Journal of Water and Climate Change* 3:257–265
- Wilby RL, Dawson CW, Barrow EM (2002) SDSM a decision support tool for the assessment of regional climate change impacts. *Environ Model Softw* 17:145–157
- Yin C, Li Y, Urich P (2013) SimCLIM 2013 Data Manual. CLIMsystems Ltd. 9 Achilles Rise, Flagstaff, Hamilton 3210 New Zealand. www.climsystems.com
- Zahid M, Rasul G (2011) Thermal classification of Pakistan. *Atmos Climate Sci* 1:206–213