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Annual minimum temperature variations in early 21st century in Punjab, Pakistan

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ABSTRACT

Climate change is a key emerging threat to the global environment. It imposes long lasting impacts both at regional and national level. In the recent era, global warming and extreme temperatures have drawn great interest to the scientific community. As in a past century considerable increase in global surface temperatures have been observed and predictions revealed that it will continue in the future. In this regard, current study mainly focused on analysis of regional climatic change (annual minimum temperature trends and its correlation with land surface temperatures in the early 21st century in Punjab) for a period of 1979–2013. The projected model data European Centre for Medium-Range Weather Forecasts (ECMWF) Re-Analysis (ERA-Interim) has been used for eight Tehsils of Punjab i.e., annual minimum temperatures and annual seasonal temperatures. Trend analysis of annual minimum and annual seasonal temperature in (Khushab, Noorpur, Sargodha, Bhalwal, Sahiwal, Shahpur, Sillanwali and Chinoit) tehsils of Punjab was carried out by Regression analysis and Mann–Kendall test. Landsat 5 Thematic Mapper (TM) data was used in comparison with Model data for the month of May from the years 2000, 2009 and 2010. Results showed that no significant trends were observed in annual minimum temperature. A significant change was observed in Noorpur, Bhalwal, Shahpur, Sillanwali, Sahiwal, Chinoit and Sargodha tehsils during spring season, which indicated that this particular season was a transient period of time.

1. Introduction

The continuous increase in the emissions of greenhouse gases affects the Earth's climate in an irrevocable manner (Farooqi et al., 2005), leads to the “global warming” which is one of the greatest challenges of today's era. During the industrial revolution of 1700–1800s, increased anthropogenic activities significantly contributed towards the climate change (SHAH et al., 2012) which has a direct impact on people and their actions (economic systems, comfort, health, mortality and farming efficiency, etc.) (Wigley, 1985; Folland et al., 1999). In general, climate change is considered as variation in the long term mean value of temperature, rainfall, or other variables. There has been a 0.6 °C increase in global mean surface temperature in the last century, and it is projected to further increase by 1.8 °C to 4 °C in the 21st century, posing a serious threat to the socioeconomic sector worldwide. Many studies (Houghton et al., 1990; Skinner et al., 1993) have revealed that this warming, to some extent, is due to the increase in greenhouse gases in the atmosphere, which have a significant effect on the environment. Rio et al., (2013) reported that the increased temperature has affected the growing period of the maize crop in Faisalabad, Pakistan. It has been observed that climate change affects the global sea level and it is expected that in 2100, the mean global sea level will rise up to 15–95 cm which may lead to coastal flooding and storm surges, whereas ecosystems and agricultural zones are also thought to shift towards the poles by 150–550 km. This shifting of ecosystems might result in the extinction of inhabiting species, thus adversely affecting the natural ecosystems (Shah et al., 2012).

According to the projections of Global Circulation Models (GCMs), increase in average temperature in Pakistan will be in the range of 1.3–1.5 °C in 2020s, 2.5–2.8 °C in 2050s and 3.9–4.4 °C in 2080s temperature (Climate change, 2012). The global temperature of the year 2009 was rated among the top 5 warmest decades since 1850, while in the past few decades, it has been the warmest in history (WMO, 2010).

Most of studies with respect to climate change have been focused on global scale changes in the recent years. However, a comprehensive analysis of the regional and local levels is needed for framing adapting and mitigating strategies to alleviate the effect of global warming. The occurrence of extreme temperature events like heat waves and cold spells in some regions may be due to the shifting of the mean temperature (Chan et al., 2012). However, variations in the pattern of temperature, precipitation,

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humidity, wind as well as sea surface temperature are due to the warming of the atmosphere (Al Buhairi, 2010). Generally, developing countries are being affected greatly by climate change. The monsoon, flooding, and prolonged droughts are constantly increasing and from all these aspects, the food, energy and water protection are under serious threat. So far, the quantitative evaluation of the sensitivity and weaknesses of modified environment, especially in conditions of agro-economic signs in the developing nations like Pakistan, is of high concern (Houghton et al., 1996).

In climate and environmental studies, land surface temperature is regarded as an important and essential variable to observe and record temperature between the atmosphere and earth's surface (Valiente et al., 2010), hence at certain points in the land area, it is the measure of how hot the area is due to subsurface radiations and solar radiations. Land surface temperature likewise directly affects the air temperature and also plays an essential role in the land surface processes (Serban and Maftei, 2011; Dousset and Gourmelon, 2003; Weng et al., 2004), and at the earth, it is also a positive signal of energy stability, which is referred to as greenhouse impact. During the 20th century, it was investigated in different studies that global land surface air temperature has increased (Easterling et al., 1997; Alexander et al., 2006). However, this prominent rise in mean surface temperature is mainly attributed to increase in the minimum temperature compared to the maximum temperature (Easterling et al., 1997).

During 1947–2000, the linear trend showed a change in the temperature at 5% per 50 years, thus the results verify that the surface temperature is increasing in Pakistan (Sajjad et al., 2009), by growing population, accompanied by the increased rate of emission of greenhouse gases and also due to the industrialization during the last few decades.

Today the general public, governments and the scientific community have paid attention to the global climate change because it has a direct effect on the socioeconomic system and the natural ecosystem. Researches on the climate change trends are extremely important because such studies play an important role in the livelihood, agricultural production and the disaster mitigation. Various regional studies since the 1990s, pertaining to precipitation and temperature has been conducted and provide solid evidence that global warming is related to significant changes in precipitation and temperature extremes (Zhang et al., 2000; Manton et al., 2001; Peterson et al., 2002; Aguilar et al., 2005; Griffiths et al., 2005; Zhang et al., 2005; Alexander et al., 2006; Haylock et al., 2006, Klein Tank et al., 2006; Skansi et al., 2013). Previous studies on temperature records showed that by the mean global surface temperature has increased about 0.3–0.6 °C over the last 100 years.

A study done by Almazroui et al. (2012) in Arabian Peninsula based on seasonal temperature trend showed that in the dry season (June–September), it has significantly increased with the rate of 0.72 °C per decade in Saudi Arabia while in the wet season (November–April), it has increased with the rate of 0.51 °C per decade during 1979–2009. It was also stated that the mean, maximum and minimum temperature has increased with the rate of 0.51 °C, 0.67 °C and 0.34 °C per decade, respectively in the wet season and 0.8 °C, 0.72 °C and 0.63 °C per decade, respectively in the dry season.

A previous study showed a non-significant increasing trend in annual mean temperature in the Upper Indus Basin (Chaudhry et al., 2009), while in the North Western Himalayan region, annual temperature analysis has shown an increasing trend since the late 19th century (Bhutiyani et al., 2010). Such increase in temperature may have a positive impact on the agriculture in the mountainous area through shortening of growing period for winter (Hussain and Mudasser, 2007). The objectives of this study are to (i) analyze the annual and seasonal minimum temperature trends of Punjab from 1979 to 2013, and to (ii) find out the correlation of annual minimum atmospheric temperature with land surface temperature.

2. Study area and datasets

2.1. Study area

Punjab province (31°79′48″N and 74°12′36″E) stretches over 205, 344 km^2 area and is positioned on the northwest border of the geological Indian plate in Southern side. Punjab is basically comprised of productive land together with the river system and valleys. Two famous deserts (Thal and Cholistan) are also located close to the edge of India and Balochistan. Weather conditions are variable in the province as many areas encounter incredible winter seasons, usually followed by rain fall. Temperature start to raise by mid-February to till mid-April (spring), and this condition prevails till the summer set in. The oncoming monsoon is expected to access the Punjab area by the month of May, however, considering the early 1970s the weather conditions offers the unpredictable behavior (Disaster risk management plan Punjab, 2008).

In this study, three major districts of interior Punjab i.e. Khushab, Sargodha, and Chinoit (Fig. 1 and Table 1) were chosen for the temperature trend analysis and analyzing the correlation of annual minimum temperature with surface temperature.

2.2. Datasets

Real time simulated data of General Circulation Model, i.e., (ECMWF) Re-Analysis Interim (ERA-interim) for average annual and seasonal minimum temperature, and surface temperature were acquired from the data archive of Pakistan Meteorological Department (PMD) for the period of 1979–2013. For land surface temperature estimation, Landsat TM images of the month 'May' for the years 2000, 2009, and 2010 were obtained.

To estimate land surface temperature data was acquired by using satellite Landsat 5 TM imagery. Primary data was acquired for land surface temperature by Landsat 5 TM consisting of three images for the years 2000, 2009 and 2010 for the month of 'May'. While, real time simulated data of General circulation model, i.e., ERA-Interim for average annual and seasonal minimum temperature and surface temperature (°C) for the period of 1979–2013 was acquired from the data archive of Pakistan Meteorological Department (PMD). Landsat offers imagery that contains seven bands, whilst the band six is a thermal band with the bandwidth of 10.4–12.5 μm. The imagery was directly downloaded through http//:glovis.usgs.gov and this website offers data in the Geo TIFF format.

2.3. Data processing

Land surface temperature was calculated through RSI's ENVI. The shape files of respective areas were created and area of interest (AOI) was extracted by using extract by the mask tool in ARC GIS 10.1. The features of Arc GIS consist of mapping areas, searching ranges, examining modifications, handling, controlling, assessment, interpretation as well as a display of geo referenced data in order to eliminate the major issues concerning the preparation and handling of resources (Ramachandran, 1998). The next step involved was Cross Validation of satellite data of surface temperature with real time data of ERA-Interim for which graphs were plotted to evaluate the accuracy of data. For the trend analysis, Mann–Kendall a non-parametric test was applied on average annual minimum and seasonal minimum temperature for the period of 1979–2013. Mann–Kendall test was performed in XLSTAT software for the analysis of average annual minimum and seasonal variation pattern.

2.4. Mann–Kendall trend analysis test

Mann–Kendall, is one of the most reliable trend tests, widely employed for climatic and environmental studies (Mann, 1945;