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Future risk assessment by estimating historical heat wave trends with projected heat accumulation using SimCLIM climate model in Pakistan

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ABSTRACT

Climate change has adverse effects at global, regional and local level. Heat wave events have serious contribution for global warming and natural hazards in Pakistan. Historical (1997–2015) heat wave were analyzed over different provinces (Punjab, Sindh and Baluchistan) of Pakistan to identify the maximum temperature trend. Heat accumulation in Pakistan were simulated by the General Circulation Model (GCM) combined with 3 GHG (Green House Gases) Representative Concentration Pathways (RCPs) (RCP-4.5, 6.0, and 8.5) by using SimCLIM model (statistical downscaling model for future trend projections). Heat accumulation was projected for year 2030, 2060, and 2090 for seasonal and annual analysis in Pakistan. Heat accumulation were projected to increase by the baseline year (1995) was represented in percentage change. Projection shows that Sindh and southern Punjab was mostly affected by heat accumulation. This study identified the rising trend of heat wave over the period (1997–2015) for Punjab, Sindh and Baluchistan (provinces of Pakistan), which identified that most of the meteorological stations in Punjab and Sindh are highly prone to heat waves. According to model projection; future trend of annual heat accumulation, in 2030 was increased 17%, 26%, and 32% but for 2060 the trends were reported by 54%, 49%, and 86% for 2090 showed highest upto 62%, 75%, and 140% for RCP-4.5, RCP-6.0, and RCP-8.5, respectively. While seasonal trends of heat accumulation were projected to maximum values for monsoon and followed by pre-monsoon and post monsoon. Heat accumulation in monsoon may affect the agricultural activities in the region under study.

1. Introduction

Climate change has adverse impacts on health, water, biodiversity and natural resources cited and accepted all over the globe (IPCC, 2014; Lu and Chen, 2016; Kikon et al., 2016; Nasim et al., 2016; Qasim et al., 2016; Abbas et al., 2017). Many developing countries of the world are

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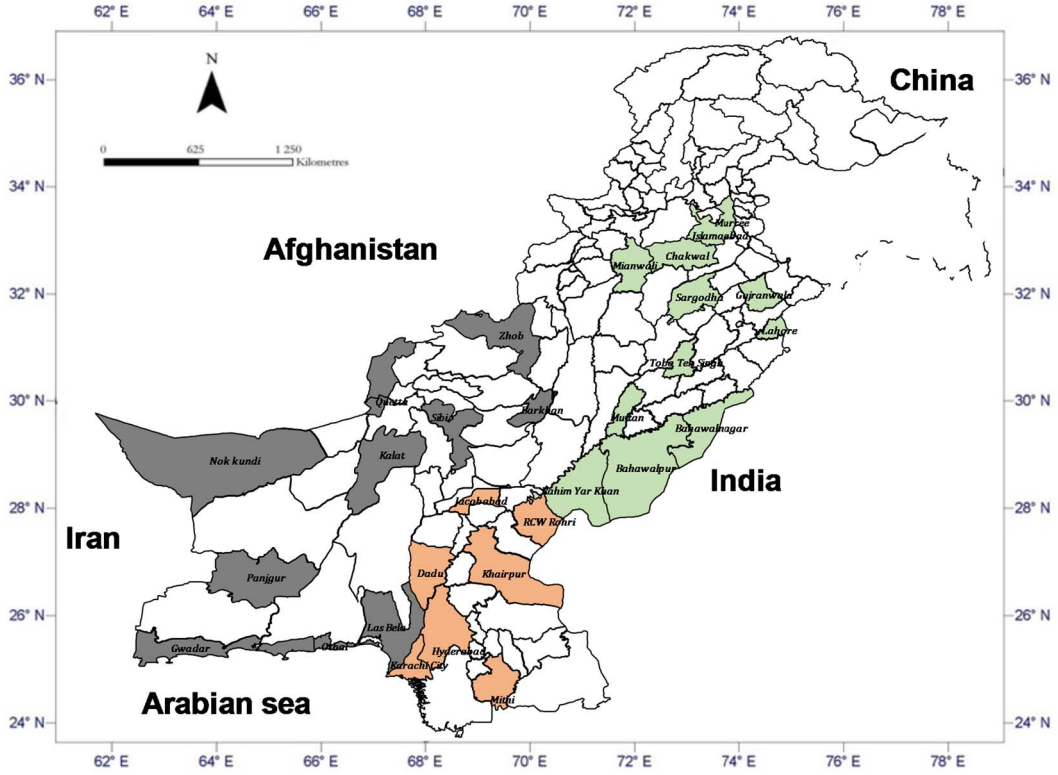

Fig. 1. Geographical representation of Pakistan with latitude and longitude.

suffering from climatic variations, and developed countries are trying to manage their anthropogenic activities for sustainable climate (Su et al., 2016). While discussing this issue at regional level it become more specific and climatic uncertainty is also increased. Anthropogenic activities are considered to be responsible for large scale regional climate disasters (Chakraborty et al., 2015; Amin et al., 2015; Amin et al., 2016; Adeel et al., 2017; Rozina et al., 2017). As with the industrialization the rate of GHG emission/concentration has increased which directly or indirectly raise the heat accumulation and uneven temperature variations (Montzka et al., 2011; Jinsart and Thepanondh, 2014; Ali et al., 2016). During 20th century the global temperature has increased by 0.76 °C and first decade of 21st century was recorded as the warmest years of the globe (Qi and Wang, 2012; Wang and Fu, 2013; IPCC, 2014; Dong and Huang, 2015; Lu and Chen, 2016; Anjum et al., 2016; Deo et al., 2017). According to the World Meteorological Organization (WMO) occurrence of heat waves has increased during 2001–2010 which increased the death rate by 2300 folds (136,000 deaths), European heat wave (~70,000 deaths), and Russian (~11,000 deaths) as compared to the last decade of 20th century (WMO, 2013). Almost 20% death rate has increased with overall temperature and heat stress, outcomes of the extreme weather events (Lu and Chen, 2016). In the last decade of 19th century, warming trends were reported almost all part of the world (Nasim et al., 2011; WMO, 2013; Rohde et al., 2013; Su et al., 2016; Ishaq and Memon, 2016; Khan et al., 2016; Nasim et al., 2017a; Lakho et al., 2017). It is worldly accepted that climatic variations will also trigger the unpredicted climate and weather events; also enlarge the intensity, duration, and extent of climate extreme events (Field et al., 2012). South Asian regional studies reported the variations in heat accumulation due to extreme climate events (Qian et al., 2011; Qi and Wang, 2012; Wang and Fu, 2013; Chakraborty et al.,2015; Dong and Huang, 2015; Feng et al., 2015; Fattahi et al., 2015; Ghajarnia et al., 2015; Lu and Chen, 2016; Easterling et al., 2016; Kikon et al., 2016; Jan et al., 2017; Javaid et al., 2017). Urban heat island or heat accumulation for last 50 years in china caused the temperature rise 0.2 °C to 0.3 °C for overall warming. In mega cities of India heat accumulation had been reported with the temperature rise 2 °C to 3 °C within just 15 years (Kikon et al., 2016; Mehmood et al., 2016). Global warming caused by the high temperature due to the increased duration of hot days and frequent heat waves (IPCC, 2013).

Pakistan is not exempted from these climatic extreme events. Pakistan lies in climatically warm geographical region which is vulnerable to climate extreme events like heat waves, drought, and floods (PMD, 2012). Temperature increase in this region is accepted to be higher than the global temperature variations. Glaciers of the Hindu Kush, Karakoram, and Himalayan ranges were receding rapidly due to heat accumulation which may enhance the risk of floods and extended droughts (IPCC, 2007; Rasul et al., 2008; Berthier et al., 2010; PMD, 2012). These climatic disasters may cause the serious threats to water, floods and energy security of the country (Chaudhary and Rasul, 2004). Risk of heat strokes, health diseases, and disturbance in settlement will rise with the variations in heat accumulation due to floods, heat waves, and droughts (Rasul et al., 2005; Haider et al., 2008; Maida and Rasul, 2011). Heat index was reported to increase from 1961 to 2007 in the country. Heat waves reported in Pakistan has killed > 200 peoples within a week in 2015 (PMD, 2015). Heat related disease and mortality rate (in animal and human) has increased because of extreme heat events during last decade. According to the Global Climate Risk Index 2014, Pakistan lies in third position among the most climate affected countries (Kreft and Eckstein, 2013).

In this region, a study reported the future projection showed a 4.0 °C