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Evaluation and analysis of temperature for historical (1996–2015) and projected (2030–2060) climates in Pakistan using SimCLIM climate model: Ensemble application

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ABSTRACT

Climate change is a global issue that's affecting food security. An increase and decrease in temperature due to climate change is expected across many regions of the world. Analysis of 39 weather stations (Pakistan) trend for maximum and minimum temperatures was done on monthly, seasonal and annual observations. Two statistical tests (Sen's slope and Mann-Kendall) were applied to find out the slopes and magnitude of climate change trend. This statistical analysis was carried out to study the possible variations for maximum and minimum temperature trend. A statistical downscaling climate projection model (SimCLIM) was used to predict magnitude of maximum and minimum temperature for 2030 and 2060. Ensemble of 40 General Circulation Models (GCMs) was used with median Representative Concentration Pathway (RCP-6.0) for future projections in SimCLIM. This study showed more number of positive trends for maximum temperature over all the weather stations. Significantly positive temperature trend was observed in February and March for maximum temperature for all sites ranges from 0.06 to 0.51 °C. Mostly, statistically significant negative trend (−0.06 to −0.30 °C) was found in Balochistan province and northern areas of Pakistan. In future, minimum temperature projected by model showed negative trends for 60% of weather sites for December where, the negative trend also increased for monthly and seasonal analysis. Minimum temperature trend reveal that December has large number of sites with negative trends with high magnitude, which further decreased for annual followed by seasonal analysis. Minimum temperature projections showed similar trends with past December results but negative trends decreased for seasonal and annual resolution. Future projections also reveal that annual maximum and minimum temperature will be increased for 2060 as compared to 2030. These results may have significant effect on agriculture of northern and high mountain areas of Pakistan, which could be managed by sustainable agricultural activities.

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1. Introduction

Global historical climate trends showedan increase of 0.72 °C decade^{-1} during 1951 to 2012 and warming rate decreased up to 0.05 °C decade^{-1} between 1998 and 2012 according to the Fifth Assessment Report (AR5) conducted by Intergovernmental Penal on Climate Change (IPCC) (IPCC, 2014). The think tank, "Germanwatch" graded Pakistan at number 3 in the list of countries most affected by climate variability after Philippines and Haiti (Cheema, 2014). Climate variability in global and regional level studies caused challenging situation due to lack of consistency in procedures and period of analysis to interpret results from these studies (Abbas, 2013; Amin et al., 2015; Ali et al., 2016; Iqbal et al., 2016; Amin et al., 2017a; Abbas et al., 2017; Adeel et al., 2017; Fahad et al., 2015a, 2015b, 2016a; Fahad et al., 2016b; Fahad et al., 2016c, 2016d; Wu et al., 2018a, 2018b). Comparative studies on the basis of these results for global/regional climate patterns varied. Similarly, in the recent decades of twentieth century a symmetric warming trend was observed in minimum and maximum temperature of Europe (Klein-Tank and Konnen, 2003). According to the study (1961–1999); Vincent et al. (2005) of Australia continent the frequency of extreme temperature events has decreased. On the other hand, for the same period of study, northern China experienced a decrease frequency of cold days however, hot days duration decreased in the eastern China (Qin et al., 2010; Anjum et al., 2016; Ishaq and Memon, 2016; Awais et al., 2017a, 2017b; Hammad et al., 2017) similar to that of Hawaii (Safeeq et al., 2013; Jabran et al., 2017a; Jan et al., 2017; Javaid et al., 2017). Pakistan climate studies (Faisalabad region) showed different trends and temperature increased by 0.23 °C over the period 1945–2004 (Abbas, 2013; Khan et al., 2016; Jabran et al., 2017b; Lakho et al., 2017). Moreover, in previous decade some temperature variations studies with neighboring areas of Pakistan includes; Panda et al. (2014), Pingale et al. (2014), Bapuji Rao et al. (2014), Subash and Sikka (2014), and Jhajharia et al. (2014) in India; Shirvani (2015), Kousari et al. (2013), and Tabari et al. (2011a;2011b) in Iran and Wang et al. (2014), Qin et al. (2010), Su et al. (2006) in China and Sheikh et al. (2015) in South Asia. According to IPCC (2013, 2014) temperature variations can also be caused by anthropogenic activities.

A number of studies have been carried out to find the minimum and maximum temperature trends for different time scales in several areas of Pakistan. At regional level, these studies focused on the main cities of Pakistan; Hussain et al. (2005) found out the climatic variations on water and agriculture in mountain regions of the country for winter and summer seasons; Sadiq and Ahmed (2012) studied the day time maximum temperature variations for Chaklala (Islamabad); Minora et al. (2013) find out the trends in the Upper Karakoram and variations in glaciers; Sajjad et al. (2009) for Karachi; Cheema et al. (2006) for Faisalabad; Rasul et al. (2008) for Sindh region and Abbas (2013) for Punjab region. Yaseen et al. (2014) finds out the seasonal and annual minimum and maximum temperature range of the Mangla Dam. Khattak et al. (2011) studied climate for minimum and maximum temperature variations and Ahmad et al. (2014) conducted the analysis of long term climate trends of upper Indus River.

Climate change is the greatest threat for this globe (Gardelle et al., 2012; Ullah and Shouting, 2013; Zhang et al., 2017). One of the major priorities to reduce the gap between the current research status and quantitative assessment of the sensitivity and vulnerability of climate change in future; is the important agro-economic factor for various developing countries like Pakistan. To continue such assessment, the most basic requirement is the presence of effective future climate projections at regional level. Different models are available (Berga et al., 2013; Mehmood et al., 2016; Nasim et al., 2016a; Mahmood et al., 2017) which can be used but we can select more precise climate model by validation. Climate models are the main statistical downscaling methods that can be used for future climate projections on the basis of previous climate trends that have the ability to provide regional or local climate information (Wilby and Dawson, 2007; Nasim et al., 2011; Berga et al., 2013; Qasim et al., 2016; Rozina et al., 2017). Representative concentration pathways (RCPs) are developed by IPCC (2014) for studying climate variability. These RCPs are named (RCP-2.6, 4.5, 6.0, 8.5) by their possible range of radiative values (+2.6, +4.5, +6.0, +8.5 in Wm^{-2}) up to year 2100 (Nasim et al., 2012; Yin et al., 2013). General Circulation models (GCMs) are used to describe the climatic variations; these are the basic tools for the future climate projections (Urich et al., 2014; Nasim et al., 2017; Amin et al., 2018; Nasim et al., 2018). Different methods are used to renationalize the climatic datasets to improve the resolutions for regional and local scales for better climate risk assessment. Similarly, SimCLIM 2013 is integrated climate projection application software which is used to manage these downscaled datasets by using median percentile results (Yin et al., 2013; Amin et al., 2017b). This approach provides more balanced perspective of climate change projections at regional or local level.

The objective of present study was to investigate the temperature anomalies in Pakistan especially in recent and previous decades. This research work was also used to analyze the possible climate variations for future 2030 and 2060 by using SimCLIM (scenario generator) tool and develop a relationship between the present and future climate variations and predict the associated risk. This study has addressed these points: analyzed the trends in both variables (maximum and minimum temperature) under study for different time scales (monthly, seasonal and annual) at different spatial scale. Secondly, this study identified the trends of temperature anomalies for all prominent locations of country which have analyzed with same methodology.

2. Methodology

2.1. Study area and regional description

Pakistan is situated in Southwest Asia with latitudes 24°N–37°N and longitudes 60°E–75°E, covering an area of 796,096 km^2. It shares border in the north with China, east with India, south with Arabian Sea and west with Iran and Afghanistan. Pakistan has more versatile climate which varies from region to region. It is divided into four seasons by climatic division (winter, spring, summer, and autum) (Iqbal et al., 2016). The climate varies from arid to semiarid with extremes in cold winters and hot summers but,itvaries locations wise in case of Pakistan (Chaudhry and Rasul, 2004; Nasim et al., 2016a) while the high rainfall was reported in the southern sub-mountain and Himalayan regions (Chaudhry et al., 2009). These variations landscape caused changesin temperature anomalies, with below zero temperature in sub-mountain regions and the warmest temperature values in the southern region of Pakistan (Iqbal et al., 2016). In semi-arid regions of Pakistan uneven temperature variability may cause the droughts and heavy rainfall in summer resulting in heavy flash floods (Zahid and Rasul, 2011; Abbas et al., 2014; Nasim et al., 2016b).

2.2. Descriptive statistic and data analysis

The historical data of minimum and maximum temperature of 39 different locations of Pakistan (Fig.1) was obtained from *National Aeronautics and Space Administration* (NASA) (http://power.larc.nasa.gov). Maximum and minimum temperatures data of 20 years (1996 to 2015) for all meteorological stations (Pakistan) were obtained. The 20-years data series for all the locations was analyzed by Runs Test at 95% significant level to check the homogeneity of the data. World Meteorological Organization (WMO) suggested the Runs Test and also several studies used this test to check the homogeneity of the climate data (Iqbal et al., 2016). Monthly climatic data was obtained from average daily weather data for all the weather stations and passed the homogeneity test. Annual and seasonal series were obtained from the average of monthly data recommended by Iqbal et al. (2016) and Subash and

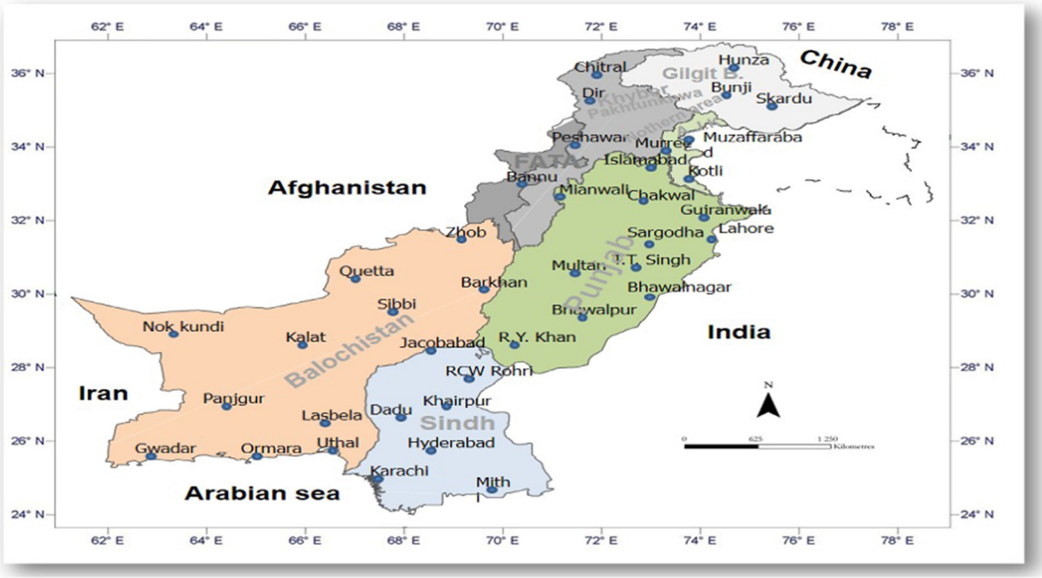


Fig. 1. Regional distribution and Meteorological stations used in the study.

Sikka (2014). Seasonal distribution according to the Pakistan Meteorological Department (PMD) is as follows: winter (January–February), spring (March–May), summer (June–September), autum (October–December). Two non-parametric tests (Mann-Kendall and Sen's slope estimate) were used to find out the trend in maximum and minimum temperature data of all the weather stations. An Excel template MAKESENS 1.0 (FMI, 2002; Salmi et al., 2002) was used to perform Mann-Kendall and Sen's slopetest for trend analysis foreach 39 weather stations. Before the application of Mann-Kendall test, less than 5% of weather stations data undergo the recommended application of "pre-whitened" to remove the serial correlation at 1% significant level (Pingale et al., 2014; Iqbal et al., 2016; Amin et al., 2017a). Maximum and minimum temperature trends for monthly, seasonal and annual (statistically significant magnitude) values were represented at maps by using ArcMap (version 10.1) and Microsoft Power Point (to rearrange and aline). For more detail Amin et al. (2017a)

2.3. Model description and emission scenarios

SimCLIM 2013 is an Integrated Assessment Model (IAM) that was developed to assess the climatic variations with the output of GCMs with greenhouse gas (GHG) concentration pathways (Yin et al., 2013). These GCMs are used at national, regional, local and site specific climate future projections by many countries of the world including Pakistan. CLIMsystem provided the data package (SimCLIM-2013) for Pakistan to predict future mean, maximum and minimum temperature and precipitation (Yin et al., 2013). To study the future climatic variations for specific location, the suitable GCM should be used (Bao et al., 2015) but for wide range climate projection, more than one GCMs pattern should be used. Selection of one GCM for specific location limited the scope of projections. It can only be attained by using more than one GCM pattern (ensemble) (Coquard et al., 2004; Amin et al., 2017c). Monthly maximum and minimum temperature data for 2030 and 2060 was obtained form the SimCLIM for 39 weather stations by using ensemble of 40 GCMs (Table 1).

In this study, to reflect the uncertainties in future GHG emission rates and in climate sensitivity, RCP-6.0 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 RCP-4.5 with low-climate sensitivity and RCP-8.5 with high-climate sensitivity was used as an indicator of the corresponding low and high bound of the uncertainty range. Another important

Table 1
Representation of CMIP5 GCMs used in SimCLIM 2013 (Ensemble) (Yin et al., 2013).

Sr. no	Model	Developed	Sr. no	Model	Developed
1	ACCESS1.3	Australia	21	GISS-E2-H-CC	USA
2	ACCESS1.0	Australia	22	GISS-E2-R	USA
3	BCC-CSM1-1	China	23	GISS-E2-R-CC	USA
4	BCC-CSM1-1-m	China	24	HADCM3	UK
5	BNU-ESM	China	25	HadGEM2-AO	UK
6	CanESM2	Canada	26	HadGEM2-CC	UK
7	CCSM4	USA	27	HadGEM2-ES	UK
8	CESM1-BGC	USA	28	INMCM4	Russia
9	CESM1-CAM5	USA	29	IPSL-CM5A-LR	France
10	CMCC-CM	Italy	30	IPSL-CM5A-MR	France
11	CMCC-CMS	Italy	31	IPSL-CM5B-LR	France
12	CNRM-CM5	France	32	MIROC4H	Japan
13	CSIRO-Mk3-6-0	Australia	33	MIROC5	Japan
14	EC-EARTH	Netherlands	34	MIROC-ESM	Japan
15	FGOALS-g2	China	35	MIROC-ESMCHEM	Japan
16	FGOALS-s2	China	36	MPI-ESM-LR	Germany
17	GFDL-CM3	USA	37	MPI-ESM-MR	Norway
18	GFDL-ESM2G	USA	38	MRI-CGCM3	Japan
19	GFDL-ESM2M	USA	39	NorESM1-M	Norway
20	GISS-E2-H	USA	40	NorESM1-ME	Norway

uncertainty in climate change scenario generation is the difference in different GCM simulations. To account for such an uncertainty in Vulnerability and Adaptation (V&A) assessment, a pattern scaling method was adopted and applied to a wide range of GCMs to build a model ensemble. The average of models' simulation of changes for a climate variable is normally used to capture the middle conditions, sincethat average often matches better with observed climate than any individual model estimates (Reichler and Kim, 2008; Hasson et al., 2016; Nasim et al., 2016c). More detail is given in Amin et al. (2017a, 2018)

3. Results and discussion

Statistically, significant trends (positive or negative or no-trend) were seen for monthly, seasonal and annual basis for maximum (Fig. 2) and minimum temperature (Fig. 4) at confidence level 95% over 39 weather stations. Graphical map representation provide the convient way to understand the overall varitions of monthly climate trends (distribution) for maximum (Fig. 3), minimum temperature (Fig. 5).

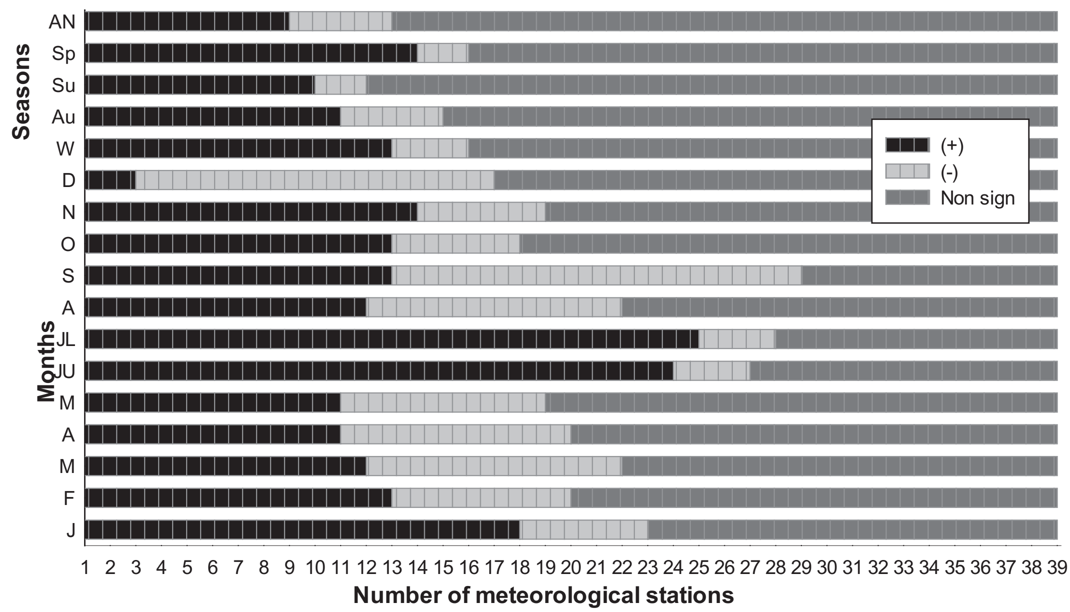


Fig. 2. Meteorological stations analysis for maximum temperature with significance positive, negative and non-trends (monthly, seasonal and annual resolution) at confidence level of 95%. Annual (AN), winter (W), autum (Au), summer (Su), and spring (Sp).

Seasonal and annual trend analysis result for base (1996–2015) and future projections for 2030 and 2060 could be seen in Figs. 6 & 7.

3.1. Maximum temperature trend analysis for future projections

Scope of projected maximum temperature in this study was analyzed for all time scale and site as shown in Fig. 2. The results of statistical analysis for maximum temperature June and July showed significant positive trend for 24 and 26 sites, respectively. While, in December temperature had significantly decreased (show negative trend) for a number of sites. By considering the monthly and seasonal resolution for spring months, March, April, and May displayed a unique behavior for significant positive trends for more weather stations of north part of country (northern areas and northwest of Pakistan) as shown in Figs. 3 & 6. Maximum temperature has significantly decreased in February in South Punjab, similar results were reported by Sheikh et al. (2009) and Iqbal et al. (2016), where they concluded that the maximum temperature significantly decreased in winter for southern Punjab. It is important to note that almost 40% of the weather stations showed the nagative trend in maximum temperature in the month of December, while more than 50% showed no trend (Fig.2). The rise in maximum temperature for June and July increased; maximum values of positive trends were also reported during the study period. A number of weather stations reported maximum temperature increase in May at lower North areas of Pakistan (Fig. 3). Similar trend was studied in the months of May and April by Sheikh et al. (2009) for the period 1951–2000 at most of the PMD stations.

While discussing the seasonal weather conditions, maximum positive temperature trend was reported in spring (Fig. 2) and similar results were reported by Iqbal et al. (2016). During this period, in the upper Indus River Basin region, same maximum temperature with positive trend was reported by Khattak et al. (2011) and Ahmad et al. (2014), who also reported the lower statistical significance than our study for lower and middle Indus River Basin region. Months of August and September showed a highest nagative trend for a number of weather stations other than December; which confirms the slight temperature decrease in summer season (Figs. 3 & 6). The smallest number of weather stations showed decrease in positive temperature trend (April, May, and December). It is important to mention that months (February, March, and April) had almost similar negative and positive temperature trends in most sites of the country, while for January and December (winter season) 30% of weather stations showed positive trend for maximum temperature (Figs. 3 & 6). It was noted that summer (April, May, June, and July) became cooler in most of the areas of southern Punjab for maximum temperature as shown in Figs. 3 & 6. Similar result was reported by Iqbal et al. (2016) where they showed significant decrease in summer at most of the weather stations. Sheikh et al. (2009) also observed the maximum temperature decrease all over the country expect Balochistan Province. During November, 5 weather sites showed the negative temperature trend (Fig. 3). While discussing the seasonal scope, autumn had similar trend with November in Azad Kashmir. These results are also justified by Iqbal et al. (2016), Khattak et al. (2011), Bocchiola and Diolaiuti (2013), and Sheikh et al. (2015).

Monthly and seasonal future predicted trend for maximum temperature is represented in maps (Figs. 3 & 6) with magnitude and sign. Monthly and seasonal data trends analyzed to develop a correlation for temperature trend of current (base) and future 2030 and 2060 shown in Figs. 6 & 7. Almost 71% of the climatic locations for winter showed the positive trend in temperature variations similar with projected climate trend with non-significant increase Fig. 6 a & b. January and February projected similar results with winter and positive trend was observed in Punjab and northern Pakistan. This analysis was done with seasonal temperature trend variations, highest positive trend variations were observed in winter (January and February) and summer (June–-September) shown in Fig. 6a & b. Different studies conducted in northern Hemisphere reported the same result and climate pattern for winter temperature. While on the other hand, significant negative trend increased at 7 to 9 stations as compared to the base weather conditions (Fig. 6a). Similarly, significant negative trend was found in the spring (March–May) for almost 21 stations (out of 39) and this negative trend deceased for 2030 as projected by climate model which revealed that 19 weather stations and almost 16 weather stations in projection year 2060 showed negative temperature trend. Kallat station showed the highest peak for negative temperature trend variations, where as Khairpur station showed highest peak of positive temperature trend in spring (Fig. 6b). In spring, negative trend showed by the weather stations mostly lies in Balochistan and southern Sindh Province. Similar results were found in the months of March, April, and May which verify the spring weather results. Summer season result showed that 95% of weather stations showed the positive trend in maximum temperature

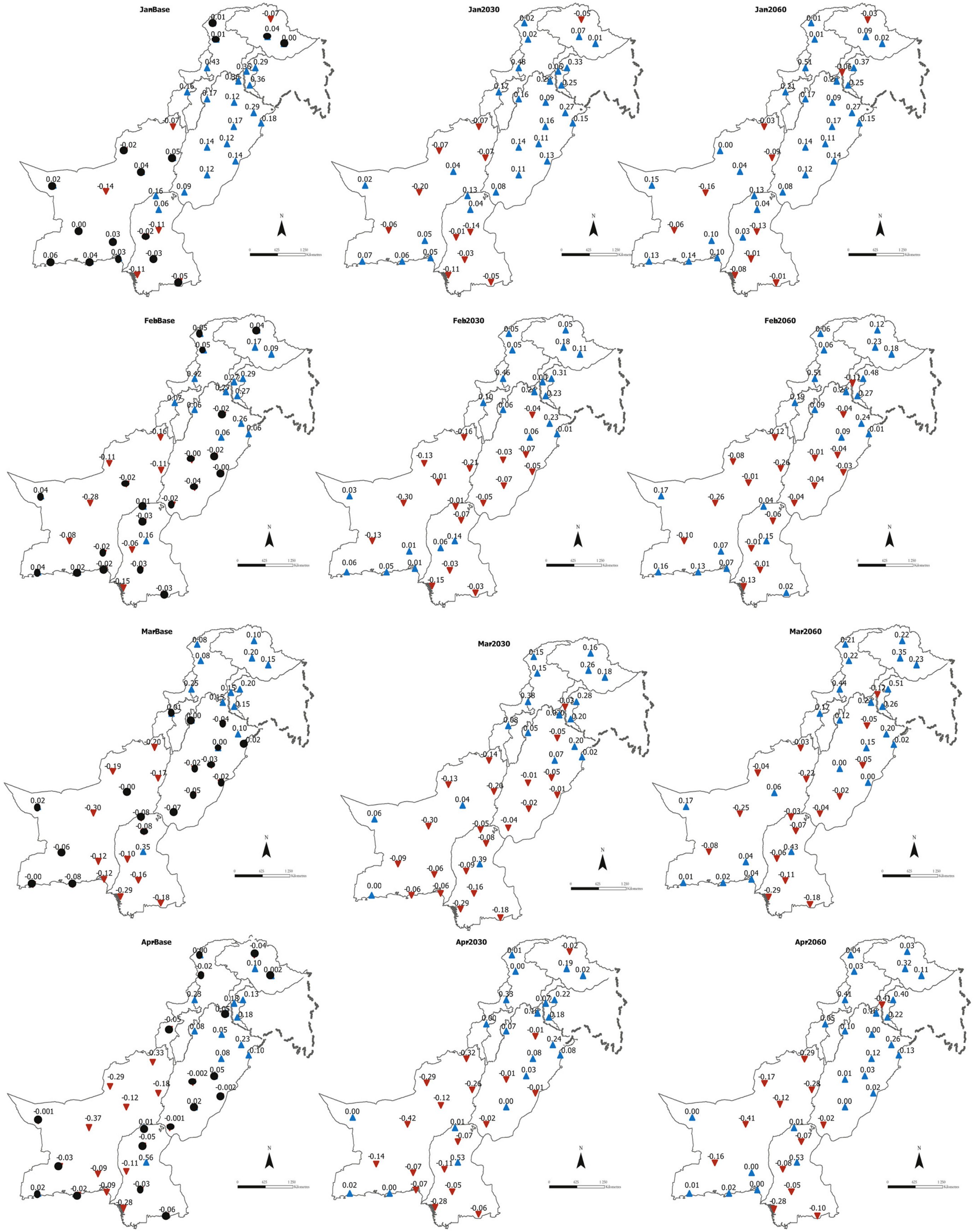
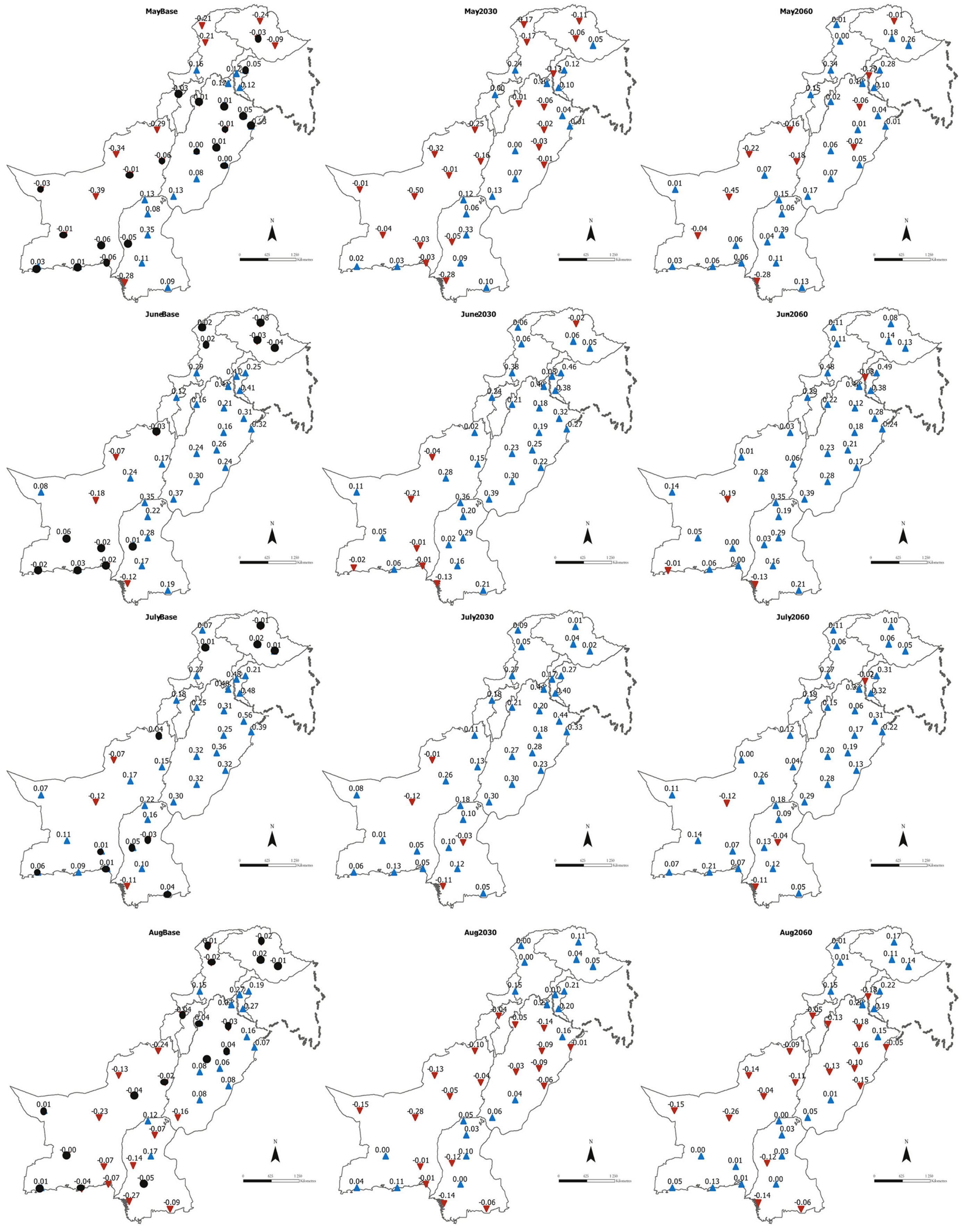


Fig. 3. Monthly trend distribution (sign and magnitude) of maximum temperature showed for 1996–2015 (Base) future projection for 2030 and 2060 with 39 metrological stations. Labels refer to the slope of positive (Blue triangle) and negative (Red triangle) trends at confidence level of 95%. Fig. 3b, c is part of this. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)



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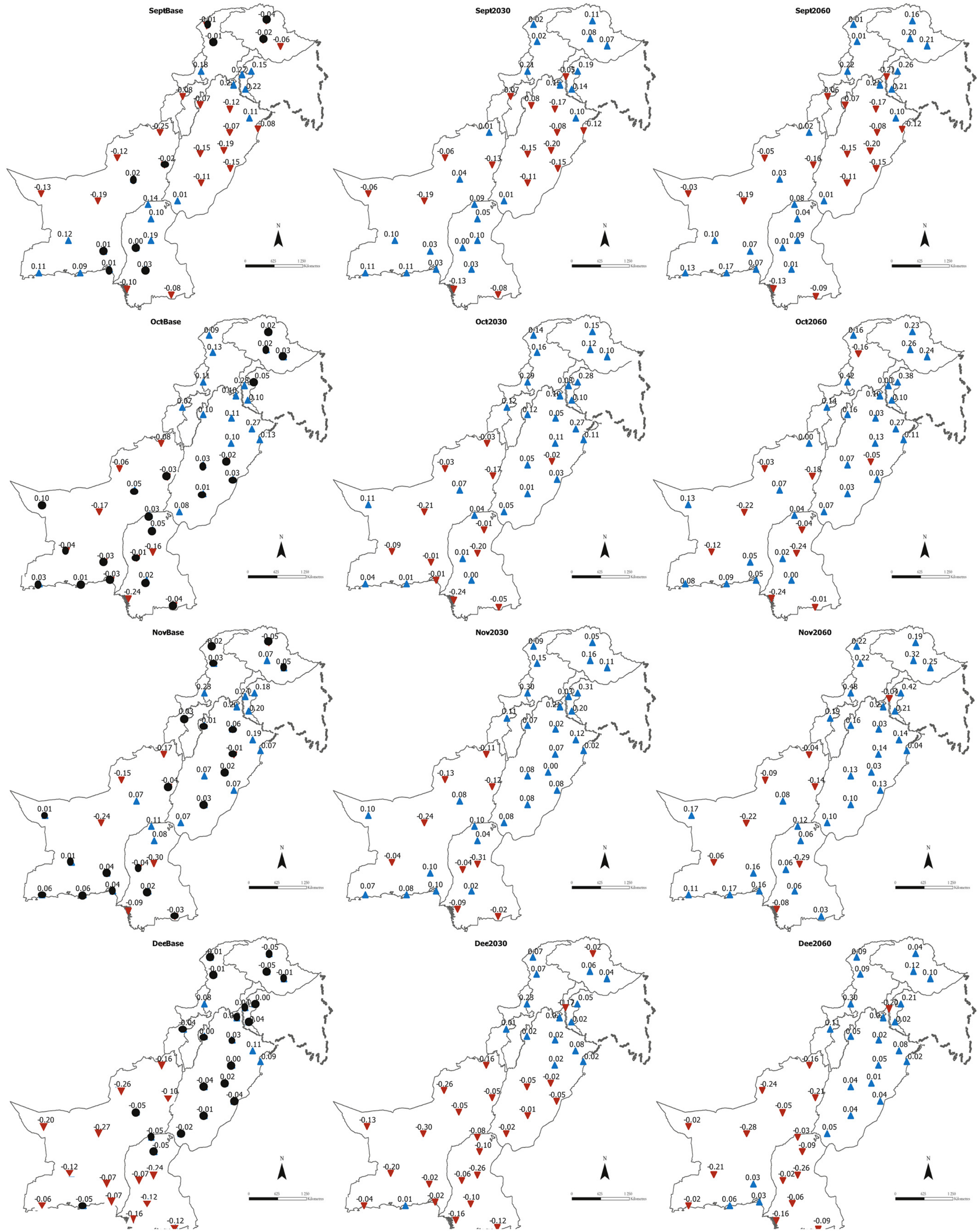

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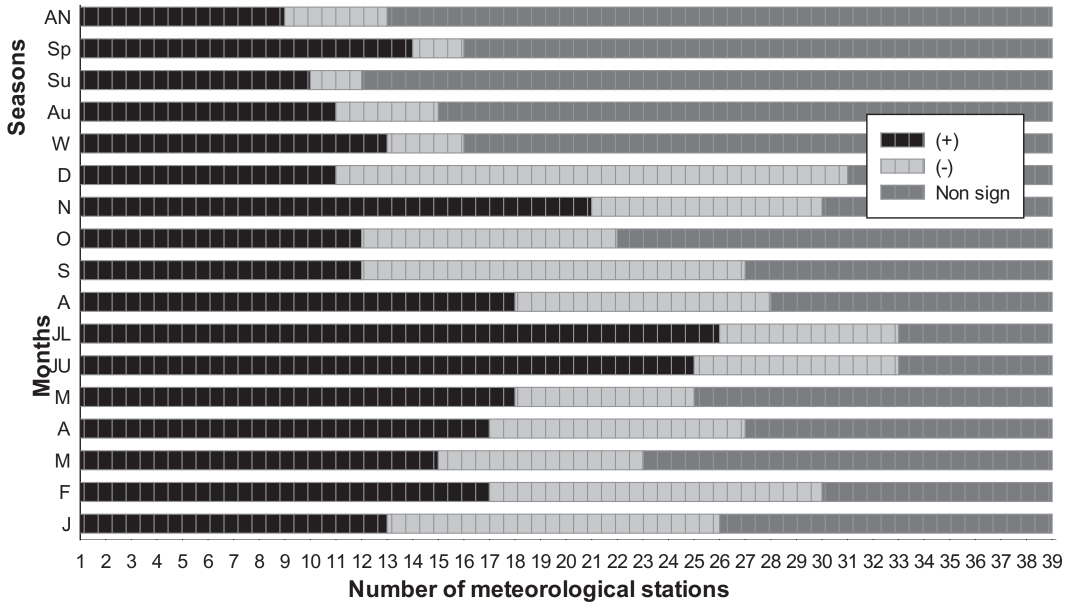


Fig. 4. Meteorological stations analysis for minimum temperature with significance positive, negative and non trends (monthly, seasonal and annual resolution) at confidence level of 95%. Annual (AN), winter (W), autum (Au), summer (Su) and spring (Sp).

(Fig. 6c) as the trend projected by the model has increased the temperature but has also reported a decrease in overall temperature trend.

Current study revealed that almost 27 weather stations (Fig. 6d) showed the positive trend for base (1996–2015) and 26 for 2030 temperature projections greater than 2060 in autum (October–December). Annual temperature variations between the base and future projection (2030) revealed four stations and seven stations for 2060 (out of 39) have significant variations while overall representation (Fig. 6e) of weather stations showedthe normal increase in temperature.

3.2. Minimum temperature trend analysis for future projections

It was revealed that projected minimum temperature has increased in winter, spring, and annually at most of the selected stations in southern and northern parts of Pakistan. It is important to mention that the higher negative temperature trends were reported in spring and autum seasons (Fig. 4). Less number of sites have negative trends in minimum temperature than maximum temperature for annual, seasonal, and monthly analysis. According to the monthly analysis, 11 weather stations (in Balochistan Province) showed the negative trend in December, closely justify with the winter as shown in Figs. 5 & 7. Positive trend in winter conform the significant increase in positive trend in January and February for Punjab and northern areas of Pakistan which conforms the result reported by Iqbal et al. (2016). Significant positive trend in minimum temperature for winter was reported for the upper and southern Punjab and Indus Basin of Pakistan (Ahmad et al., 2014). Central and southern areas of Punjab Province also showed the similar trend studied by Sheikh et al. (2009). This is the most important agricultural production area having highest contribution in total economic status of Pakistan (Cheema et al., 2006); therefore any temperature variations may affect the agriculture productivity. An increase in the temperature trend was reported for the sites located in the Punjab Province, similar trend was found in December. Similar positive trend was found in July as noted in summer season; almost 90% of positive trend in weather stations was observed in Punjab, Sindh Province and northern areas of Pakistan. Most prominent negative trends were noted in summer season (June to September) in northern areas and northwest regions (Azaad Kashmir and Khyber Pakhtunkhwa) of Pakistan. However, these climatic risks need to be checked more precisely in future. Most significant increase was found in weather stations of Azaad Kashmir and Khyber Pakhtunkhwa (North of Pakistan) in December (Fig.6).Temperature decrease was reported in high mountain regions of Pakistan (Khattak et al., 2011).

Minimum temperature in northern areas of Pakistan showed non-significant negative trends (Qamar-Uz-Zaman et al., 2009; Sheikh et al., 2009). Minimum temperature trend variations (Fig.7a) revealed that negative trend was found in eleven weather stations in January to February (winter season), while positive trend increased inspring (March to May) as compared to previous season. Fig. 7b showed that the range of minimum temperature for summer has quite similar trend with spring but temperature range slightly decrease (Fig. 7c). In general, it can be observed that Punjab Province and north of the country revealed positive trend (Fig. 6). By the comparison of maximum and minimum temperature trend variations, it is noted that minimum temperature showed high magnitude than minimum temperature trends (Figs. 6 & 7).

Fig.5 showed the result of minimum temperature trend in map representation for future projections 2030 and 2060. Maps showed thehighest negative trend in winter (January and February) i.e. about 36% at all weather stations. These trends showed more variations in winter for negative trend in minimum temperature reported for future 2030 and 2060 than past trend (1996–2015). Similar, trends are shown in spring (March–May) at number of stations showing negative trend being increased in future; 2060 than projection year 2030. This showed the strongest relation with similar trends with maximum temperature (Figs. 5 & 7). Monthly minimum temperature trends for April, June, and July showed the similar trend for past and future. In relevance with Ahmad et al. (2010) highest correlation in July shows 10 weather stations in northern areas and 3 stations of Balochistan region revealing negative trends. The results showed that spring season has more negative trend than summer season in lower Sindh and Balochistan Province. While spring has similar negative trend for past (1996–2015) and future (2030) with an increase in overall temperature for 2060.

4. Summary/conclusion

Temperature anomalies for monthly, seasonal, and annual basis statistical analysis for 39 PMD stations were carried out. To conduct future trend predictions at the monthly, seasonal, and annual basis, a statistical downscaling climate model SimCLIM-2013 was used. The

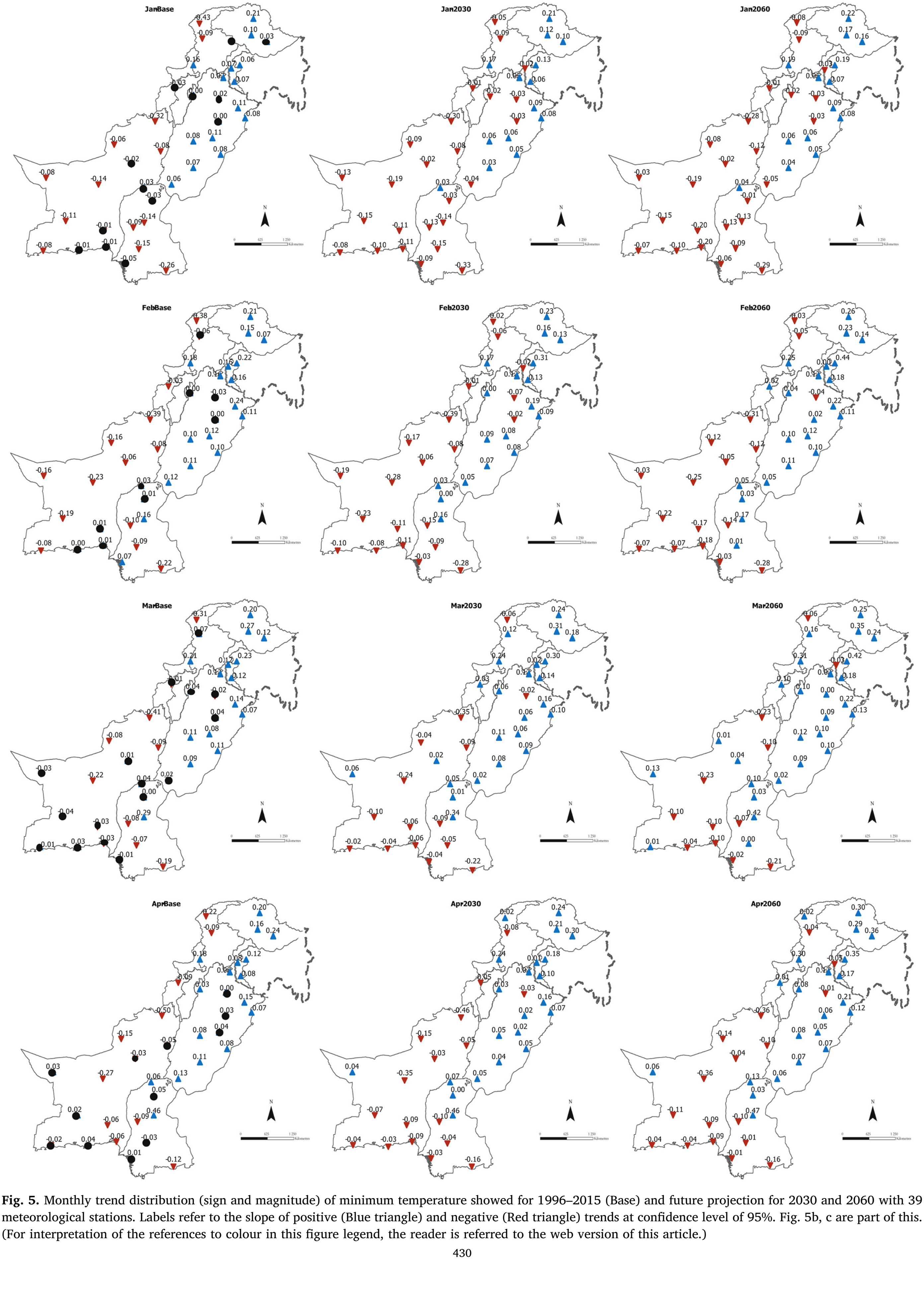
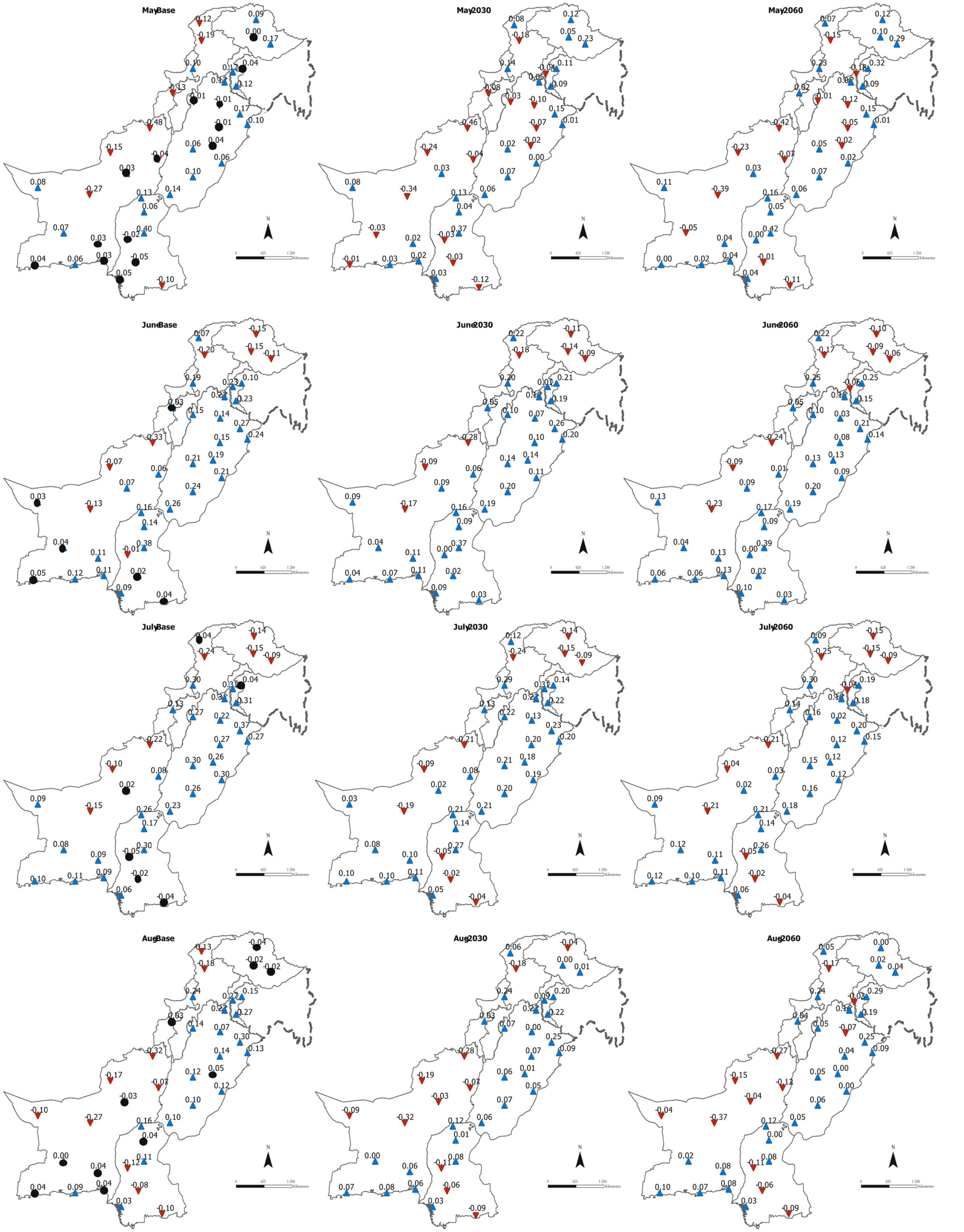


Fig. 5. Monthly trend distribution (sign and magnitude) of minimum temperature showed for 1996–2015 (Base) and future projection for 2030 and 2060 with 39 meteorological stations. Labels refer to the slope of positive (Blue triangle) and negative (Red triangle) trends at confidence level of 95%. Fig. 5b, c are part of this. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)



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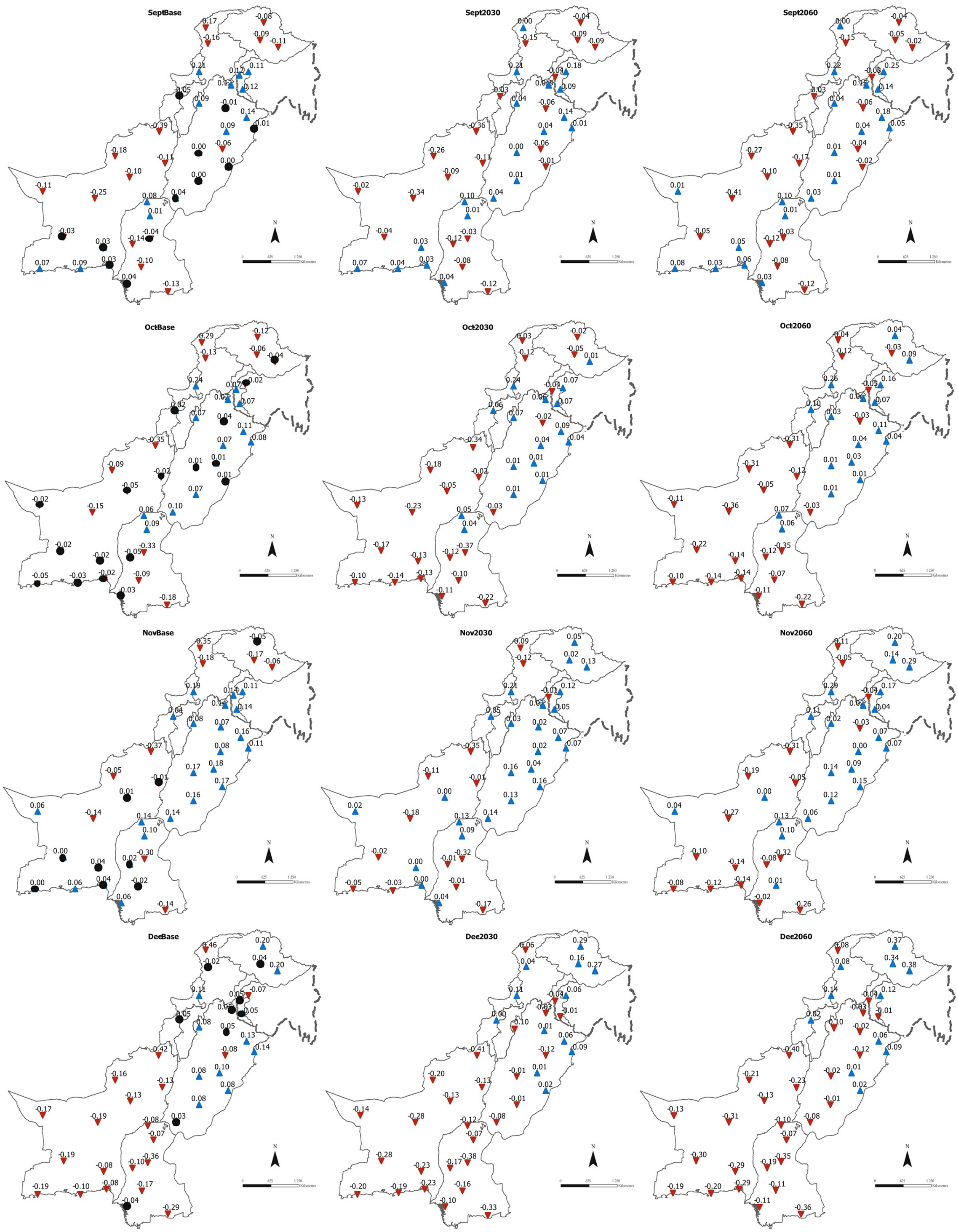

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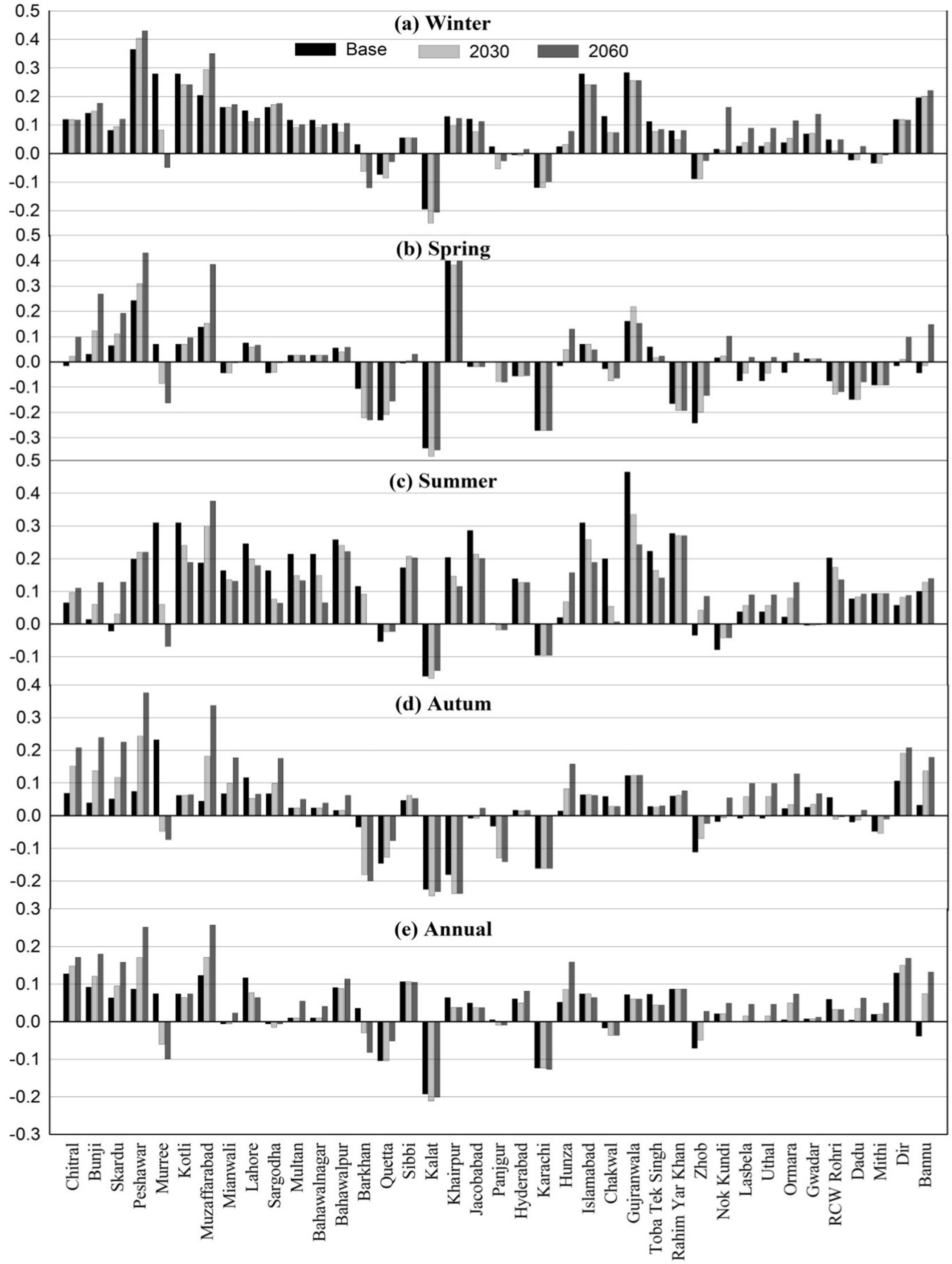

Fig. 6. Maximum temperature trend variation plotted for 1996–2015 (Base) and future projection for 2030 and 2060 at the seasonal and annual resolution. (a) winter, (b) spring, (c) summer, (d) autum, and (e) annual.

study revealed that 1) Temperature increase or decrease largely influenced the agricultural activities and water resources of Pakistan. Therefore, this type of study is very important for present and future climate risk assessment, 2) Positive trend was noted for most of the region and time scale for maximum and minimum temperature, particularly maximum and minimum temperature showed more positive trend in winter, summer, and annual. The highest increase in maximum temperature trends was found in December and minimum temperature trend was found in July, 3) Different locations showed the high significant variations in magnitudes (positive and negative) for maximum and minimum temperature, 4) A decrease in overall maximum and minimum temperature was reported mostly for northern areas of Pakistan (Azaad Kashmir and Khyber Phukhtunkhwa) for winter, spring, autumn and on annual basis. While, for maximum temperature, summer season also has positive trend for these areas, 5) Maximum temperature trend was observed and continue to increase in number from January to March but decreased for the rest months of the year. Maximum temperature was reported in high magnitude, mostly for northern regions of Pakistan at seasonal and annual resolution, 6) Maximum and minimum temperature was projected by an ensemble of (40 GCMs) which showed slightly high magnitude for monthly, seasonal, and annual basis. Maximum temperature projected for 2030 and

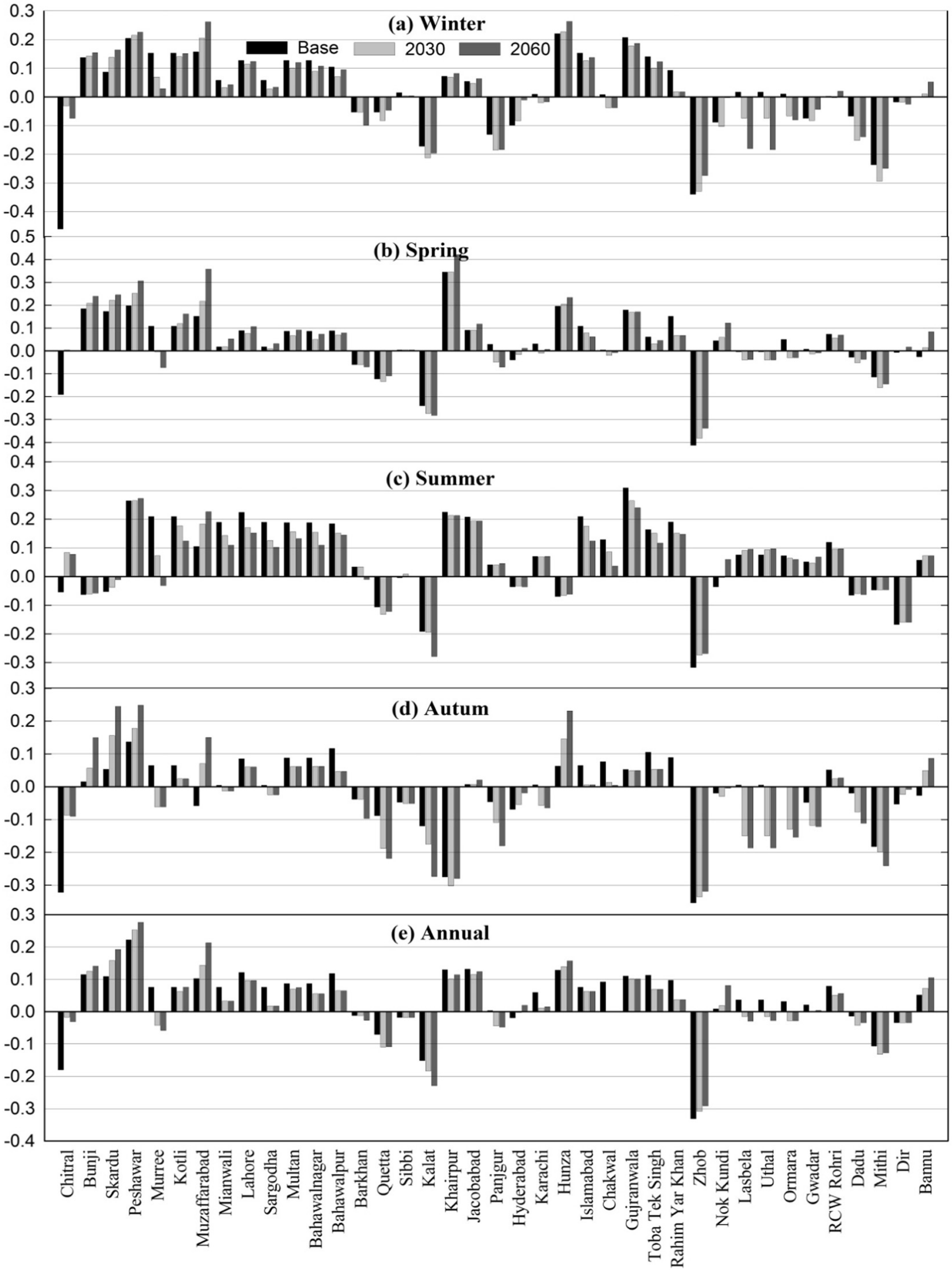

Fig. 7. Minimum temperature trend variation plotted for 1996–2015 (Base) and future projection for 2030 and 2060 at the seasonal and annual resolution. (a) winter, (b) spring, (c) summer, (d) autum, and (e) annual.

2060 was worth noting where negative trends were increased as compared to past temperature trend on annual and seasonal (summer) basis. Minimum temperature projected for future 2030 and 2060 revealed that negative trends were increased by almost 3 time for number of weather stations (larger for 2060 than 2030) then past weather trends (1996–2015) for summer and annual. Future studies should focus on evaluation and application of climate models for other agro-climatic regions for adapting temperature drawbacks on different aspects of society or environments.

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