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An Assessment of the Temperature Change Scenarios Using RS & GIS Techniques-A Case study of Sindh

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Abstract:

The rising temperatures are the most significant aspect in the period of climate variability. In this study PRECIS model data and observed data are used for assessing the temperature change scenarios of Sindh province during the first half of the present century. Observed data from various meteorological stations of Sindh are the primary source for temperature change detection. The current scenario (1961–1990) and future one (2010-2050) are acted by the PRECIS Regional Climate Model at a spatial resolution of 25 * 25 km. Regional Climate Model (RCM) can yield reasonably suitable projections to be used in the climate - scenario. The main objective of the study is to prepare maps. The simulated temperature as obtained from climate model-PRECIS and their comparison with observed temperatures. The analysis is done on all the districts of Sindh in order to have a more precise picture of temperature change scenarios. According to the results the temperature is likely to increase by 1.5 - 2.1°C by 2050, compared to the baseline temperature of 1961-1990. The model assesses more accurate values in northern districts of Sindh as compared to the coastal belt of Sindh. All the district of the Sindh province exhibits an increasing trend in the mean temperature scenarios and each decade is seemed to be warmer than the previous one. An understanding of the change in temperatures is very vital for various sectors such as weather forecasting, water, agriculture and health etc.

Key words: PRECIS Model, Real Observed Data, Arc GIS, Interpolation Techniques

سيناريوهات لتقييم تغيير درجات الحرارة بأستخدام تقنيات التحسس النائي ونظم المعلومات الجغرافية –الجي اي اس– منطقة الدراسة السند

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الخلاصة

في عصر التقلبات المناخية أن ارتفاع درجات الحرارة هو الجانب الأكثر أهمية. في هذه الدراسة أستخدم موديل لأجمالي درجات الحرارة ودرجات الحرارة الملحوظة كسيناريوهات لتقييم التغيير في درجات الحرارة في السند في النصف الأول من القرن الحالي.اعتبرت البيانات المرصودة من مختلف محطات الأرصاد الجوية في السند هي المصدر الرئيسي للكشف عن التغييرات في درجات الحرارة. في السيناريو الحالي تم دراسة التغيير بدرجات الحرارة خلال الفترة (1990-1961) و في السيناريو المستقبلي تم دراسة الفترة (2010-2050) من خلال عمل نموذج مناخي للمنطقة بقدرة تحليل 25*25 كم. من خلال النموذج الأقليمي المناخي ممكن تفسير توقعات مناسبة ومعقولة للتنبؤ بدرجات الحرارة المستقبلية.أن الهدف الرئيسي من هذه الدراسة هو لأنشاء خرائط لدرجات الحرارة المستقبلية ومقارنتها مع درجات الحرارة الملحوظة. وتم التحليل من خلال دراسة جميع مناطق السند من أجل الحصول على صورة أكثر دقة من سيناريوهات التغيير في درجات الحرارة. بينت النتائج المتوقعة انه من المرجح ان تزيد درجات الحرارة 5و1 – 2و1 درجة مئوية بحلول عام 2050، مقارنة مع درجات الحرارة الأساسية 1961-1990. كذلك بين النموذج دقة أكبر للمناطق الشمالية من السند بالمقارنة مع الحزام الساحلي للسند. كل الأحياء من أقليم السند تبين أرتفاع في معدل درجات الحرارة وكل فترة زمنية تبدو أنها اكثر دفئا من سابقتها. أن فهم التغيير في درجات الحرارة أمر حيوي للغاية لمختلف القطاعات مثل التنبؤ بالطقس والمياه والزراعة والصحة وغيرها.

Introduction

The planet earth has unique environmental conditions, which is called climate. The classical period for a climate of any region is determined as an average weather condition of 30 years. The climate experts explicitly announced after prolonged discourse that the climate changes occur over the different regions on the globe, either due to natural variability in the earth's atmosphere or due to human activities, especially by burning of fossil fuels, greenhouse gas emissions and deforestation [1]. Impacts of climate change are multifaceted as global warming, rising sea level, uneven distribution of rainfall at spatiotemporal level etc. [2]. The climate scientists are agreed with 95% confidence that the increasing concentrations of greenhouse gases in the atmosphere are the dominant cause of the global warming since the mid-20th century. It is also reported that the earth's climate has warmed extraordinarily since the 1950s, as compared to the previous decades and millennia [3]. South Asia is among those regions, which are the most susceptible due to the climate changes. Changing patterns of rainfall or melting snow and ice are altering the freshwater systems, affecting the quantity and quality of water available in many South Asian regions. Temperature change scenarios have extensive impacts on every region of the world, which include flooding of reimbursements and arrangement, heat-related losses, ecosystem destruction, food and water shortages. It also progressively threatens the economic growth and human security in any region. It is reported that the warming has occurred, at a country scale, across most of the South Asian countries over the 20th century and into the 2000s [4]. It is indicated that the numbers of cold days and nights have significantly decreased and the numbers of warm days and nights have shown a rapid increase across the most of the Asia since 1950 and particularly after 1980s. Frequency, intensity and duration of heat waves have also increased since the middle of the 20th century in large parts of Asia, including Pakistan [5].

The major area of Pakistan lies in the arid to semiarid climatic conditions with a large spatiotemporal variability in many climatic parameters. Kruss et al., (1992) analyzed various climatic parameters of 35 observatories in Pakistan (30 years normal for 1931-60 and for 1961-90). They found cooling trends over northern Pakistan and a small area in the southeast part of Pakistan and attributed that cooling to the increase of monsoon rainfall and cloudiness conditions. Singh and Sontakke (1996) used monthly variances of surface air temperature dataset in various weather stations of Pakistan (with the base period 1947-70). They prepared mean annual surface air temperature anomaly series for the period 1876-1993 and observed large inter-annual variability. A definite warming trend was seen particularly from the start of the 21st century. The linear trend in their study was observed ~ 0.20^{OC} / 100 years at 5% significance level. They also constructed long time series of mean annual rainfall using dataset of 34 stations across Pakistan. Their anomaly showed the similar variability for the period 1856 to 1993. The inter-annual variability of the mean annual rainfall showed several years with high rainfall during 1856-1920, which has attributed partly to problems with the data network since 1930. However, no long term trends were visible in the series. It is revealed that numerous natural phenomenon as well as the anthropogenic activities is responsible for climate changes.

Meanwhile, the anthropogenic activities are recognized to be the major cause of higher greenhouse gas concentration in the atmosphere. Although, the contribution of greenhouse gases in global atmosphere is less too negligible in Pakistan, yet the climate change impact has marked during the last three decades [6]. Therefore, Pakistan is being listed among the countries which are negatively impacted by the climate changes. Some regions of Pakistan, like southwest Balochistan and southeast Sindh are more vulnerable to that of climate change [7]. As a small negative climate change would exacerbate their vulnerability due to topographical conditions of the area. The Southeast Sindh comprising of mainly arid area has such a peculiar kind of topography that the monsoon currents seldom enter to give the regular kind of rain during summer season [8]. The people living in that arid zone mainly rely on rain water for their crops, animals and even drinking. Imran et al. [9] analyzed the variations in the monsoon pattern over Pakistan indicated about the increase in the frequency of extreme precipitation events over the monsoonal belt of Sindh province. He concluded that Instead of having more rainy days, heavy events contribute more to the total amount of precipitation. For long term strategy, an authentic idea about the future climate behavior would help them to alter the cropping system, introducing climate resilient crops and resistant cultivars, and other socioeconomic activities. This study is carried out to explore the future climate trends and possible climate change impact in the drought prone parts of Sindh. This study will help the inhabitants of the area to plan activities as per the climate pattern and prepare themselves for facing severe drought conditions.

Study Area

The Province of Sindh is situated in the south- eastern part of the Pakistan. Most areas of Sindh are more susceptible to that of climate change. It is more vulnerable to temperature change because it has commonly a warm environment; it lies in a geographical region where the temperature rises are expected to be higher than the global average. Geographically, the province of Sindh is bounded by the Arabian Sea in south, India in east and Punjab in the north and Balochistan in the west. Majority land area of the province is arid and the river Indus flows in the middle of the province. There are seasonal tributaries which are mostly being active in the monsoon season, they originate from the Khirthar hill range from west of Sindh, which fallout in River Indus and Arabian Sea.

Figure 1- Study Area, including the district boundaries

Data and Methodology

In this study, two data sources namely PRECIS model data and observed data for assessing the temperature change scenarios are used. The General Circulation Model (GCM) data, named "PRECIS" stand for "Providing Regional Climate for Impacts Studies" is used and validate with the meteorological observed data of Pakistan Meteorological Department to assess the temperature change scenarios of all districts of Sindh province. In the methodology, raw data in the format of excel sheet input into the software and apply the different tools such that Geo-referencing of data, extraction by the mask, the Geo-statistical analytical tools and go-spatial interpolation techniques are used in the study area to map the baseline period of model data from 19961 to 1990 and compare its result with observed temperature baseline period from 1961 to 1990. However, Geo-statistical analytical and Geo-spatial interpolation techniques are more complex and changes spatially as a various functions of topographic variation, sea breeze effect on coastal areas, and relative humidity values but are still best for mapping the temperature change scenario. Same techniques applied to map model data from 2001 to 2010 for further verification of an observed temperature provided by Pakistan Meteorological Department. Remote Sensing and GIS technology makes the results of our research look worthy and facilitated us in validating the climate model. The more techniques such as raster math of ArcGIS software and graphs developed by excel, used to calculate and assessed the more accurate results of the changing circumstances of every district of Sindh province.

Results and Discussion

Basically the baseline period is required to describe the observed climate through which climate change data are generally combined to generate a temperature change scenario. Once using climate model outcomes for scenario structure, the baseline also serves as the reference period from which the demonstrated future change in environment is easily calculated. During the baseline period from 1961 to 1990 Figure- 2 , using spatial analytical techniques, the maximum temperature range was observed in the northern half of Sindh ranging from 28.1^{o}C to 29.1 ^{o}C. Larkana and the adjoining areas experienced the hottest weather with average values above 29 ^{o}C. The coastal belt of Sindh province experienced the lowest temperatures as compared to the inland parts of the province. Temperature range lies between 24.3 ^{o}C to 25.3 ^{o}C. Desert areas of Sindh show a temperature range between 26.8 ^{o}C to 28 ^{o}C.

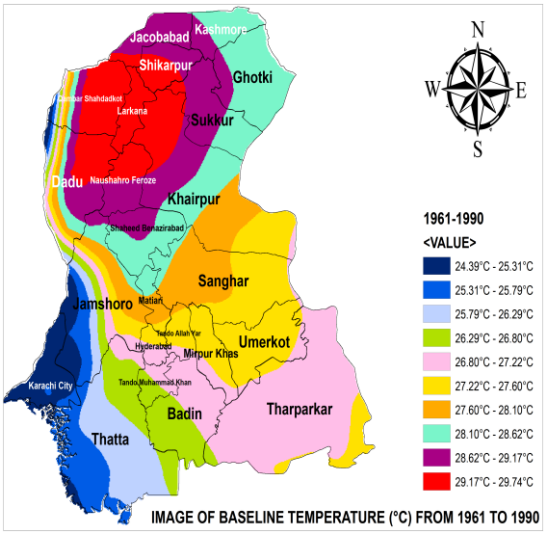

Figure 2- Baseline (1961-1990) temperatures district wise distribution

In the below given Figure-3 Increase in mean temperature during the two decade period is calculated. By applying the techniques of Arc GIS software on the raster map of average temperature of the two decade period of 2001-2010 and 2011-2020 is calculated. The 0.8 ^{o}C more increase in temperature is observed in the districts of Dadu and Qambar Shahdadkot as from the current values of temperature of these both districts which will be the hottest regions of Sindh in future change

scenarios especially up to 2020. Tharpakar also shows a significant increase in temperature values. The coastal area shows the minimum increase in temperature with a value around 0.1 ^{o}C. The remaining inland portion of Sindh exhibits an increase in temperature between these two extremes.

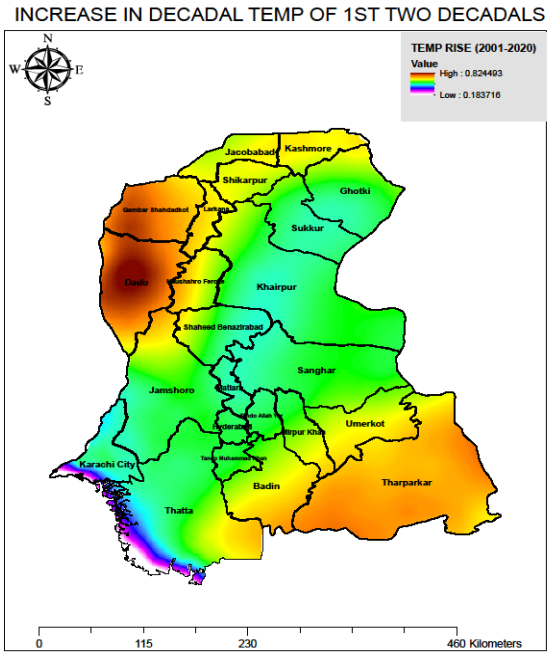

Figure 3- Mean temperature increases in first two decades (2001-2020)

In the below given Figure-4 By applying the same techniques on raster maps of decade period of 2010-2020 and 2021-2030 is observed in the coastal districts of Sindh province, but the value of the increment is quite small as compared of the increment observed between the decades 2010-2020. The districts of Kashmore and Ghotki are expected to be least affected by the increasing trend of temperature during the second and third decades of the present century. Although these areas have high mean temperature, but change is expected to be very small.

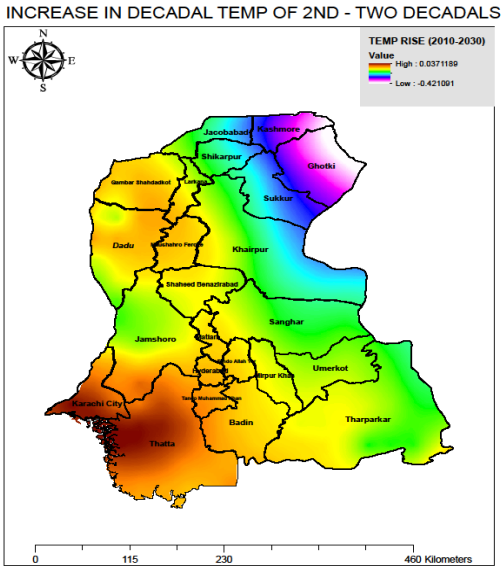

Figure 4- Mean temperature Increases in 2nd two decades (2010-2030)

In the below given Figure-5 Contrary to the previous case the average temperature is expected to be increase most of the districts of Ghotki and Kashmore and increase is very significant with a value as high as 1.1 ^{o}C. The lowest value the increase is again expected in the coastal regions of the province.

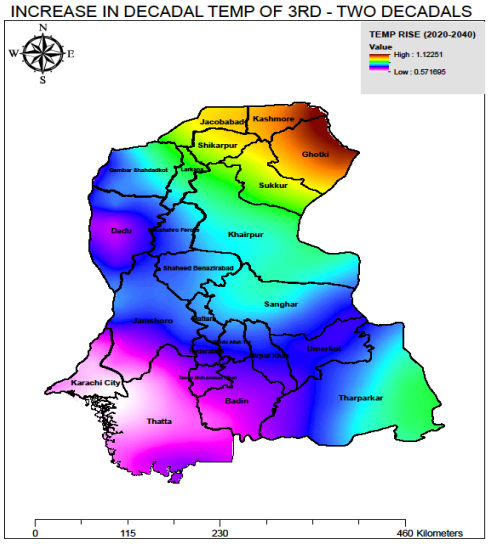

Figure 5- Mean Temperature Increases in 2nd two decades (2020-2040)

In the below given Figure-6 the mean decadal temperature is expected to be increased by a value of about 1.0 ^{o}C during the decade 2040-2050 as compared to 2030-2040. This increase is expected to be observed in the districts of Ghotki, kashmore, Dadu and Qambar Shahdadkot. The coastal areas are again expected to be least affected by the increasing trend of temperature, which is a good sign of the marine life and the socio economic activities associated with the seas. The central parts of the Sindh province are expected to experience a moderate heating effect during the first half of the 21st century.

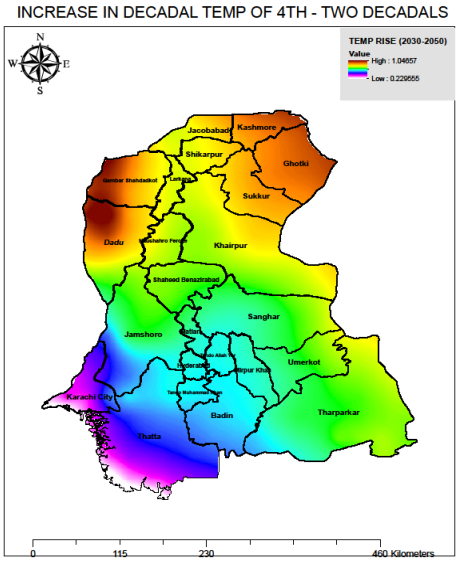

Figure 6-Mean Temperature Increases in 2nd two decades (2030-2050)

Increase in temperature from the baseline value to the average temperature of the decade 2001-2010 is calculated Figure-7. The highest increase in temperature from baseline (1961-1990) during

the ten year period (2001-2010) is observed at the coastal belt of Sindh.The increase is about 0.5 ^{o}C. The increase in the coastal temperature is a sign of danger for fauna and flora which is important not only from environmental aspects but also from the economic point of view. The least increment in temperature is observed in the parts of Dadu and Qambar adjoin balochistan and also in the southeastern parts of tharparker. Its value is about 0.3 ^{o}C. All these areas have higher mean temperatures, but show less variations over the twenty year period. Central parts of Sindh experienced an increment in temperature lies between these two extremes, although the range is quite narrow.

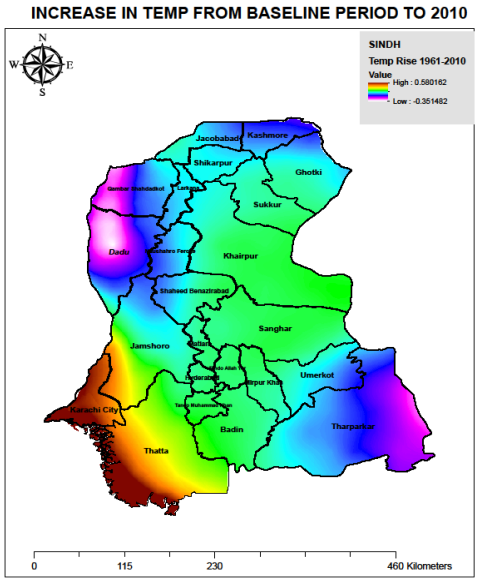

Figure 7- Increase from baseline period to 1st decade period

For the baseline period of the second decade (2011-2020) of the twenty first century, the highest temperature increase is again observed at the coastal belt of Sindh province (Figure-8). The pattern is almost same as that of the first decade, but the value is high. Karachi is seemed to be the most affected city, perhaps the consequence of increased urbanization. Again, the minimum increase is observed in the parts of Dadu and Qambar Shadadkot. All the remaining parts of Sindh exhibit an increase about 0.5 ^{o}C.

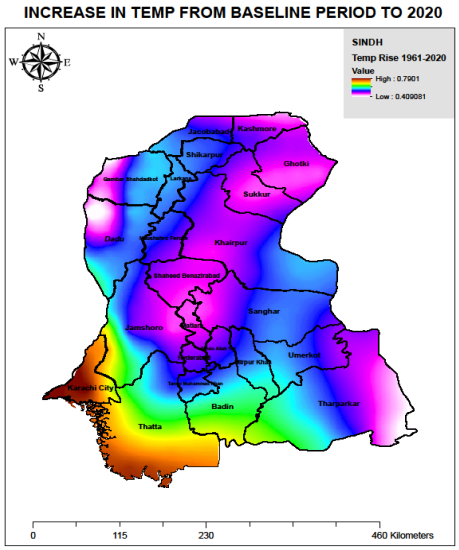

Figure 8- Increase from baseline to the 2nd decade period

The model shows very similar trends as in case of the first two decades in terms of the highest increase in temperature during the third decade (2021-2030) (Figure-9). The value of increment 0.78 ^{o}C is also very close to the previous decade. The last increase in temperature is observed in kashmore and Ghotki with a value as low as 0.057 ^{o}C each.

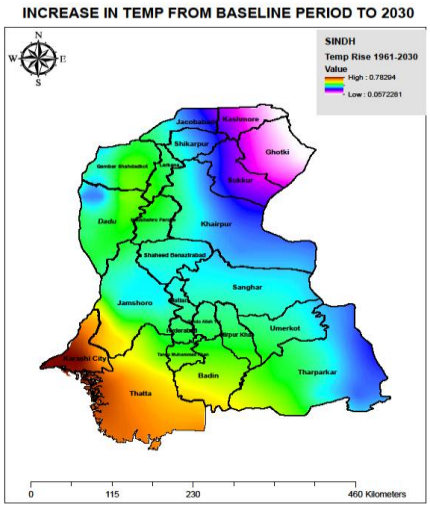

Figure 9- Increase from baseline to the 3rd decade period

During the fourth decade, in the area of maximum increase in temperature districts of Larkana, Shikarpur, Jacobabad and the eastern half of Qamabar Shadadpur is also included along with the coastal belt (Figure-10). The amount of increase is quite high as compared to first three decades i.e 1.4 ^{o}C. The areas of minimum increment in temperature are also located in patches in the districts of Dadu, Jamshoro, Umerkot and Sanghar. This is also a high value of more than 1.06 ^{o}C. The fourth decade of the present century is expected to be a very warm decade in the Sindh province. The trend during the decade 2041-2050 is seems to be totally changed. The northern parts of the province are expected to be the hottest parts with a very high value increase reaching more than 2^{o}C. Contrary to all the other decades' coastal areas are expected to be the areas with least increase during the decade. The value of the increase is 1.54 ^{o}C which is still a very high value and higher than all the previous values. This shows that coastal areas will still continue to be warmer and warmer, but the northern parts of province shoots over this part follow the trend originates in the fourth decade. Overall the entire province is expected to follow this warming trend.

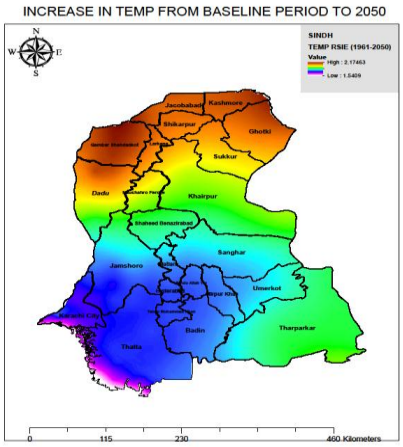

Figure 10- Increase from baseline to the 5th decade period

Mean Decadal Temperature is calculated in order to analyze the temperature trends within a decade. During the decade 2001-2010, northwestern part of Sindh experienced the highest mean temperature ranging from 27.9°C to 29.5°C(Figure-11). The coastal belt of Sindh exhibits the mean temperature cooler as compared to the inland areas. This exactly matches with the climatic trend.

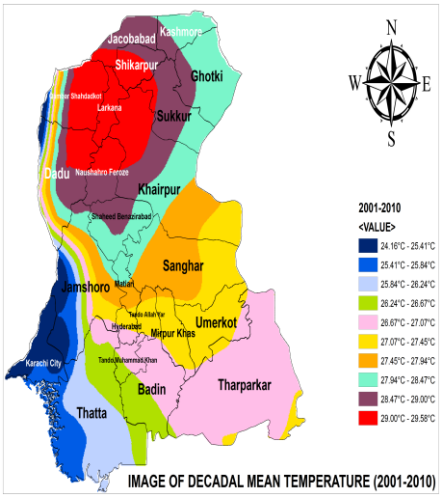

Figure 11- Mean decadal temperature of the first decade (2001-2010)

The trend of the mean temperature during the decade 2011-2020 follow the same trend as that of previous decade 2001-2010 but the temperature is higher than the previous decade (Figure-12). Its mean northern half of the Sindh is getting hotter. For coastal areas also the situation is same as previous decade, but the temperature is on higher side. The desert areas of Sindh experienced mean temperature range from 26.6 °C to 27.9 °C.

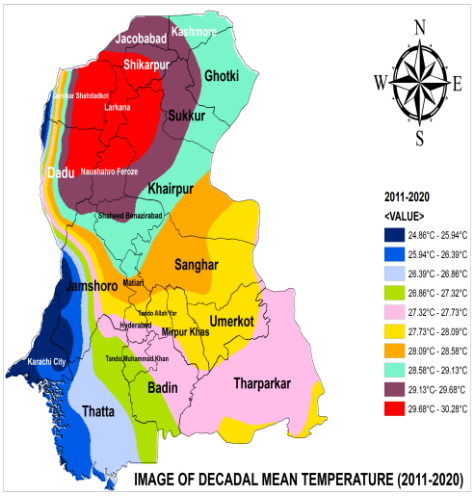

Figure 12- Mean decadal temperature of the second decade (2011-2020)

For the decade 2021-2030 the again the northwestern part experienced a higher mean temperature than the other parts of the province and Larkana district is again the center of this hot weather and intensity is same as that of the previous decade Figure- 13. Coastal areas of Sindh are not expected to face much change in temperature values as compared to the previous decade. Deserts of Sindh are also becoming hot as mean temperature seemed to be higher than the previous decade.

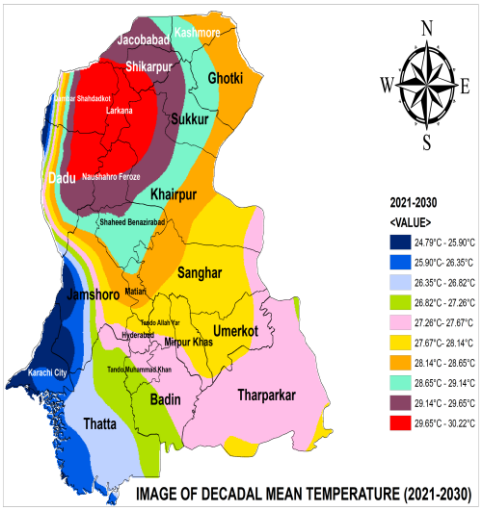

Figure 13- Mean decadal temperature of the third decade (2021-2030)

For the decade 2031-2040 the all the areas of the Sindh province are expected to experience higher temperatures as compared to the previous decades Figure-14. Coastal areas are also expected to become warmer. In the decade 2021-2030 Sindh province is not expected to face much change in temperature trends as compared to the decade 2011-2020.

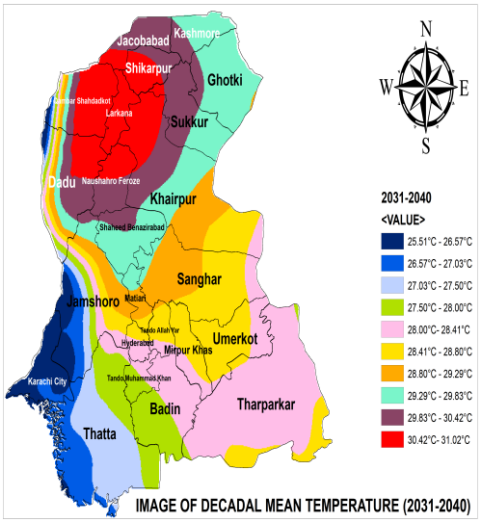

Figure 14- Mean decadal temperature of the fourth decade (2031-2040)

The decade 2041-2050 is expected to be even warmer than the previous decade Figure-15. The increase in temperature is more significant as compared to the previous decades. The increase in temperatures in the coastal areas makes these areas most vulnerable to the effect of global warming.

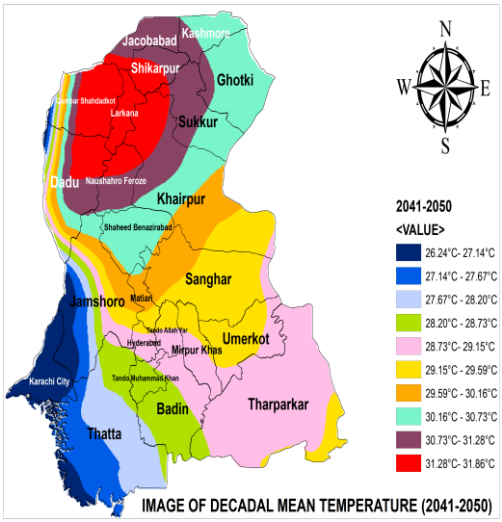

Figure 15- Mean decadal temperature of the fifth decade (2041-2050)

A comparison of the rise in temperature of different districts of Sindh is also made in order to make the understanding of the scenario clearer. It is evident from these graphical representations that all the districts of Sindh province have an increasing trend of temperature (Figure-17, 18, 19 and 20). Each decade is seemed to be warmer than the previous one for all the districts. This trend shows that Sindh is prone to be a victim of global warming. The coastal line areas such that Karachi, Thatta and Badin districts from which Karachi city is near to the coast of the Arabian sea as compared the others two districts namely Thatta and Badin where climate model results are failing because of high humidity and the effect of sea breeze. In the following Figure-16 also showed the lot of variation in coastal city Karachi as compared other city. The urban areas of districts Badin & Thatta are located very far from coastal belt and ground data station also situated in urban areas where the sea breeze and humidity ratio is less effective on the temperature as compared the Karachi city. Finally, it is verified that the PRECIS model data are showing lots of variation on those areas which is too close near the coast.

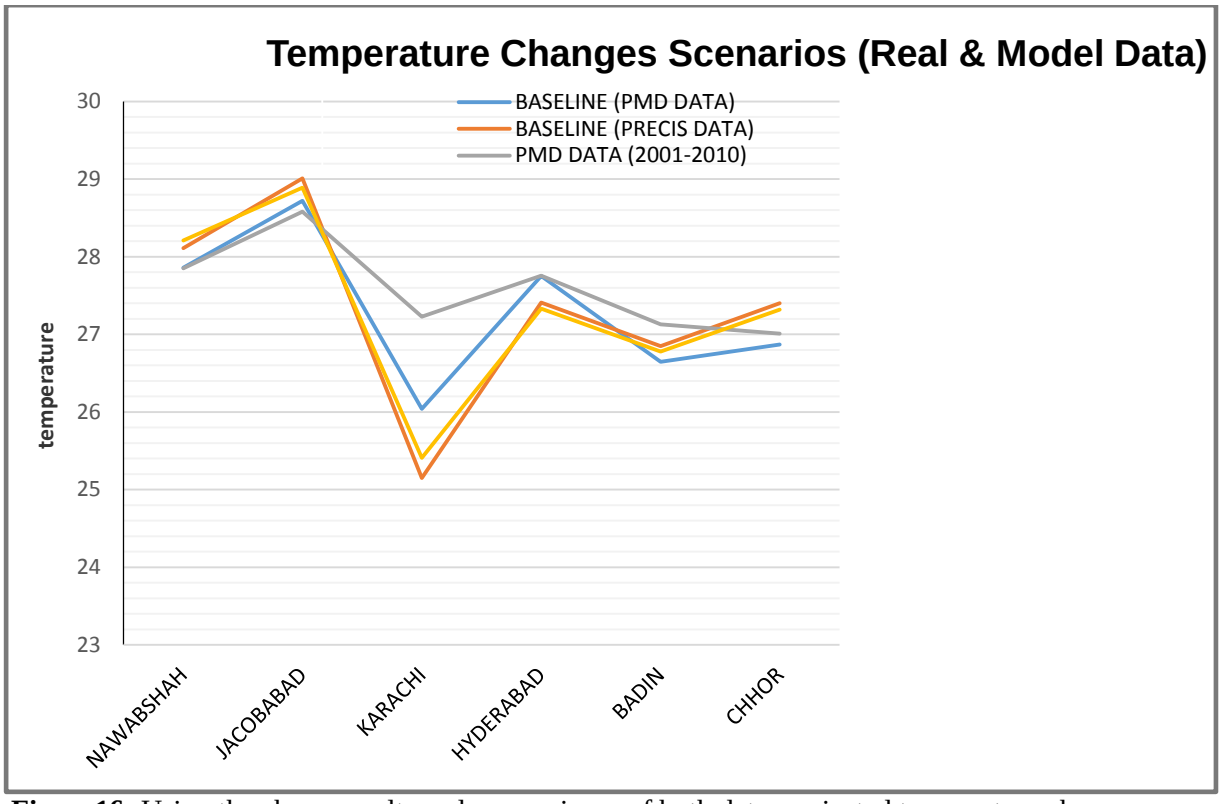

Figure16- Using the above results and comparisons of both data, projected temperature change scenarios of every district of Sindh.

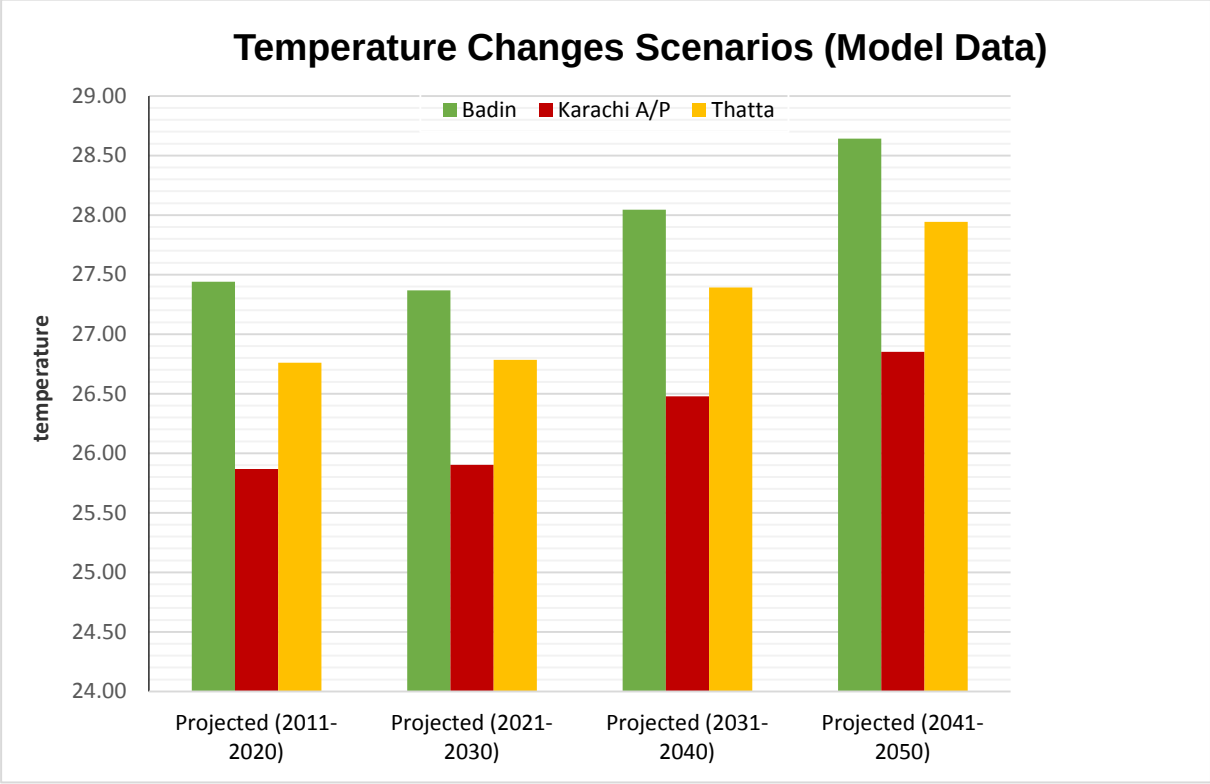

Figure 17- Projected Temperature Change Scenario of Badin, Karachi & Thatta.

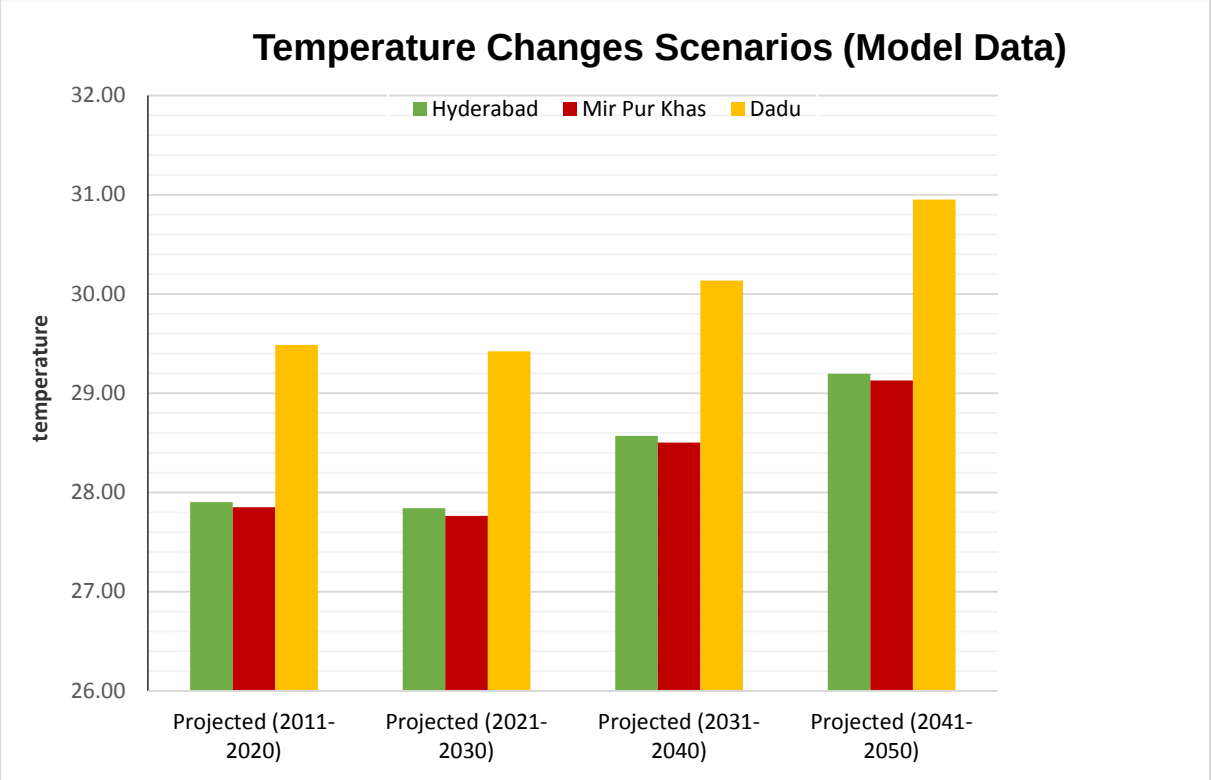

Figure 18- Temperature Change scenario of Hyderabad, Mirpurkhas & Dadu.

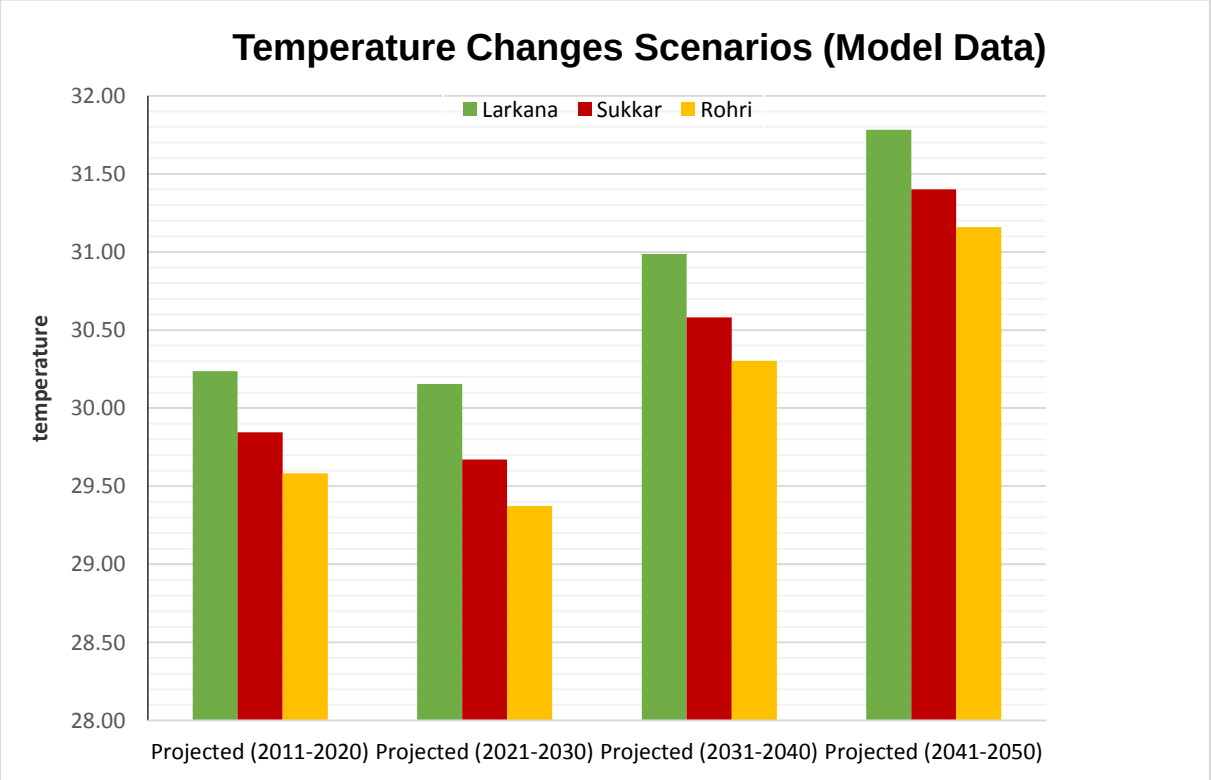

Figure 19- Temperature change scenario of Larkana, Sukker & Rohri.

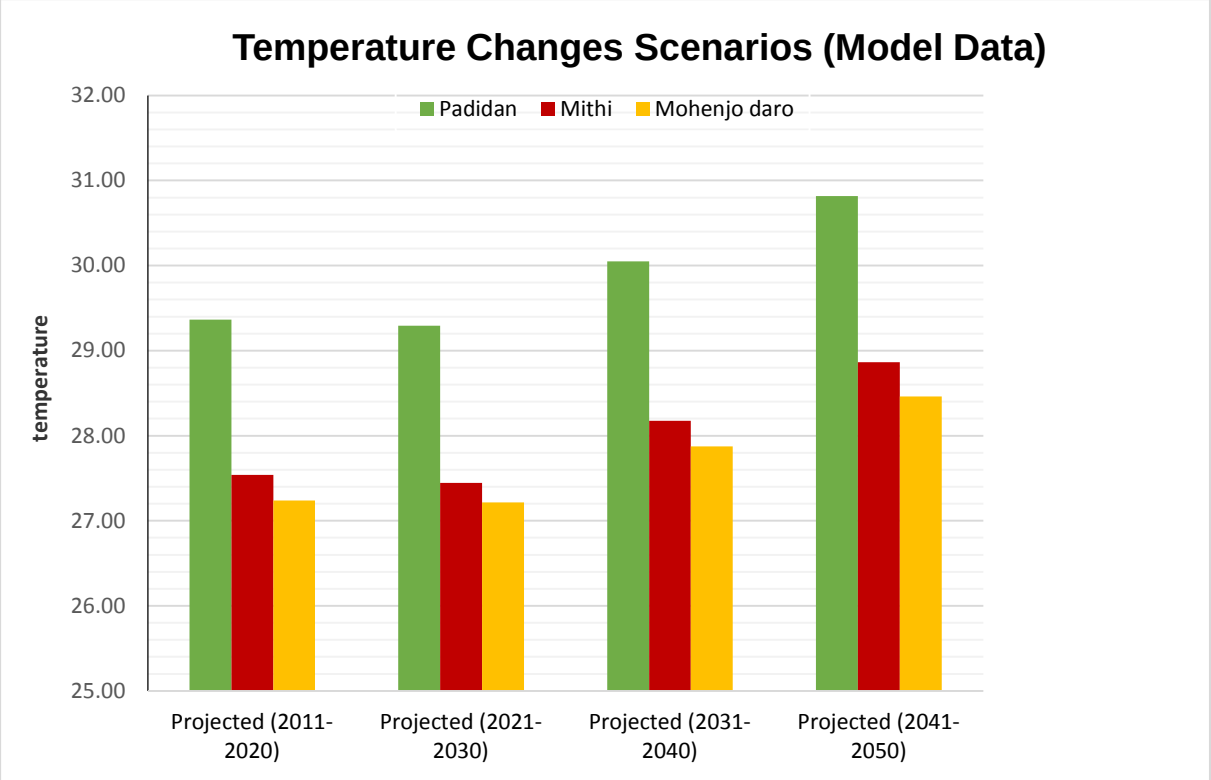

Figure 20- Temperature change scenario of Padidan, Mithi & Mohenjo Daro.

Conclusion

An increase in extreme temperatures of Sindh is due to global warming impacts and also anthropogenic activities. Global warming is the life-threatening hazard for the human civilization in twenty-first century. According to the results the temperature is likely to increase by 1.5 - 2.1°C by 2050, compared to the baseline temperature of 1961-1990 of regional climate model data and observed temperature data of 1961-1990 of meteorological satiations of the study area. An increase of temperature scenarios is the warning to face highly extreme weather events such as monitoring floods, droughts, cyclone activities of Sindh.

The model projections indicate significant warming over Sindh towards the end of the 2050. An enriched understanding of the change in temperatures accessibility till to 2050 is very crucial for improving the progress in various sectors such as weather forecasting, agriculture production, health issues, etc. The model assesses precise values in northern districts of Sindh with increases the extreme temperatures as compared to the coastal belt of Sindh. The coastal areas of Sindh display more complex variations in temperatures due to the causes of the sea breeze effect and relative humidity. That's why future prediction of this regional model-PRECIS is not more accurate results for the coastal belt of Sindh.

The temperature increases in the majority of districts of Sindh would result in reduced agricultural productivity. The decadal average result of temperatures highly effect on the maximum and minimum temperature, which both increased in summer as well as winter seasons almost throughout Sindh.The decadal temperature increased from Baseline (19961-1990) up to 2050, 2040, 2030, and 2020 are notified as in the range of 2.17-1.5 ^{o}C, 1.40-1.06 ^{o}C, 0.78-0.05 ^{o}C and 0.79- 0.40 ^{o}C respectively. Due to increase in temperature, visible fluctuations in hydrological cycle have been detected in the form of shifting rainfall pattern, increases the intensity of heat waves, harvesting pattern, sudden developed flash flooding events, continuously prevail drought conditions, lack of water availability periods and weather-induced natural disasters.

Reference

1. Vanderheiden, S. **2008**. *Atmospheric justice: a political theory of climate change*. oxford university press, Inc. New York.
2. Song, X., Zhang, Z., Chen, Y., Wang, P., Xiang, M., Shi, P., and Tao, F. **2014**. Spatiotemporal changes of global extreme temperature events (ETEs) since 1981 and the meteorological causes. *Natural hazards*, 70(2), pp: 975-994.
3. Stocker, T. F., Qin, D., Plattner, G. K., Tignor, M., Allen, S. K., Boschung, J., Nauels, A., Xia, Y., Bex, V., and Midgley, P. M. **2013**. *Climate change 2013: The physical science basis.* Intergovernmental Panel on Climate Change, Working Group I Contribution to the IPCC Fifth Assessment Report (AR5). Cambridge University Press.
4. Frich, P., Alexander, L. V., Della-Marta, P., Gleason, B., Haylock, M., Klein Tank, A. M., and Peterson, T. **2002**. Observed coherent changes in climatic extremes during the second half of the twentieth century. *Climate Research*, 19(3), pp: 193-212.
5. Mishra, A. K., and Singh, V. P. **2010**. A review of drought concepts. *Journal of Hydrology*, 391(1), pp: 202-216.
6. Farooqi, A. B., Khan, A. H., and Mir, H. **2005**. Climate change perspective in Pakistan. *Pakistan J. Meteorol*, 2(3), pp: 11-21.
7. Mirza, M. M. Q. **2011**. Climate change, flooding in South Asia and implications- *Regional Environmental Change*, 11(1), pp: 95-107.
8. Salma, S., Rehman, S., and Shah, M. A. **2012**. Rainfall trends in different climate zones of Pakistan. *Pakistan Journal of Meteorology*, 9(17), pp: 37-47.
9. Imran, A., Zaman, Q., Rasul, G. and Mahmood, A. **2014**. Temporal Trends in the Peak Monsoonal Precipitation Events over Northeast Pakistan. *Pakistan journal of Meteorology*, 10(19), pp: 19-30.