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ESTIMATING THE EXTREME TEMPERATURE OCCURRENCE OVER PAKISTAN USING INTERANNUAL AND INTERDECADAL TEMPERATURE VARIATION AND TELECONNECTIONS DURING 1901-2018

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ABSTRACT

Temperature changes across Asia have significant impacts on human livelihoods and habitats through their impacts on drought, irrigation, water availability, vegetation, and agriculture. The spread of South Asian temperatures is characterised by a heavy seasonality across most of the subcontinent. This research focuses on the interpretation of temperatures and disturbances occurring in this part of the South Asian zone and their association with sea surface temperature (SST). Data from the Climate Research Unit (CRU) and data from the SST (1901-2018) were obtained from the National Centers for Environmental Prediction (NCEP). The findings reveal that the years from 1901 to 1945 begin to look cooler, becoming less cool as we pass into the 1950s, and rapid warming over the last few decades, both of which show the last decade to be the warmest, particularly since 1980. The findings also demonstrate that there is more warming over land than over oceans because water is slower to consume and emit heat (thermal inertia).

Contribution/Originality: This study assesses the warming occurring in the south Asian zone and global sea surface temperature over the last few decades, the warming is more rapidly over land than over oceans.

1. INTRODUCTION

A number of recent studies have attempted to correlate changes in global circulation or local climate change with inter-annual and inter-decade variations in sea surface temperatures (SST) [1]. According to IPCC the global temperature is rising and causing an increase in extensive weather events, Whether the cause is human activity or natural variability and the preponderance of evidence says it's humans [2]. Thermometer readings all around the world have risen steadily since the beginning of the Industrial Revolution [3, 4]. According to the latest temperature study performed by scientists at the NASA Goddard Institute for Space Studies (GISS), the average world temperature on Planet has risen by around 0.8° Celsius (1.4° Fahrenheit) since 1880 [5]. Since 1975, two-thirds of the warming has happened at a rate of about 0.15-0.20°C per decade [6].

Global temperatures, which we experience locally and in short, differ widely due to predictable cyclical events (night and day, summer and winter) and complicated to predict wind and precipitation patterns, yet global temperature depends primarily on how much energy the earth absorbs from the Sun and how much it radiates out into space [7]. The quantity of energy radiated by the Planet, entirely depends on the chemical composition of the atmosphere, in particular the amount of greenhouse gas heat-absorbing [8].

A one-degree rise in temperature is notable because it takes a large amount of heat to warm the seas, atmosphere, and land. In the past, a one-to-two-degree fall was what it took to sink the World into the Little Ice Age. A five-degree fall was enough to bury a significant portion of North America under a high mass of ice 20,000 years ago [9, 10]. Annual temperature changes across Asia have significant impacts on human livelihoods and habitats through their impacts on drought, irrigation, water availability, vegetation, and agriculture [11]. The spread of South Asian temperatures is characterised by a heavy seasonality across most of the subcontinent [12]. The recent research focuses on the examination of temperatures and anomalies occurring in this part of the South Asian zone.

1.1. Objectives

To analyse the inter-annual and inter-decadal temperature variation (sea and surface) over Pakistan by using CRU data.

2. MATERIALS & METHODOLOGY

2.1. Study Area

Pakistan lies at 30.3753° N, 69.3451° E in South Asia. It is the sixth most populous nation in the world with a population of more than 212,742,631 people in the region, it is the 33rd largest country, covering 881,913 square kilometers (340,509 square miles). Pakistan has 108 peaks above 7,000 meters as shown in Figure 1, elevation map of Pakistan, and a list of many peaks over 5,000 and 4,000 m. Five of the 14 highest mountains in the world (eight thousand) are in Pakistan.

Pakistan has a coastline of 1,046 kilometers (650 miles) between the Arabian Sea and the Gulf of Oman in the south and borders India to the east, Afghanistan to the west, Iran to the southwest, and China to the northeast. It is narrowly isolated from Tajikistan by the Wakhan Corridor of Afghanistan in the northwest and also shares a maritime boundary with Oman [13, 14].

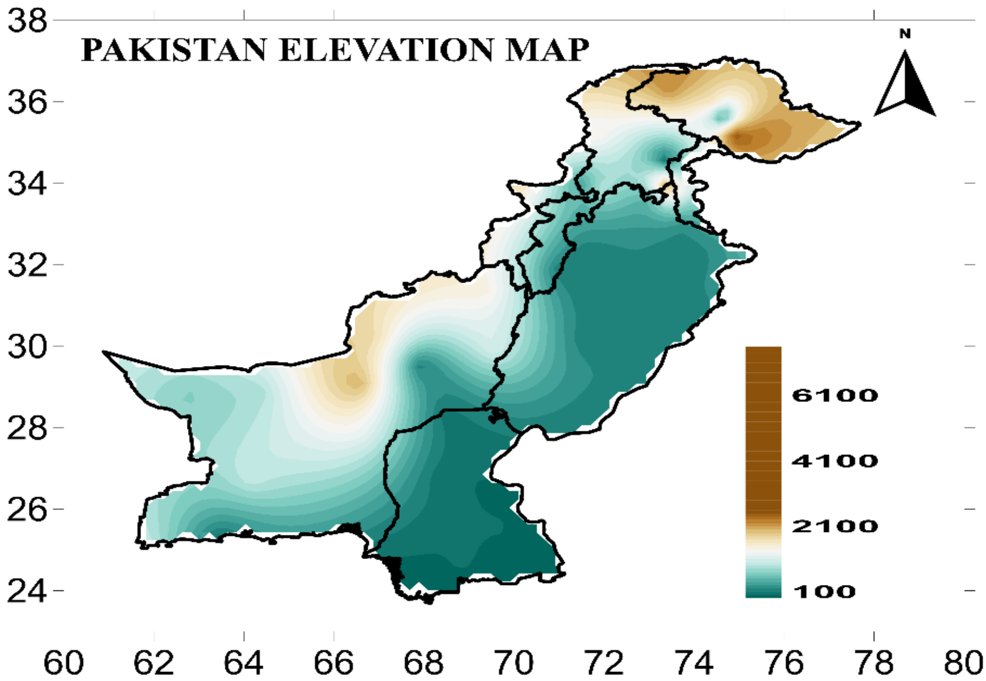

Figure-1. The study area (Pakistan elevation map).

Pakistan reported one of the high-temperature range throughout the world – 53.5 °C (128.3 °F) on 26 May 2010, the highest temperature ever reported in Pakistan, as well as the hottest temperature ever recorded on the Asian continent.

Pakistan is situated on a large landmass north of the Tropic of Cancer (among latitudes 25° and 36° N) [15], with a continental climate marked by significant temperature variations, both due to seasonal and daily. Very high altitudes change the climate in the cold, snow-covered northern mountains, temperatures on the Balochistan Plateau are marginally higher around the ocean [16].

In the rest of the country, temperatures hit high levels in summer, the mean temperature in June is 38 °C (100 °F), and the maximum temperatures may surpass 47 °C (117 °F) [17]. Over the summer, the hot winds called Loo were sweeping through the plains during the day, trees shed their leaves to prevent moisture loss, dry humid weather is disrupted by dust storms and thunderstorms that temporarily lower the temperature. The nights are cool.

Diurnal temperature fluctuations can vary from 11°C to 17°C. Winters are cold, with a minimum mean temperature in Punjab of around 4 °C (39 °F) in January, and freezing weather in the far north and Balochistan [18, 19].

2.2. Methodology

The analyses used in this study were the global monthly and yearly mean surface temperature and sea surface temperature (SST) and SST anomalies (1901- 2018) compiled by the National Centers for Environmental Prediction (NCEP) and available through the National Oceanic and Atmospheric Administration (NOAA) online archive.
(http://www.cdc.noaa.gov/cdc/data.ncep.oisst.v2.html.

1. Analysis of monthly or yearly mean temperature the techniques used here to extract monthly or yearly mean temperature:-

ave(expr, dim1, dim2 <,tinc> <,-b>)

Averages the result of *expr* over the specified dimension range. If the averaging dimension is time, an optional time increment *tincr* may be specified.

expr - any valid GrADS expression.
dim1 - the start points for the average.
dim2 - the endpoint for the average.
tinc - optional increment for time averaging.
-b - use exact boundaries.

For example:-
Define mean= ave(sst,t=1,t=117)

2. Analysis of monthly or yearly variance temperature define variance = ave(pow(sst-mean,2),t=1,t=117).
3. Analysis of monthly or yearly variance temperature define standard deviation= sqrt(var).

3. RESULTS AND DISCUSSION

The plot below shows yearly temperature average, variance, standard deviation, and anomalies from 1901 to 2018 as recorded by NASA, NOAA, the Japan Meteorological Agency, and the Met Office Hadley Centre (United Kingdom). Though there are minor variations from year to year, all records show peaks and valleys in sync with each other. All show rapid warming in the past few decades, and all show the last decade as the warmest.

3.1. Average Temperature Climatology for DJF & JJA over Pakistan (CRU Data. 1901-2018)

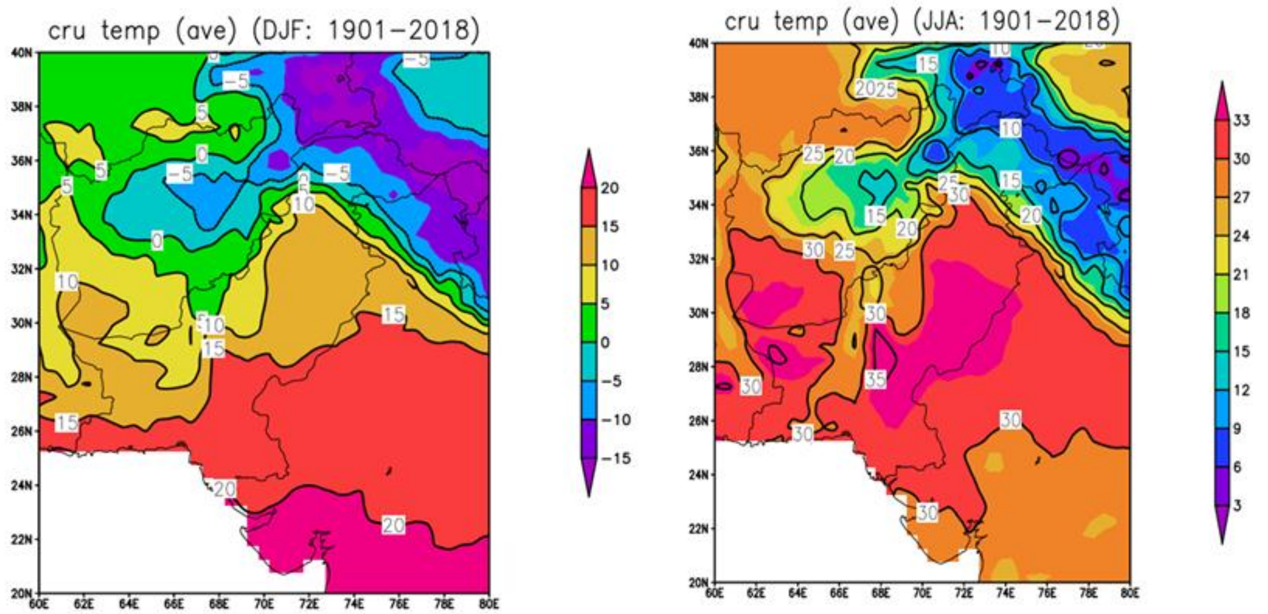

Figure-2. Ave temp (DJF&JJA. 1901-2018).

Figure 2 presents the 117-years (1901-2018) average climatology of CRU data. These data sets provide an updated climatology of zonal mean temperatures over Pakistan. The data shows that the temperature in the winters drops to the -5-degree centigrade in northern areas of Pakistan and the maximum temperature goes to the 15-degree centigrade, same as in the summer the maximum temperature goes to the 30-35 degree centigrade.

3.2. Variance Temperature Climatology for DJF & JJA over Pakistan (CRU Data. 1901-2018)

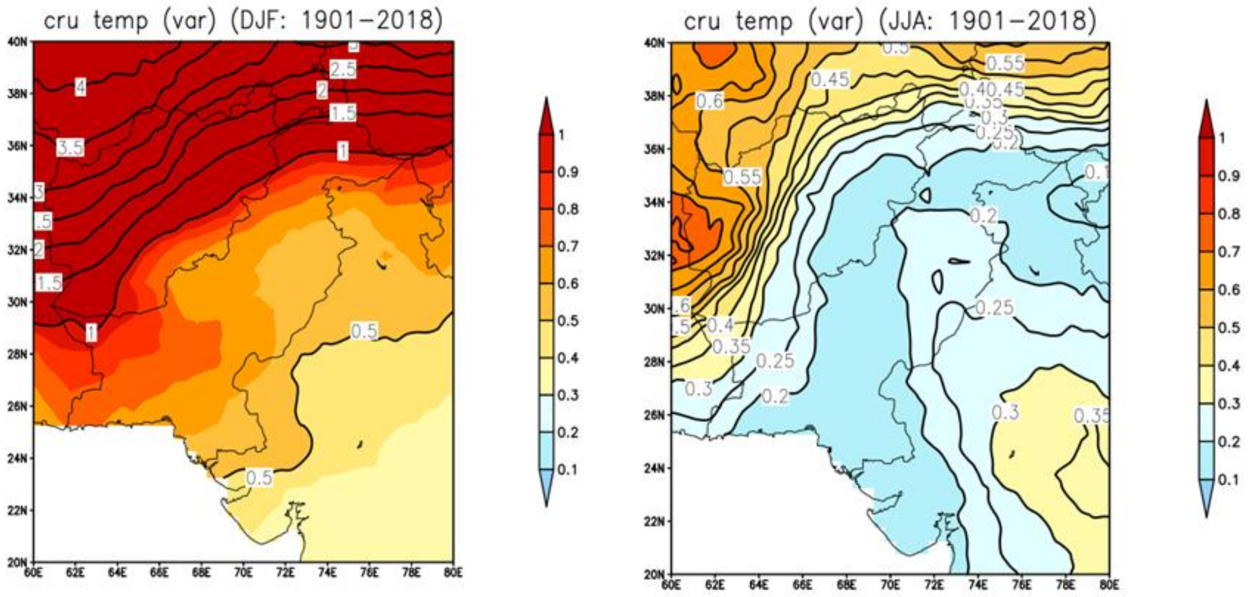

Figure-3. Variance temp (DJF&JJA. 1901-2018).

Figure 3 shows the 117-years (1901-2018) Variance temperature (CRU data) over Pakistan. This data set shows that the variance of the temperature in the Winter is greater than the variation of temperature in summers.

3.3. Standard Deviation Temperature Climatology for DJF & JJA over Pakistan (CRU Data. 1901-2018)

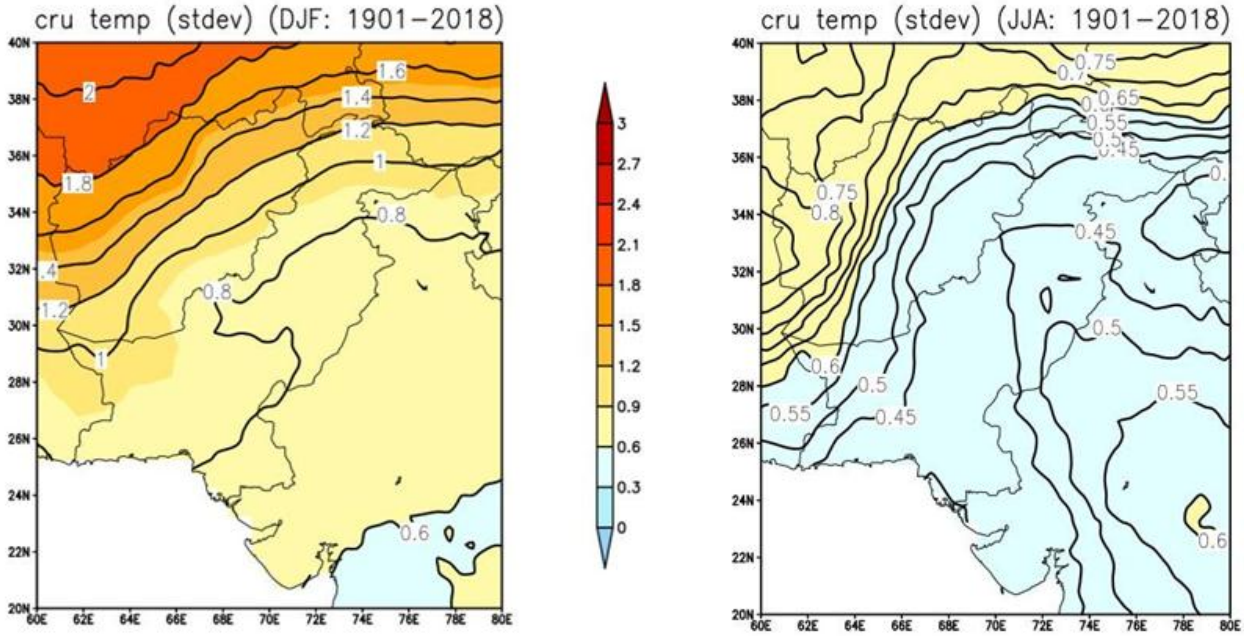

Figure-4. Stdev temp (DJF&JJA. 1901-2018).

Figure 4 shows the 117-years (1901-2018) Standard deviation temperature (CRU data) over Pakistan. This data set shows that the standard deviation in the winter rapidly changing as compared to the summer season.

3.4. Inter-Annual Temperature Times Series Over Pakistan (1901-2018)

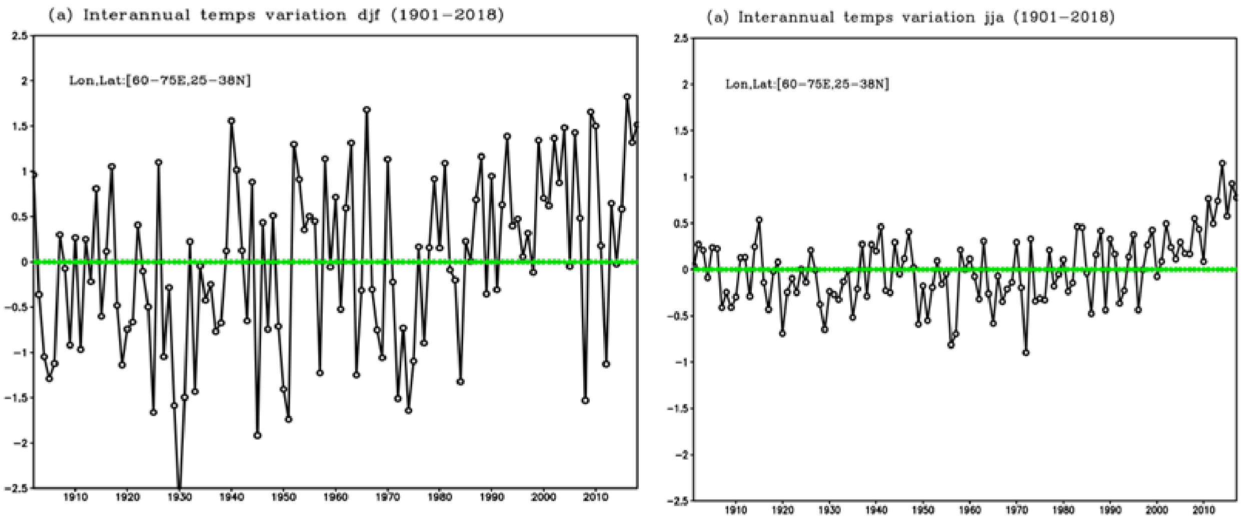

Figure-5. Temp time series (DJF&JJA. 1901-2018).

Figure 5 *shows the 117-years (1901-2018) inter-annual temperature time series (CRU data) over Pakistan. The data set shows that the temperature from 1980 rapidly starts increasing. which means that the overall mean temperature of Pakistan is increasing yearly.*

3.5. Inter-Decadal Temperature Times Series over Pakistan (1901-2018)

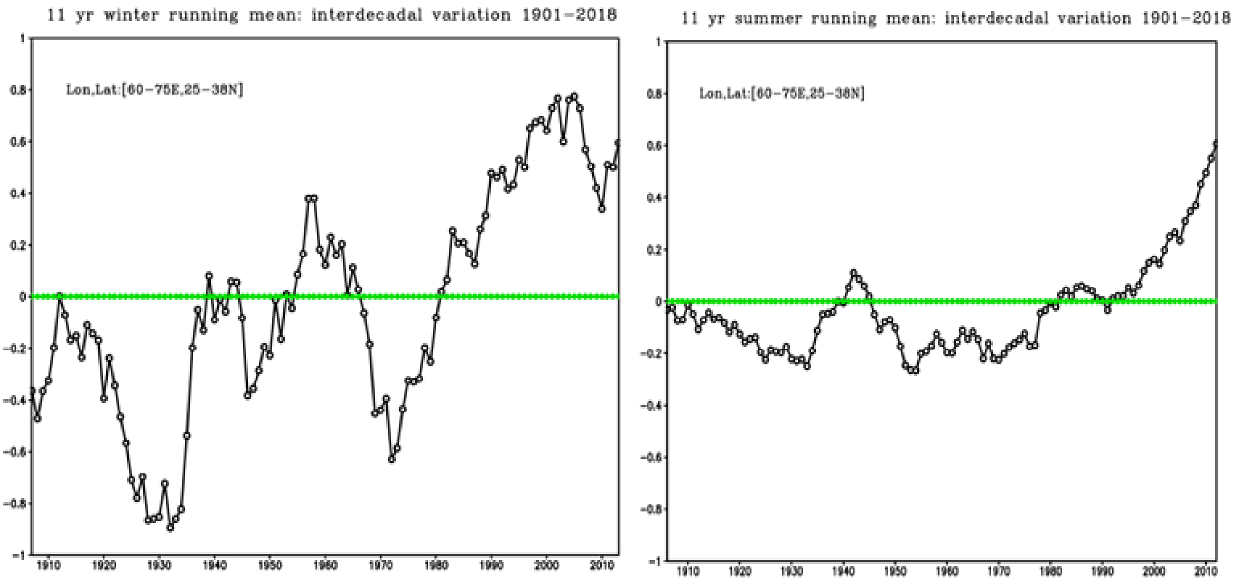

Figure-6. Temp time series (DJF&JJA. 1901-2018).

Figure 6 shows the 117-years (1901-2018) inter-decadal temperature time series (CRU data) over Pakistan. the data set shows that 10 years mean temperature from 1901 to 2018.

3.6. Average Sea Surface Temperature Climatology for DJF & JJA (1901-2018)

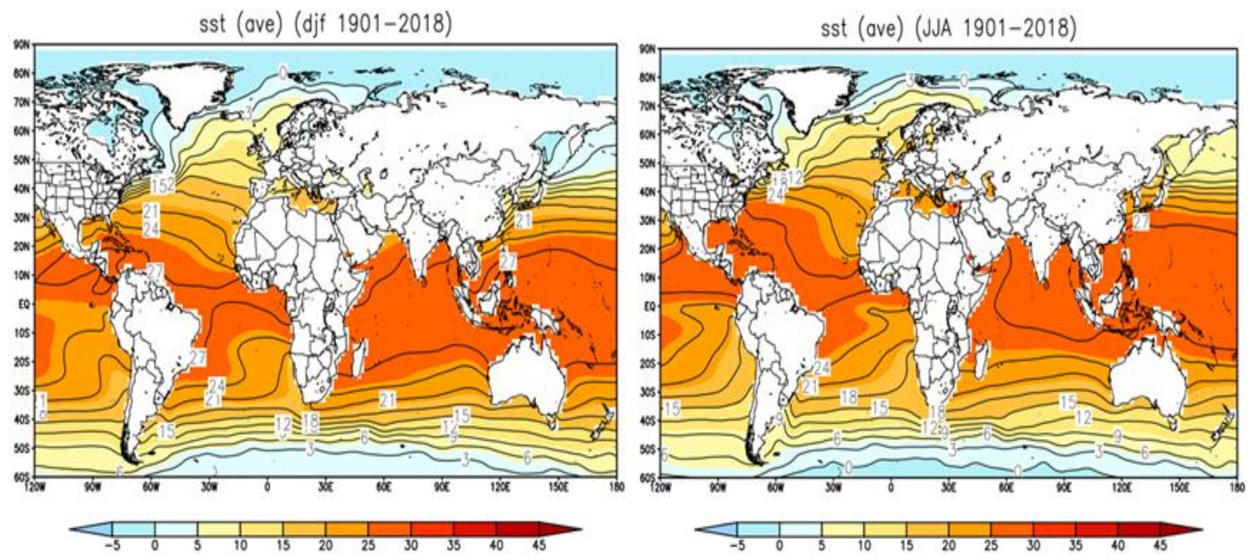

Figure-7. Ave sea surface temp (DJF&JJA.1901-2018).

Figure 7 presents the 117-years (1901-2018) average climatology of sea surface temperature. These data sets provide an updated climatology of zonal mean sea surface temperatures. The data shows that the overall temperature of the sea in winter and summer are the same. This means warming is greater over land than over the oceans because water is slower to absorb and release heat (thermal inertia).

3.7. Standard Deviation Sea Surface Temperature Climatology for DJF & JJA (1901-2018)

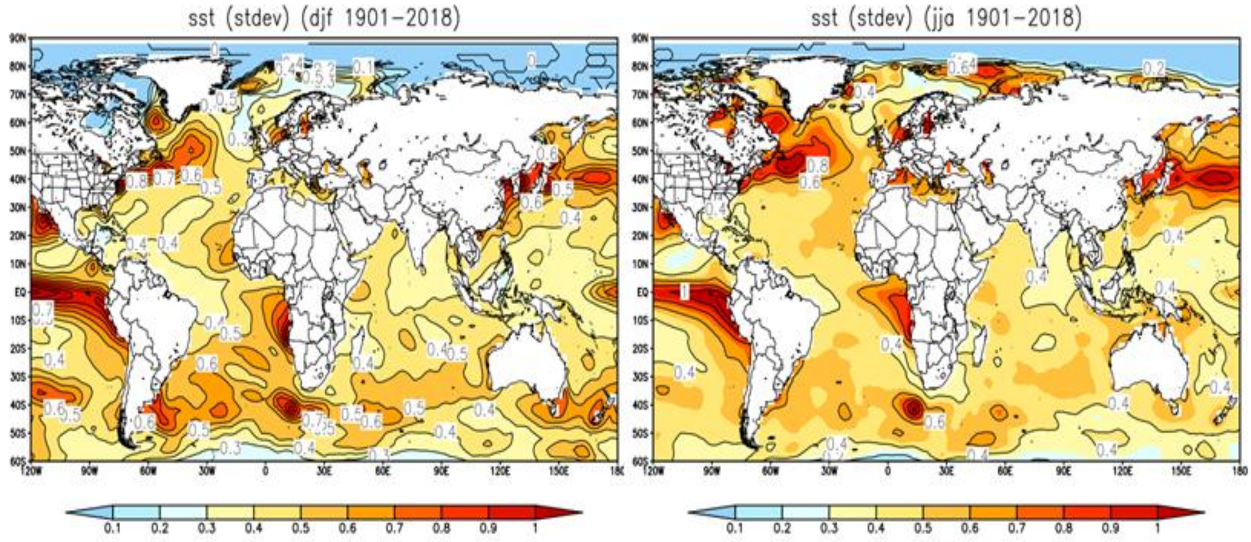

Figure-8. Standard deviation sea surface temp (DJF&JJA.1901-2018).

Figure 8 presents the 117-years (1901-2018) Standard deviation climatology of sea surface temperature. The standard deviation is in between the
0.1 to 1-degree centigrade.

3.8. Inter-Annual Sea Surface Temperature Time Series (1901-2018)

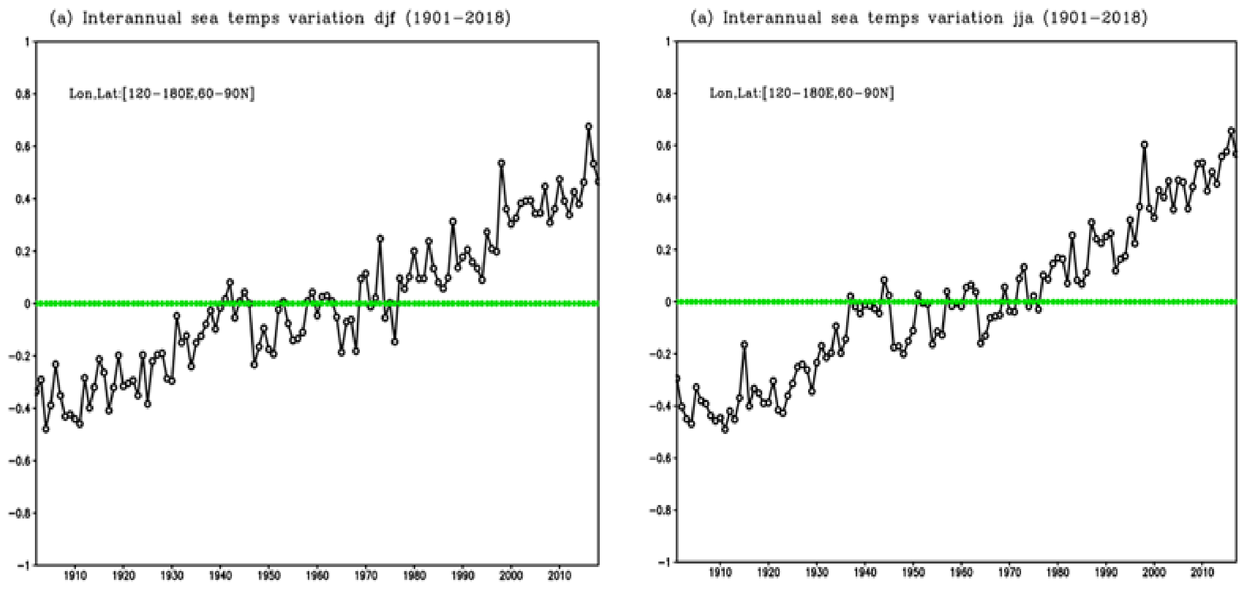

Figure-9. SST inter-annual time series (DJF&JJA.1901-2018).

Figure 9 shows the 117-years (1901-2018) inter-annual sea surface temperature time series over the globe. The data set shows that the sea surface temperature from 1980 rapidly starts increasing. which shows that the global temperature is rising and causing an increase in extensive weather events.

3.8. Inter-Decadal Sea Surface Temperature Time Series (1901-2018)

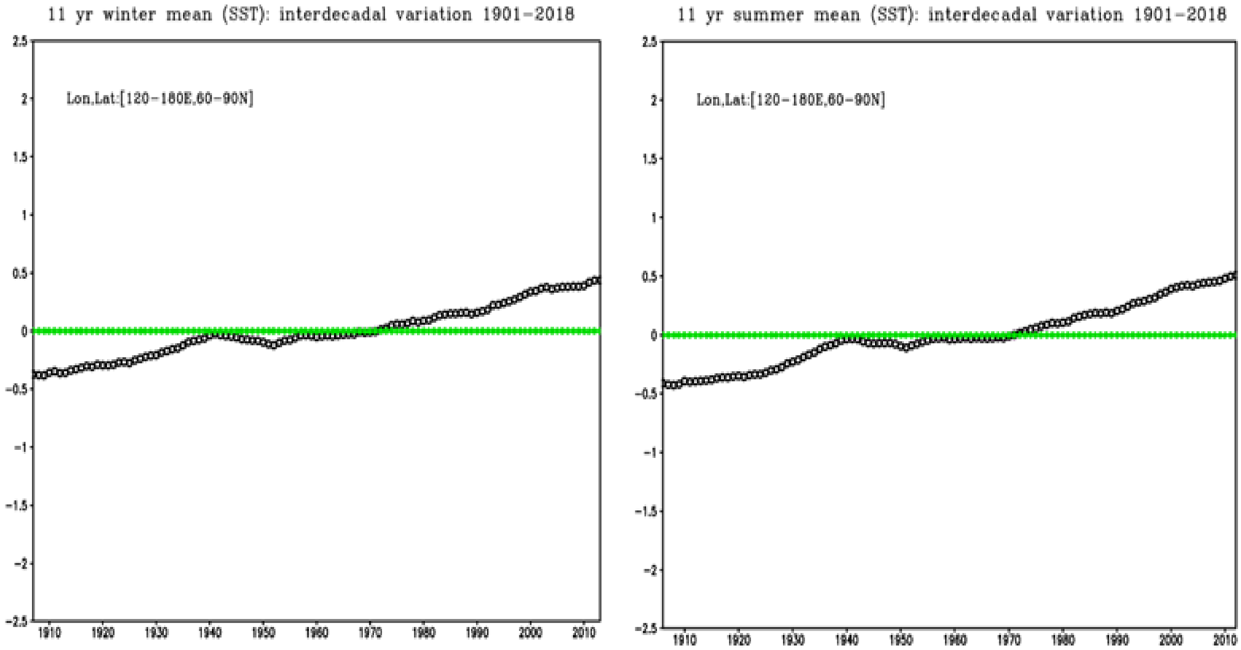

Figure-10. SST inter-decadal time series (DJF. &JJA.1901-2018).

Figure 10 shows the 117-years (1901-2018) inter-decadal sea surface temperature time series over the globe. The data set shows that 10 years mean temperature from 1901 to 2018.

3.9. Correlation between Surface Area Average Temps Vs Sea Surface Temps Global (1901-2018)

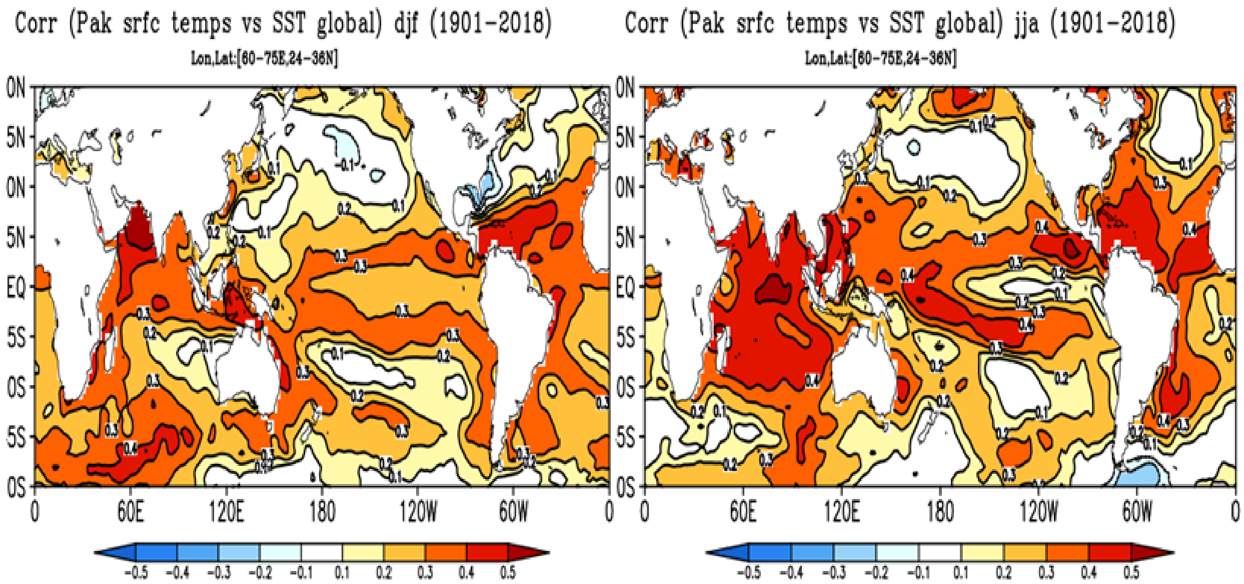

Figure-11. Correlation surface temps vs SST (DJF&JJA. 1901-2018).

Figure 11 presents the 117-years (1901-2018) correlation climatology between Pakistan's surface temperature and the global seas surface temperature. These data sets show the extensive high temperature over the Indian ocean. Generally, warming is greater over land than over the oceans because water is slower to absorb and release heat (thermal inertia). Warming may also differ substantially within specific land masses and ocean basins. The graph below shows the long-term temperature trends in relation to El Niño or La Niña events, which can skew temperatures warmer or colder in any one year.

4. CONCLUSION

This research work shows that the years from 1901 to 1945 tend to appear cooler, growing less cool as we move toward the 1950s. Decades within the base period do not appear particularly warm or cold because they are the standard against which all decades are measured. The leveling off between the 1940s and 1970s may be explained by natural variability and possibly by the cooling effects of aerosols generated by the rapid economic growth after World War II.

Fossil fuel use also increased in the post-War era (5 percent per year), boosting greenhouse gases. But aerosol cooling is more immediate, while greenhouse gases accumulate slowly and take much longer to leave the atmosphere. The strong warming trend of the past three decades likely reflects a shift from comparable aerosol and greenhouse gas effects to a predominance of greenhouse gases, as aerosols were curbed by pollution controls.

The plot above shows yearly temperature average, variance, standard deviation, and anomalies from 1901 to 2018 as recorded by NASA. Though there are minor variations from year to year, all records show peaks and valleys in sync with each other. All show rapid warming in the past few decades, and all show the last decade as the warmest one especially since 2009 was tied for the second warmest year in the modern record.

5. RECOMMENDATIONS

There are a number of gaps in our research that follow from our findings and would benefit from further research. Following are some recommendation for future research:

i. Through this data, we can further research the drought condition in Pakistan and the annual precipitation rate in arid and semi-arid areas.
ii. We can identify the reason behind the drastic change in global temperature trends since 1980.

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Acknowledgement: All authors contributed equally to the conception and design of the study.

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