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Role of Solar & Atmospheric Disparity on Climate of Western India, Kota, Rajasthan, India

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ROLEOFSOLARATMOSPHERICDISPARITYONCLIMATEOFWESTERNINDIAKOTARAJASTHANINDIA

Strictly as per the compliance and regulations of:

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Vinay Kumar Pandey

Abstract- In the last three decades, India has been facing the unusual weather condition that the affects the social-ecological balance. The summers are getting hotter; winters colder, drought, stronger storms, heat waves, floods, cloud burst, cyclones, and anomalous seasonal weather frequency and intensity have been historical expectations. Indian climate is affected by winds coming from the Indian Ocean as well as cold, dry northern winds along with atmospheric Hedley and Farrell cell wind and variation in these atmospheric winds. The change in solar radiation may impact these wind patterns, and extreme climatic events that happened globally. To better understand the impact and trend of solar and atmospheric disparities and associated climatic factors such as mean solar radiation, atmospheric pressure, precipitation, wind speed & wind direction and temperature, on extreme climatic conditions in Western India, selected the confluence area of Hedley and tropical wind. They divert at 30°N -25°N latitude as a variation of ITCZ, would be beneficial to understand the actual reason behind the increasing the extreme climatic condition. The city Kota is situated at 25°N latitude under the state of Rajasthan, India, selected for the study. After the detailed data interpretation, it observed that the average solar radiation has decreased by 1.15%, 0.28%, and 2.33% for the yearly, Ist half, and IInd half-year, the atmospheric pressure has increased by 0.066%, 0.035%, and 0.097% in the yearly, Ist half and IInd half-year respectively, the precipitation has decreased by 26.16 % the yearly, 10.61% and 28.66% in the the yearly, Ist half and IInd half-year respectively from the year 1988-1997 to the year 2008-2019. The maximum and minimum temperature was increased by 3.29% and 4.62% from the year 1988-1997 to the year 2008-2019. The Ist half and IInd half-year average maximum and minimum temperature were increased by 3.91% & 4.09%, and 4.04% & 5.14% respectively. Based on data out comes, predicted the future climatic condition for the years 2051-2060 and possible extreme climatic conditions over Western India that could be helpful in mitigation and land use plan for the extreme climatic conditions.

Keywords: Extreme weather condition, Solar Radiation, Atmospheric Pressure, Wind events, Temperature, Precipitation.

I. Introduction

Earth receives energy from the sun and varies according to sun energy, which has been the main driver of climate change over the billion the years of geologic time. Climate change is a natural phenomenon, which happened several times in Earth's history. Major evidence of previous Climate Change has been deducted by glacier studies and geological deposition. A study of previous climate change data suggested that natural causes such as terrestrial factors, atmospheric and tectonic factors were responsible for it.

The last three decades, India has been facing unusual extreme weather condition that affects the social-ecological balance. The summers are getting hotter; winters colder, drought, stronger storms, heat waves, floods, cloud burst, cyclones, and anomalous seasonal weather frequency and intensity have been historical expectations.

Indian climate is affected by winds coming from the Indian Ocean as well as cold, dry northern winds along with atmospheric Hedley and Farrell cell wind and variation in these atmospheric winds affecting the Indian weather. The change in solar radiation may impact these wind patterns, and extreme climatic events happen in the affected area. The extreme weather condition involves high precipitation, extreme summer, heat wave, cold wave, cyclone, etc. Precipitation frequency may be high means most of the annual rainfall happens a very short duration and causes flood, flash floods, landslides, ground subsidence, and another disaster.

To better understand the role of solar and atmospheric disparities and associated climatic factors such as mean temperature, precipitation, wind speed, and wind direction on extreme climatic conditions in Western India, selected the confluence area of Hedley and tropical wind. They divert at 30°N -25°N latitude as variation of Inter Tropical Convergence Zone(ITCZ), would be beneficial to understand the actual reason behind the increasing the extreme climatic condition. The Kota city is situated at 25°N latitude, suitable for study. Based on data interpretation for solar and atmospheric disparities, predicted the future climatic condition and possible extreme climatic conditions over Western India that could be helpful in mitigation and land use plan for the extreme climatic conditions.

a) *Previous studies*

The Serbian geophysicist and astronomer Milutin Milanković (the year 1920) had developed the relationship between the terrestrial factor and climate change based on the study of Vostok Ice Core that relationship called Milankovitch cycles, that describe the collective effects of changes in the Earth's movements on its climate over thousands of the years.

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National Academy of Sciences (NAS, 1982) in his study, suggested that Solar induced changes in the stratosphere could have a variety of indirect influences on the troposphere and climate. Investigations with general circulation models (Kodera, 1991; Rind & Balchandran, 1995) suggest that variations in solar ultraviolet energy input modify the ozone and temperature structure of the stratosphere, affecting the latitude temperature gradient. The latitude temperature gradient, modifies stratospheric wind speeds and the ability of long wave energy to propagate out of the troposphere. Altered tropospheric stability affects various tropospheric dynamic processes, including the Hadley cell intensity at low and subtropical latitudes and low-pressure systems in the extratropics. (NRC, 1994).

Climate variability is amongst the major phenomenon occurring worldwide which has caused major changes in climate variables such as precipitation, air temperature, relative humidity, and solar radiation (Haskett et al., 2000; Bates et al., 2008; Yu et al., 2013). Because of these alterations, there is a consistent warming trend, clearly reflected by the increasing occurrence of extreme climate events like droughts, floods, and heatwaves (Meehl et al., 2007). Natural disasters worldwide are result from extreme events rather than just a variation of the mean climate (Plummer et al., 1999).

Many studies have been documented worldwide on extreme climatic events (Easterling et al. 1997; Gaffen and Ross 1998; Karl and Easterling 1999; Easterling et al. 2000; Frichet al. 2002; Zhai and Pan 2003; Aguilar et al. 2005; Alexander et al. 2006; Qian and Qin 2006; New et al. 2006; Klein Tank et al. 2006; Bartolini et al. 2008; Wei and Chen 2009; You et al. 2008, Pandey at el, 2016). They analyze variation in temp & precipitation patterns during extreme weather conditions & the impact of climate change on it. Frichet al. (2002) and Alexander et al. (2006) analyzed the global changes in daily climate extremes and concluded that there has been significant warming throughout the 20th century. Most of the temperature trend studies in India have focused on the analysis of mean maximum and minimum temperatures along with extreme weather conditions and concluded that increasing trends in both maximum and minimum temperatures over India (Hingane et al. 1985; Srivastava et al. 1992; Rupa Kumar et al. 1994; Arora et al. 2005; Kothawale and Rupa Kumar 2005; Dash et al. 2007; Pal and Al-Tabbaa 2010). Some of the studies have investigated extreme maximum temperature, and case studies of heat wave spell over some regions as well as over the entire country (Natarajan 1964; Raghavan 1966; Subbaramayya and Surya Rao 1976; Chaudhury et al. 2000; De 2001; Pai et al. 2004, 2013; De et al. 2005; Ray et al. 2013, Jaiswal A K, et at. 2015, Pandey et al 2015a). Singh, A et.al., 2000 had observed that the frequency of Tropical cyclones in the north Indian ocean has significantly increasing trends during November & May, which account for the maximum number of intense cyclones. Ugnar (1999) has shown that losses due to extreme events are increasing steeply especially in the last decade of the 20th century.

On a global scale, the Indian summer monsoon is considered as a part of the warm season northward migration of the Intertropical Convergence Zone (ITCZ) in the eastern Northern Hemisphere (Chao and Chen, 2001; Gadgil, 2003; Fleitmann et al., 2007) and is key circulation component that transports heat/energy from the tropical and subtropical regions to the high-latitude and polar region (Trenberth and Stepaniak 2003; Hazeleger, 2005). Among the studies that examined multidecadal variations in Indian monsoon, some have investigated and suggested the multidecadal variation in the solar irradiance as a possible cause (Mehta and Lau, 1997; Neff et al., 2001; Agnihotri et al., 2002; Burns et al., 2002; Fleitmann et al., 2003, 2004; Kodera, 2004; Bhattacharyya and Narasimha, 2005; Berkelhammer et al., 2010, Pandey et al., 2014; Pandey V. K.& Mishra Ajai 2015 b, 2015 c). These studies show that the solar irradiance and monsoon intensity variations have been comparable in phase at decadal-centennial timescales. Positive anomaly in solar irradiance corresponds to heavy monsoon rainfall. However, as also indicated by Neff et al. (2001), Burns et al. (2002), and Kodera (2004), a direct effect of changing solar irradiance on the monsoon is unlikely, and irradiance anomaly has to go through the lower boundary of the atmosphere, e.g., via the surface, including sea surface temperature anomalies, to influence the monsoon (Wu Qianru and Hu Qi 2014).

II. Objective and Methodology

Considering the above natural phenomena, it seems that solar variation and atmospheric disparities affect the extreme weather condition, and considering this point, proposed to find out the role of solar activity and atmospheric variation in extreme weather conditions in the Western India subcontinent. Every year it is noticed that weather pattern has been shifted. The time duration of the winter season is less and extremes for few days, summer break the previous years in its temperature record. It is also observed that low rainfall areas face the floods, while others are facing droughts like the Gangetic plan and another part of India. The Intensity and frequency of hydro-meteorological disasters have been increased and varied that affecting the socio-ecological losses.

The Role of solar activities and atmospheric variations has been observed and analyzed by the study the last 30 the years' solar variation data, atmospheric pressure data, and study the past 42 the years wind patter, precipitation pattern, and daily average temperature.

This study might be comparing the amount of precipitation, daily temperature, wind flow, and solar variation in the event to similar past events to estimate the effect of atmospheric disparity and solar variation. The proposed study will be helpful for planning and interpretation of mitigation measures and land use patterns for future extreme weather condition.

a) Methodology

The methodology is the specific procedures used to collect, select, preparation of tools, and analyze information to obtain desired results of any problem. The solar and atmospheric raw data have been obtained from Indian Meteorological Department (IMD), Pune, India, and the internet (www.meteoblue.com) for study.

b) Data interpretation methodology

The collected daily data have been studied from January 1988 to December 2019 for solar radiation and atmospheric pressure and for the data of Precipitation, temperature, and wind data have studied from January 1978 to December 2019 (as per data availability). The row data have mentioned as daily maximum, minimum, and mean data for Ist half-yearly (January to June), IInd half-yearly (July to December), and the yearly wise. After that, data has compiled a ten year groups, i.e. the year 1978-1987, the year 1988-1997, the year 1998-2007 and the year 2008-2019.

Basis on research outcomes, predicted the next three-decades (i.e. the year 2051-2060) climatic conditions and probable natural disasters, extreme weather events, changes in precipitation patterns, atmospheric pressure, and solar radiation. This research work will help to open a new way to study the extremes climatic condition basis on atmospheric and solar disparities.

III. Data Interpretation

Summary of data interpretation have given below:

a) Solar Radiation Data for the year 1988-2019

Basis on of solar radiation observed from the year 1988-2019, prepared below table 1 a summarized sheet of data:

Table 1: Kota Solar Radiation summarized sheet from the year 1988 to the year 2019

The year	1988-1997	1998- 2007	2008-2019
Mean radiation for IstHalf-year(in Watt/square meter- W/m^2)	6244.65	6237.14	6227.02
Mean radiation for IIndHalf-year(in W/m^2)	4561.15	4833.11	4454.78
Mean radiation (W/m^2)	5402.90	5535.12	5340.90

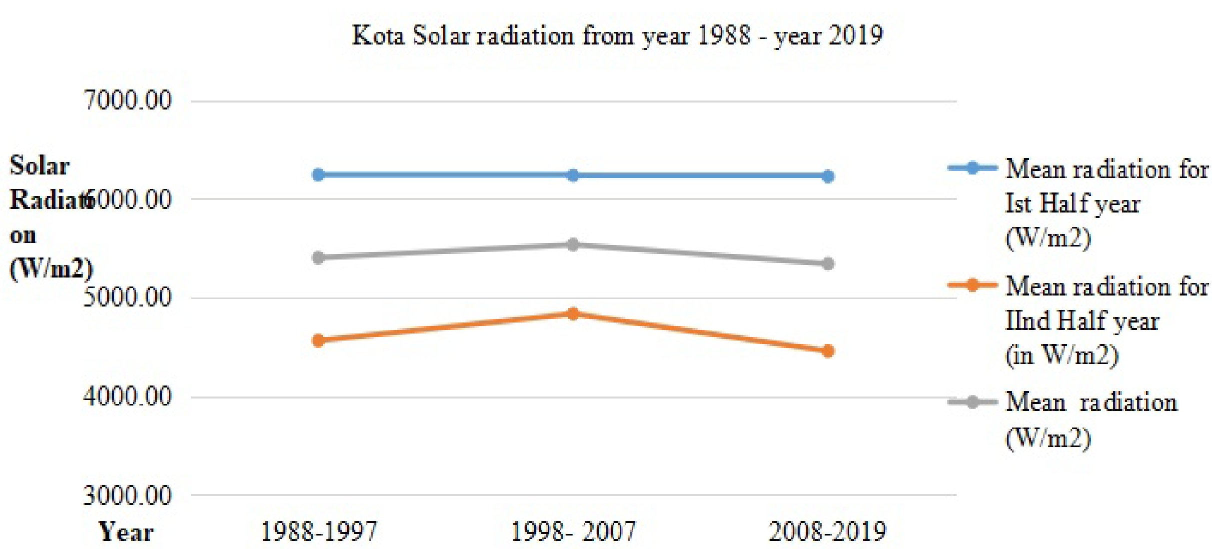

Fig. 1: Kota means line diagram for Solar Radiation for the year 1988-2019

From table 1, it is observed that mean Solar Radiation was increased in the year 1998-2007 compared to the previous period the year 1988-1997 and decreased in the year 2008-2019. For the Ist half-yearly Solar Radiation continues decreased from the year 1988 to the year 2019 and Solar Radiation increased in the year 1998-2007 compared to previous period year 1988-1997 and decreases in the year 2008-2019 for IInd half-yearly. The line diagram for Kota Solar Radiation for the year 1988-2019 has shown in figure 1.

b) Atmospheric Pressure data for the year 1988-2019

Table 2: Kota atmospheric pressure summarized sheet from the year 1988 to the year 2019

The year	Mean Pressure for Ist half yearly (in hector Pascals - hPa)	Mean Pressure for IInd half yearly (in hPa)	Mean yearly Pressure (in hPa)
1988-1997	1007.34	1007.45	1007.40
1998- 2007	1007.53	1007.53	1007.53
2008-2019	1007.69	1008.43	1008.06

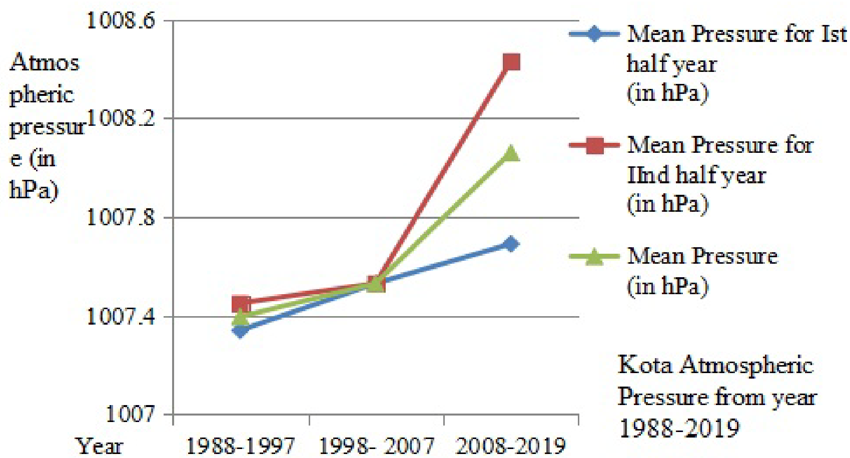

Fig. 2: Kota means line diagram for atmospheric pressure for the year 1988-2019

From table 2, it is observed that atmospheric mean pressure was continuously increasing. For the Ist half-yearly atmospheric pressure in the year, 2008-2019 were increased by 0.35 h Pa & 0.16 hPa compared to the year 1988-1997, and the year 1998-2007 respectively, and 0.98 hPa & 0.90 hPa pressure increased in the year 2008-2019 compared to the year 1988-1997, and the year 1998-2007 respectively for the month of IInd half-yearly. The yearly mean atmospheric pressure in the year 2008-2019 has increased by 0.66 hPa & 0.53 hPa compared to the year 1988-1997, and the year 1998-2007 respectively. The line diagram for atmospheric pressure for the year 1988-2019 has shown in figure 2.

c) Wind data for the year 1978-2019

Total 126427 wind data have been analyzed from January 1978 to Dec 2019. The wind data were observed twice a day, one at noon and second at 3 pm at a height of 10 m from ground level. The wind data have been shown by wind direction and wind speed.

The ten the yearly comparative wind data sheet is given in below table:

Table 3: A summary sheet of Wind data from the year 1978 to the year 2019 (N- North, NE-North-east, NNE-North-north-east, W-West, S- South, SW- South-west, NW- North-west, WNW- West-north-west, WSW- West -south-west)

The Year	Calm Wind %	I Highest wind % with direction	II Highest wind % with direction	III Highest wind % with direction	IV Highest wind % with direction	V Highest wind % with direction	% of Wind events >25 km/h/ maximum wind speed
1978-1987	13.90	18.49	16.73	11.15	9.50	7.63	1.56
		NW	NE	W	SW	N	95-100
1988-1997	19.56	12.19	10.77	10.73	8.17	7.66	0.25
		W	NW	NE	SW	N	95-100
1998-2007	36.50	9.27	9.10	8.8	8.10	7.60	0.30
		W	N	SW	NW	NE	95-100
2008-2019		14.35	12.17	7.97	7.37	7.29	0.03
		WSW	W	WNW	NE	NNE	25-30

Based on the above table no 3, it is shown that the years 1978-1987 and the year 1988-1997 were affected by West and East direction winds. But in corresponding the year 1998- 2007 and the year 2008-2019, West direction winds events were increased. The year 1978-1987 were received winds in NW, NE and West direction, but in corresponding year 1988-1997, the west direction had received maximum wind events followed by NW, NE, and SW directions. In the year 1998-2007, West direction received the maximum wind events followed by North, SW, NW and NE, but in the year 2008-2019, WSW had received the maximum wind events followed by West, WNW, and NE, NNE direction. The events of calm winds have increased every period from 13.90% to 19.56% and 36.50% and the number of wind events speed more than 25 km/h is decreased every the year i.e. the year 1978-1987, the year 1988-1997, the year 1998-2007, and the year 2008-2019 respectively. It is also observed that the total numbers of wind event and extreme wind events are decreasing.

Comparison of wind event, and wind speed to know the variation in wind speed, prepare the below table 4:

Table 4: Comparison of wind events and wind speed

% Wind Events	1978-1987			1988-1997			1998-2007			2008-2019		
Wind Speed (km/h)	The Yearly	Ist half the year	IInd half the year	The Yearly	Ist half the year	IInd half the year	The Yearly	Ist half the year	IInd half the year	The Yearly	Ist half the year	IInd half the year
0-5	45.5	41.31	49.63	55.73	49.61	61.83	69.89	67.31	72.61	34.17	29.06	38.69
5—10	28.56	31.64	25.53	27.05	30.05	24.06	18.06	18.20	17.91	39	41.16	36.93
10—15	19.09	19.21	18.97	14.21	16.16	12.28	9.37	10.90	7.79	18.16	18.64	17.76
15-20	3.45	4.67	2.44	2.16	3.10	1.22	2.08	2.69	1.43	7.41	9.03	6.10
20-25	1.74	2.36	1.14	0.60	0.73	0.47	0.29	0.37	0.21	1.24	2.05	0.51
>25	1.56	0.82	2.30	0.25	0.36	0.14	0.32	0.54	0.09	0.03	0.06	0.01

The yearly wind events from speed less than 5 km/h had increased from the year 1978-1987 to the year 1998-2007 but decreased in the year 2008-2019. For remaining wind speed 5-10 km/h, 10-15 km/h, 15-20 km/h, 20-25 km/h were decreased from 1978-1987 to the year 1998-2007 but increased in the year 2008-2019. The wind events speed was more than 25 km/h, was continuously decreased from the year 1978- 1987 to the year 1988-1997, increased in the year 1998-2007 but again decreased in the year 2008-2019.

The wind event was received from Ist & IInd half-year are following the yearly trend. The wind events increased from the year 1978-1987 to the year 1998-2007 but decreased in the year 2008-2019. For remaining wind speed 5-10 km/h, 10-15 km/h, 15-20 km/h, 20-25 km/h decreases from the year 1978-1987 to the year 1998-2007 but increased in the year 2008-2019. The wind events for speed of 15-20 km/h increased from the year 1998 to the year 2019. The wind events speed was more than 25 km/h was continuously decreased from the year 1978-1987 to the year 1988-1997, increased in the year 1998-2007 but again decreased in the year 2008-2019.

d) Half-yearly wind data

For detailed wind data interpretation, prepared the six-monthly wind data observations and discussed below table 5 and 6 for the Ist & IInd half-year respectively.

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Table 5: A summary sheet of Wind data for the Ist half-year (the year 1978–2019)

The Year	Calm Wind %	I Highest wind % with direction	II Highest wind % with direction	III Highest wind % with direction	IV Highest wind % with direction	V Highest wind % with direction	% of Wind events >25 km/h/ maximum wind speed
1978-1987	12.23	22.27	17.52	10.57	8.97	8.35	0.82
		NW	NE	W	N	SW	95-100
1988-1997	13.90	13	12.44	11.75	9.8	7.2	0.36
		NW	W	NE	N	SW	45-50
1998-2007	34	10.70	9.93	9.82	7.90	7.05	0.54
		N	W	NW	NE	SW	95-100
2008-2019		14.73	13.42	10.62	8.34	7.08	0.06
		W	WSW	WNW	NW	NNE	

Table 6: A summary sheet of Wind data for the IInd half-year (the year 1978–2019)

The Year	Calm Wind %	I Highest wind % with direction	II Highest wind % with direction	III Highest wind % with direction	IV Highest wind % with direction	V Highest wind % with direction	% of Wind events >25 km/h/ maximum wind speed
1978-1987	15.54	15.95	14.76	11.71	10.63	6.31	2.30
		NE	NW	W	SW	N	95-100
1988-1997	25	12	9.70	9.10	8.60	8.10	0.14
		W	NE	SW	NW	WSW	95-100
1998-2007	39.10	10.70	8.56	7.31	7.28	6.30	0.09
		SW	W	N	NE	NW	95-100
2008-2019		15.10	10.04	8.11	8.05	7.42	0.01
		WSW	W	NE	SW	ENE	

Based on half-yearly wind data, it is observed that the Ist half the year; West direction wind was dominantly in the year 1978 to the year 2019, but from the year 1978 to the year 1997, east ward winds were dominant and NW direction received the maximum wind events. Events of the calm winds are increasing throughout the years. The wind intensity has decreased from the year 1978 to the year 2007 and increased in the year 2008-2019. The highest wind events had decreased in the year 1978 to the year 1998 and the year 2008 to the year 2019, but increased in the year 1998- the year 2007. The overall frequency of wind events is decreasing.

For IInd half-year, East direction winds were dominantly in the year 1978-1987 after that West direction winds were dominantly and NE wind events decreased. Events of the calm winds are increasing throughout the year. The wind intensity has decreased from the year 1978 to the year 2007 and increased in the year 2008-2019. The highest wind events had decreased throughout the years from the year 1978 to the year 2019. The wind events in the year 2008-2019 have increased. The wind event direction was variable between NE to WSW from the year 1978 to 2019.

e) Precipitation data for the year 1978-2019

Based on data analysis prepared half-yearly precipitation data with total average precipitation data tenyears' period and for the year 1978 to the year 2019. Data has mentioned in table 7:

Table 7: The half-yearly average precipitation data for the year 1978- 2019

The Year	Ist half-yearly average Precipitation (in mm)	IInd half-yearly average Precipitation (in mm)	Total average Precipitation (in mm)	Percentage precipitation received in Ist half-yearly	Percentage precipitation received in IInd half-yearly
1978-1987	104.67	608.50	713.17	14.68	85.32
1988-1997	114.88	715.82	830.70	13.83	86.17
1998-2007	108.29	443.31	551.60	19.63	80.37
2008-2019	102.69	510.68	613.38	16.74	83.26
Average precipitation from the year 1978 to 2019 (in mm)	107.63	569.58	677.21	15.89	84.11

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Based on half-yearly average temperature data following points have been concluded from the year 1978 to the year 2019. Refer to figure no 3.

i. *Ist half-year*

The wettest decade was the year 1998-2007 with 114.88 mm precipitation and the driest decade was the year 2008-2019 with 102.69 mm precipitation. The average maximum precipitation was decreased by 0.85 % in the decade 1988-1997 compared to the year 1978-1987 and increased by 5.80 % in the year 1998-2007 compared to the year 1988-1997 and again decreased by 2.89% in the year 2008-2019 compared to the year 1998-2007. The average precipitation in the year 2008-2019 were 2.91%, and 2.06% higher than the year 1988-1997, and the year 1978-1987 respectively. The average precipitation from the year 1978 to the year 2019, was 107.63 mm.

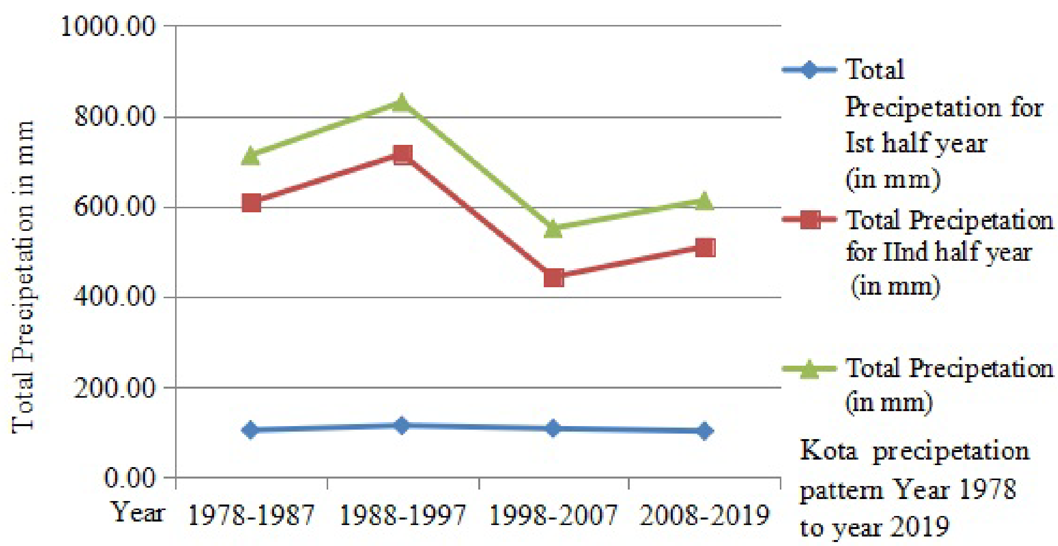


Fig. 3: Total precipitation with half-yearly precipitation graph for the year 1978-2019

ii. *IInd half-year*

The wettest decade was the year 1988-1997 with 715.82 mm precipitation and the driest decade was the year 1998-2007 with 443.31 mm precipitation. The average maximum precipitation was increased by 0.85 % in the year 1988-1997 compared from the year 1978-1987 and decreased by 5.80 % in the year 1998-2007 compared to the year 1988-1997 and again increased by 2.89% in the year 2008-2019 compared to the year 1998-2007. The average precipitation in the year 2008-2019 were 2.06% and 2.91% decreased compared to the year 1978-1987 and the year 1988-1997 respectively and 2.89% higher compared to the year 1998-2007. The average precipitation from the year 1978 to the year 2019 was 569.58 mm.

The decade 1988-1997 was recorded the highest precipitation with the average 830.70 mm and decade 1998-2007 was recorded with minimum precipitation of 551.60 mm.

f) *Temperature data*

Based on data it observed that the average maximum temperature was decreased in decade 1998-2007 for January to March, May, and June and again increased in the decade 2008-2019. The maximum temperature was increased throughout from the year 1978 to the year 2019 for April, November, and December. The average minimum temperature was increased from the year 1978 to the year 2019 for January, July, November, and December. The minimum temperature was increased from the year 1978 to the year 1997 and decreased in the year 2008-2019 for February, March, and October.

The yearly average maximum and minimum temperature data has prepared and given in table 9, showing that the year 1998-2007 were received maximum temp with 34.80°C and the year 2008-2019 were the lowest maximum temp 34.28°C. The average minimum temperature was maximum in the year 2008-2019 and the lowest were in the year 1988-1997 with 12.29°C, and 10.21°C, respectively. Further it shown that average minimum temperature was increased rapidly, the year 2008-2019 was recorded 1.44°C & 2.08°C temperature higher than the average temperature of the year 1978-1987, and the year 1988-1997, respectively. The average maximum temperature were decreased in the year 2008-2019 with 0.28°C, and 0.52°C compared to the year 1978-1987 and the year 1998-2007, respectively. The Graphical presentation of average maximum and minimum temperature is being given in figure 4.

Table 9: The yearly average temperature data from the year 1978 to the year 2019

The Year	Average Maximum Temp (in°C)	Average Minimum Temp. (in°C)
1978-87	34.56	10.85
1988-97	34.37	10.21
1998-2007	34.80	10.98
2008-2019	34.28	12.29

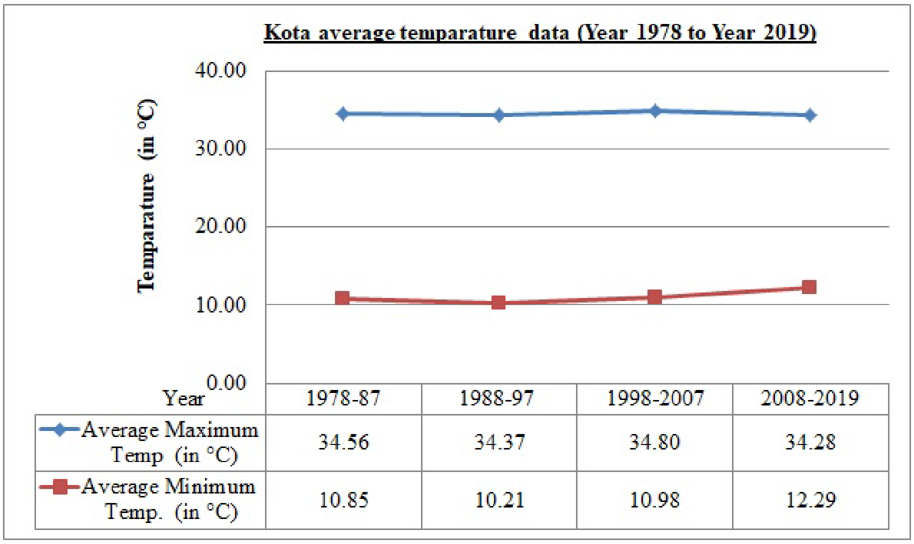


Fig 4: Kota average temperature data from the year 1978 to the year 2019

Table 10: Ist half-yearaverage Maximum and minimum temperature data for the year 1978- 2019

The Year	Average Maximum Temp (in°C)	Average Minimum Temp. (in°C)	Half-yearly	Temperature Variation (in°C) from last decades	
1978-1987	34.65	8.97	Ist Half-yearly	max	min
1988-1997	34.68	8.09		0.03	-0.88
1998- 2007	35.48	9.02		0.80	0.94
2008-2019	34.91	10.31		-0.57	1.29

Table 11: IInd half-yearaverage Maximum and minimum temperature data for the year 1978- 2019

The Year	Average Maximum Temp (in°C)	Average Minimum Temp. (in°C)	Half-yearly	Temperature Variation (in°C) from last decades	
1978-1987	34.47	12.74	IInd Half-yearly	max	min
1988-1997	34.06	12.34		-0.40	-0.39
1998- 2007	34.12	12.94		0.05	0.59
2008-2019	33.65	14.26		-0.47	1.32

Based on half-yearly average temperature data following point have concluded for the year 1978-2019:

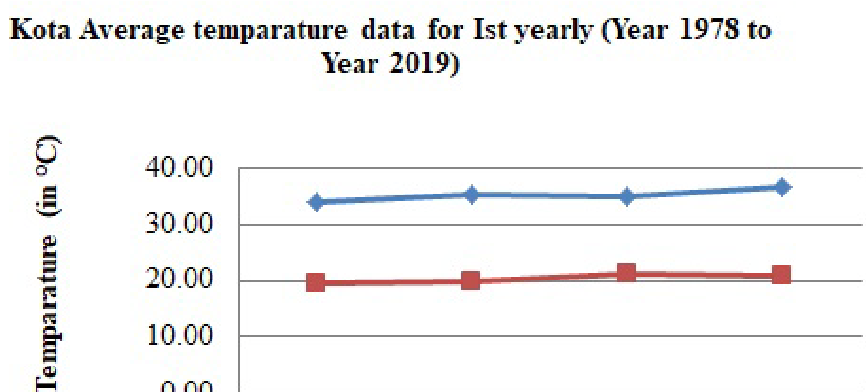
i. *Ist Half-yearly*

The average maximum temperature of 35.48°C was recorded in the decade 1998-2007 and the average minimum temperature of 8.09°C was recorded in the decade 1988-1997. The average maximum temperature in decade 2008-2019 was increased by 0.26°C compared to the year 1978-1987 and decreased by 0.57°C compared to the year 1998-2007. The average minimum temperature in the year 2008-2019 was increased by 1.35°C and 2.23°C compared to the year 1978-1987 and the year 1998-2007.

ii. *IInd Half yearly*

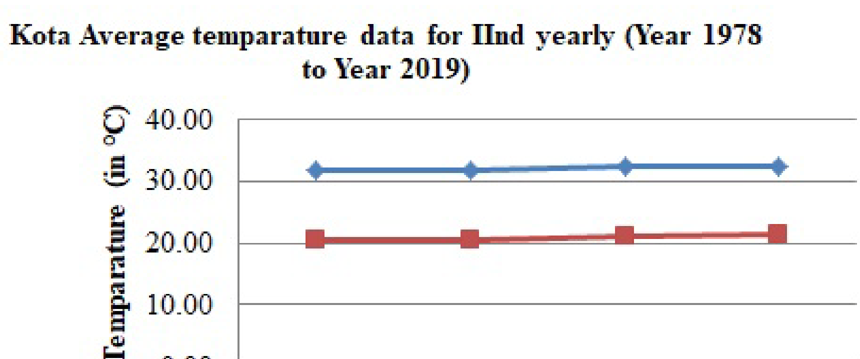
The average maximum temperature was recorded 34.47°C in the decade 1978-1987, and the average minimum temperature of 12.34°C was recorded in the decade 1988-1997. The average maximum temperature was decreased by 0.40°C from the decade 1978-1987 to the decade 1988-1997 after that increased by 0.05°C in the year 1998-2007 and finally decreased in the year 2008-2019 by 0.47°C temperature. For the year 1978-1987 to the year 1988-1997, the average minimum temperature was decreased by 0.39°C after that increased by 0.59°C and 1.32°C for the year 1998 -2007 and the year 2008- 2019, compared to last period the year 1988-1997 and the year 1998-2007 respectively. The average maximum temperature was in the year 2008-2019 increased by 0.82°C compared to the year 1978-1987 and decreased by 0.41°C compared to the year 1988-1997. The average minimum temperature in decade 2008-2019 was increased by 1.53°C and 0.41°C, compared to the year 1978-1987 and the year 1988-1997.

Based on table 10 & 11 data, a line diagram has been prepared shown in fig 5 & 6; and concluded that the average maximum temperature was decreased continuously but the minimum temperature in increasing trend.



Year	1978-1987	1988-1997	1998-2007	2008-2019
Average Maximum Temp (in °C)	34.00	35.20	35.02	36.58
Average Minimum Temp. (in °C)	19.58	19.89	21.28	20.70

Fig. 5: Kota average temperature data for Ist half-year1978- 2019



Year	1978-1987	1988-1997	1998-2007	2008-2019
Average Maximum Temp (in °C)	31.69	31.65	32.45	32.47
Average Minimum Temp. (in °C)	20.35	20.37	21.19	21.42

Fig. 6: Kota average temperature data for IInd half-year1978-2019

IV. Discussion

After the individual interpretation of data, needs to be done overall correlation of studied data to predict the future climatic condition. For best correlation of data, we should find out the percentage variation from last time decades. Stepwise data have given below:

Table 12: Kota Solar Radiation percentage variation from last decades

The Year	Mean radiation for Ist half-year (W/m2)	Mean radiation for IInd half-year (W/m2)	Mean yearly radiation in (W/m2)	Percentage variation from last decade Ist half year	Percentage variation from last decade IInd half year	Percentage variation from last decade (yearly)
1988-1997	6244.65	4561.15	5402.90			
1998- 2007	6237.14	4833.11	5535.12	-0.120	5.962	2.447
2008-2019	6227.02	4454.78	5340.90	-0.162	-7.828	-3.509

Table 13: Kota atmospheric pressure percentage variation from last decades

The Year	Mean Pressure for Ist half-year (in hPa)	Mean Pressure for IInd half-year(in hPa)	Mean Pressure (in hPa)	Percentage variation from last decade Ist half-year	Percentage variation from last decade IInd half-year	Percentage variation from last decade (yearly)
1988-1997	1007.34	1007.45	1007.40			
1998- 2007	1007.53	1007.53	1007.53	0.019	0.008	0.013
2008-2019	1007.69	1008.43	1008.06	0.016	0.089	0.053

Table 14: Maximum observed wind event direction with speed the yearly, Ist half and IInd half-yearly

Items	1978-1987			1988-1997			1998-2007			2008-2019		
	The Yearly	Ist half	IInd half	The Yearly	Ist half	IInd half	The Yearly	Ist half	IInd half	The Yearly	Ist half	IInd half
MWD	NW	NW	NE	W	NW	W	W	N	SW	WSW	W	WSW
HWES	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	5--10	5--10	0-5

HWES: Highest Wind Event Speed

Table 15: Kota precipitation percentage variation from last decades

The Year	Average Precipitation for Ist half-year	Average Precipitation for IInd half-year	Average yearly Precipitation (in mm)	Percentage variation from last decade Ist half-year	Percentage variation from last decade IInd half-year	Percentage variation from last decade (yearly)
1978-1987	104.67	608.50	713.17			
1988-1997	114.88	715.82	830.70	9.75	17.64	16.48
1998-2007	108.29	443.31	551.60	-5.74	-38.07	-33.60
2008-2019	102.69	510.68	613.38	-5.17	15.20	11.20

Table 16: Kota the yearly percentage temperature variation from last decades

The Year	Average Maximum Temp (in°C)	Average Minimum Temp. (in°C)	Average Maxi. Temp. Percentage variation from last decade	Average Mini. Temp. Percentage variation from last decade
1978-87	32.85	19.97		
1988-97	33.43	20.13	1.76	0.82
1998-2007	33.73	21.23	0.92	5.49
2008-2019	34.52	21.06	2.34	-0.82

Table 17: Kota Ist half-year percentage temperature variation from last decades

Ist half-year	Average Maximum Temp (in°C)	Average Minimum Temp. (in°C)	Average Maxi. Temp. Percentage variation from last decade	Average Mini. Temp. Percentage variation from last decade
1978-1987	34.00	19.58		
1988-1997	35.20	19.89	3.52	1.56
1998- 2007	35.02	21.28	-0.52	7.01
2008-2019	36.58	20.70	4.45	-2.73

Table 18: Kota IInd half-year percentage temperature variation from last decades

IInd half-year	Average Maximum Temp (in°C)	Average Minimum Temp. (in°C)	Average Maxi. Temp. Percentage variation from last decade	Average Mini. Temp. Percentage variation from last decade
1978-1987	31.69	20.35		
1988-1997	31.65	20.37	-0.14	0.11
1998- 2007	32.45	21.19	2.53	4.01
2008-2019	32.47	21.42	0.07	1.09

a) Overall Data Interpretation and Future Climatic Condition

It is observed that the average solar radiation decreased by 1.15%, 0.28%, and 2.33% for the yearly, Ist half and IInd half-year compared between the year 1988-1997 to the year 2008-2019. The atmospheric pressure has increased by 0.066%, 0.035%, and 0.097% in the yearly, Ist half and IInd half-year respectively. The precipitation has decreased by 26.16 % the yearly, 10.61 %, and 28.66% in the yearly, Ist half and IInd half-year, respectively. The maximum and minimum temperature was increased by 3.29% and 4.62% from the year 1988-1997 to the year 2008-2019. The Ist half and IInd half-year average maximum and minimum temperature was increased by 3.91% & 4.09%, and 4.04% & 5.14%, respectively.

The expected average Solar radiation for the decade 2051-2060 would be 5279.59 W/m^2, 6209.46 W/m^2, and 4350.89 W/m^2 for the yearly, Ist half, and IInd half-year, respectively. The expected atmospheric pressure would be increased by 0.67 hPa, 0.35 hPa, and 0.98 hPa and reached by 1008.73 hPa, 1008.04 hPa, and 1009.41 hPa for the yearly, Ist half and IInd half-year, respectively. The average precipitation would be 452.92 mm, 91.80 mm, and 364.32 mm for the yearly, Ist half-year and IInd half-year, respectively.

The maximum and minimum temperature for the decade 2051-2060 would be increased by 1.14°C & 0.97°C for the yearly and reached by 35.66°C & 22.03°C. For the Ist half-year average maximum temperature would be increased by 1.43°C, and reached by 38.01°C and the average minimum temperature would be increased by 0.85°C and reached by 21.55°C. For the IInd half-year, the average maximum and minimum temperature would be increased by 1.31°C and 1.10°C and reached by 33.79°C & 22.52°C, respectively.

Table 19: Expected climatic condition in the year 2051-2060

Factors	The Yearly Comparison between the year 1988-97 to the year 2008-2019 (in percentage)	Ist half-year Comparison between the year 1988-97 to the year 2008-2019 (in percentage)	IInd half-year Comparison between the year 1988-97 to the year 2008-2019 (in percentage)
Solar Radiation	(-1.15)	(-0.28)	(-2.33)
Atmospheric pressure	0.066	0.035	0.097
Precipitation	-26.16	-10.61	-28.66
Temperature (Avg Maxi. Temp /Avg. Min. temp.)	3.29/4.62	3.91/4.09	4.04/5.14
Expected in next three decade (The Year 2051-2060)			
Solar Radiation (in W/m2)	5279.59	6209.46	4350.89
Atmospheric pressure (in hPa)	1008.73	1008.04	1009.41
Precipitation (mm)	452.92	91.80	364.32
Temperature (°C) (Avg Maxi. Temp /Avg. Min. temp.)	35.66/22.03	38.01/21.55	33.79/22.52

V. Conclusions and Suggestions

In the present synthesis of available data and analysis, it observed that the average solar radiation and precipitation pattern have decreased during the past 32 the years (the year 1988-2019). The atmospheric pressure and mean temperature have increased during the past 32 the years. Due to changes in atmospheric pressure, wind events and intensity of extreme wind events have decreased from the decade1978-1987 to the decade 2008-2019. The speed of extreme wind events decreased from 95-100km/h in the decade 1978-1987 to 25-30 km/h in the decade 2008-2019. The wind calm events were increased from the year 1978 to 2007 but decreased in the year 2008 to 2019.The precipitation received in Ist half-year has increased concerning the total precipitation.

The above interpretation, it is indicating that variation in wind flow happened due a change in atmospheric pressure. The continued variation in atmospheric pressure indicates that the thickness of atmosphere is decreasing at Kota due to present climate change. It also seems that the arid winds are moving towards Kota and increasing the temperature, decrease the precipitation with more calm winds. The change in wind flow and increase in minimum temperature may increase the probability of Hydro-meteorological disasters.

It is observed that the highest winds events direction might shift towards West and South direction and causing the hot and humid weather with the decrease in precipitation. Extreme wind events have increased as well as calm wind events have increased.

It is predicted that the confluence zone of the Heddle Cell and mid-latitude Cell is shifting/fluctuating towards the equator, and the confluence zone is receiving the maximum calm wind events and extreme weather conditions. It is also possible that during the Ist half-year, the Heddle Cell may move more towards the North and due to it, more precipitation received in Ist half-year and high temperature/extreme summer. The Mid-latitude cell moves towards the equator during IInd half the year, which is cold and dry, decreasing the precipitation and temperature. But the yearly impact of these winds shows a decrease in the precipitation, increase in the temperature and calm winds, variation in wind events, and frequency of extreme weather events will be increased. We can take pre-disaster mitigation measures for hazard-prone areas and identify the new prone-area. Public awareness, disaster prediction, hazard mitigation structures, and communication methods would be helpful for saving the ecosystem.

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