Meteorological Factors and Climate Change: A Case Study of North West India

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Abstract

In the last three decades, India has been facing the extreme weather conditions 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. To understand the impact and trend of meteorological factor such as solar radiation, atmospheric pressure, precipitation, wind speed & wind direction and temperature, on extreme climatic conditions in North West (NW) India, considered the confluence area of Hedley and tropical wind, that falling between 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. Accordingly, selected the three nearby best locations, first location Kota, Rajasthan at latitude 25.2138° N; Second Amritsar, Punjab at 31.6340° N latitude; and last Leh, Ladak at latitude 34.1526° N. After the detailed data interpretation, it is observed that the solar radiations are decreasing for all three locations but Atmospheric pressure at higher latitude is increasing and decreasing at lower latitude. It is also observed that the highest winds events direction is shifting towards West and South direction and causing the hot and humid weather with decrease in precipitation. Based on research data outcomes, mentioned the correlation between the meteorological factors and predicted the future climatic condition for the next three decades years 2051-2060, which would be helpful in mitigation and landuse plan from the impact of extreme climatic conditions over NW India.

Keywords: *Extreme weather condition, solar radiation, atmospheric pressure, wind events, temperature, precipitation.*

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1. Introduction

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. The extreme weather condition involves high precipitation, extreme summer, heat wave, cold wave, cyclone, etc.

To better understand the role of meteorological and associated climatic factors in North-Western India, selected the confluence area of Hedley and tropical wind. That falling between 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. Accordingly, we have selected the three nearby best locations that situated between the buffer zone. First location at latitude 25.2138° N, 75.8648°E, Kota, Rajasthan; wet summers and dry winters. Savanna and Monsoon type of vegetation. Second is at latitude 31.6340° N, 74.8723° E, Amritsar, Punjab; having summers are short, sweltering, humid, and clear and the winters are short, cold, dry, and mostly clear and last at latitude 34.1526° N, 77.5771° E, Leh, Ladak; having cold desert climate with long, cold winters from late November to early March, with minimum temperatures well below freezing for most of the winter. Studying of these areas, we could predict the meteorological disparities on global scale. On the basis of meteorological factors in proposed research, will predict the future climatic condition. The outcomes would be helpful for human society to take the precautionary measure from extreme climatic condition in India as well as other part of world.

1.1 Previous Studies

Climate variability is amongst the major phenomenon occurring worldwide which has caused major changes in climate variables (Haskett et al., 2000; Bates et al., 2008; Yu et al., 2013).

For understand the causes and impact of climate change and extreme weather condition, The United Nations Environment Program (UNEP) and the World Meteorological Organization (WMO) had established. The Intergovernmental Panel on Climate Change (IPCC) in year 1988 for provide policymakers with regular scientific

assessments on the current state of knowledge about climate change and potential response strategic and elements for inclusion in a possible future international convention on climate.

Kodera, 1991; Rind & Balchandran, 1995 had suggested 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 longwave 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 extra tropics. (NRC, 1994).

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; Frich et 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)on variation in temp & precipitation patterns during extreme weather conditions and the impact of climate change on it. Frich et 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 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 heatwave 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.

Some researchers such as 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; have investigated and suggested the multidecadal variation in the solar irradiance as a possible cause. 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).

Ministry of Earth Science Govt of India has studied the Assessment of Climate Change Over the Indian Region (2020) and observed that 0.7°C temperature has raised during year 1901 to 2018 and projected that 4.4° C temperature would be raised by year 2100 in India. Summer monsoon has declined by 6% from year 1951 to 2015 and 27% higher dry spells during year 1981 to 2011 relative to year 1951-1980. Frequency of localized rainfall has increased with daily extreme rainfall. They also mentioned that frequency of very sever cyclone storms during the post monsoon seasons has increased significantly during the last two decades and projected that increase in future.

2. Objective And Methodology

Considering the above natural phenomena, it seems that meteorological factors affecting the extreme weather condition; and considering this point, proposed to find out the role of meteorological factors in extreme weather conditions at NW India. The Role of meteorological factors have been observed and analyzed by the study the last three-decade solar variation data, atmospheric pressure data, and study the last four-decade wind pattern, precipitation pattern, and daily average temperature.

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 balanced from the internet (www.meteoblue.com, https://www.indiawaterportal.org and https://www.weatheronline.in).

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 are 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. This research work will help to open a new way to study the extremes climatic condition basis on atmospheric and solar disparities.

3. DISCUSSION

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

3.1 Solar Radiation

Table 1: Kota Solar Radiation Percentage Variation from Last Decades

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

As per table no 1, the yearly Kota Solar Radiation were 2.447% higher in year 1998-2007 compared to last decade year 1988-1997 and decreased by 3.509% in year 2008-2019 compared to year 1998-2007 and 1.148% lower than year 1988-1997.

Kota Solar Radiation were continue decreased from year 1988-1997 to year 2007-2019 in Ist half year and for IInd half yearly, Solar Radiation were followed the yearly trend; increased by 5.962% in year 1998-2007 compared to year 1988-1997 and decreased by 7.828% in year 2008-2019 compared to year 1998-2007.

Table 2: Amritsar Solar Radiation Percentage Variation from Last Decades

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	5612.67	5085.49	5349.08			
1998-2007	5774.69	5230.96	5502.82	2.887	2.861	2.874
2008-2019	5640.70	5101.59	5371.15	-2.320	-2.473	-2.393

As per table no 2, Amritsar yearly Solar Radiation were 2.874% higher in year 1998-2007 compared to last decade year 1988-1997 but decreased by 2.393% in year 2008-2019 compared to year 1998-2007.

Amritsar Solar Radiation for Ist and IInd half year have followed the yearly Solar Radiation, year 1998-2007 received highest Solar Radiation and year 2008-2019 received lowest Solar Radiation. Solar radiation was increased by 2.887% and 2.861% in year 1998-2007 for the Ist half year and decreased by 2.32% and 2.473% in year 2008-2019 compared to year 1998-2007 for IInd half yearly respectively.

Table 3: Leh Solar Radiation Percentage Variation from Last Decades

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	6023.57	5660.74	5842.15			
1998-2007	6066.61	5629.43	5848.02	0.715	-0.553	0.100
2008-2019	5979.82	5577.16	5778.49	-1.431	-0.928	-1.189

As per table no 3, Leh Solar Radiation was 0.10% higher in year 1998-2007 compared to last decade year 1988-1997 but decreased by 1.189% in year 2008-2019 compared to year 1998-2007.

Leh Solar Radiation were increased by 0.715% in year 1998-2007 compared to year 1988-1997 and decreased by 1.431% in year 2008-2019 compared to year 1998-2007 in Ist half year and IInd half yearly Solar Radiation were decreased continuously by 0.553% and 0.928% in year 1998-2007 and year 2008-2019 compared to respective last decade for year 1988-1997 and year 1998-2007 respectively.

3.2 Atmospheric Pressure

Table 4: Kota Atmospheric Pressure Percentage Variation from Last Decades

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

As per table no 4, Kota atmospheric pressure were continue increased by 0.013% and 0.053% in year 1998-2007 and year 2008-2019 respectively compared to last decade year 1988-1997 and year 1998-2007 respectively.

Kota atmospheric pressure were continue increased from year 1988-1997 to year 2007-2019 in Ist half year and IInd half yearly. Atmospheric Pressure has followed the yearly trend, increased by 0.019% and 0.016% in year 1998-2007 and year 2008-2019 compared to respective last decade year 1988-1997 and year 1998-2007 for Ist half year. For IInd half year increased by 0.008% and 0.089% in year 1998-2007 and year 2008-2019 compared to respective last decade year 1988-1997 and year 1998-2007.

Table 5: Amritsar Atmospheric Pressure Percentage Variation from Last Decades

Year	Mean Pressure for January-June (in hPa)	Mean Pressure for July-December (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	1007.68	1006.86	1007.27			
1998-2007	1007.55	1006.96	1007.25	-0.014	0.010	-0.002
2008-2019	1007.98	1007.13	1007.56	0.043	0.017	0.030

As per table no 5, Amritsar atmospheric pressure was decreased by 0.002% in year 1998-2007 compared to year 1988-1997 and increased by 0.03% in year 2008-2019 compared to year 1998-2007.

Amritsar atmospheric pressure was decreased by 0.014% in year 1998-2007 compared to year 1988-1997 and increased by 0.043% in year 2008-2019 in Ist half year and IInd half yearly atmospheric pressure was increased by 0.010% and 0.017% in year 1998-2007 and year 2008-2019 compared to respective last decade year 1988-1997 and year 1998-2007 for Ist half year.

Table 6: Leh Atmospheric Pressure Percentage Variation from Last Decades

Year	Mean Pressure for Ist half year (in hPa)	Mean Pressure for IInd half year (in hPa)	Mean Yearly 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	1026.92	1020.22	1023.57			
1998-2007	1025.49	1019.59	1022.54	-0.139	-0.061	-0.100
2008-2019	1024.87	1017.89	1021.38	-0.060	-0.167	-0.113

As per table no 6, Leh atmospheric pressure were decreased continuously by 0.10% in year 1998-2007 compared to year 1988-1997 and 0.113% in year 2008-2019 compared to year 1998-2007.

Leh atmospheric pressure was decreased by 0.139% in year 1998-2007 compared to year 1988-1997 and decreased by 0.060% in year 2008-2019 in Ist half year and IInd half yearly atmospheric pressure was decreased by 0.061% and 0.167% in year 1998-2007 and year 2008-2019 compared to respective last decade year 1988-1997 and year 1998-2007.

3.3 Wind Data

Table 7: Maximum Observed Wind Event Direction with Speed Yearly, Ist Half and IInd Half Yearly

Location	Items	1978-1987			1988-1997			1998-2007			2008-2019		
		Yearly	Ist half	IInd half	Yearly	Ist half	IInd half	Yearly	Ist half	IInd half	Yearly	Ist half	IInd half
Kota	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
Amritsar	MWD	W	NW	W	NW	NW	E	NW	W	NW	W	W	W
	HWES	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5
Leh	MWD	W	W	W	E	E	WNW	WNW	E	WNW	WNW	E	WNW
	HWES	0-5	0-5	0-5	5—10	5—10	5--10	5--10	5--10	5--10	5--10	5--10	5--10
		Note: MWD:- Max Wind Direction						HWES: Highest Wind Event Speed					

As per table no 7, Kota it is observed that average maximum wind events vary from NW -W- W- WSW direction from year 1978-87, year 1988-1997, year 1998-2007 to year 2008-2019 respectively. Average yearly and Ist half yearly, maximum wind speed event increased from 0-5 km/h to 5-10 km/h in year 2008-2019 comparative from year 1978 to year 2007.

As per table no 7, Amritsar it is observed that average maximum wind events vary from W- NW -NW- W direction from year 1978-87, year 1988-1997, year 1998-2007 to year 2008-2019 respectively.

As per table no 7, Leh it is observed that average maximum wind events vary from W- E -WNW- WNW direction from year 1978-87, year 1988-1997, year 1998-2007 to year 2008-2019 respectively. Average wind speed event increased from 0-5 km/h to 5-10 km/h from year 1988-1997 to year 2008-2019.

3.4 Precipitation

Table 8: Kota Precipitation Percentage Variation from Last Decades

Year	Average Precipitation for Ist half (in mm)	Average Precipitation for IInd half (in mm)	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

As per table no 8, Kota were observed the increase in yearly precipitation by 16.48% in year 1988-97 from year 1978-87. Later on the yearly precipitation was decreased by 33.60% in year 1998-2007 and again increased yearly precipitation was increased by 11.20% from last decade in year 2008-19. It is also observed that precipitation percentage in Ist half year is in decreasing trend from year 1988-1997. It is also observed that maximum precipitation was received in year 1988-1997 and minimum in year 1998-2007.

Table 9: Amritsar Precipitation Percentage Variation from Last Decades

Year	Average Precipitation for Ist half (in mm)	Average Precipitation for IInd half (in mm)	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	167.39	454.62	622.01			
1988-1997	167.51	404.36	571.87	0.07	-11.05	-8.06
1998-2007	123.98	312.24	436.23	-25.98	-22.78	-23.72
2008-2019	243.61	385.44	629.05	96.49	23.44	44.20

As per table no 9, Amritsar were observed the decrease in yearly precipitation by 8.06% and 23.72% in year 1988-97 and year 1998-2007 compared to respective last decade. Later on the yearly precipitation were increased by 44.20% in year 2008-2019 from last decade in year 1998-2007. It is also observed that precipitation percentage in Ist half year were decreased by 25.98% in year 1998-2007, but next decade year 2008-2019 observed 96.49% higher than last decade year 1998-2007. For IInd half year, decreasing trend were observed by 11.05% and 22.78% in year1988-1997 and year 1998-2007 compared to respective last decade year. The average precipitation was increased by 23.44% in year 2008-2019 compared to last decade year. The maximum precipitation was received in year 2008-2019 and minimum in year 1998-2007.

Table 10: Leh Precipitation Percentage Variation from Last Decades

Year	Average Precipitation for Ist half (in mm)	Average Precipitation for IInd half (in mm)	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	138.88	141.52	280.39			
1988-1997	179.02	126.65	305.68	28.91	-10.50	9.02
1998-2007	115.75	72.63	188.38	-35.34	-42.66	-38.37
2008-2019	83.14	28.23	111.37	-28.17	-61.14	-40.88

As per table no 10, Leh were observed the decrease in yearly precipitation by 38.37% and 40.88% in year 1998-2007 and year 2008-2019 compared to respective last decade. It is also observed that precipitation percentage in Ist half year were increased by 28.91% in year 1988-1997 compared to last decade year 1978-1987 after that decreased by 35.34% and 28.17% in year 1998-2007 and year 2008-2019. For IInd half year, decreasing trend were observed by 10.50%, 42.66% and 61.14% in year 1988-1997, year 1998-2007 and year 2008-2019 compared to respective last decade. The maximum precipitation was received in year 1988-1997 and minimum in year 2008-2019 and continue decreasing trend were observed in Leh and Ist half receiving the more yearly precipitation from year 1988-1997 to year 2008-2019.

3.5 Temperature Data

Table 11: Kota Average Temperature Variation from Last Decades.

Year	Yearly average Maximum/ Minimum temp (in °C)	Ist half-yearly average Maximum/ Minimum temp (in °C)	IInd half-yearly average Maximum/ Minimum temp (in °C)	Yearly average Maxi./ min Temp. Percentage variation from last decade	Ist half yearly average Maxi./ min Temp. Percentage variation from last decade	IInd half yearly average Maxi./ min Temp. Percentage variation from last decade
1978-1987	32.85/19.97	34.00/19.58	31.69/20.35			
1988-1997	33.43/20.13	35.20/19.89	31.65/20.37	1.76/0.82	3.52/1.56	(-0.14)/0.11
1998-2007	33.73/21.23	35.02/21.28	32.45/21.19	0.92/5.49	(-0.52)/7.01	2.53/4.01
2008-2019	34.52/21.06	36.58/20.70	32.47/21.42	2.34/-0.82	4.45/(-2.73)	0.07/1.09

Table 11 is showing the Kota average maximum and minimum temperature variation for study period. The average maximum temperature has continue increased by 1.76%, 0.92% and 2.34% in year 1988-1997, year 1998-2007 and year 2008-2019 from respective previous decade year. The average minimum temperature was increased from year 1978 to year 2007 by 0.82% and 5.49% in year 1988-1997 and year 1998-2007 compared to previous year 1978-1987 and year 1988-1997.

For the Ist half yearly the average maximum temperature has increased by 3.52% in year 1988-1997 compare to last decade year 1978-1987. Then decreased by 0.52% in year 1998-2007 compare to last decade year 1988-1997 and aging increased by 4.45% in year 2008-2019 from previous decade. The average minimum temperature was increased from year 1978 to year 2007 by 1.56% and 7.01% in year 1988-1997 and year 1998-2007 compared to previous year 1978-1987 and year 1988-1997. But 2.73% average minimum temperature was decreased in year 2008-2019 compared to previous year.

For the IInd half yearly the average maximum temperature was decreased by 0.14% in year 1988-1997 compare to last decade year 1978-1987. Then increased by 2.53% and 0.07% in year 1998-2007 and year 2008-2019 compare to last decade. The average minimum temperature was increased throughout the study period from year 1978 to year 2019 by 0.11%, 4.01% and 1.09% in year 1988-1997, year 1998-2007 and year 2008-2019 compared to previous year.

Table 12: Amritsar average temperature variation from last decades.

Year	Yearly average Maximum/ Minimum temp (in °C)	Ist half-yearly average Maximum/ Minimum temp (in °C)	IInd half-yearly average Maximum/ Minimum temp (in °C)	Yearly average Maxi./ min Temp. Percentage variation from last decade	Ist half yearly average Maxi./ min Temp. Percentage variation from last decade	IInd half yearly average Maxi./ min Temp. Percentage variation from last decade
1978-1987	34.56/10.85	34.65/8.97	34.47/12.74			
1988-1997	34.37/10.21	34.68/8.09	34.06/12.34	(-0.54/-5.86)	0.10/(-9.82)	(-1.18/-3.08)
1998-2007	34.80/10.98	35.48/9.02	34.12/12.94	1.24/7.50	2.30/11/61	0.16/4.81
2008-2019	34.28/12.29	34.91/10.31	33.65/14.26	(-1.48)/11.90	(-1.60)/14.30	(-1.36)/10.23

Table 12 is showing the Amritsar average maximum and minimum temperature variation for study period. The average maximum temperature was decreased by 0.54% in year 1988-1997 compared to previous decade year. After that increased 1.24% and decreased by 1.48% in year 1998-2007 and year 2008-2019 from respective previous decade year. The average minimum temperature was decreased in year 1988-1997 compared to previous decade year 1978-1987 by 5.86%. After that minimum temperature were increased by 7.50% and 11.90% in year 1998-2007 and year 2008-2019 compared to previous year.

For the Ist half yearly the average maximum temperature was increased by 0.10% and 2.30% in year 1988-1997 and year 1998-2007 compare to last decade year. Then decreased by 1.60% in year 2008-2019 compare to last decade year 1998-2007. The average minimum temperature was decreased for year 1988-1997 by 9.82% compared to previous year 1978-1987. Then increased by 11.61% and 14.30% in year 1998-2007 and year 2008-2019 compared to previous decade.

For the IInd half yearly the average maximum temperature was decreased by 1.18% in year 1988-1997 compare to last decade year. Then increased by 0.16% in year 1998-2007 compare to last decade year 1988-1997 and again decreased by 1.36% in year 2008-2019 compared to year 1988-2019. The average minimum temperature was decreased by 3.08% in year 1988-1997 compare to last decade year. After that temperate increased from year 1998-2007 to year 2008-2019 by 4.81% and 10.23% in year 1998-2007 and year 2008-2019 compared to previous year.

Table 13: Leh average temperature variation from last decades.

Year	Yearly average Maximum/ Minimum temp (in °C)	Ist half-yearly average Maximum/ Minimum temp (in °C)	IInd half-yearly average Maximum/ Minimum temp (in °C)	Yearly average Maxi./ min Temp. Percentage variation from last decade	Ist half yearly average Maxi./ min Temp. Percentage variation from last decade	Iind half yearly average Maxi./ min Temp. Percentage variation from last decade
1978-1987	19.82 (-6.04)	16.88/(-8.90)	22.75/(-3.18)			
1988-1997	11.25/ (-14.58)	7.91/(-19.73)	14.59/(-9.44)	(-43.23/-141.37)	(-53.14/-121.63)	(-35.87/-196.55)
1998-2007	18.91 (-6.26)	16.24/(-9.37)	21.58/(-3.15)	68.12/ 57.08	105.29/ 52.51	47.95/ 66.63
2008-2019	17.23/ (-7.12)	13.54/ (-11.40)	20.91/(-2.83)	(-8.92/-13.71)	(-16.64/-21.75)	(-3.10/ 10.17)

Table 13 is showing the Leh average maximum and minimum temperature variation for study period. The average maximum temperature was decreased by 43.23% in year 1988-1997 compared to previous decade. After that increased 68.12% and decreased by 8.92% in year 1998-2007 and year 2008-2019 from respective previous decade. The average minimum temperature was decreased in year 1988-1997 by 141.37% compared to previous decade year. After that minimum temperature were increased by 57.08% in year 1998-2007 compared to previous decade year 1988-1997 and in year 2008-2019 average minimum temperature were decreased by 13.71 % compared to previous year.

For the Ist half yearly the average maximum temperature was decreased by 53.14% in year 1988-1997 compared to previous decade year. After that increased 105.29% and decreased by 16.64% in year 1998-2007 and year 2008-2019 from respective previous decade year. The average minimum temperature was decreased in year 1988-1997 by 121.63% compared to previous decade year. After that minimum temperature were increased by 52.51% in year 1998-2007 compared to previous decade year 1988-1997 and in year 2008-2019 average minimum temperature were decreased by 21.75 % compared to previous year.

For the IInd half yearly the average maximum temperature was decreased by 35.87% in year 1988-1997 compare to last decade year. Then increased by 47.95% in year 1998-2007 compare to last decade year and again decreased by 3.10% in year 2008-2019. The average minimum temperature was decreased by 196.55% in year 1988-1997. After that temperate increased by 66.63% and 10.17% for year 1998-2007 and year 2008-2019.

4.0 Data Interpretation and Future Climatic Condition

As per above table 1 to 3, it is observed that yearly Solar radiation percentage have decreased for Kota and Leh location and increased for Amritsar but Atmospheric pressure have increased for Kota and Amritsar and decreased for Leh as per table 4 to 6. The wind events and wind directions are variable for each location. The highest wind events have increased for Kota from 0-5 km/h to 5-10 km/h from year 1978 to year 2019 and for Leh highest wind events were increased and observed 5-10km/h in year 1988-2019 compared to 0-5 km/h in year 1978-1987. The wind direction was variable from W-NW to WNW-W-WNW from the year 1978-1987 to year 2008-201 for all the locations. The calm wind events also increased and frequency of High wind events have

increased. On the basis of table 8 to 10 it is observed that year 1998-2007 were received the lowest precipitation for the Kota and Amritsar and year 2008-2019 for the Leh location. The decade 1988 -1997 were observed the wettest decade for all the studied area. It is also observed more precipitation have received in Ist half yearly compared to IInd half yearly for Leh location compared to decade 1978-1987 to decade 2008-2019. Table 11 to 13 showing that average yearly minimum temperature was increased for Kota and Amritsar but decreased at Leh location. For Ist half yearly average maximum and minimum temperature are increased for Kota and Amritsar but decreased for Leh location. For the IInd half year average minimum temperature is increasing for all the three locations and average maximum temperature are decreasing for Amritsar and Leh. The line diagram for comparative data results are given below as figure 1, 2 and 3 for yearly, Ist half and IInd half year.

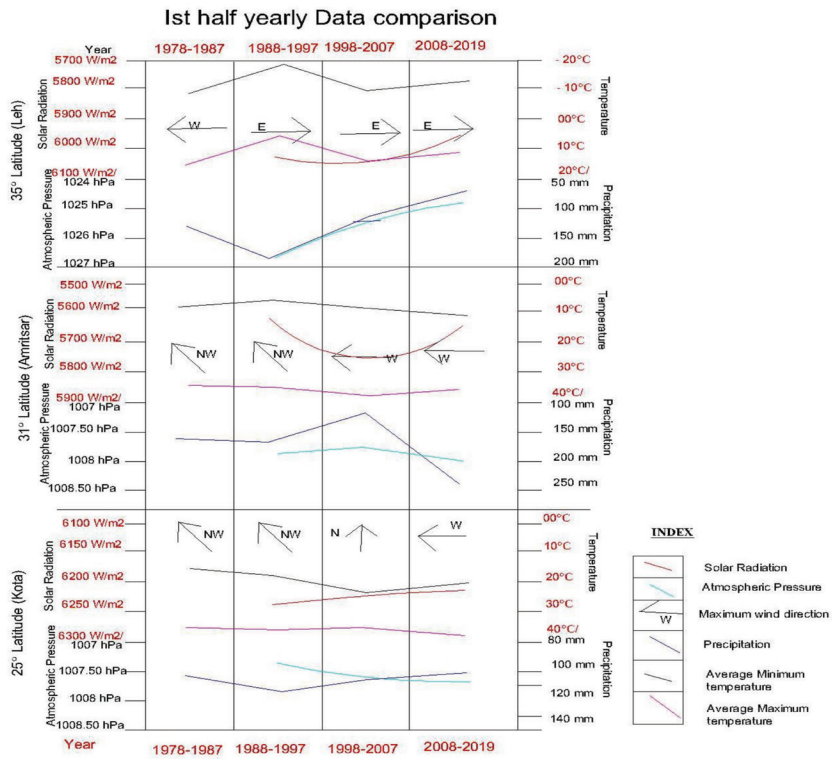

Figure 1: Yearly data comparison shown as line diagram for year 1978 to year 2019.

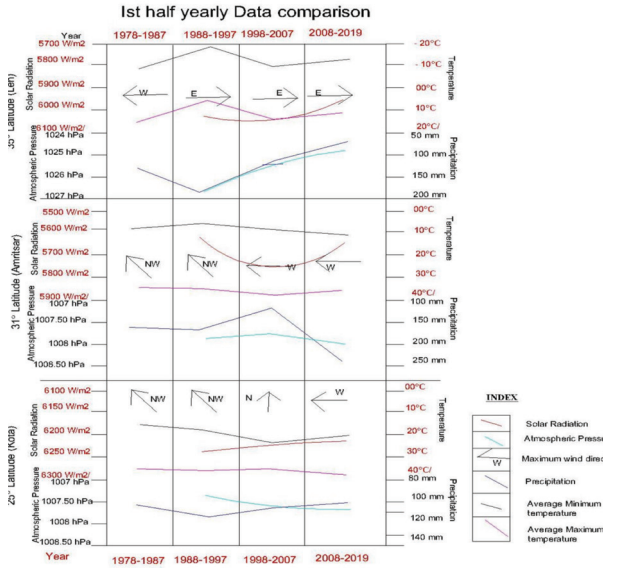

Figure 2: Ist half yearly data comparison shown as line diagram for year 1978 to year 2019.

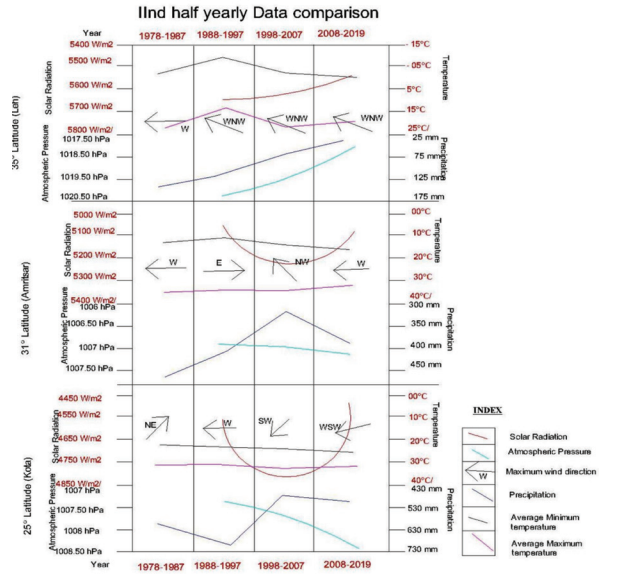

Figure 3: IInd half yearly data comparison shown as line diagram for the year 1978 to year 2019.

On the basis of results outcomes from year 1978 to year 2019, predicted the average Solar Variation, atmospheric pressure, wind events, precipitation and average maximum and minimum temperature for the next third decade (i.e. year 2051-2060) and mentioned in table 14 and bar chart for the same shown in figure 4 for year 2051-2060 with comparative observation for year 1988-2019. These data have discussed below accordingly:

4.1 At 25° N latitude

On the basis of outcomes, predicted the maximum and minimum temperature in year 2051-2060 would be increased by 1.14°C & 0.97°C for 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 average minimum temperature would be increased by 0.85°C and reached by 21.55°C. For the IInd half year 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 14: Location wise weather factor variation with expected factors in next three decade

Location	Factors (in %) Average / Comparison between year 1988-97 to year 2008-2019	Yearly	Ist half Year	IInd half Year
		Average / Comparison between year 1988-97 to year 2008-2019	Average / Comparison between year 1988-97 to year 2008-2019	
25°N latitude	Solar Radiation Avg/(%)	5426.31/(-1.15)	6236.27/(-0.28)	4616.35/(-2.33)
	Atmospheric pressure Avg/(%)	1007.66/0.066	1007.52/0.035	1007.80/0.097
	Precipitation Avg/(%)	665.23/ -26.16	108.62/ -10.61	556.60/ -28.66
	Temperature Avg/(%) (Avg Maxi. Temp /Avg. Min. temp.)	33.89/20.81-3.29/4.62	35.60/20.62/3.91/4.09	32.19/20.994.04/5.14
	Expected in next three decade (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

31°N latitude	Solar Radiation Avg/(%)	5407.68/(-0.41)	5676.02/(-0.50)	5139.35/(-0.32)
	Atmospheric pressure Avg/(%)	1007.36/0.029	1007.74/0.030	1006.98/0.027
	Precipitation Avg/(%)	545.72/10.00	178.37/45.43	367.35/-4.68
	Temperature Avg/(%) (Avg Maxi. Temp/Avg. Min. temp.)	34.48/33.48--/ (0.26)/20.29	35.02/9.14-- / 0.66 /27.56	33.94/13.18--/ (-1.21)/ 15.53
	Expected in next three decade (Year 2051-2060)			
	Solar Radiation (in W/m2)	5373.36	5668.85	5117.76
	Atmospheric pressure (in hPa)	1007.85	1008.28	1007.40
	Precipitation (mm)	691.96	354.28	367.40
	Precipitation (mm)	691.96	354.28	367.40
	Temperature (°C) (Avg Maxi. Temp /Avg. Min. temp.)	34.18/14.78	35.18/11.87	32.85/15.97
35°N latitude	Solar Radiation	5822.89/(-1.09)	6023.33/(-0.73)	5622.44/(-1.48)
	Atmospheric pressure Avg/(%)	1022.50/(-0.214)	1025.76/(-0.199)	1019.23 (-0.228)
	Precipitation Avg/(%)	224.25/(-63.57)	125.97/(-53.56)	75.84/(-77.71)
	Temperature Avg/(%) (Avg Maxi. Temp /Avg. Min. temp.)	15.80/ (-9.32)--(53.13 /(-51.20))	12.56/ (-13.50)--(71.13/ (-42.19))	19.03/ (-5.14)--(43.37 / (-70.02))
	Expected in next three decade (Year 2051-2060)			
	Solar Radiation (in W/m2)	5766.13	5967.92	5564.45
	Atmospheric pressure (in hPa)	1019.2	1022.84	1015.57
	Precipitation (mm)	40.57	38.61	6.29
	Temperature (°C) (Avg Maxi. Temp /Avg. Min. temp.)	26.38/(-3.47)	23.17/(-6.59)	29.98/(-0.85)

4.2 At 31° N latitude

On the basis of outcomes, predicted the maximum and minimum temperature in year 2051-2060 would be decreased by 0.10°C & increased by 2.49°C for yearly and reached by 34.18°C& 14.78°C. For the Ist half year average maximum and minimum temperature would be increased by 0.23°C & 2.84°C and reached by 35.18°C and 11.87°C respectively. For the IInd half year average maximum and minimum temperature would be decreased by 0.41°C & increased by 2.21°C and reached by 32.85°C& 15.97°C respectively.

4.3 At 35° N latitude

On the basis of outcomes, predicted the maximum and minimum temperature in year 2051-2060 would be decreased by 2.25°C & 0.53°C for yearly and reached by 14.98°C& 8.38°C. For the Ist half year average maximum and minimum temperature would be decreased by 2.68°C & 3.21°C and reached by 10.86°C and 14.61°C respectively. For the IInd half year average maximum and minimum temperature would be decreased by 1.69°C & increased by 0.31°C and reached by 19.23°C& (-2.52°C) respectively.

5 CONCLUSIONS AND SUGGESTION

On the basis of studies outcomes following points to be concluded,

1) Solar radiation and atmospheric pressure with precipitation are inversely proportion at 25° N and 31°N latitudes but directly proportion at 35°N latitudes. The maximum temperature is directly proportion at 25°N latitudes but inversely proportion at 31° N and 35° N latitudes but average minimum temperature is directly proportion at 25° latitudes.

   The frequency and intensity of extreme wind events has increased with temperature. For the Ist half-year precipitation is inversely proportion with atmospheric pressure at 25°N latitudes and inversely proportion for maximum temperature at 25° N and 31° N latitudes but for IInd half -year directly proportion to 35°N latitudes.

3) The Solar radiations are decreasing for all three studied locations but Atmospheric pressure at higher latitude is increasing and decreasing at lower latitude. It is also observed that the highest winds events direction is shifting towards West and South direction and causing the hot and humid weather with decrease in precipitation in the studied zone.

4) From the above study, it is also indicating that variation in wind direction and wind speed happened due to change in atmospheric pressure. The continue variation in atmospheric pressure indicates that thickness (height) of atmospheric is decreasing at 25°N latitudes and increasing at 35°N latitude area due to present climate change.

5) It also seems that arid winds moving towards 25°N latitudes and increasing the temperature and decreasing the precipitation with more calm wind events.

6) The change in wind frequency and intensity with increase in minimum temperature would increase the chances of Hydro-meterological disasters at glaciated and cold desert area of Himalaya zone. As due to increase in temperature may impact the melting rate of glaciers and frequency of rainfall (not snowfall) might be increased, which may badly impact the ecosystem, topography and soil condition of glaciated and cold desert area of Himalaya

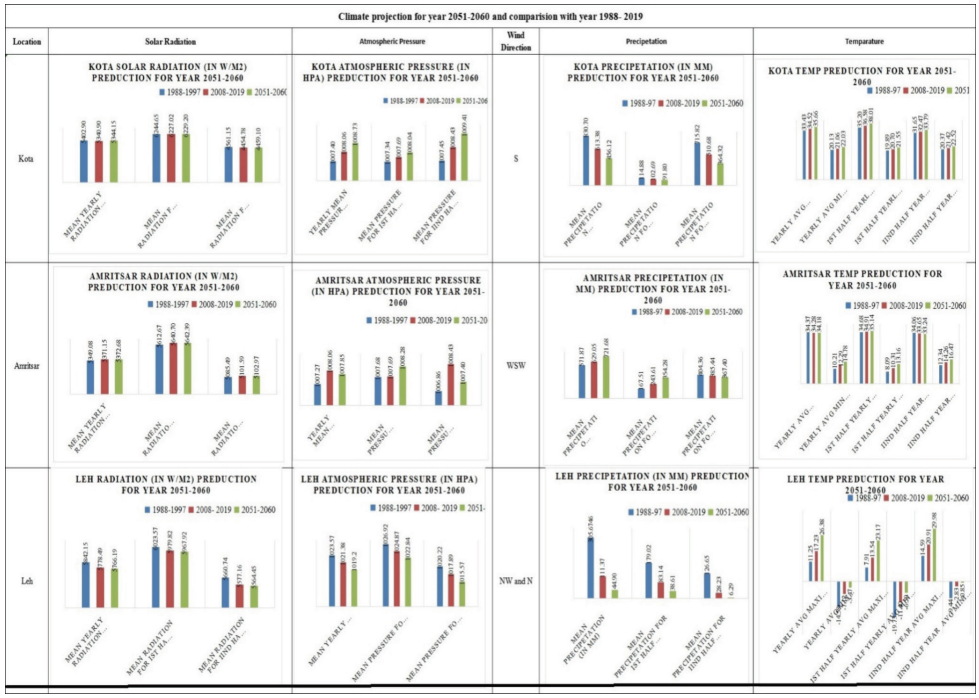

Figure 4: Climate Projection for year 2051-2060 and comparison with year 1988-2019.

As this variation is happening under the confluence zone of Heddle Cell & Mid latitude Cell and high atmospheric pressure always above 30° latitudes but this study indicates that atmospheric pressure at 35° N latitudes is decreasing rapidly and increasing at 25° N latitude area. It is predicted that confluence zone of Heddle Cell and mid latitude Cell is shifting/fluctuating towards equator and confluence zone is receiving the maximum calm wind events and extreme weather condition. It is also possible that during Ist half of year, Heddle Cell may move more towards North and due to it more precipitation received in Ist half-year as well as high temperature/extreme summer.

The Mid latitude cell move towards equator during IInd half year, which is cold and dry, decreasing the precipitation and temperature. But yearly impact of these winds are showing the decrease in the precipitation, increase in the temperature and calm winds, variation in wind events and frequency of extreme weather events such as hydro-meteorological events and its related impact will be increased. We can take pre-disaster mitigation measures at hazard prone area as well as identify the new prone area. The public awareness, disaster prediction, hazard mitigation structures and communication methods would be helpful in save the ecosystem.

A detailed study is required on impact of atmospheric wind variation on hydro-meteorological disaster, hydrological cycle, ecological impact, greenhouse gases, Earth albedo impact, agriculture, vegetation patter, urbanization etc, reference to Indian subcontinents as well as find out the detailed relationship between atmospheric wind variation and terrestrial factors (Earth tilt axis, change in Solar radiation, variation in earth magnetic field/poles etc.) for detailed behavior/prediction for future wind pattern. Apart from this it confirmed that variation in solar radiation and atmospheric pressure has impacted the temperature, precipitation pattern, wind events and frequency, humidity and Indian monsoon pattern.

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