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Spatial and Temporal Land Surface Temperature Analysis of Kashmir Valley (India)

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Abstract: The present study was undertaken to compute the normal maximum and minimum temperature in seven districts of Kashmir namely, Anantnag, Pulwama, Srinagar, Budgam, Baramulla Kulgam and Kupwara during 1980-2016. The normals were then used to study the weather extremes like heat waves and cold waves in the region. All the districts experienced heat waves of moderate intensity during summer. However, the cold waves in all the districts were of moderate to severe intensity. The district Baramulla was most severely affected by cold waves while district Srinagar was most affected district by heat waves.

Keywords: Temperature, Normal, Heat waves, Cold waves, Kashmir Valley

High mountains as a reservoir play a vital role in regional hydrological, biogeochemical, and atmospheric processes in rangeland ecosystem. Since the mid-twentieth century, these pristine areas have been experiencing earlier snowmelt with increased vegetation greenness by changed land surface temperature due to global warming. Thus mountain areas are considered for climate change studies. Land surface temperature (LST) is an essential parameter in the climate change studies. It plays a key role in the energy and water transfers between the ground and the atmosphere. LST is controlled by solar radiation and the land-atmosphere heat exchange (Manzo-Delgado et al 2004). Therefore, its spatial and temporal distributions reflect not only the variations of climate factors but also the land surface characteristics. Several studies have been conducted to study the spatial and temporal variations of LST (Manzo-Delgado et al 2004, Julien et al 2006, Westermann et al 2011). Apart from land surface temperature analysis heat and cold waves have been a part of LST called as extreme events, which cause enormous losses in terms of lives and human discomfort and ailments arising out of them. These waves cause wide range of damage types. There have been various cases of death and injuries from direct exposure to heat/ cold. Although there are generally a higher human mortality rate in terms of extreme events. Weather related natural disasters and extreme events have increased considerably in recent decades (Mahdi and Dhekale 2016). In last few decades the climate of Kashmir Valley has witnessed a different change in climate and climatological

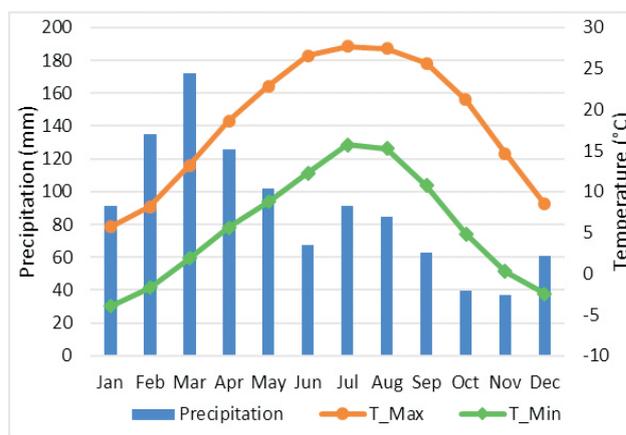


Fig. 1. Monthly normals of precipitation and temperature for Kashmir Valley during the period 1980-2016

variables as compared to the other parts of India. The maximum and minimum temperatures of the region have shown no significant increasing or decreasing trends (Parvaze et al 2017). In this study, the main aim is to use local weather (temperature) information at the district level, of an over 36 years period (1980-2016) to examine the climatology and trends in the occurrence, frequency and duration of heat and cold waves to generate the information at a local level, in order to address the challenges of climate change and its extremes in Kashmir valley

MATERIAL AND METHODS

Study area: The state of Jammu and Kashmir is located

between 32°17' and of 37°5' North latitudes and 73°26' and 80°30' and 81° East longitudes. Kashmir valley lies in the temperate zone of the state. The valley has an elevation range of 1500-4200 m a.s.l. The meteorological data for the study was obtained from Regional Meteorological Centre, Rambagh Srinagar. The climate parameters was obtained for a period of 36 years (1980- 16). The study area with their GPS location in Table 1.

Climatological information about temperature at seven stations located in seven different districts of Kashmir valley was analyzed. The preliminary analysis for this study included computing the monthly and annual normal at the stations for the years 1980-2016. The extreme events that occurred in the past in all the districts were studied. The data required for the present study was obtained from Agro-meteorological Field Unit-Shalimar and Regional Meteorological Center-Shalimar. Daily values of Maximum and Minimum Temperature were obtained for the duration 1980-2016. The heat and cold wave/severe cold waves were classified as per the criteria provided by the IMD (2002), based on maximum and minimum daily temperature thresholds. Daily anomalies were computed and using the criteria given in the Table 2. Days that satisfied the heat wave (HW)/severe heat wave (SHW) and cold wave (CW)/severe cold wave (SCW) conditions were identified.

RESULTS AND DISCUSSIONS

Temperature normal: The highest temperature was recorded on July 10, 1999 as 37.6°C at Kupwara station and the lowest temperature of -19.8°C at Gulmarg station on January 1, 1990. The monthly normal maximum temperatures in different districts are presented in Table 2 and the normal monthly minimum temperatures for different districts of Kashmir Valley in Table 3.

Heat and cold waves: The number of heat waves/ severe

Table 1. GPS location of different districts of Kashmir Valley

District	Lat. (N)	Long (E)	Altitude (amsl)
Anantnag	33.43	75.09	1603
Baramulla	34.12	74.20	1562
Budgam	34.01	74.47	1560
Kulgam	33.39	75.01	1705
Kupwara	34.25	74.18	1609
Pulwama	34.54	74.53	1582
Srinagar	34.03	74.48	1564

heat waves and cold waves/ severe cold waves was observed for three decades 1980-1989, 1990-1999 and 2000-2009 and the remaining 7 years from 2010-2016.

Data on the month-wise distribution of HW/SHW and CW/SCW events of Kashmir valley show that in the last 37 years, all the stations have witnessed heat waves (Table 4). The highest number of heat waves was in the Srinagar district. A total of 1853 heat waves were experienced in the district with 460, 472, 561 and 350 HWs during 1980-89, 1990-1999, 1999-2009 and 2010-2017. The least number of heat waves were experienced in Baramulla only 36 during 1980-2016. During 1980-89, no heat waves were experienced in the district. There were 20 and 15 incidences of heat waves during 1990-99 and 2000-09, respectively and only 1 heat wave during 2010-2016. The highest temperature of Kashmir valley was on July 10, 1999 in Kupwara as 37.6°C.

Kashmir Valley experiences a very long and harsh winter. Cold waves are very common in the region. The least recorded temperature in Kashmir Valley was -19.8 C in Baramulla on February 1, 1990. During the last 37 years (1980-2016), the district has experienced 2711 cold waves and 2255 severe cold waves. All other districts have also received very frequent spells of cold waves and severe cold waves which forced the farmers to go for protected cultivation and crop diversification

Table 2. Criteria for heat wave/severe heat wave and cold wave/severe cold wave for hilly region used in this study (India Meteorological Department)

Heat event	<ol style="list-style-type: none"> 1. When the climate normal maximum temperature of a station is 40°C: <ol style="list-style-type: none"> a. HW: Departure from climate normal is +5°C to 6°C b. SHW: Departure from climate normal is +7°C or more 2. When the climate normal maximum temperature of a station is 40°C: <ol style="list-style-type: none"> a. HW: Departure from climate normal is +4°C to 5°C b. SHW: Departure from normal is +6°C or more 3. When actual maximum temperature remains 45°C or more irrespective of normal 4. Maximum temperature
Cold event	<ol style="list-style-type: none"> 1. When climate normal minimum temperature is equal to 10°C or more: <ol style="list-style-type: none"> a. CW: Departure from climate normal is - 5°C to - 6°C. b. SCW: Departure from climate normal is - 7°C or less 2. When climate normal minimum temperature is < 10°C: <ol style="list-style-type: none"> a. CW: Departure from climate normal is - 4°C to - 5°C. b. SCW: Severe Cold Wave Departure from normal is -6°C or less. 3. Cold Wave should be declared when minimum temperature is 0°C or less and normal minimum temperature is above 0°C.

Table 3. Normal maximum temperature (°C) in different districts of Kashmir valley (1980-2016)

Month	Anantnag	Baramulla	Budgam	Kulgam	Kupwara	Pulwama	Srinagar	Kashmir
January	4.6	2.9	7.0	6.8	7.0	5.3	6.4	5.7
February	6.8	4.7	9.9	9.4	9.0	7.8	9.6	8.2
March	11.8	9.1	14.9	14.5	14.3	13.0	14.5	13.2
April	17.2	14.2	20.3	20.1	20.1	18.6	19.7	18.6
May	21.2	18.7	24.7	23.8	24.4	23.0	24.2	22.9
June	24.5	22.4	28.7	27.2	28.3	26.6	28.3	26.6
July	25.5	23.4	29.8	28.2	30.0	27.4	29.7	27.7
August	25.4	23.2	29.5	27.8	30.0	27.1	29.2	27.5
September	23.7	21.3	27.4	26.2	28.3	25.3	27.2	25.6
October	19.4	16.9	22.4	23.3	22.9	20.8	22.1	21.1
November	13.2	11.3	15.8	16.4	16.1	14.2	15.4	14.6
December	7.3	6.1	9.4	9.7	9.4	8.3	9.1	8.5
Annual	16.7	14.5	20.0	19.5	20.0	18.1	19.6	18.3

Table 4. Normal minimum temperature (°C) in different districts of Kashmir valley (1980-2016)

Month	Anantnag	Baramulla	Budgam	Kulgam	Kupwara	Pulwama	Srinagar	Kashmir
January	-6.8	-7.3	-2	-3.2	-2.8	-3.3	-2.3	-4.0
February	-4.5	-5.4	0.4	-0.8	-0.8	-1.1	0.1	-1.7
March	-0.5	-1.7	4.1	2.8	2.6	2.7	3.2	1.9
April	3.2	2.3	7.9	6.5	6.5	6.6	6.6	5.7
May	5.8	5.4	11.2	9.7	9.6	9.7	9.8	8.7
June	8.7	8.7	15	13.4	13.1	13.3	13.7	12.3
July	12.7	12.1	18.3	16.7	16.8	16.1	17.2	15.7
August	12.8	12	17.7	15.9	16.2	15.5	16.6	15.2
September	8.5	8.1	12.8	11.1	11.2	11.6	11.9	10.7
October	2.7	2.5	6.2	5.3	5.3	6.6	5.3	4.8
November	-1.6	-1.7	1.1	1	0.4	2	0.6	0.3
December	-4.3	-4.4	-1.5	-1.6	-2	-1.8	-1.7	-2.5
Annual	3.1	2.6	7.6	6.4	6.3	6.5	6.8	5.6

Table 5. Heat waves, severe heat waves, cold waves and severe cold waves in in different districts of Kashmir valley (1980-2016)

District	Years	HW	SHW	CW	SCW	District	Years	HW	SHW	CW	SCW
Anantnag	80-89	7	0	740	641	Kupwara	80-89	531	0	668	144
	90-99	21	0	720	569		90-99	240	0	769	106
	00-09	15	0	723	420		00-09	189	0	761	110
	10-16	52	0	523	288		10-16	146	0	509	58
Baramulla	80-89	0	0	780	750	Pulwama	80-89	55	0	643	180
	90-99	20	0	729	586		90-99	173	0	629	219
	00-09	15	0	683	448		00-09	82	0	658	74
	10-16	1	0	519	471		10-16	136	0	446	92
Budgam	80-89	102	0	609	116	Srinagar	80-89	460	0	679	117
	90-99	116	0	579	147		90-99	472	0	651	167
	00-09	113	0	551	112		00-09	561	0	688	147
	10-16	74	0	409	71		10-16	350	0	490	152
Kulgam	80-89	320	0	686	172						
	90-99	240	0	656	162						
	00-09	189	0	684	110						
	10-16	146	0	457	118						

as they found abrupt frost injury in plants.

CONCLUSIONS

The temperature data analysis of Kashmir valley gave an insight into the weather of Kashmir Valley. The 37 year normal were computed for seven districts of Kashmir valley namely, Anantnag, Pulwama, Srinagar, Budgam, Baramulla Kulgam and Kupwara. The annual normal maximum temperature was 18.3 °C and the annual minimum normal temperature was 5.65 °C. The valley experiences heat waves during summer season. However these waves are of moderate intensity with no severe heat waves recorded in the region for the period 1980-2017. Cold waves on the other hand are very common in Kashmir Valley having moderate to severe intensity.

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