# Climate of the Gilgit-Baltistan Province, Pakistan

## Saifullah Khan[1], Zahoor Hussain Javed[2], Abdul Wahid[3], Asif Naveed Ranjha[4], Mahmood Ul Hasan[5]

1*Institute of Social Sciences, Bahauddin Zakariya University, Multan, Pakistan
2. Department of Economics, Government College University, Faisalabad, Pakistan
3. Chairman, Department of Environmental Sciences, Bahauddin Zakariya University, Multan, Pakistan.
4.Chairman, Department of Social Work, Islamia University Bahawalpur, Punjab, Pakistan
5.Institute of Geography, Urban and Regional Planning, University of Peshawar, Khyber Pakhtunkhwa, Pakistan

*Email:* saifullahkhan33@gmail.com

**Abstract:** The present study focuses on the climate conditions of Gilgit Baltistan. It includes the distribution of different weather elements like precipitation, temperature, number of rainy days, humidity, wind speed, air pressure, evapotranspiration, sunshine, factors affecting climate, and climate classification. Due to glaciation, the area is badly eroded and consists of deep valleys and moraines. There is a marked variability between the climates of the eastern and western observatories of the area. Mostly, terrace agriculture is practiced in the area with deciduous and alpine forests. Based on temperature, the area has been divided into three distinct climate regions, namely, mild, cool, and cold. Whereas, based on precipitation, it classified into arid, semi-arid and undifferentiated highlands. Chilas is the hottest area of the province, while Astor and Skardu are the coldest. The study area receives heavy precipitation from local thunderstorms, particularly during April and May. There are four rainy seasons, namely winter, pre-monsoon, monsoon, and post monsoon precipitation. The highest precipitation in the area is observed at Astore, while the lowest at Gupis. The relative humidity is below 55% throughout the year and causes chill with low temperature and cracking in human skins. Based on the variability of weather elements, the province has been divided into three macro, three meso and six micro climate regions.

## Introduction

The climate is one of the important elements of our physical environment, not only controlling the evolutionary process of human beings, but also influences their characters, mode of existence, cultural and social characteristics. On the other hand, the climate is affected by human activities like agriculture, population growth, industrialization and transportation etc. Generally, the science of climatology is intimately interwoven with the affairs of everyday life. The agriculture is still almost entirely at the mercy of the weather and climate, as industries depend on climate conditions. Climate also limits the choice of crops and the local production of food, and determines the site for the cultivation of foodstuffs and raw materials for industries (Miller, 1959). Climates, therefore, controls the direction as well as the existence of trade routes. It appears to be a direct relationship between mental vigor and climate variability. It is clear that by encouraging decay, nourishing sources of insect life, decline human resistance to disease, and in a host of other ways, climate are at the bottom of the ill health. Mountain air, because of its clear, dry, rarefied nature, is frequently recommended for lung diseases.

Kendrew (1941) was the first to have divided Pakistan into four climate regions. Spate and Learmonth in 1951, Nasrullah (1968) classified climate of Indo-Pakistan by using Thronthwaite system. Kazi (1951) suggested four climatic zones of Kendrew's criteria

and divided these macro regions into sub-climate zones. Though, other scholars like Trewartha 1968, Griffith in 1978, Johnson, 1979; Critchfield, 1987, Shamshad, 1988; Raja and Nicol, 1990-92; Khan. 1993; Rasul and Zahid. 2011; Khan and Hasan. 2019 have discussed the climate of Gilgit Baltistan province have been lacking a wider picture of climate, it is therefore, necessary to present the climate of the area taking into account all of the major variables of climate and weather.

The work is useful for the study of environment, agriculture, water management, soil conservation, CPEC, forestry and tourism departments. The Gilgit Baltistan is located between $72^0.54`$ to $78^0$ East longitude and $34^0.54`$ to $37^0$ North latitude (Fig-1). The northeastern and northwestern part consists of high mountain ranges like the Himalayas, Hindu Kush and Karakorum with the highest peaks like, K-2 (8475m), Nanga Parbat (7980m), Rakaposhi (7665m) and Trichmir (7569 meters).

## Methods and Materials

The specific objectives of the study is to process and calculate the averages collected data, interpret and discuss the distribution of weather elements along with characteristic seasons and climate types in Gilgit-Baltistan province. There are a number of weather elements used for the study and observation of weather and climate condition. But the current work focused on the distribution of precipitation, temperature, number
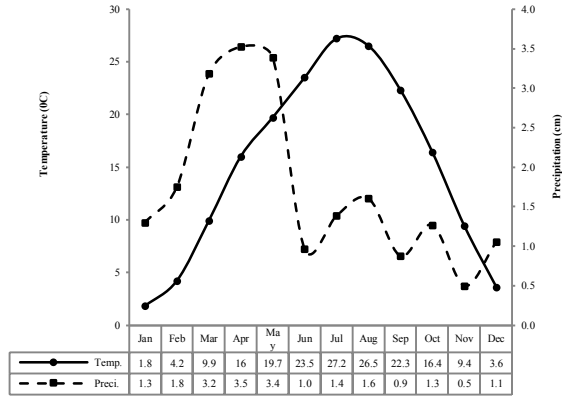
of rainy days, humidity, wind speed and direction,



Figure-2: Mean Monthly Precipitation and Temperature (1931-2019)

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp. | 1.8 | 4.2 | 9.9 | 16 | 19.7 | 23.5 | 27.2 | 26.5 | 22.3 | 16.4 | 9.4 | 3.6 |
| Preci. | 1.3 | 1.8 | 3.2 | 3.5 | 3.4 | 1.0 | 1.4 | 1.6 | 0.9 | 1.3 | 0.5 | 1.1 |

sunshine, evapotranspiration and atmospheric pressure. The meteorological observatories considered for the purpose consist of Skardu, Astore, Gilgit, Gupis, Chilas, and Bunji. The work is based on the normal data covering the time period of ninety years (1931-2019) published by Pakistan Meteorological Data Processing, center Karachi. The secondary data about sunshine, and evapotranspiration by UNO, World Food Program, and physiographical, forest maps and population data from their concern government institutes. To know about the distribution of various weather elements in Pakistan, the year was divided into two main seasons that is summer and winter. The mean monthly and mean monthly maximum temperature is suggested as a primary deciding factor, but in marginal cases, where the mean monthly and mean monthly maximum temperature is above or below the suggested values, the mean monthly minimum temperature has been considered as the criteria. Months of the year with a mean temperature above 20 degree Celsius are considered as summer months, otherwise winter. On

climate classification is based upon the annual and monthly means of weather element's, whereas the temperature and precipitation are considered as primary variables in deciding the boundaries of climate regions. In view of the importance of the flora, for climates, the native vegetation has also been taken into account, while deciding the climate boundaries, as the vegetation of an area is the best expression of the totality of the climates.
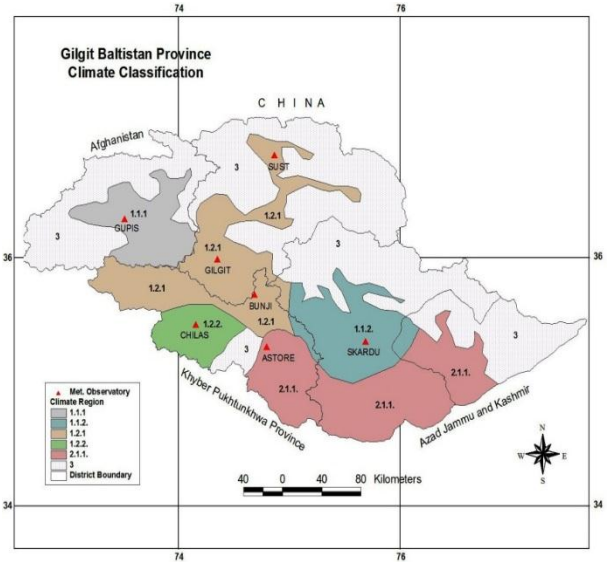


Fig. 1 Gilgit Baltistan province, location and climate classification

Based on monthly and annual means of temperature, the area has been divided into cool, cold and undifferentiated highlands. The boundaries have been selected in accordance with the criteria laid down for the worldwide classification of climates. For seasonal distribution of rainfall, the year has been divided into two main seasons that are summer and winter, that has

Table 1 Gilgit Baltistan province, mean daily and mean monthly temperature (°C) 1930-2019, PMDC, Karachi.

| Station | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Daily Range | 10.5 | 10.3 | 10.8 | 12.1 | 13.2 | 14.6 | 13.8 | 13.6 | 14.4 | 14.6 | 13.7 | 11.0 | 12.7 |
| Daily Minimum | -3.0 | -1.1 | 4.0 | 8.9 | 12.3 | 16.8 | 20.0 | 19.5 | 14.8 | 8.2 | 1.7 | -2.1 | 8.3 |
| Daily Maximum | 6.9 | 9.2 | 14.8 | 21.0 | 25.5 | 31.4 | 33.8 | 33.1 | 29.2 | 22.8 | 15.7 | 8.8 | 21.0 |
| Mean Monthly | 1.8 | 4.2 | 9.9 | 16.0 | 19.7 | 23.5 | 27.2 | 26.5 | 22.3 | 16.4 | 9.4 | 3.6 | 15.0 |
| Mean Minimum | -7.6 | -5.9 | -1.0 | 4.0 | 7.3 | 11.1 | 14.4 | 13.9 | 9.3 | 3.8 | -2.4 | -6.2 | 3.4 |
| Mean Maximum | 11.1 | 14.3 | 20.8 | 28.0 | 32.0 | 35.9 | 40.0 | 39.1 | 35.3 | 28.9 | 21.2 | 13.5 | 26.7 |

the basis of variability in the mean monthly precipitation, these two seasons are further divided into four rainy seasons, namely winter, pre-monsoon, monsoon, and post monsoon seasons. The regional

further been subdivided into four sub-seasons that are winter rainfall, pre-monsoon rainfall, monsoon rainfall, and post monsoon rainfall. The boundaries in the rainfall seasons have been selected on the basis of

Table 2 Gilgit Baltistan province, mean monthly precipitation (cm) 1930-2019, PMDC, Karachi.

| Station | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Astore | 3.5 | 4.9 | 8.3 | 8.7 | 7.1 | 2.0 | 2.1 | 2.4 | 1.9 | 3.0 | 1.4 | 2.6 |
| Bunji | 0.4 | 0.6 | 1.6 | 2.3 | 2.9 | 0.7 | 1.5 | 1.8 | 0.9 | 1.1 | 0.3 | 0.4 |
| Chilas | 0.8 | 1.3 | 3.0 | 3.2 | 2.8 | 0.8 | 1.2 | 1.2 | 0.3 | 1.3 | 0.4 | 1.1 |
| Gilgit | 0.4 | 0.6 | 1.3 | 2.3 | 2.5 | 0.6 | 1.6 | 1.6 | 0.7 | 0.8 | 0.2 | 0.4 |
| Gupis | 0.5 | 0.7 | 0.9 | 2.0 | 2.4 | 0.8 | 1.1 | 1.6 | 0.9 | 0.4 | 0.1 | 0.4 |
| Skardu | 2.1 | 2.4 | 4.0 | 2.6 | 2.6 | 0.9 | 0.9 | 1.1 | 0.7 | 1.0 | 0.6 | 1.4 |
| Mean | 1.3 | 1.8 | 3.2 | 3.5 | 3.4 | 1.0 | 1.4 | 1.6 | 0.9 | 1.3 | 0.5 | 1.1 |

Table 3 Gilgit Baltistan province, number of rainy days/months, 1930-2019, PMDC, Karachi.

| Station | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Astore | 3.6 | 5.1 | 6.1 | 6.9 | 5.3 | 2.3 | 2.4 | 2.8 | 2.2 | 2.4 | 1.3 | 1.2 | 40.4 |
| Bunji | 0.6 | 0.8 | 1.7 | 1.9 | 3.2 | 1.0 | 2.1 | 2.3 | 1.0 | 1.0 | 0.2 | 1.6 | 15.8 |
| Chilas | 1.1 | 1.5 | 2.7 | 3.0 | 2.3 | 0.9 | 1.2 | 1.8 | 0.4 | 1.0 | 0.4 | 0.2 | 16.3 |
| Gilgit | 0.4 | 0.7 | 1.5 | 2.3 | 2.3 | 0.6 | 2.2 | 2.1 | 0.9 | 0.9 | 0.2 | 0.3 | 14.1 |
| Gupis | 0.6 | 0.8 | 1.2 | 1.8 | 2.3 | 0.9 | 1.5 | 2.1 | 1.2 | 0.5 | 0.1 | 0.7 | 13.0 |
| Skardu | 2.6 | 2.9 | 3.5 | 2.4 | 2.6 | 0.9 | 1.4 | 1.1 | 0.7 | 0.9 | 0.7 | 0.1 | 19.7 |
| Sum | 8.9 | 11.8 | 16.7 | 18.3 | 18.0 | 6.6 | 10.8 | 12.2 | 6.4 | 6.7 | 2.9 | 2.9 | 119.3 |
| Mean | 1.5 | 2.0 | 2.8 | 3.1 | 3.0 | 1.1 | 1.8 | 2.0 | 1.1 | 1.1 | 0.5 | 0.5 | 19.9 |

positive and negative deviation from the annual mean condition. Based on precipitation distribution, the methodology has been devised with two rainfall regions that are arid and semi-arid regions. The criteria developed for the distribution of precipitation, has also been used for the distribution of number of rainy days, relative humidity, air pressure, evapotranspiration and sunshine. Based on annual variability and distribution of weather elements, the study area has been divided into three macro, three meso, and six micro climate regions and discussed in detail.

area is 12.7$^0$C with 8.3$^0$C mean daily minimum and 21$^0$C mean daily maximum temperature. The ever recorded maximum temperature of 48.1$^0$C recorded on 1$^{st}$ August, 1983 at Chilas and ever minimum temperature of -21$^0$C on 9$^{th}$ February, 1974 at Astore. (Figure-2 and Table-1). Based on temperature, the Gilgit-Baltistan province has been divided into mild-climates, Cool climates and Cold climates.

The mild-climates make a boundary between warm and cool areas, where the temperature of the warmest month, November remains between 10$^o$C and 21$^o$C.

Table 4 Gilgit Baltistan province, mean monthly relative humidity (%), 1930-2019, PMDC, Karachi.

| Station | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Astore | 64 | 63 | 57 | 52 | 48 | 43 | 47 | 49 | 47 | 42 | 47 | 60 | 51 |
| Bunji | 53 | 47 | 44 | 44 | 42 | 35 | 40 | 44 | 44 | 45 | 46 | 51 | 45 |
| Chilas | 53 | 49 | 45 | 25 | 33 | 24 | 30 | 34 | 31 | 32 | 37 | 50 | 37 |
| Gilgit | 70 | 56 | 47 | 49 | 49 | 44 | 48 | 56 | 57 | 61 | 64 | 70 | 56 |
| Gupis | 56 | 50 | 41 | 39 | 37 | 27 | 31 | 36 | 37 | 36 | 40 | 55 | 40 |
| Skardu | 73 | 67 | 54 | 43 | 42 | 38 | 41 | 44 | 43 | 48 | 58 | 70 | 52 |
| Mean | 61 | 55 | 48 | 42 | 42 | 35 | 39 | 44 | 43 | 44 | 49 | 59 | 47 |

## Results and Discussions

### Mean Monthly Temperature

The annual cycle of temperature in Gilgit-Baltistan province reveals that July is the hottest month with mean monthly temperature of 27.2$^0$C, mean monthly maximum temperature of 40$^0$C, and mean monthly minimum temperature above 14$^0$Celsius. In January, the mean monthly temperature is 1.8$^0$C, while the maximum temperature rises to 11.1$^0$C, and the minimum temperature of -7.6$^0$C and being a coldest month of the area. After January, the graph shows rapid increase in temperature, till July and then decreases till December. The area recorded the mean monthly temperature of about 15$^0$C, mean maximum temperature of 26.7$^0$C and mean minimum temperature of 3.4$^0$C. The mean daily range of temperature of the

The region consists of Chilas and Gilgit. In Chilas, the mean monthly, mean maximum and minimum temperatures are higher as compared to rest of the region. The area has eight months winter and four month summer season. The summer is hot and winter is cool. The region is characterized by warm summers, cool and cold winters, with mean temperature of the coldest months January and December between 0$^o$C to 10$^o$Celsius. In Skardu and Adjoining Areas the winter season generally, lasts for eight months, while the summer season of four months. In Astore district the mean monthly maximum temperature is below 34$^0$C throughout the year with no summer month. The extreme north of the region is characterized by colder climates, where the temperature remains below the freezing point especially in January and February.

Table 5 Gilgit Baltistan province, mean monthly pressure (mb), 1930-2019, PMDC, Karachi.

| Station | Jan | Feb | Mar | April | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Astore | 1048 | 1047 | 1047 | 1048 | 1047 | 1044 | 1042 | 1043 | 1046 | 1050 | 1051 | 1050 | 1047 |
| Bunji | 1045 | 1042 | 1041 | 1041 | 1038 | 1033 | 1029 | 1030 | 1036 | 1041 | 1045 | 1046 | 1039 |
| Chilas | 1043 | 1041 | 1039 | 1038 | 1035 | 1030 | 1026 | 1027 | 1033 | 1039 | 1043 | 1045 | 1037 |
| Gilgit | 1049 | 1046 | 1045 | 1044 | 1045 | 1037 | 1033 | 1035 | 1040 | 1046 | 1049 | 1050 | 1043 |
| Gupis | 1073 | 1071 | 1070 | 1070 | 1069 | 1066 | 1063 | 1063 | 1068 | 1073 | 1074 | 1075 | 1070 |
| Skardu | 1072 | 1070 | 1070 | 1069 | 1068 | 1065 | 1062 | 1063 | 1066 | 1072 | 1074 | 1074 | 1069 |
| Mean | 1055 | 1053 | 1052 | 1052 | 1050 | 1046 | 1043 | 1044 | 1048 | 1054 | 1056 | 1057 | 1051 |

**Precipitation, Rainy Days and Humidity**

The mean annual precipitation of Gilgit-Baltistan province is 20.8cm with a high of 3.5cm in April and lowest of 0.5cm in November. As can be seen from table-2, the heaviest total annual precipitation of 47.8cm is recorded at Astore and the lowest of 11.9cm at Gupis. In April, the heaviest precipitation of 8.7cm recorded at Astore and the lowest of 0.1cm in November at Gupis. Based on precipitation, the Astore observatory shows semi-arid climates (47.8cm),

till December (summer months). The maximum of 70% of relative humidity recorded at Gilgit and Skardu in January as well as December, whereas the low of 24% at Chilas in June.

**Pressure, Wind Speed, Evapotranspiration and Sunshine**

The high pressure of the study area is 1057mb in December and a lowest of 1043mb in July. The annual mean pressure of the area is 1051mb having 1070mb maximum at Gupis and lowest of 1037mb at Gilgit

Table 6 Gilgit Baltistan province, mean monthly wind speed (knots), 1930-2019, PMDC, Karachi.

| Station | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Astore | 1.4 | 1.6 | 3.0 | 2.8 | 2.1 | 2.1 | 2.7 | 2.4 | 2.9 | 2.5 | 1.7 | 1.2 | 2.2 |
| Bunji | 2.4 | 2.9 | 3.1 | 2.8 | 2.6 | 2.7 | 3.1 | 2.3 | 2.2 | 1.8 | 1.6 | 1.6 | 2.4 |
| Chilas | 0.2 | 0.3 | 1.2 | 1.3 | 1.1 | 2.0 | 2.4 | 1.9 | 1.4 | 0.6 | 0.3 | 0.2 | 1.0 |
| Gilgit | 0.6 | 0.9 | 1.8 | 1.5 | 1.6 | 1.2 | 1.1 | 0.7 | 1.0 | 0.8 | 0.3 | 0.3 | 1.0 |
| Gupis | 1.6 | 2.1 | 2.9 | 3.7 | 3.0 | 3.0 | 3.3 | 3.5 | 3.1 | 2.8 | 1.6 | 0.7 | 2.6 |
| Skardu | 0.1 | 0.6 | 1.1 | 2.3 | 2.8 | 1.6 | 2.0 | 1.6 | 1.1 | 0.6 | 0.3 | 0.1 | 1.1 |
| Mean | 1.1 | 1.4 | 2.2 | 2.4 | 2.2 | 2.1 | 2.4 | 2.1 | 2.0 | 1.5 | 1.0 | 0.7 | 1.7 |

whereas the excluding areas fall in arid climates. However, due to perpetual snow and ice, the majority of the hill slopes fall in undifferentiated highland climates, where the temperature remains below the freezing point throughout the year. The annual trend of mean monthly precipitation reveals that it increases from November (0.5cm) to March (3.5cm) and then slackens till June and rises up in August (1.6cm) and then dropped down till September (0.9cm) and rises to 1.3cm in October (Figire-2and Table-2).

The maximum number of rainy days in Gilgit-Baltistan province is 3.1 in April, while the lowest is 0.5 in November and December with an average of 19.9 throughout the year (Table-3). The annual trend indicates that the number of rainy days increases from December to April due to western depressions and then decreases up to November because of high summer temperature and dry monsoon and post monsoon spell with little rise in July and August. The data reveal that

observatory. The annual trend of the mean monthly pressure reveals that it is decreasing from January to July (winter season) and increase onward till December. Generally, the pressure of the area remains low during the summer months and high during winter (Table-5).

The Gilgit-Baltistan province recorded a highest wind speed of 2.4 knots in April and July, while the low of 0.7 knots in December with annual wind speed of 1.7 knots. Months of the year, having high wind speed indicates high temperature and low pressure, while months, having low wind speed has the converse condition (Table-6). The maximum wind speed of 2.6 knots observed at Gupis and the minimum of 0.1 knots at Chilas and Gilgit respectively.

The average evapotranspiration of the Gilgit-Baltistan province is 2.8mm having 5.1mm (highest) in July and 0.7mm in January (lowest). The maximum annual

Table 7 Gilgit Baltistan province, mean monthly evapotranspiration (mm), 1930-2019, PMDC, Karachi.

| Station | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Astore | 0.6 | 0.9 | 1.5 | 2.6 | 3.6 | 4.5 | 4.5 | 4.2 | 3.4 | 2.3 | 1.3 | 0.7 | 2.5 |
| Chilas | 0.9 | 1.4 | 2.4 | 3.6 | 4.4 | 5.4 | 6.1 | 5.7 | 4.5 | 2.8 | 1.5 | 1.0 | 3.3 |
| Gilgit | 0.7 | 1.2 | 2.1 | 3.0 | 4.0 | 4.9 | 4.9 | 4.4 | 3.5 | 2.2 | 1.2 | 0.8 | 2.7 |
| Gupis | 0.6 | 1.0 | 2.0 | 3.2 | 4.2 | 5.2 | 5.1 | 4.6 | 3.7 | 2.3 | 1.2 | 0.7 | 2.8 |
| Skardu | 0.6 | 0.9 | 1.7 | 3.0 | 4.0 | 4.9 | 4.8 | 4.5 | 3.6 | 2.3 | 1.2 | 0.7 | 2.7 |
| Mean | 0.7 | 1.1 | 1.9 | 3.1 | 4.0 | 5.0 | 5.1 | 4.7 | 3.7 | 2.4 | 1.3 | 0.8 | 2.8 |

the area receives less rain from monsoon and remain wet during winter season (western depressions).

The relative humidity of the study area is above 40%, excluding June and July that shows a converse condition (Table-4). The average relative humidity of the area is 47% having a maximum of 56% in Gilgit and a minimum of 37% in Chilas. The annual trend of the relative humidity shows that it decreases from January to June (winter months) and increases onward

evapotranspiration of 3.3mm observed at Chilas and the minimum of 2.5mm at Astore. The mean monthly maximum of 6.1mm evaportranspiration has been noted in July at Chilas and the low of 0.6mm in January at Astore, Chilas and Gupis observatories (Table-7).

The annual sunshine of the study area is 6.5 hrs/day with a highest 6.8 hrs/day at Skardu and lowest of 6 hrs/day at Astore. The mean monthly maximum

sunshine 10.1 hrs/day has recorded in June at Skardu and the minimum 2 hrs/day in January at Astore. The sunshine increases from January to June and decrease onward till December. The sunshine duration remains maximum during summer season and minimum in winter months (Table-8).

### Climate Classification

### Arid Climate

This climate type characterized by low rainfall and covers a vast region area of Gilgit Baltistan province, Pakistan, where the annual total rainfall is between 0-10inches. At Gupis observatory, the annual total precipitation is less than 5inches with cold long dry winters and short moist summers. In winters, low precipitation mostly in the form of snow and ice is received, whereas the summer rains are high, particularly from the local thunderstorms. At Skardu the annual total precipitation varies from 5inches to

evapotranspiration is 2.5mm or 0.1inches, with sunshine duration of 6hr/day, and with a total number of rainy days as 43.1 per year, and wind speed of 2.2knots. The mean temperature varies between 5°C and 10°C, with 20°C to 25°C maxima, and to1°C minima (Fig.1).

### Undifferentiated Highland

The region is characterized by perpetual snow and ice, where the mean monthly temperature is equal to or less than the freezing point throughout the year and is located at an altitude of 2500m above the sea level. It is located at the extreme north of the country with lofty mountains and narrow valleys. The region has rough topography with morainic materials deposited by glaciers. The landforms have been formed by glacier action. The mountain slopes are completely barren, however, some deciduous and coniferous forests cover the lower slopes of the Astore valley (Fig.1).

Table 8 Gilgit Baltistan province, mean monthly sunshine (hrs/day), 1930-2019, PMDC, Karachi.

| Station | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|--------|
| Astore | 2 | 2.9 | 4 | 6 | 7.9 | 9.9 | 7.9 | 7.8 | 7.7 | 6.9 | 5.9 | 3 | 6 |
| Chilas | 3 | 3.9 | 5.5 | 6.6 | 7.9 | 9.9 | 8.2 | 8.2 | 7.9 | 7.4 | 6.1 | 3.9 | 6.5 |
| Gilgit | 2.9 | 3.7 | 5.3 | 6.5 | 7.9 | 10 | 8.4 | 8.3 | 7.8 | 7.2 | 5.8 | 3.6 | 6.5 |
| Gupis | 2.9 | 3.8 | 5.6 | 7 | 8.4 | 10 | 8.4 | 8.3 | 7.9 | 7.3 | 6.1 | 3.6 | 6.6 |
| Skardu | 3.1 | 4 | 5.8 | 7.5 | 8.6 | 10.1 | 8.3 | 8.2 | 7.9 | 7.3 | 6.5 | 3.7 | 6.8 |
| Mean | 2.8 | 3.7 | 5.2 | 6.7 | 8.1 | 10.0 | 8.2 | 8.2 | 7.8 | 7.2 | 6.1 | 3.6 | 6.5 |

10inches, particularly in the form of snow and ice in winter season. However, the summers are not dry and the region receives more than 1 cm or 0.18 inch rainfall in April and May from local thunderstorms (Fig.1). Gilgit district and Bunji, located close to Hunza and Indus rivers, fall in this region. The annual total rainfall of the area varies from 5inches to 10inches. This sub-type receives both summer and winter rains with summer concentration particularly from local thunderstorms. Chilas and parts of the Kohistan district are included in this sub region, where the annual total rainfall varies between 5inches and 10inches. Rainfall is receiving both in summers and winters, with summer concentration, especially from local thunderstorms.

### Semi-Arid Climates

These areas receive an annual rainfall of 10 to 20inches. In this region the mean monthly temperature of the hottest month, June is 21°C to 32°C, and that of January is 0°C to 10°C or below the freezing point, with an average winter temperature of above 15°Cesius. The region consists of Astore and parts of Mansehra district. It receives both summer and winter rains, particularly from local thunderstorms. The winter precipitation is mostly in the form of snow and ice, keeping the temperature of the area low throughout the year. The mean annual total rainfall of the region is 15inches to 20inches with average day relative humidity of 50% to 55percent. The annual

### Conclusion and Recommendations

The factors bringing variation in the climates of Gilgit Baltistan province are latitudinal location, proximity to sea level, rough topography, continentality, snow and ice caps, vegetation cover, and soil contents. On the basis of temperature, Gilgit Baltistan province has been classified into three distinct regions, namely, mild, cool, and cold. The Chilas has been recorded high temperature in summer and the lowest in winter season at Astore and Skardu. Three rainfall regions comprise of arid, semi-arid and undifferentiated highlands climates have been identified. The Gilgit Baltistan province has heavy rains from local thunderstorms. The area experiences four rainy seasons that are winter rainfall, pre-monsoon rainfall, monsoon rainfall, and post monsoon rainfall. The winter, pre-monsoon and monsoon are the moist seasons, while the post monsoon is the driest seasons of the province. The heaviest precipitation of the area along with the number of rainy days recorded at Astore, while the lowest at Gupis. The relative humidity remains below 60% throughout the year with a maximum at Skardu and minimum at Chilas. The highest atmospheric pressure of the province recorded at Gupis with high wind speed, whereas the lowest pressure and wind speed at Chilas. The Skardu recorded a long sunshine duration, which reduces to its lower limits at Astore. The high rate of evapotranspiration observed at Chilas and a lowest at Astore. The summer season of the

province lasts for five months (May to September), while the winter season varies from October to April (seven months). These two main seasons of the area are further sub-divided into four sub-seasons that are cold, cool, warm, and mild. On the basis of distribution and variation of weather elements, the Gilgit Baltistan province can be divided into three macro, three meso and six micro climate regions. As the mountains of the area are barren that help to increase the temperature as well as soil erosion and caused climate change and glaciers retreat. It is therefore recommended to plant trees on the mountain slopes and to log the water at different places for the irrigation purpose particularly using *khushkaba* and *sailaba* systems. The glacier avalanches are more dominant throughout the province, so the construction should be made on some distance from the water slope. The area consists of different geographical, geological, geomorphological and highest peaks, so it is suggested to explore it on national as well as international level for tourism as well as physical research activities.

## References

Critchfield, H. J. (1987). General climatology, 4th Edition, Prentice' Hall of India, New Delhi-110001, 429 pages.

GoP., (1989), Climate normals of Pakistan, 1931-60, PMD Karachi, 230 pages.

GoP., (1993), Climate normals of Pakistan, 1961-90, PMD Karachi, 220 pages.

Griffiths, J.F. (1978). Applied climatology, *An Introduction*, 2nd Edition, Oxford University Press, London, 136 pages.

Hasan, M., Khan, S., (2019). Climate classification of Pakistan, *Int. J. Econ. Environ. Geol. Karachi,* **10** (2), 60-71.

Johnson, B.L.C. (1979). Pakistan, Heincemann, London, 51-59.

Kazi, S. A. (1951). Climatic regions of West Pakistan, *Pakistan Geographical Review, Lahore*, **VI** (1), 1-39.

Kendrew, W.G., (1941). Climates of the continents, Oxford University Press, London. 608 pages

Khan, J. A. (1993). The climate of Pakistan, Rahber Publishers, Karachi. 79 Pages

Koppen, C. E., (1953-58). Weather and climate., McGraw-Hills Book Company, Inc. New York, Toronto, Melbourne., 341pages.

Miller, A. A., (1959). Climatology, Mehtewn London and E. P. Dulton and Co. Inc. New York. 313 Pages.

Nasrullah, K. (1968). Climate of west Pakistan according to Thornthwaite system of classification of climates, *PGR*. **23** (1). 12-25.

Rasul, G., Zahid, M. (2011). Thermal classification of Pakistan, *Atmospheric and Climate Sciences*, **1**, 206-213.

Raja, A. I., Nicol, J. F. (1996). Climate and thermal comforts standards in Pakistan; *Journal of Science and Technology*, 6-12.

Raja, I. A., Twidal, J. W. (1990). Distribution of global insulation over Pakistan, *Journal of Solar Energy*, **44** (2). 21-29.

Shamshad, K. M. (1988). The meteorology of Pakistan, Climate and weather of Pakistan, Royal Book Company Karachi, Pakistan, 313 Pages.

Thornthwaite, C. W. (1948). An approach towards a regional classification, *Geographical Review*, **38** (1). 55-94.

Trewartha, G. T. (1969). An Introduction to climate, 4th Edition, Mc Grawhill Kogakusha, Ltd. 408 Pages.

WFO., (1995). Sunshine normal of the world, UNESCO, World Food Programme, Cropwat program, Online.

WMO. (1977). Solar energy, Proceedings of the WMO. No. 477, UNESCO/WMO, Sympo. Geneva, Secretariat of the World Meteorological Organization, 654 pages.