State of the Climate 2023

National Centre for Hydrology and Meteorology
Royal Government of Bhutan
2024

PUBLISHED BY:
National Centre for Hydrology and Meteorology (NCHM) Royal Government of Bhutan
PO Box: 207
Thimphu: Bhutan

ISBN 978-99980-52-05-5

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FOREWORD

The National Centre for Hydrology and Meteorology (NCHM) is the national focal agency responsible for studying, developing and providing services on meteorology, hydrology and the cryosphere. The hydro meteorological services play a major role in climate change, disaster risk reduction and sustainable development. The core mandate of the Centre is to provide early warning information that helps the nation to protect lives and properties from the impacts of climate change and variability.

Changes in climate and its variation presents both risks and opportunities and it affects all aspects of the domain. With precarious mountainous terrain topography, Bhutan is exposed to several hazards including flash floods, GLOF (Glacial Lake Outburst Flood), landslides, cyclone induced storms and erratic rainfall affecting the lives and livelihoods of the people. The planners and developers will require the information on various fields such as weather and climate, water resources and glaciers and glacial lakes for effective planning, management and making a sustainable approach to the changing climate patterns.

Therefore, NCHM strives to deepen the scientific understanding of weather and climate, hydrological and cryosphere services to improve public information about the impacts of a changing climate. NCHM will continue to provide a seamless suite of weather and climate services and facilitate efforts to identify and address the climate-related needs of planners and decision makers in various social and economic sectors.

(Karma Dupchu)

Director

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Content

SECTION A: CLIMATE

1. OVERVIEW

Global Scenario: WMO State of the Global Climate 2023

As per the World Meteorological Organization (WMO) State of the Global Climate 2023, the global mean near-surface temperature for the year 2023 was around 1.40 [1.28-1.52] °C above the 1850–1900 baseline, used as an approximation of pre-industrial levels. The WMO evaluation is based on six global temperature datasets, as shown in Figure 1 below, and all of these datasets presently rank 2023 as either the warmest year in the 174-year observational record, surpassing the previous warmest years, 2016 and 2020.

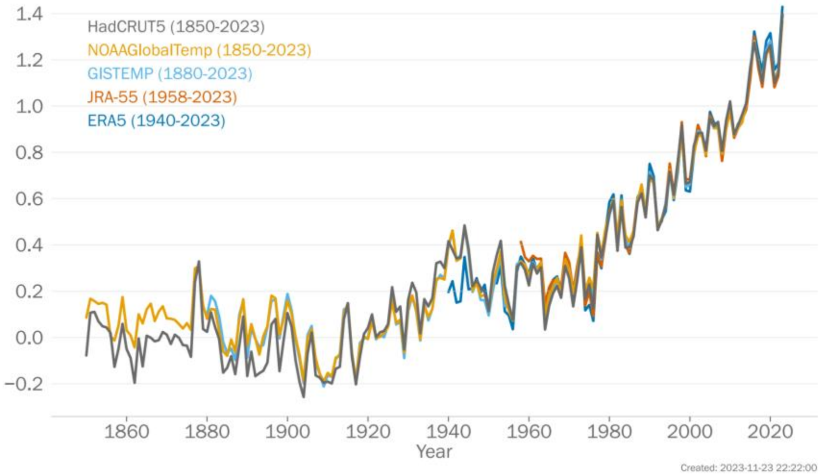


Figure 1: Global annual mean temperature difference from pre- industrial conditions 1850–1900 baseline for the six global temperature datasets 1850–2023.

The International Panel on Climate Change's sixth Assessment report states that a multi-year average was used to evaluate the long-term assessments of changes in the global mean temperature. The average for the years 2011 - 2020 was predicted to be 1.09 [0.95 - 1.20] °C warmer than the average for the industrial era between 1850 - 1900. The average is predicted to be 1.19 [1.07 - 1.31] °C for the 10-year period from 2014 - 2023, showing continued warming. The overall warmth of variations in temperature anomalies across the globe is shown in Figure 2.

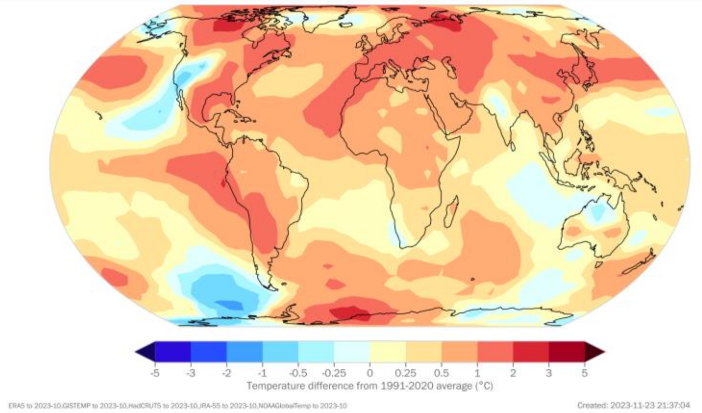


Figure 2: Near surface temperature differences between 2023 relative to the 1991-2020 long-term average.

2. CLIMATE HIGHLIGHTS - 2023

2.1 Location of the Class A meteorological stations

The computation under this section is based on 20 Agrometeorological (Class A) stations located at each Dzongkhag or district.

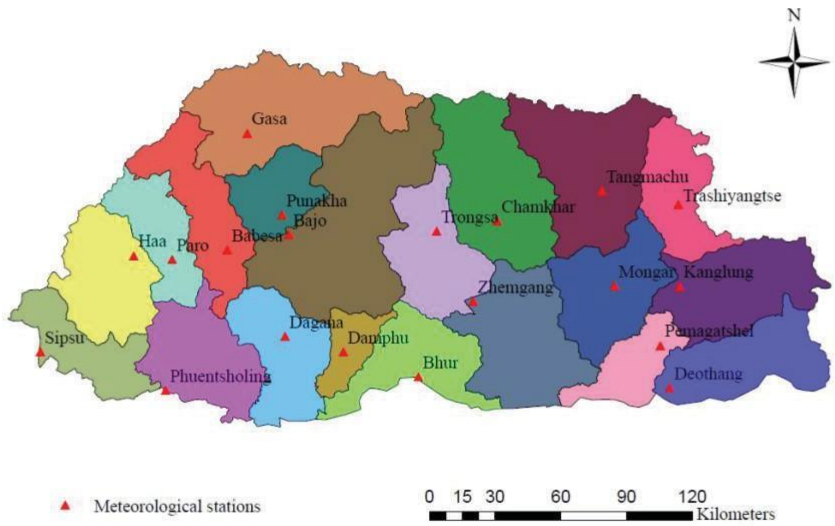


Figure 3: Location of Class A meteorological stations

2.2 Annual rainfall

The annual average rainfall (area average) was 1794.30 mm in 2023. The country as a whole received slightly below normal rainfall against the long-term average. The highest 24-hour rainfall was recorded at Bhur with 306.0 mm. Deothang experienced the highest number of rainy days with 365 days (rainy days is defined as rainfall greater than or equal to 1 mm). It is to be noted that a greater number of rainy days does not translate to more accumulated rain. However, the highest total annual rainfall was recorded at Phuentsholing with 6549.10 mm, Sipsu with 5604.10 mm followed by Bhur with 5376.20 mm.

2.3 Maximum and Minimum Temperature

The annual average maximum temperature was 23.18°C and minimum temperature was 12.18°C across the country. The highest daily maximum temperature was recorded at Phuentsholing met station with 38.5°C and the lowest daily minimum temperature was recorded at Haa met station with -10.5°C. Haa experienced a greater number of days with the minimum temperature below or equal to zero with 135 days (minimum temperature <=0).

2.4 Monsoon Monitoring

Bhutan experiences the summer monsoon from June to September (JJAS). Bhutan receives most of its annual rainfall during summer monsoon so it is one of the predominant seasons of the year that influences much of the climate in Bhutan.

2.4.1 Rainfall

During the summer of 2023, the country as a whole received slightly below normal rainfall against the long-term average 1996-2022. The accumulated rainfall for the season (JJAS) was equivalent though.

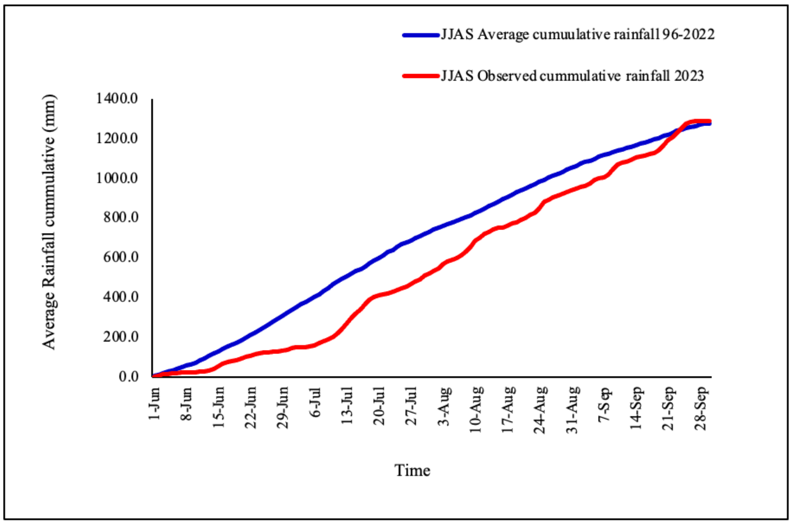


Figure 4: Observed rainfall of 2022 (JJAS) with long term average (1996-2022)

2.4.2 Temperature

During the summer of 2023, the country as a whole observed below normal average temperature initially and then near normal average temperature against the long-term average 1996-2022.

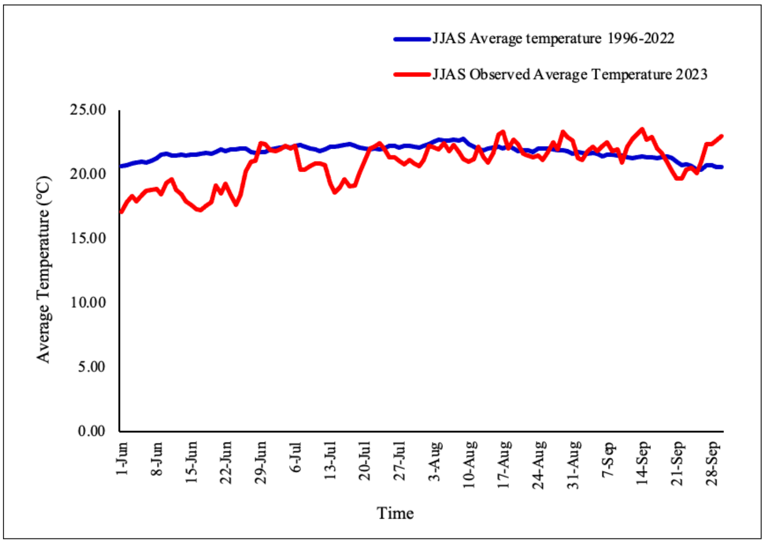


Figure 5: Observed average temperature of 2023 (JJAS) with long term average (1996-2022)

3. ANALYSIS OF TEMPERATURE - 2023

3.1 Maximum Temperature

A monthly climate monitoring report for the year 2023 is generated. The maps and extremes of monthly maximum temperature can be viewed and downloaded from the given website link *http://www.nchm.gov.bt/*. In this section, the spatial maps for annual average and seasonal variation of the average maximum temperature are included.

3.1.1 Annual average maximum temperature

The following map (Figure 6) shows the spatial distribution of annual average maximum temperature during the year 2023. Meteorological stations such as Sipsu, Phuentsholing, Bhur, Punakha and Bajo experienced higher annual average maximum temperatures. Conversely, Haa, Gasa, Paro and Chamkhar stations have recorded lower annual average maximum temperatures.

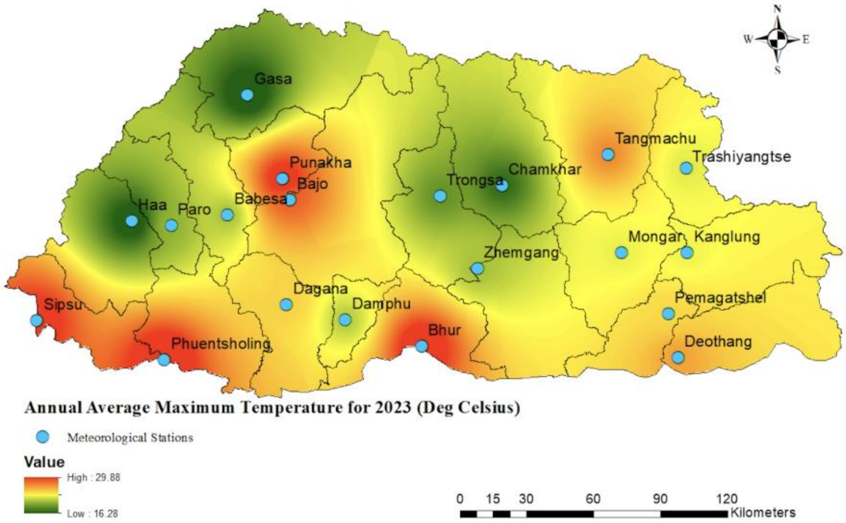


Figure 6: Spatial distribution of annual average maximum temperature for the year 2023

3.1.2 Seasonal average maximum temperature

The spatial distribution for average maximum temperature across four seasons is mapped. In Bhutan based on the rainfall and temperature pattern, 12 months in a year are divided into four seasons.

3.1.2.1 Spring/ Pre-monsoon – March to May (MAM)

3.1.2.2 Summer/Monsoon – June to September (JJAS)

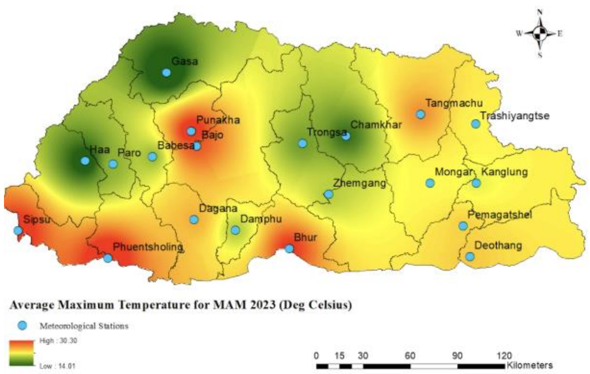
3.1.2.3 Autumn/Post-monsoon – October to November (ON)

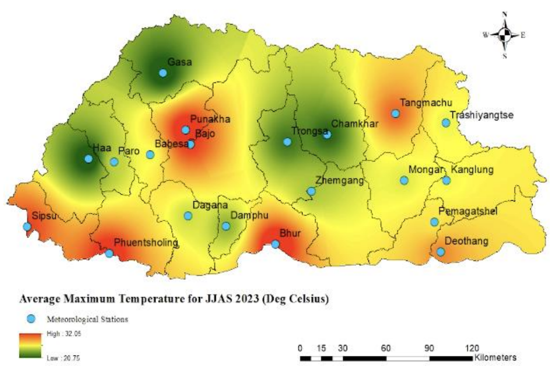
3.1.2.4 Winter/Monsoon – December to February (DJF)

3.1.3 Seasonal spatial distribution average maximum temperature

The following maps (Figure 7) show the spatial distribution of seasonal average maximum temperature for the year 2023.

(a) Spring/Pre-monsoon (March-May) (b) Summer/Monsoon (June-September)





(c) Autumn/Post-monsoon (October-November) (d) Winter/Monsoon (December-February)

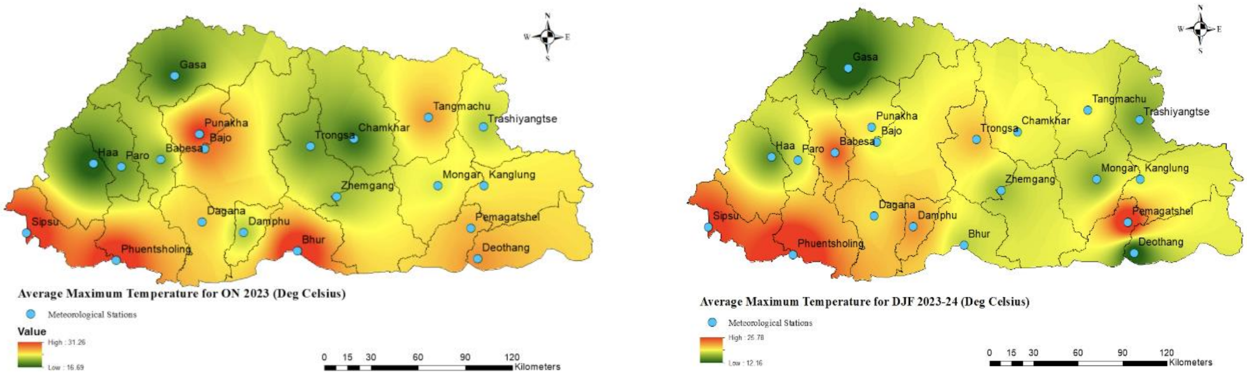


Figure 7: Spatial distribution of seasonal average maximum temperature for the year 2023

3.2 Minimum Temperature

A monthly climate monitoring report for the year 2023 is generated. The maps and extremes of monthly minimum temperature can be viewed and downloaded from the given website link http://www.nchm.gov.bt/. In this section, the spatial maps for annual average and seasonal variation of the average minimum temperature are included.

3.2.1 Annual average minimum temperature

The following map (Figure 8) shows the spatial distribution of annual average minimum temperature during the year 2023. Meteorological stations such as Sipsu, Phuntsholing, Bhur, Deothang, Punakha and Bajo experienced higher annual average minimum temperatures.

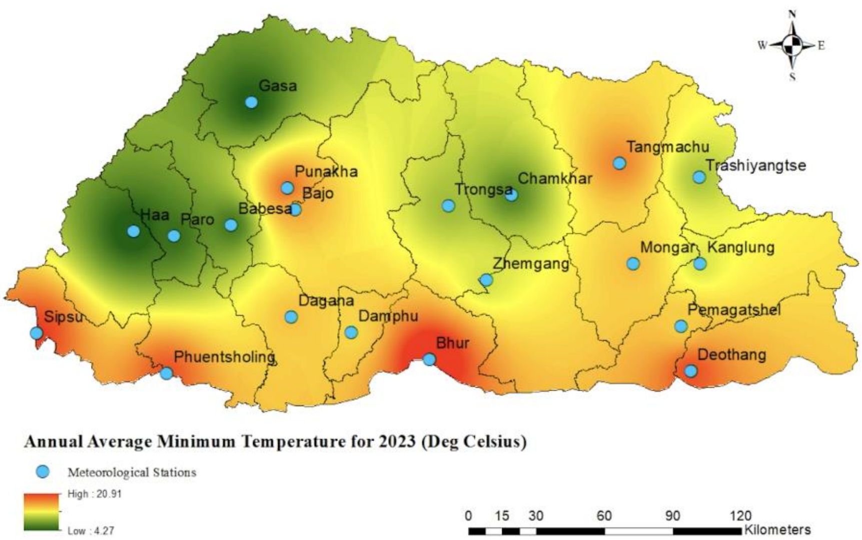
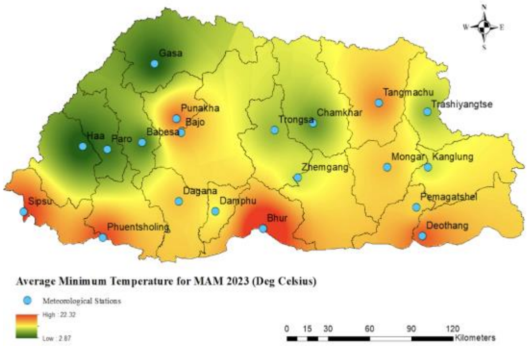


Figure 8: Spatial distribution of annual average minimum temperature for the year 2023

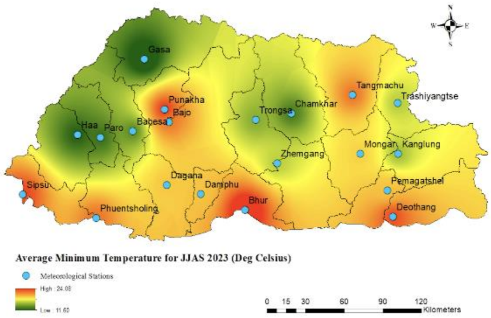
3.2.2 Seasonal spatial distribution of average minimum temperature

The following maps (Figure 9) show the spatial distribution of seasonal average minimum temperature for the year 2023.

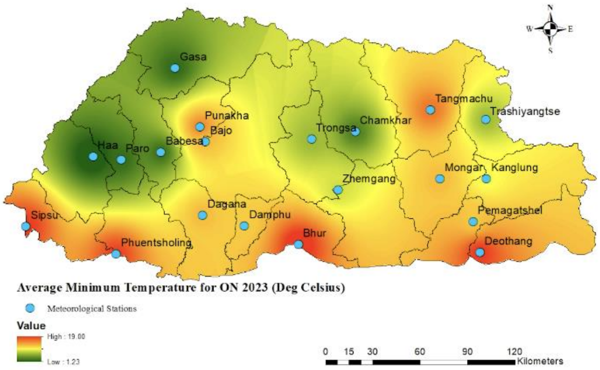
(a) Spring/Pre-monsoon (March-May)



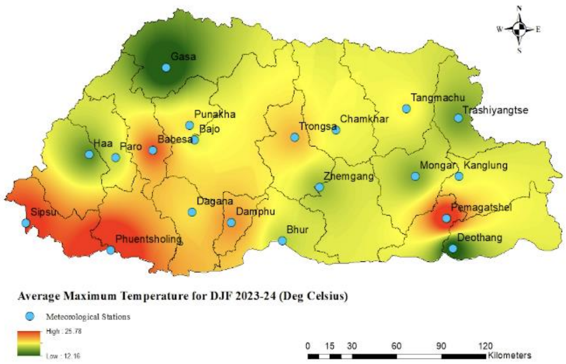
(b) Summer/Monsoon (June-September)



(c) Autumn/Post Monsoon (October-November)



(d) Winter/Monsoon (December-



February)

Figure 9: Spatial distribution of seasonal average minimum temperature for the year 2023

4. ANALYSIS OF RAINFALL - 2023

A monthly climate monitoring report for the year 2023 is generated. The maps and extremes of monthly accumulated rainfall can be viewed and downloaded from the given website link *http://www.nchm.gov.bt/*. In this section, annual and seasonal accumulated rainfall are included.

4.1 Annual Accumulated Rainfall

The following graph (Figure 10) shows the distribution of annual accumulated rainfall in the year 2023.

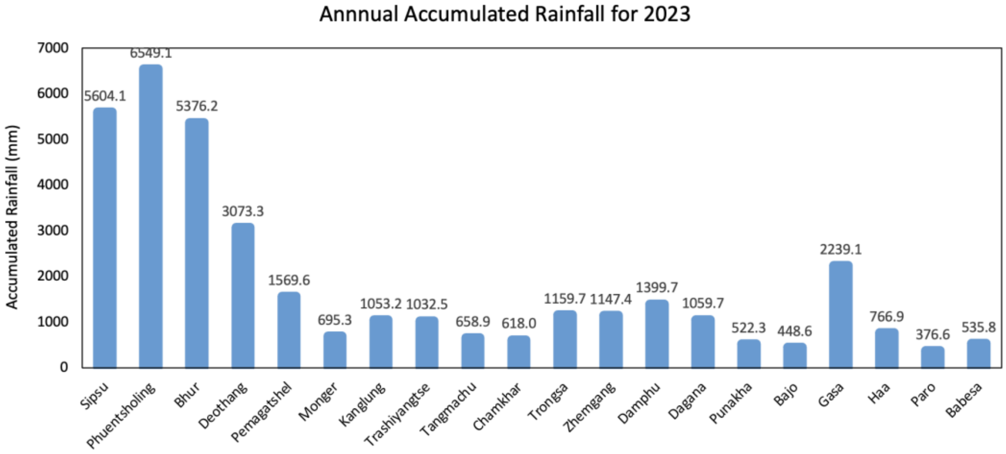
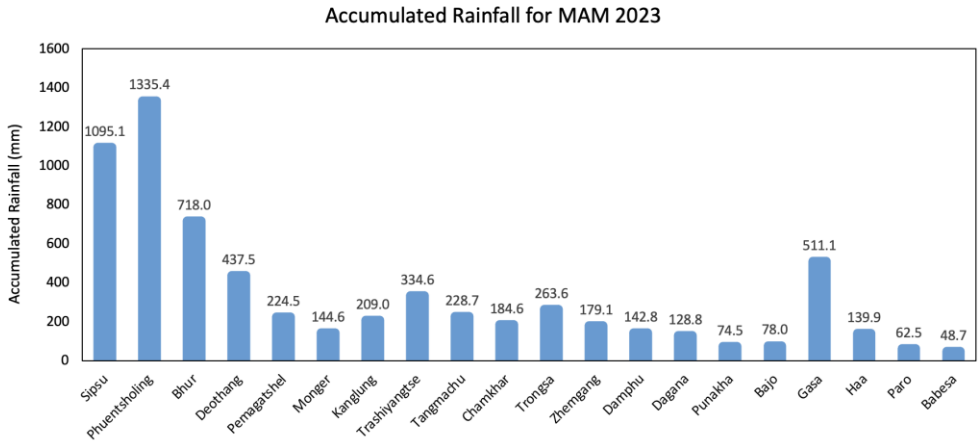


Figure 10: Annual accumulated rainfall for the year 2023

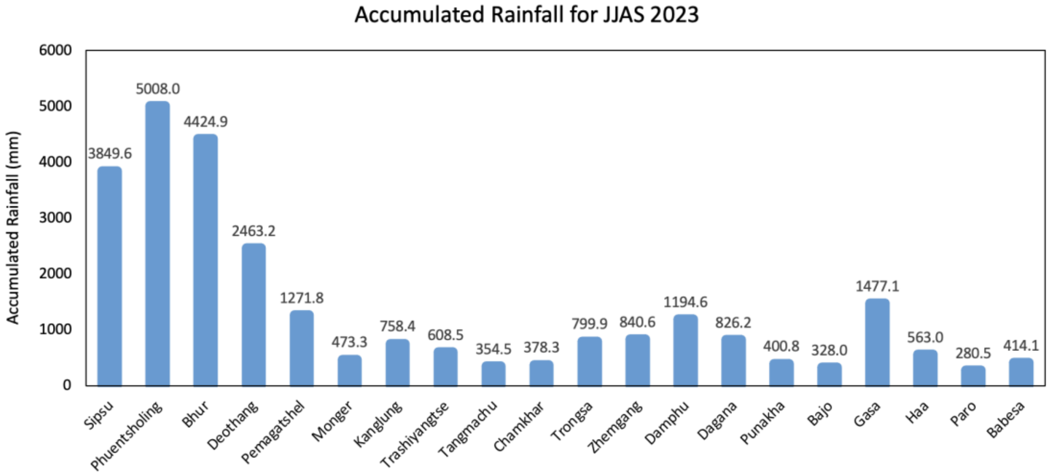
4.2 Seasonal spatial distribution of accumulated rainfall

The following graph (Figure 11) shows the distribution of seasonal accumulated rainfall.

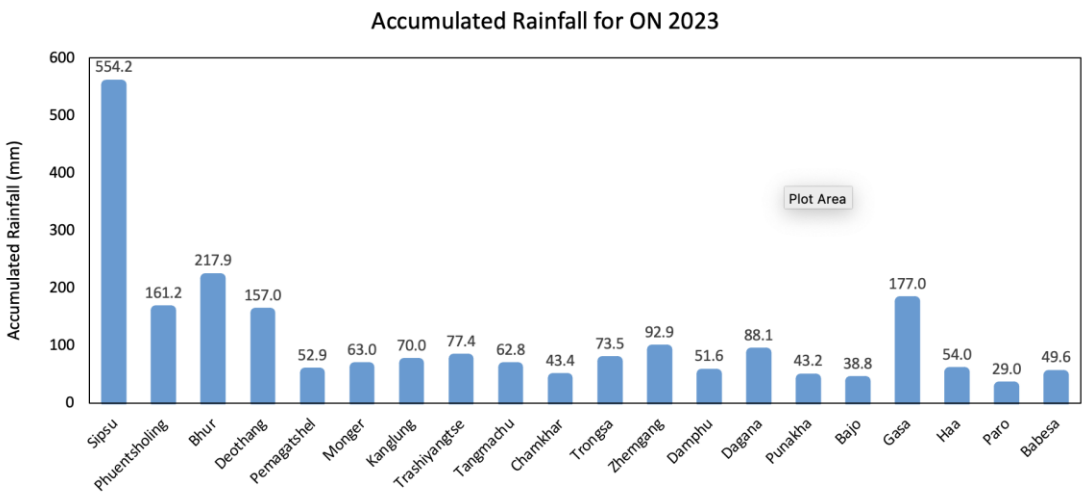
a. Spring/Pre-monsoon (March-May)



b. Summer/Monsoon (June-September)



c. Autumn/Post Monsoon (October-November)



d. Winter/Monsoon (December-February)

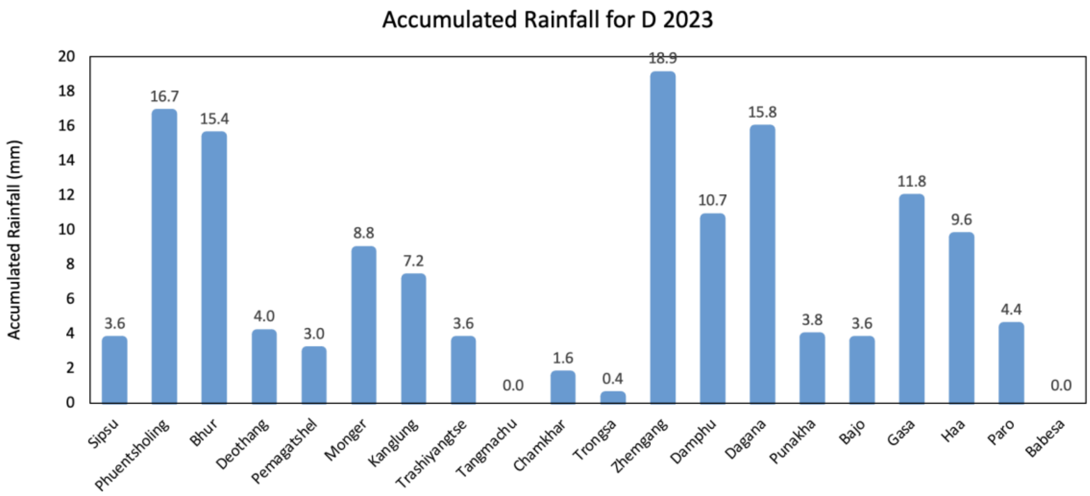
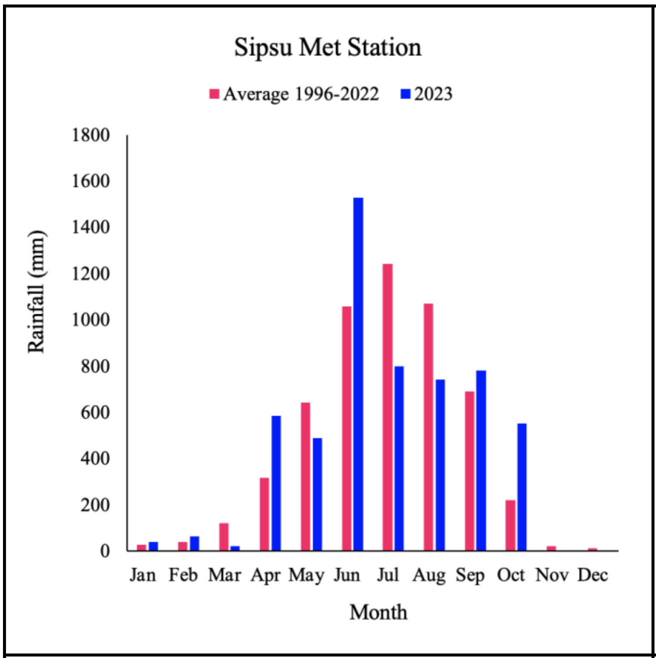
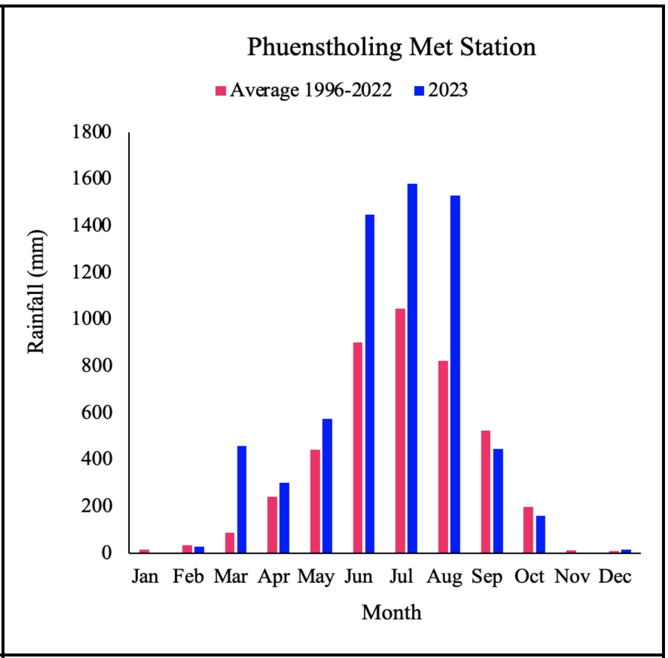


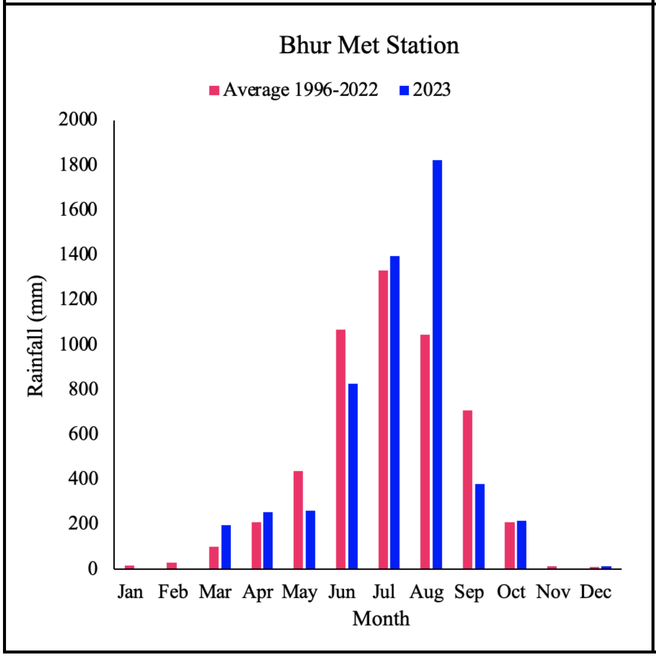
Figure 11: Spatial distribution of seasonal accumulated rainfall for the year 2023

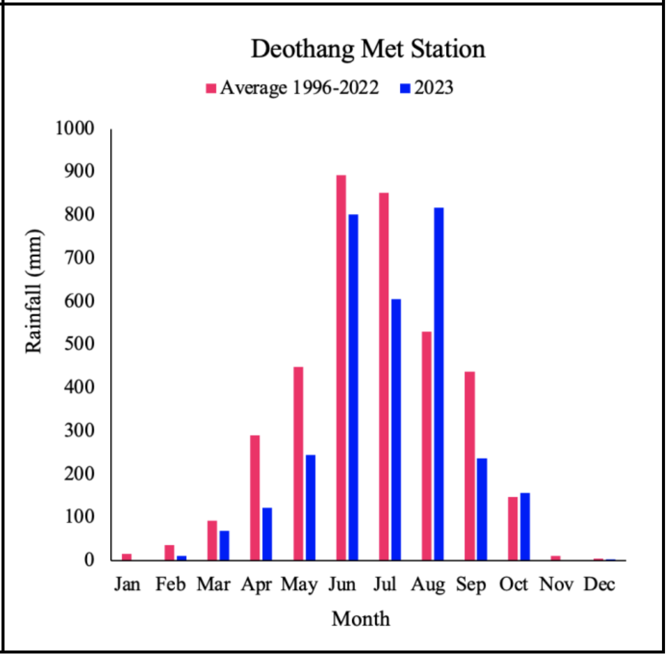
4.3 Comparison of monthly accumulated rainfall against long term average

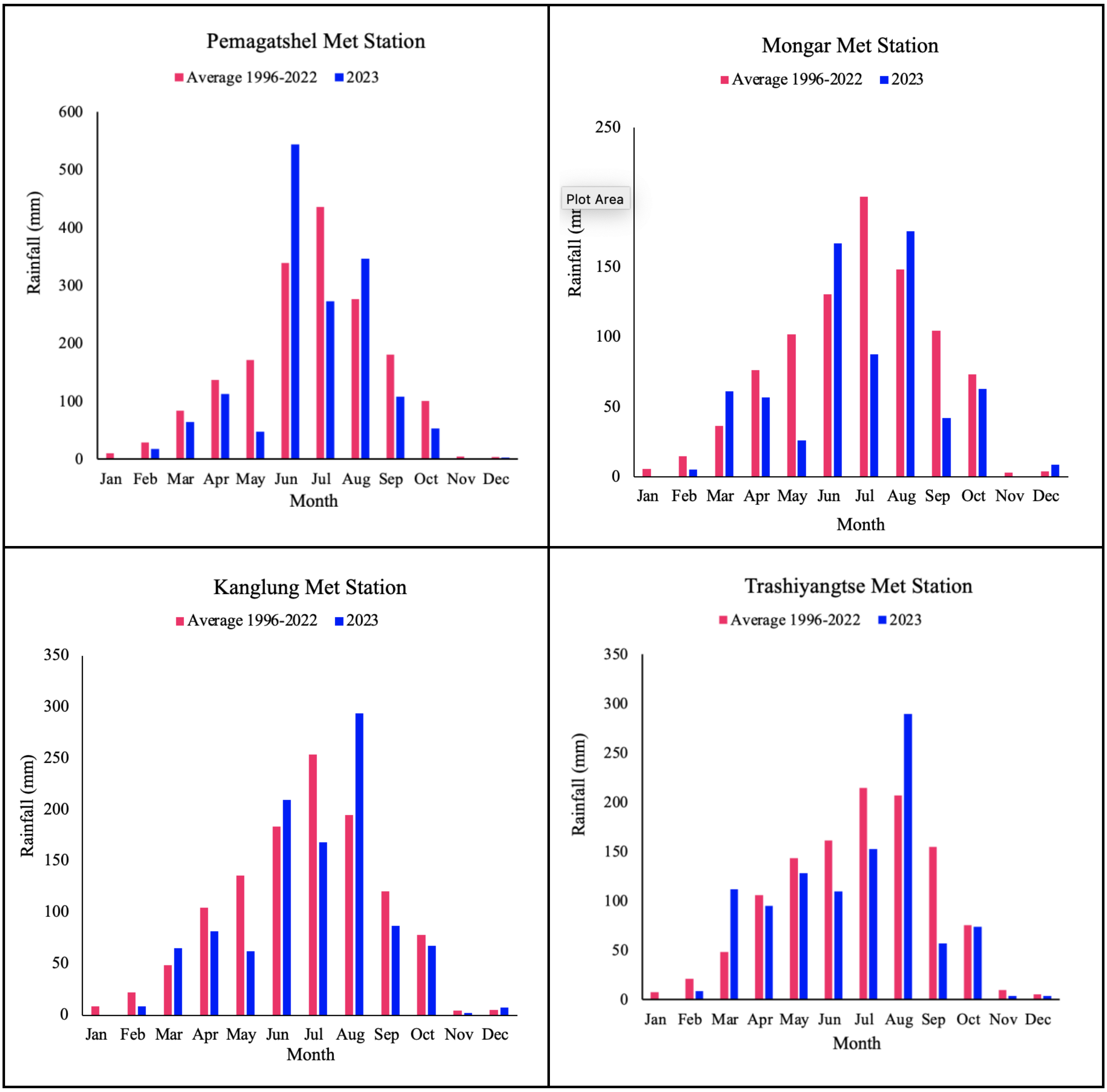
The following figures show the comparison of monthly accumulated rainfall of the year 2023 with their long-term average. Please note that the long-term averaging period in each station varies based on the data availability.

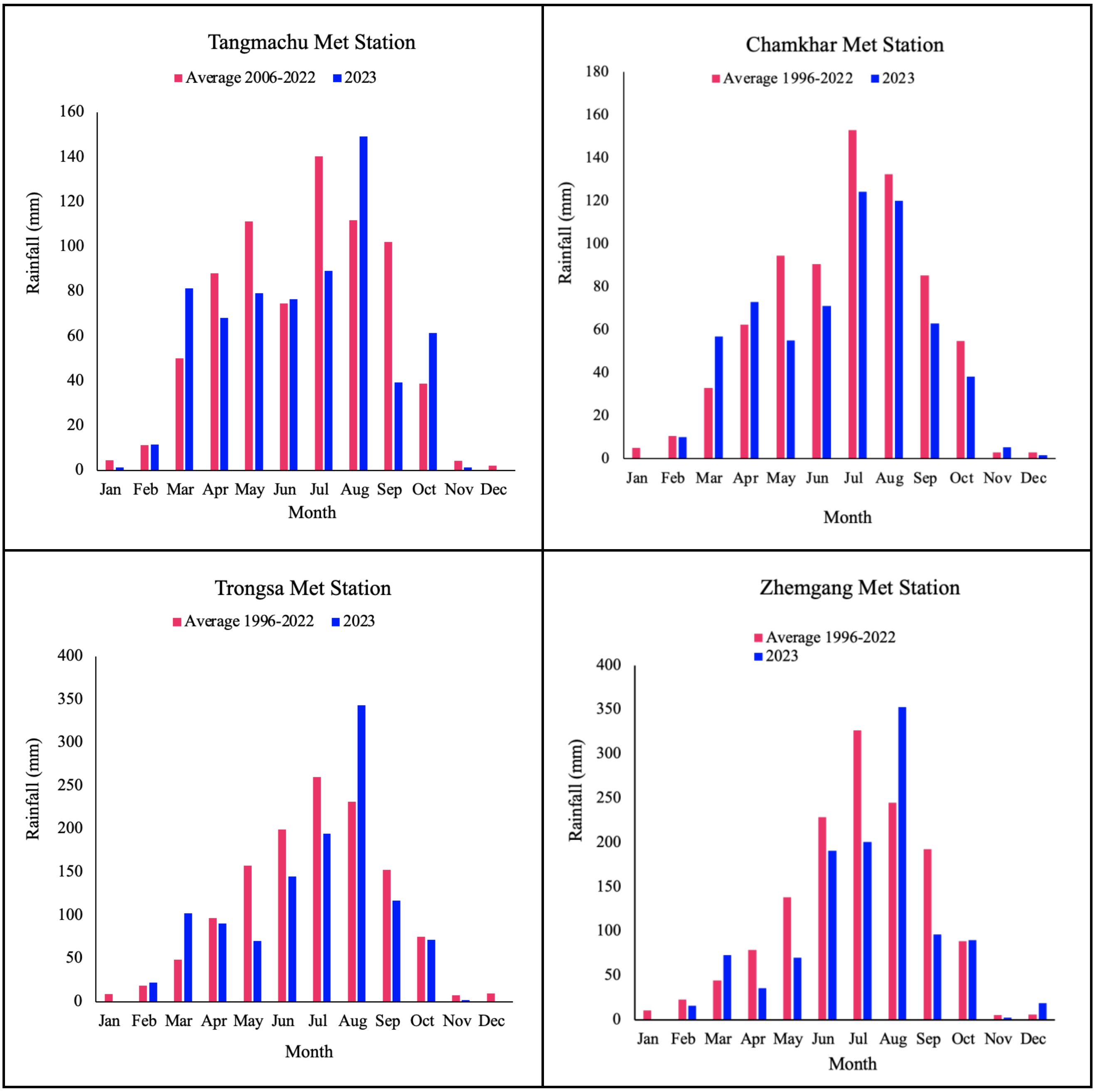


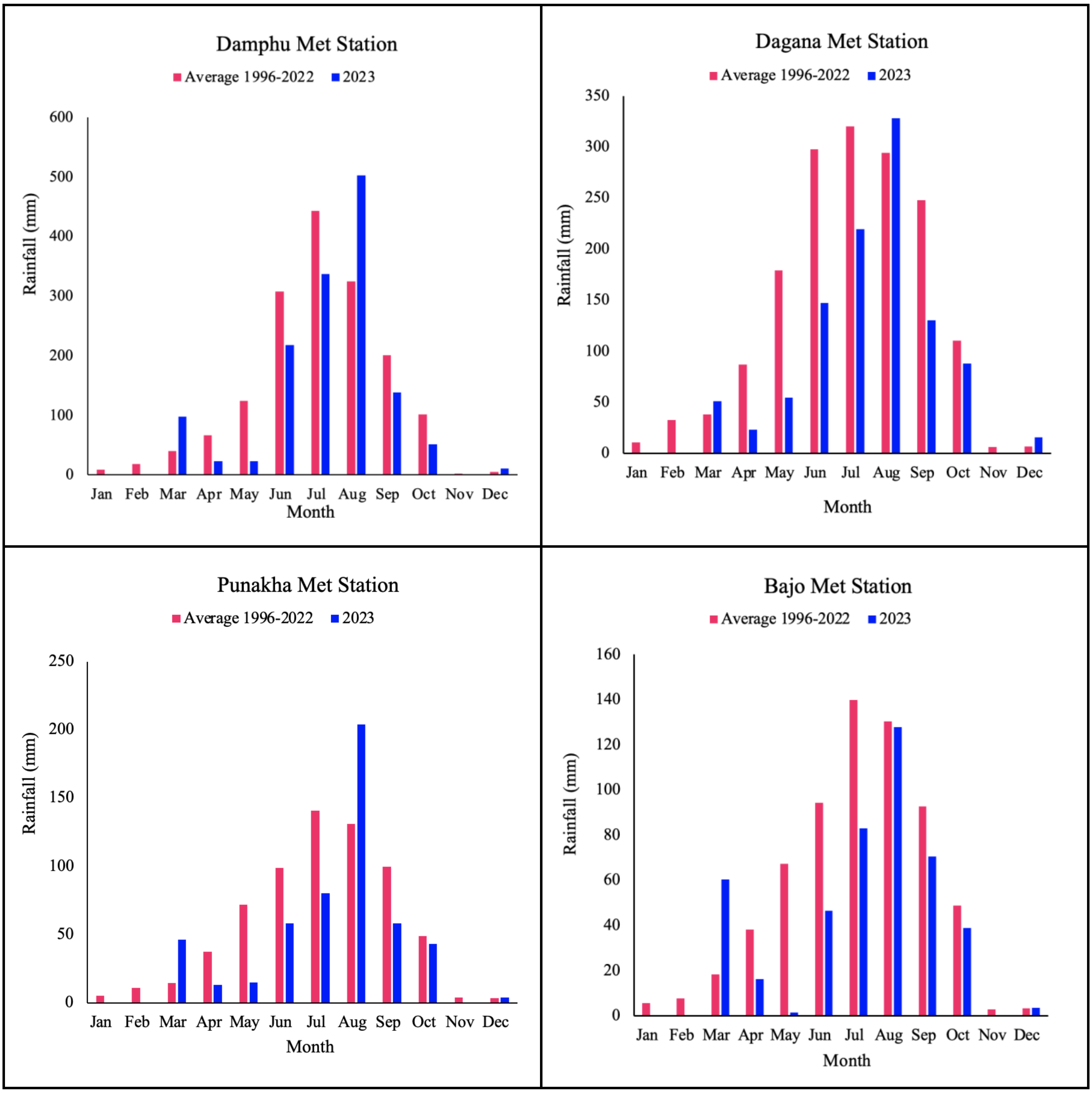







Pemagatshel Met Station
Average 1996-2022
2023
Rainfall (mm)
600
500
400
300
200
100
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month
Mongar Met Station
Average 1996-2022
2023
Plot Area
Rainfall (m
250
150
100
50
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month
Kanglung Met Station
Average 1996-2022
2023
Rainfall (mm)
350
300
250
200
150
100
50
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month
Trashiyangtse Met Station
Average 1996-2022
2023
Rainfall (mm)
350
300
250
200
150
100
50
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month


Tangmachu Met Station
Average 2006-2022
2023
Rainfall (mm)
0
20
40
60
80
100
120
140
160
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Chamkhar Met Station
Average 1996-2022
2023
Rainfall (mm)
0
20
40
60
80
100
120
140
160
180
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Trongsa Met Station
Average 1996-2022
2023
Rainfall (mm)
0
50
100
150
200
250
300
350
400
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Zhemgang Met Station
Average 1996-2022
2023
Rainfall (mm)
0
50
100
150
200
250
300
350
400
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month


Damphu Met Station
Average 1996-2022
2023
Rainfall (mm)
0
100
200
300
400
500
600
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month
Dagana Met Station
Average 1996-2022
2023
Rainfall (mm)
0
50
100
150
200
250
300
350
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month
Punakha Met Station
Average 1996-2022
2023
Rainfall (mm)
0
50
100
150
200
250
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month
Bajo Met Station
Average 1996-2022
2023
Rainfall (mm)
0
20
40
60
80
100
120
140
160
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month

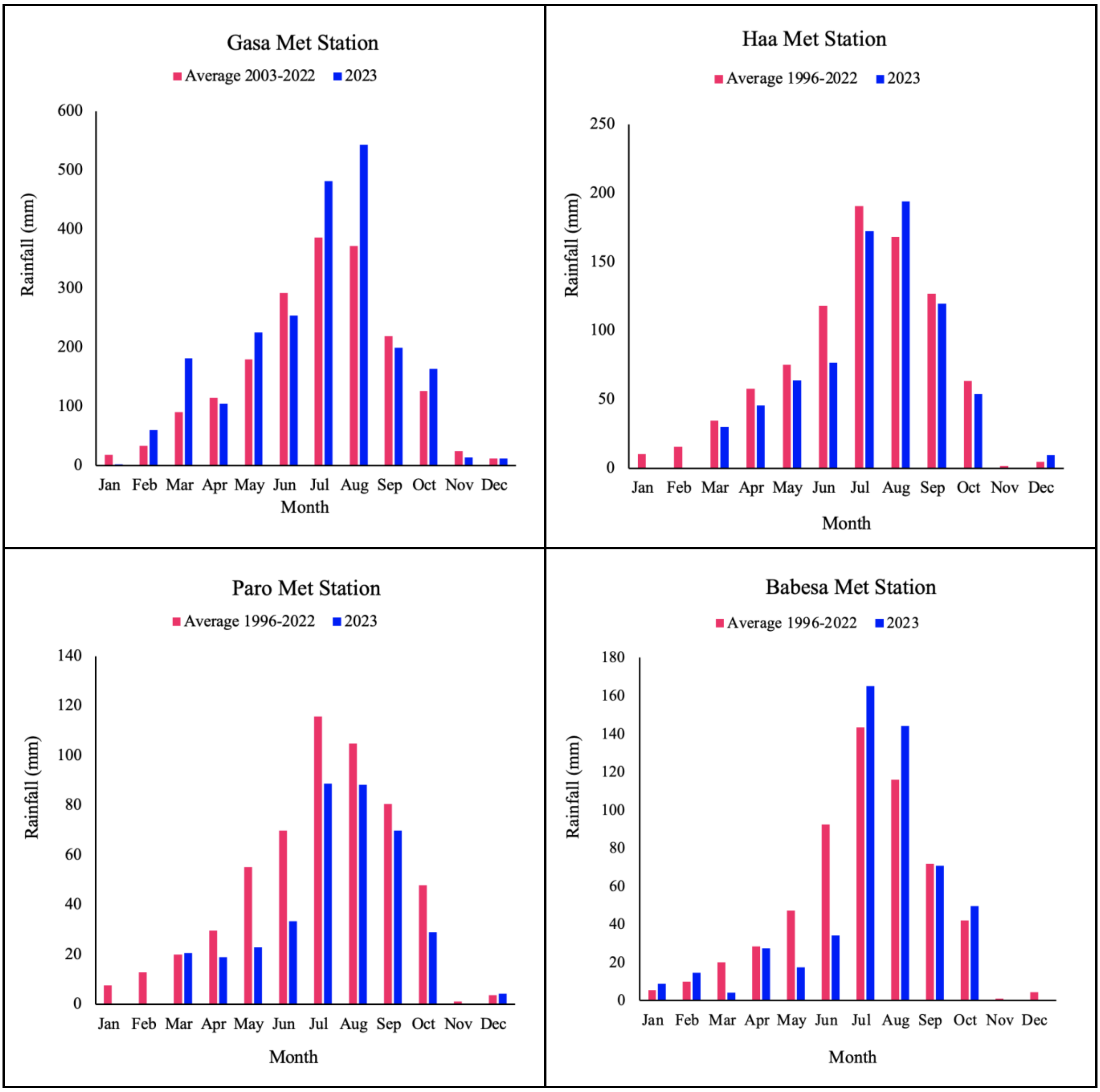


Figure 12: Comparison of total monthly rainfall of observed 2023 with long term average

5. ANNUAL STATISTICS

5.1 Annual statistics for 20 Agrometeorological stations – 2023

Table 1. Annual statistics for 20 Agrometeorological stations

Station	Annual total rainfall (mm)	Annual average maximum temp (°C)	Annual average minimum temp (°C)	Number of days with rainfall>=1mm	Number of days with Tmax>=30	No. of days with Tmin<=0
Sipsu	5604.10	28.76	18.19	164	159	0
Phuentsholing	6549.10	29.89	17.34	162	199	0
Bhur	5376.20	29.65	20.92	136	170	0
Deothang	3073.30	25.29	17.58	365	30	0
Pemagatshel	1569.60	23.71	13.30	94	33	0
Mongar	695.30	22.30	13.76	90	17	0
Kanglung	1053.20	22.40	10.85	112	5	0
Trashiyangtse	1032.50	22.17	9.71	134	10	17
Tangmachu	658.90	25.85	15.68	121	87	0
Chamkhar	618.00	17.84	7.05	112	0	54
Trongsa	1159.70	19.33	9.35	141	0	6
Zhemgang	1147.40	20.89	10.75	123	0	2
Damphu	1399.70	21.25	13.00	90	0	0
Dagana	1059.70	23.90	13.71	100	21	0
Punakha	522.30	29.28	16.48	77	187	0
Bajo	448.60	26.91	14.42	82	100	0
Gasa	2239.10	16.28	4.99	200	0	93
Haa	766.90	16.45	4.27	116	0	135
Paro	376.60	20.46	5.92	66	0	92
Babesa	535.80	20.94	6.39	83	1	84

5.2 Extreme records for 20 Agrometeorological stations - 2023

Table 2. Annual extremes for 20 Agrometeorological stations

Station	24 hour Rainfall (mm)	Date of occurrence	Maximum temperature (°C)	Date of occurrence	Minimum temperature (°C)	Date of occurrence
Sipsu	189.60	12th July	36.00	5th, 18th and 29th September	9.00	15th January, 18th January
Phuentsholing	213.60	13th July	38.50	5th July	8.00	17th January, 22nd October
Bhur	306.00	13th August	38.00	5th, 6th and 29th September	11.50	14th December
Deothang	245.00	28th August	36.00	24th July, 8th and 10th September	7.00	10th January
Pemagatshel	114.60	19th June	34.00	5th September	2.50	17th and 18th January
Mongar	33.00	4th October	31.00	31st May 7th - 8th June 6th September	3.00	18th January
Kanglung	58.6	11th July	30.50	5th September	1.50	18th and 20th January
Trashiyangtse	33.10	3rd August	30.50	20th and 22nd July 16th September	-1.50	5th-8th January 31st December
Tangmachu	21.40	10th August	38.00	4th August	5.00	8th, 11th and 19th January
Chamkhar	34.70	21st July	26.50	19th July	-9.00	7th January
Trongsa	64.20	17th August	27.50	3rd and 29th September	-1.50	5th January
Zhemgang	54.10	24th August	29.50	19th July 5th September	-0.50	19th January
Damphu	144.60	12th August	28.50	1st August	3.00	18th - 21st January
Dagana	58.00	12th August	32.00	8th June	2.50	18th January

Punakha	27.00	12th March	35.20	7th September	3.00	7th, 8th and 10th January
Bajo	24.40	13th August	35.00	31st May 1st - 2nd June	1.00	7th-9th January
Gasa	58.40	24th August	26.00	19th July	-6.00	17th January
Haa	31.50	20th July	25.00	19th and 20th August	-10.50	5th, 17th and 18th January
Paro	27.20	20th July	29.00	24th, 25th June 15th July 19th August 3rd and 7th September	-7.00	18th January
Babesa	24.20	13th August	30.30	2nd June	-7.50	18th January

SECTION B: HYDROLOGY

1. MAJOR FACTORS INFLUENCING RIVER FLOW VARIABILITIES IN BHUTAN

River Regimes

The river regime is the direct consequence of the climatic factors influencing the catchment runoff, which is derived or estimated from the climate knowledge of the region. The expected pattern of river flow during a year is known as the river regime. A flow records of 20-30 years are generally required to represent a pattern since there may be considerable variation in the seasonal discharge from year to year. The averages of the monthly mean discharges over the years of record calculated for each month, January to December, give the general or expected pattern: the regime of the river.

Temperature-dependent Regimes

Rivers with a dominant single source of supply, initially in the solid state (snow or ice), produce a simple maximum and minimum in the pattern of monthly mean discharges according to the seasonal temperatures.

• Glacial: When the catchment area is over 25-30 per cent covered by ice, the river flow is dominated by the melting conditions. Such rivers are found in the high mountain areas of the temperate regions. There is little variation in the pattern from year to year, but in the main melting season, July and August, there are great diurnal variations in the melt water flows.

• Mountain snowmelt: The seasonal peak from snowmelt is lower and earlier than in a glacial stream, but the pattern is also regular each year providing there has been adequate winter snowfall. The low winter flows are caused by freezing conditions.

Rainfall-dependent Regimes

In the equatorial and tropical regions of the world with no high mountains, the seasonal rainfall variations are the direct cause of the river regimes. Temperature effects in these areas are mostly related to evaporation losses, but with these being dependent on rainfall, the overall effect of evaporation is of secondary importance in influencing the river flow pattern.

Drainage basins within the equatorial belt experience two rainfall seasons with the annual migration of the inter-tropical convergence zone, and these are reflected directly in the river regime.

2. ANNUAL FLOW OF 2023 COMPARED WITH THE HISTORICAL FLOW

The annual average flow from recorded data as early as 1992-2020 is compared to the average flow of 2021 for stations located across Bhutan. Each station is located in different basins but does not serves as the representative flow of the whole basin. The following table shows the details.

Table 3. Comparative flow in each basin

Sl. No	Station Name	Basin/Sub Basin	Historical Average flow (till 2022) in m^3/s	Average flow 2023 in m^3/s
1	Tamchu	Wangchhu	59.4	47.6
2	Lungtenphu	Wangchhu	22.06	17.6
3	Kerabari	Punatsangchhu	450.6	425.5
4	Wangdirapids	Punatsangchhu	296.4	287.2
5	Yebesa on Mochhu	Punatsangchhu	118.5	97.3
6	Kurjey on Chamkhar	Manas	53.2	50.7
7	Muktirap on Kholongchhu	Manas	63.9	57.0
8	Sumpa on Kurichhu	Manas	174.3	163.2
9	Kurizampa on Kurichhu	Manas	291.8	274.2
10	Panbang on Drangmechhu	Manas	781.9	774.7

3. MAXIMUM AND MINIMUM FLOW RECORDED IN 2023

Table 4. Maximum and Minimum flow record

Sl. No	Station Name	Catchment area in sq.km	Max flow in m^3/s	Min flow in m^3/s
1	Tamchu	2529.17	426.44	10
2	Lungtenphu	665.71	90	3.9
3	Kerabari	9627.237	2618	95.6
4	Wangdirapids	5647.62	1882.7	65.3
5	Yebesa	2223.30	614.2	19.7
6	Kurjey	1354.97	220.1	11
7	Muktirap	876.36	376.7	10.3
8	Sumpa	7101.15	765.4	27
9	Kurizampa	8997.70	1262.03	61.2
10	Panbang	21006.1	4100.7	122.09

4. LOCATION MAP OF PRINCIPLE HYDROLOGICAL STATIONS

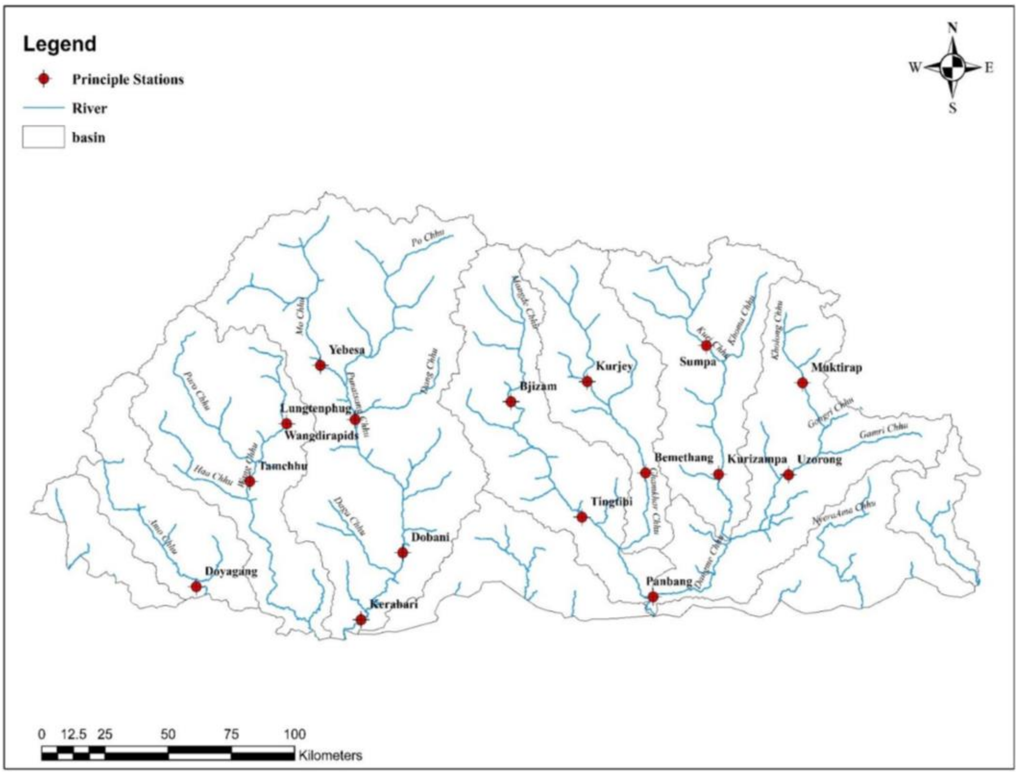
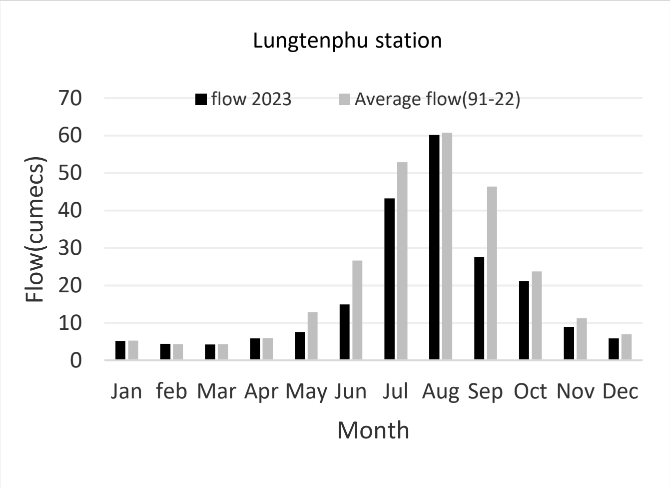
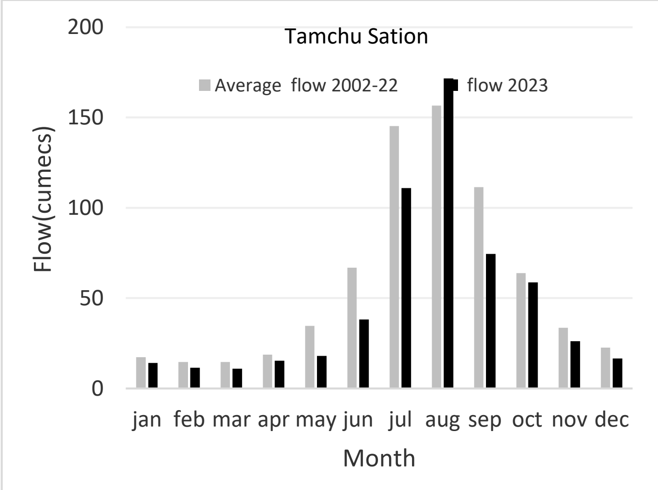


Figure 13: Location of Principle Stations

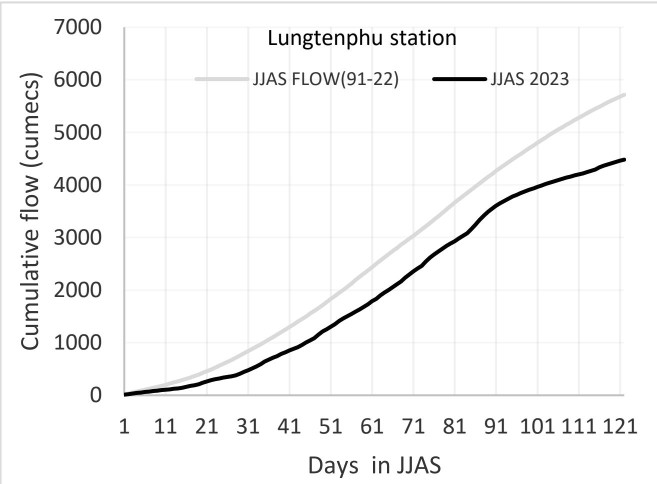
5. WANGCHU BASIN RIVER FLOW STATUS

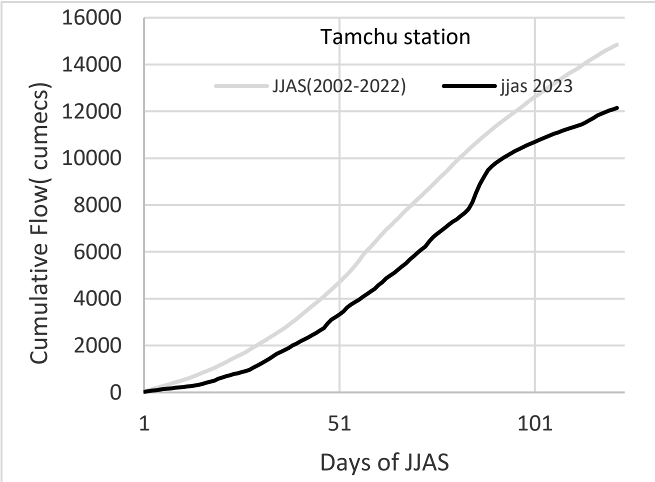
5.1 STATION WISE AVERAGE MONTHLY FLOW





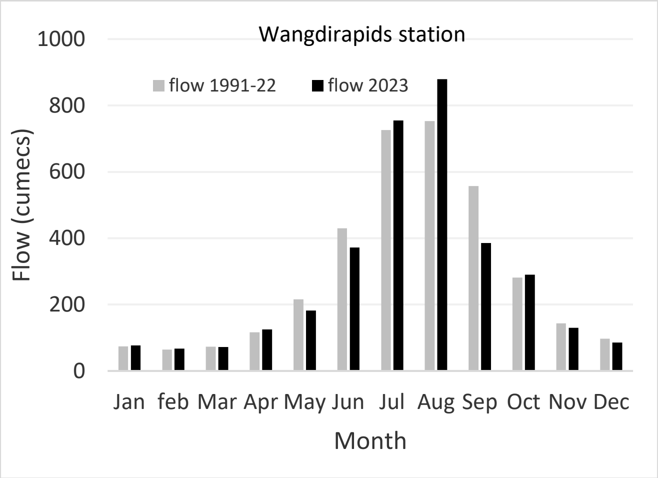
5.2 STATIONWISE JJAS CUMMULATIVE FLOW

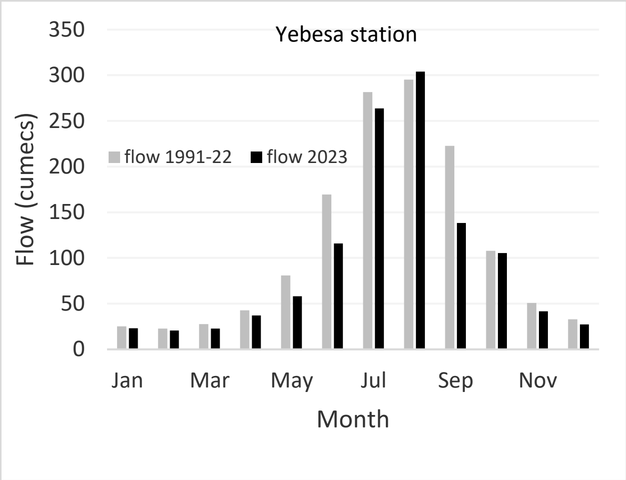


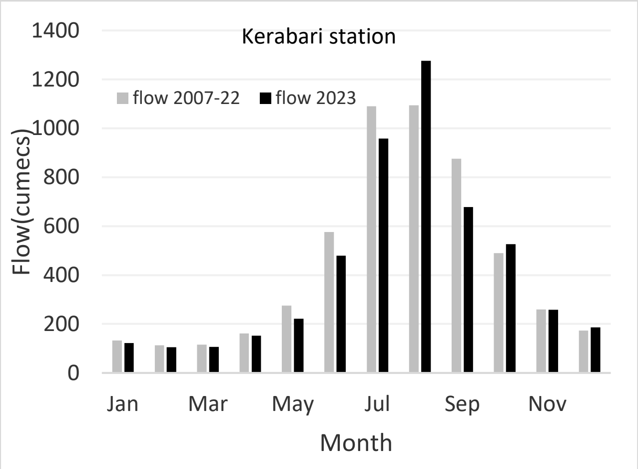


6. PUNATSANGCHHU RIVER FLOW STATUS

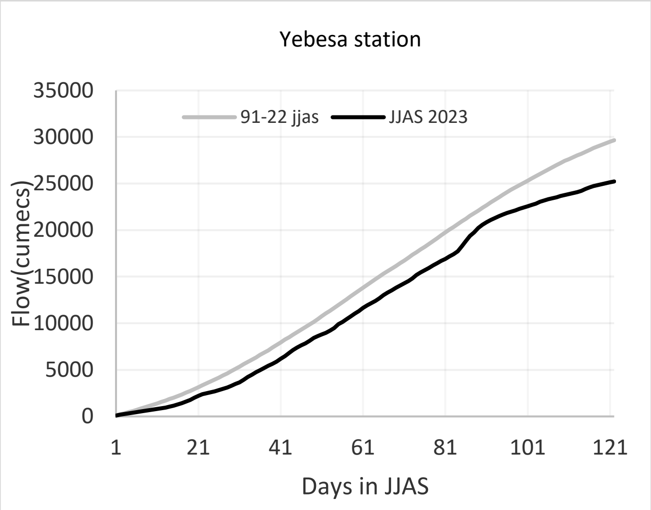
6.1 STATIONWISE AVERAGE MONTHLY FLOW

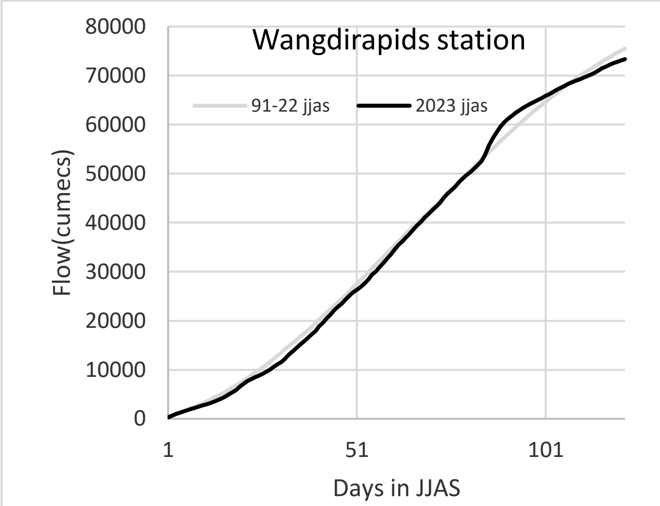


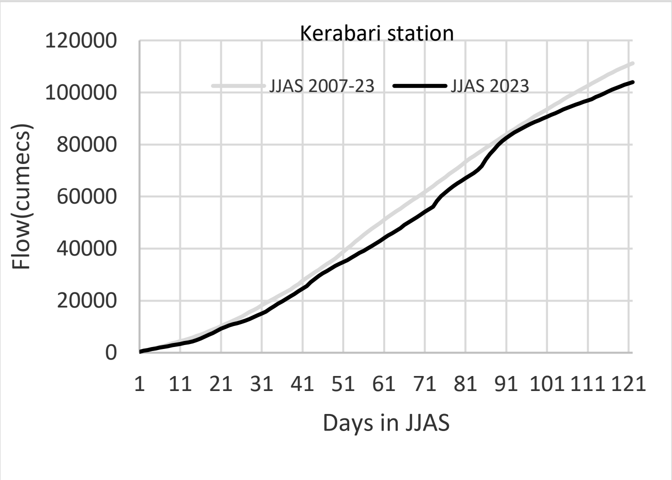




6.2 STATIONWISE JJAS CUMULATIVE FLOW

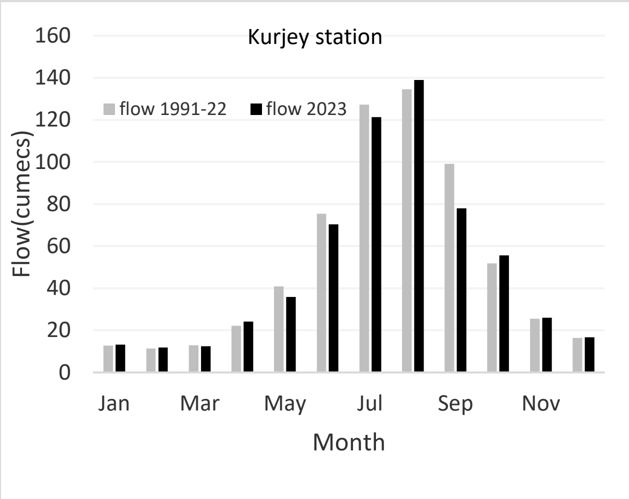


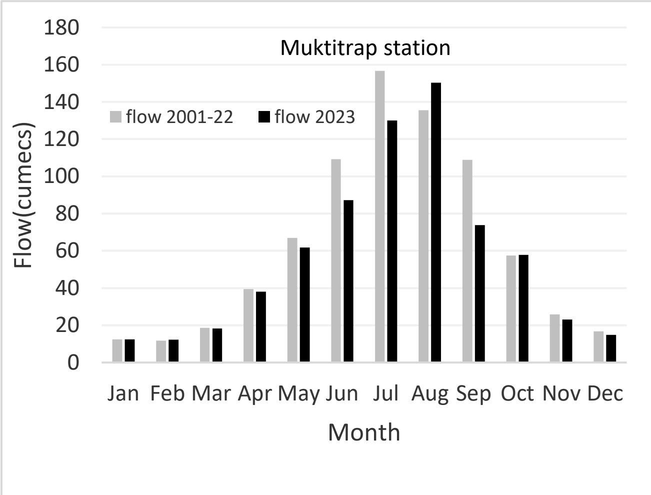


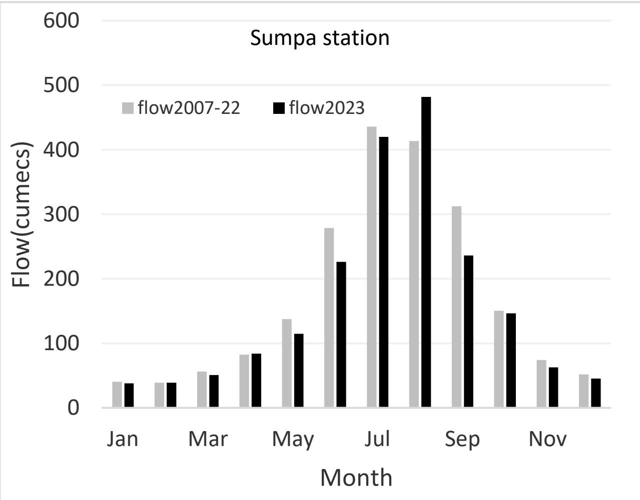


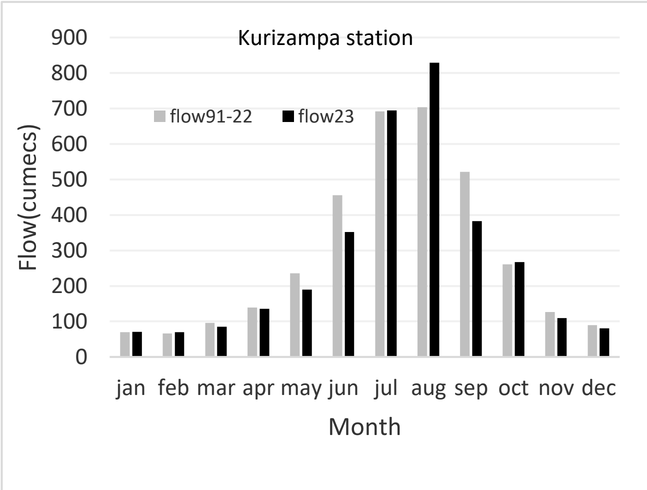
7.MANAS BASIN RIVER FLOW STATUS

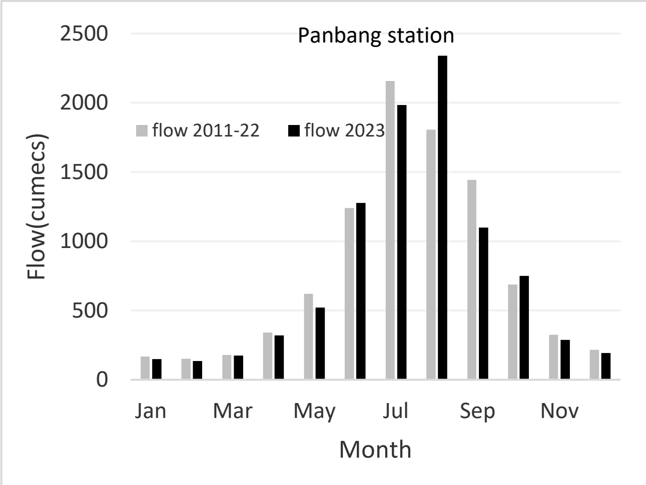
7.1 STATIONWISE AVERAGE MONTHLY FLOW



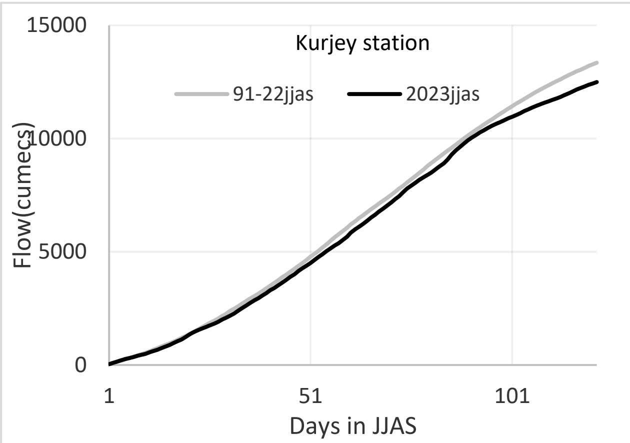


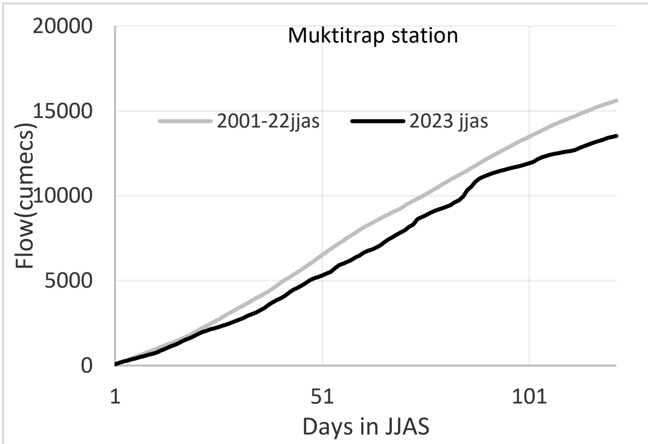


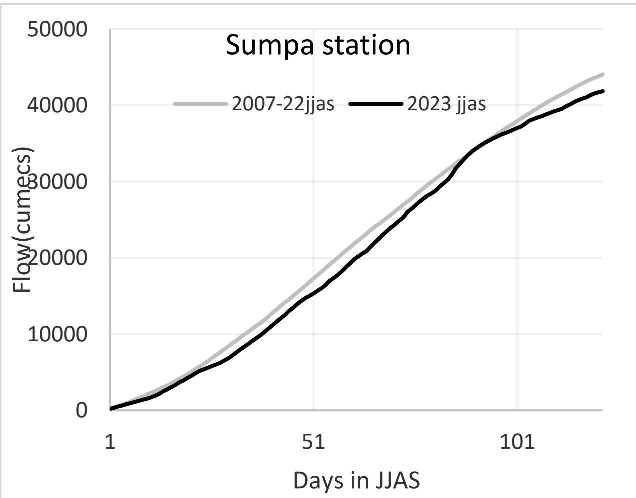


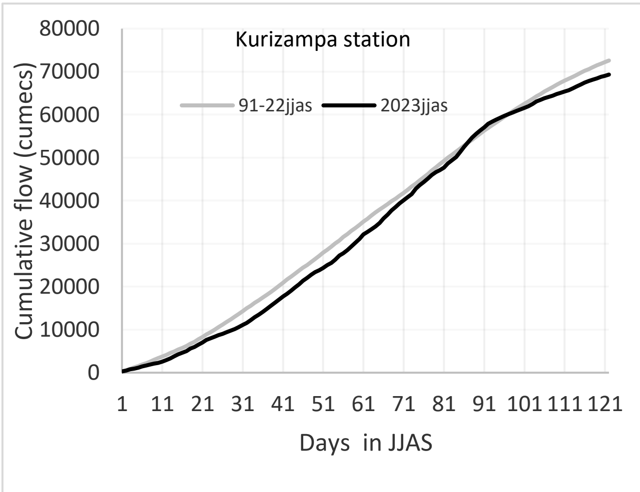


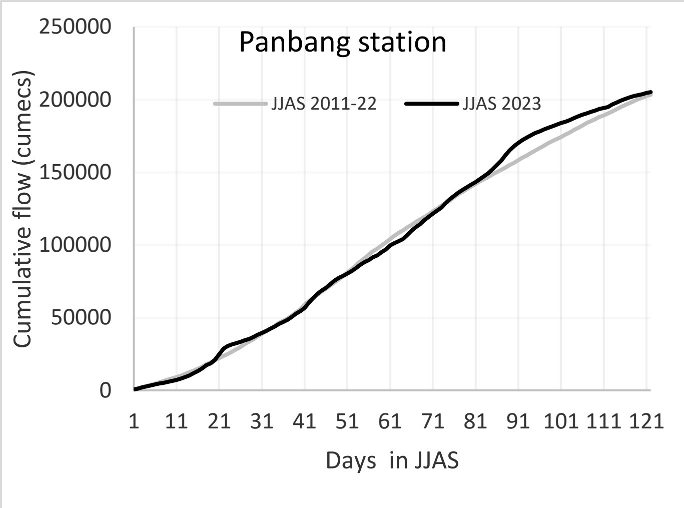
7.2 STATIONWISE JJAS CUMMULATIVE FLOW










Panbang station
JJAS 2011-22
JJAS 2023
Cumulative flow (cumecs)
250000
200000
150000
100000
50000
0
1 11 21 31 41 51 61 71 81 91 101 111 121
Days in JJAS

SECTION C: CRYOSPHERE

1. GLACIERS

Bhutan, nestled in the Eastern part of the Himalayas is renowned for its majestic glaciers, distributed across the northern frontiers of the country. These glaciers are vital sources of freshwater for Bhutan's perennial rivers supporting agriculture, hydropower generation and ecosystem. As per the BGI 2018, Bhutan has 700 glaciers covering an area of approximately 630 km^2 accounting to 1.6 percent of the total area of the country. However, in the recent decades, these glaciers have been experiencing the impact of global climate change. Rising temperatures and changing precipitation patterns have led to glacier retreat, resulting in reduced glacier ice surface area and volume.

Out of 700 glaciers, the highest number of glaciers are situated in the Punatsang Chhu basin with 341 glaciers covering an area of 361.07 km^2 and the least is in Wang Chhu basin with 47 glaciers covering an area of 33.38 km^2. The glacier MMagr16_482 (G090443E28024) with a length of 15.56 km and having an area of 45.85 km^2 located in Mangde Chhu sub-basin is the largest glacier in Bhutan. Figure 14 and table 5 shows the glacier map and basin to sub-basin wise distribution of glaciers in Bhutan respectively.

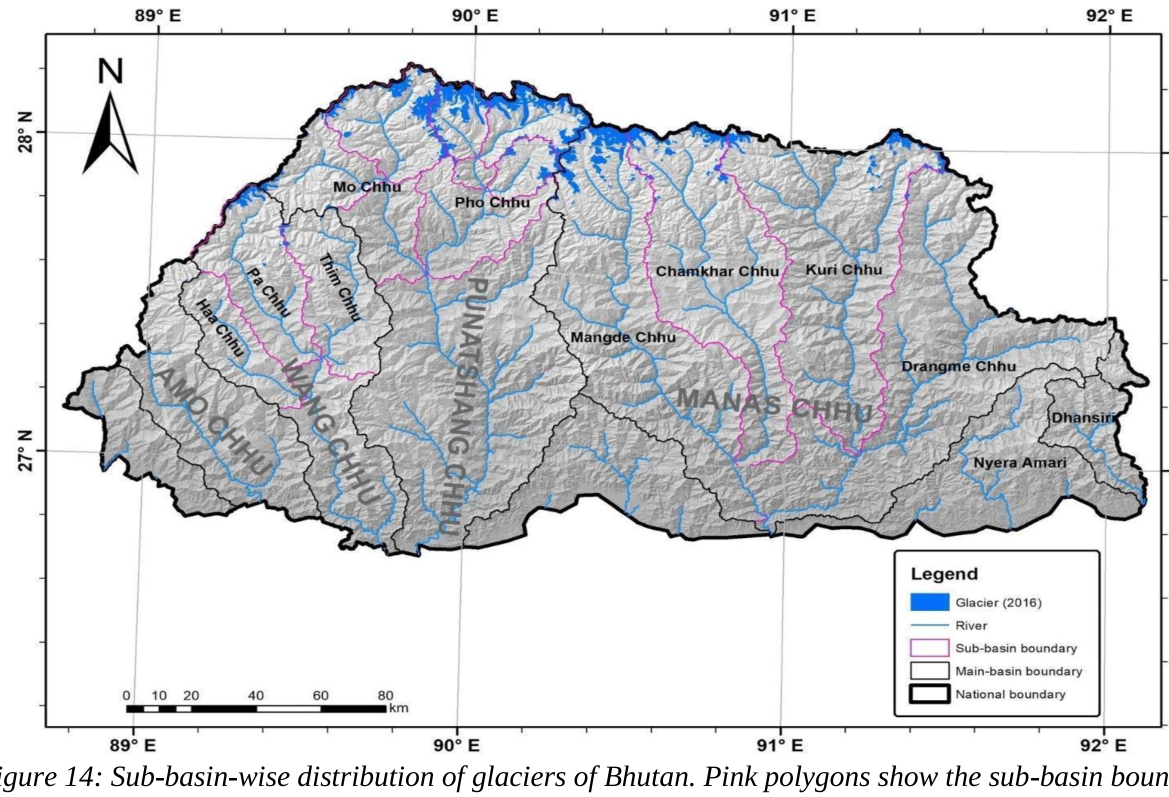


Figure 14: Sub-basin-wise distribution of glaciers of Bhutan. Pink polygons show the sub-basin boundary, dark blue polygons show the glaciers and light blue polygons are rivers of Bhutan

Table 5. Basin to sub-basin wise distribution of glaciers of Bhutan

Major Basin	Sub-basin	Glaciers (number)	Area (in km^2)
Wang Chhu	Ha Chhu	31	0.27
	Pa Chhu	13	28.39
	Thim Chhu	3	4.72
PunatsangChhu	Mo Chhu	135	108.64
	Pho Chhu	206	252.42
Manas	Mangde Chhu	111	108.26
	Chamkhar Chhu	90	68.277
	Kuri Chhu	90	55.29
	Drangme Chhu	21	3.28
Total		**700**	**629.55**

2. GLACIAL LAKES

Owing to numerous glaciers found in the northern frontiers of the country, Bhutan hosts hundreds of glacial lakes. As per the glacial lake inventory published (BGLI, 2021) in the past, Bhutan has 567 glacial lakes mapped through updated criteria. When Bhutan has numerous glacial lakes including some of the largest and most spectacular ones, they also pose a significant risk to the local communities due to the potential threat of glacial lake outburst flood (GLOFs). Altogether, these glacial lakes cover an area of 55.04 km^2. The highest number of glacial lakes are found in Manas basin with 331 glacial lakes covering an area of 29.2 km^2 and the least in Wang Chhu basin (31 glacial lakes) covering an area of 0.6 km^2. Figure 15 and table 6 shows the distribution of glacier lakes in the northern frontiers and sub-basin wise distribution of the lakes respectively

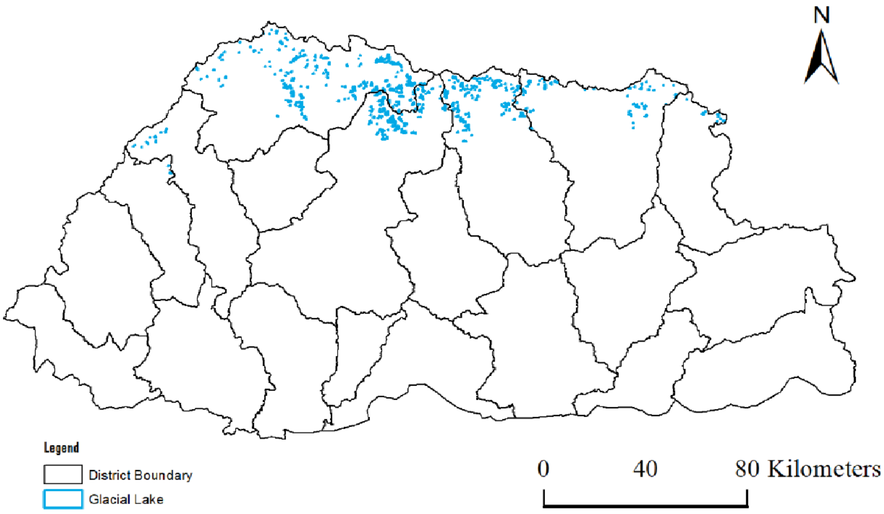


Figure 15: Distribution of glacial lakes in the northern frontiers of the country. Blue polygons are the distribution of glacial lakes and the black polygons are district boundaries.

Table 6. Basin to sub-basin wise distribution of glacial Lakes of Bhutan

Major Basin	**Sub-basin**	**Glacial lakes (number)**	**Area (in km²)**
Wang Chhu	Ha Chhu	0	0
	Pa Chhu	13	0.60456
	Thim Chhu	0	0
PunatsangChhu	Mo Chhu	66	4.254
	Pho Chhu	157	20.98
Manas	Mangde Chhu	130	11.8558
	Chamkhar Chhu	131	11.5627
	Kuri Chhu	61	5.00721
	Drangme Chhu	9	0.77262
Total		**567**	**55.0369**

3. POTENTIALLY DANGEROUS GLACIAL LAKES (PDGL)

According to the inventory on glaciers and glacial lakes of Bhutan (2001), Bhutan had 25 potentially dangerous glacial lakes. Later, through ground verification of those potentially dangerous glacial lakes, the number of potentially dangerous glacial lakes of the country has been updated. According to the updated inventory, Bhutan now has 17 potentially dangerous glacial lakes of which a maximum number of potentially dangerous glacial lakes are found in Pho Chhu sub-basin. Figure 16 and table 7 shows the locations and sub-basin wise distribution of 17 potentially dangerous glacial lakes of the country.

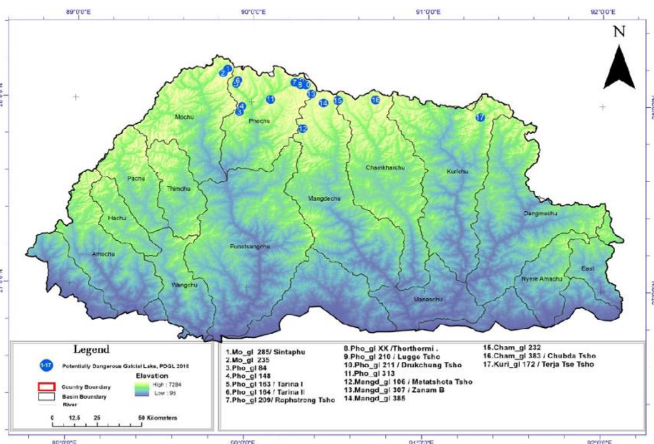


Figure 16: Sub-basin-wise distribution of potentially dangerous glacial lakes of Bhutan.

Table 7: Sub-basin-wise distribution of potentially dangerous glacial lakes of the Bhutan

Potentially Dangerous Glacial Lakes								
#	Lake Number	Local Name	Latitude	Longitude	Altitude	Area (m^2)	Volume (m^3)	Remarks
Mo Chu Sub-basin								
1	Mo_gl 37	Sintaphu	28° 10' 06.00	89° 51' 21.10	4480	238,314	6,410,000	PDGL
2	Mo_gl 39		28° 08' 35.40	89° 51' 21.10	4960	128,803	NA	PDGL
Pho Chhu Sub-basin								
3	Pho_gl 33	Tarina II	28° 06' 37.22	89° 54' 37.81	4338	446,325	13,000,000	PDGL
4	Pho_gl 32	Tarina I	28° 06' 06.43	89° 54' 11.83	4266	250,813	5,400,000	PDGL
5	Pho_gl 21		27° 58' 09.42	89° 56' 16.69	5072	637,422	26,310,000	PDGL
6	Pho_gl 8		27° 56' 48.53	89° 55' 14.03	4997	742,329	9,280,000	PDGL
7	Pho_gl 98		27° 59' 58.72	90° 07' 18.86	5049	211,705	NA	PDGL
8	Pho_gl 75	Raphstreng	28° 06' 43.56	90° 14' 03.65	4368	1,241,970	54,650,000	PDGL
9	Pho_gl 76	Thorthormi	28° 06' 19.90	90° 15' 48.46	4446	2,908,490	NA	PDGL
10	Pho_gl 77	Lugge	28° 05' 00.34	90° 18' 28.58	4570	1,460,870	65,190,000	PDGL
11	Pho_gl 78	Drukchung	28° 05' 40.45	90° 19' 11.95	4701	101,096	NA	PDGL
Mangdechhu Sub-basin								
12	Mang_gl 35	Metatshota	27° 53' 19.45	90° 17' 33.94	5065	1,203,880	41,740,000	PDGL
13	Mang_gl 81	Zanam B	28° 02' 21.01	90° 21' 58.87	5208	862,181	37,030,000	PDGL
14	Mang_gl 119		27° 58' 58.53	90° 26' 21.90	5089	248,574	NA	PDGL
Chamkhar Chhu Sub-basin								
15	Cham_gl 33		27° 59' 11.33	90° 30' 31.42	5205	188,550	NA	PDGL
16	Cham_gl 89	Chubda Tsho	28° 01' 25.91	90° 42' 31.77	4868	1,388,320	21,690,000	PDGL
Kurichhu Sub-basin								
17	Kuri_gl 140	Terja tse Tsho	27° 55' 47.56	91° 18' 08.77	4373	167,540	NA	PDGL

4. GLACIER MASS BALANCE

Bhutan has identified two benchmark glaciers for long-term monitoring for the understanding of glacier behaviors since 2003 and 2012 for Gangju La (headwater of Pho Chhu) and Thana (headwater of Chamkhar Chhu) glaciers respectively. Over the observation periods, both the glaciers have exhibited negative mass balance indicating glacier ice mass loss. In addition to the existing two benchmark glaciers, an additional benchmark glacier has been identified in the headwater of Thim Chhu, Shodug glacier representing uniform spatial distribution in the country. Figure 17 and Table 8 shows the location of three benchmark glaciers and glacier mass balance data of Gangju La and Thana glacier over the observation periods.

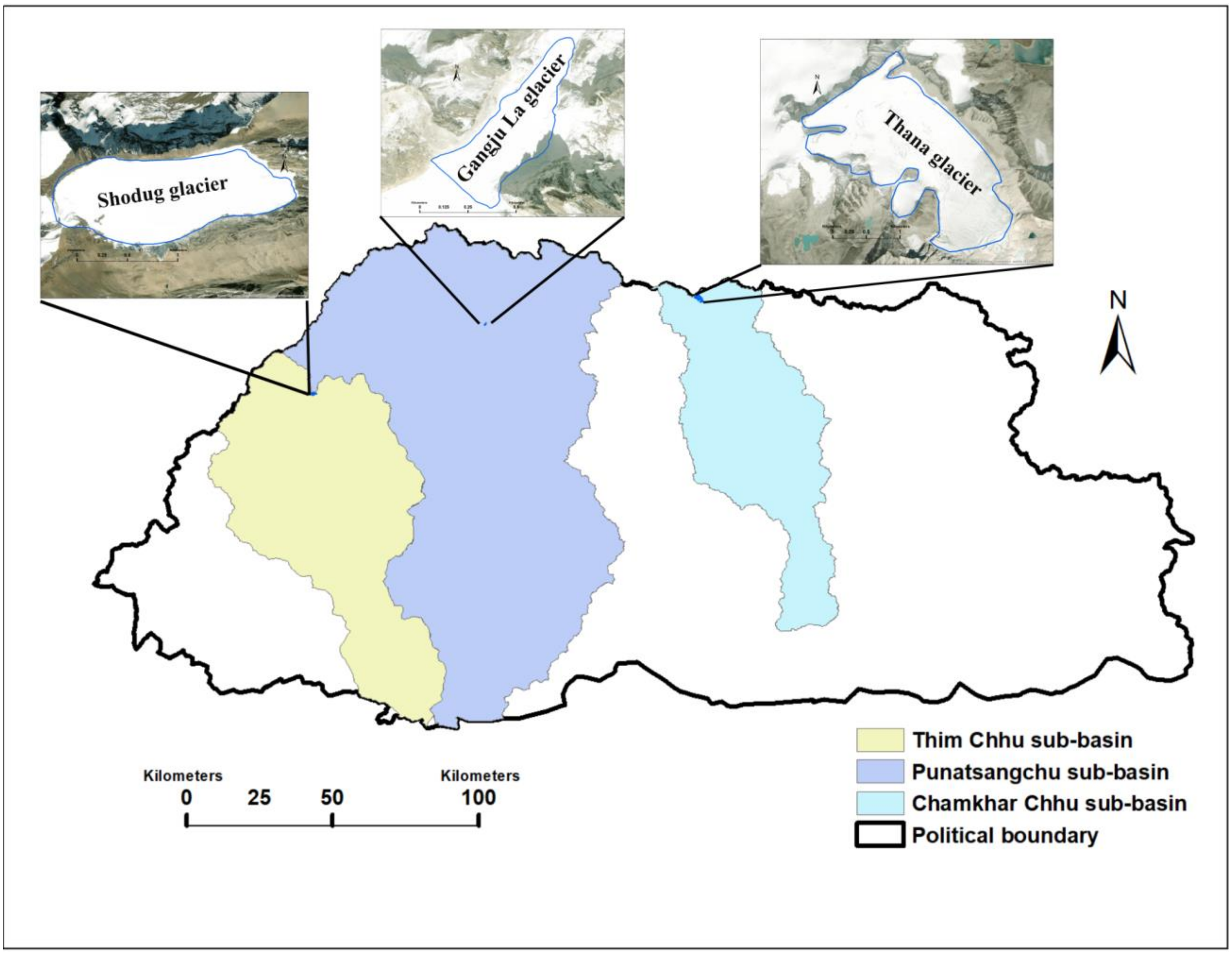


Table 17: Glacier mass balance of Thana and Gangju La

Table 8: Details on GangjuLa and Thana

Year	Gangju La (mm w.e. a^{-1})		Thana (mm w.e. a^{-1})	
	Direct	**Geodetic**	**Direct**	**Geodetic**
2003 – 04	**-1230±230**	–	–	–
2004 – 11	–	**-1790±260**	–	–
2011 – 12	–	**-2040±460**	–	–
2012 – 13	**-1810±160**	**-2020±290**	–	–
2013 – 14	**-1110±160**	**-1120±310**	–	–
2014 – 17	–	**-1350**	–	–
2016 – 17	–	–	**-660**	**-930**
2017 – 18	–	**-2390**	**-1570**	**-1870**
2018 – 19	–	**-1470**	**-1650**	–
2019 – 20	–	**-1660**	**-2645**	**-2910**
2020-21	-	**-1054**	**-1699**	**-2336**