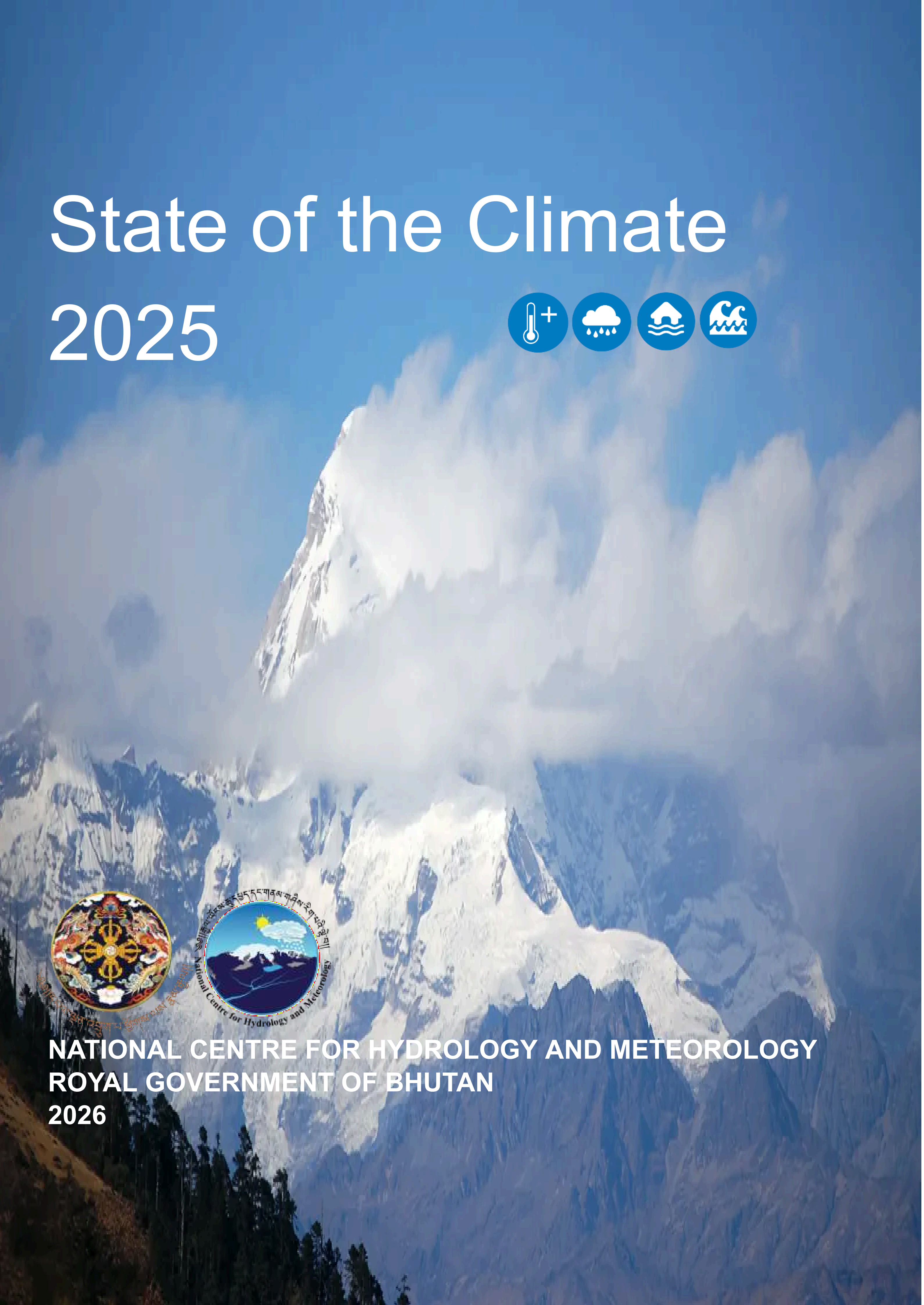
State of the Climate 2025



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ROYAL GOVERNMENT OF BHUTAN
2026

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FOREWORD

It is my privilege to present the *State of Climate Report for Bhutan 2025*. This report constitutes an annual scientific assessment of the climate conditions experienced across the country during the year, documenting the local expressions of global climate change. As the national focal agency responsible for meteorology, hydrology, and cryosphere, the National Centre for Hydrology and Meteorology (NCHM) has prepared this report to provide information in support of national policy formulation, disaster risk reduction, and sustainable development.

According to the World Meteorological Organization (WMO), 2025 was one of the warmest years on record globally, with near-surface temperatures approximately 1.44°C above the pre-industrial baseline. In Bhutan, the warming trend is even more pronounced: 2025 has emerged as the warmest year on record, surpassing the previous high recorded in 2024. The national average maximum temperature reached 23.33°C, reflecting a continuing pattern of rising thermal extremes with significant implications for ecosystems, infrastructure, and livelihoods.

The hydrological year exhibited considerable variability. While aggregate annual rainfall remained within normal ranges, its temporal and spatial distribution was highly erratic. In particular, the intense and prolonged rainfall event in October 2025, induced by a low-pressure system originating from the Bay of Bengal, resulted in substantial damage to transportation networks and hydropower infrastructure. These events underscore the critical importance of strengthening early warning systems and developing climate-resilient infrastructure.

The cryosphere continues to experience significant stress. Long-term monitoring of benchmark glaciers — Gangju La, Thana, and Shodug — indicates a sustained negative mass balance, confirming ongoing ice loss. Furthermore, with 17 glacial lakes classified as Potentially Dangerous Glacial Lakes (PDGLs), the risk of Glacial Lake Outburst Floods (GLOFs) remains a prominent concern for downstream communities and national water security.

I wish to express my sincere appreciation to the experts, technical staff, and field observers whose unwavering commitment to data collection under challenging high-mountain conditions has enabled the production of this report. NCHM remains steadfast in its commitment to advancing scientific understanding and delivering reliable climate services to safeguard the lives, livelihoods, and sustainable development of the people of Bhutan in an era of rapid climate change.

Trashi Delek!

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SECTION A: CLIMATE

1. OVERVIEW

Global Scenario: WMO State of the Global Climate 2025

As per the World Meteorological Organization (WMO) State of the Global Climate 2025, the global mean near-surface temperature for the year 2025 was around 1.44°C above the 1850–1900 baseline according to WMO's consolidated analysis of eight datasets. Two of these datasets ranked 2025 as the second warmest year in the 176-year record, and the other six ranked it as the third warmest year as shown in Figure 1 below. 2025 was slightly cooler than 2024, which recorded a higher global mean temperature anomaly of around 1.55 °C above the 1850–1900 baseline.

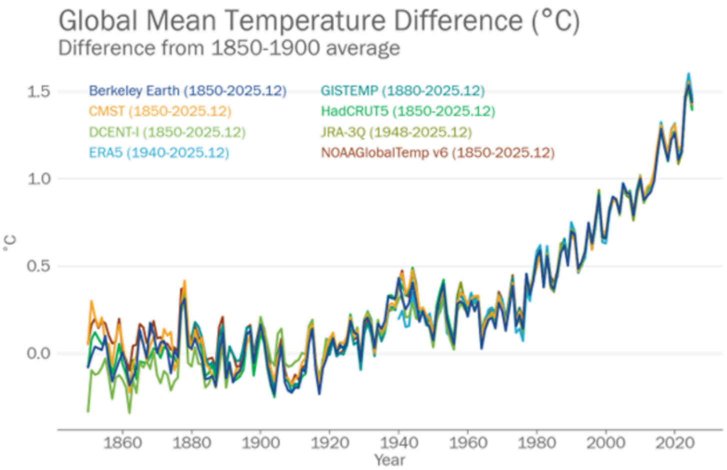


Figure 1: Annual global mean temperature anomalies relative to the 1850-1900 average shown from 1850 to 2025 for eight datasets as shown in the legend

Surface air temperature anomalies

The map shows the spatial distribution of annual mean surface air temperature anomalies for 2025 relative to the 1991–2020 reference period. Positive anomalies are observed over the majority of the global surface, indicating that annual temperatures were above the long-term average in most regions. Regions of comparatively strong warming are evident, particularly at high northern latitudes, including the polar regions and parts of western Russia.

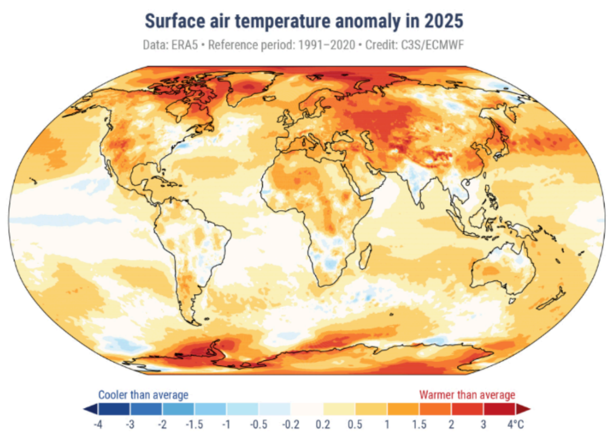


Figure 2: Global distribution of annual mean surface air temperature anomalies for 2025 relative to the 1991–2020 reference period. Data source: ERA5 (C3S/ECMWF)

2. CLIMATE HIGHLIGHTS - 2025

1.1 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.

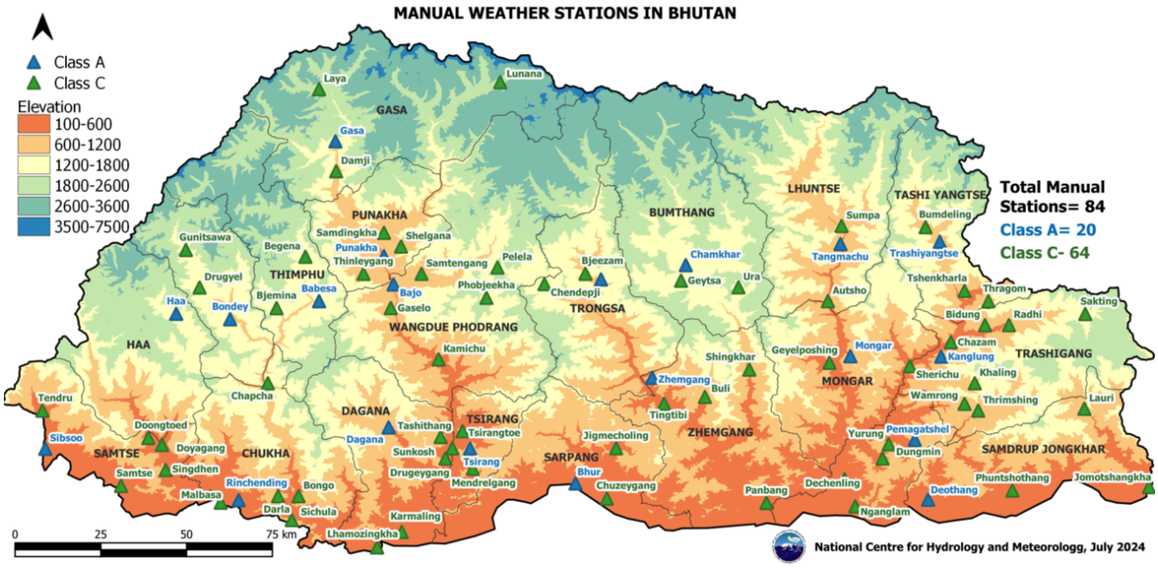


Figure 3: Location of Class A meteorological stations

1.2 Annual rainfall

The annual average rainfall (area average) was 1742.91 mm in 2025. The country as a whole received normal rainfall against the long-term average. The highest 24-hour rainfall was recorded at Phuntsholing with 385 mm. Gasa experienced the highest number of rainy days with 202 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 5402.31 mm, Sipsu with 5385.30 mm followed by Bhur with 4165.70 mm.

1.3 Maximum and Minimum Temperature

The annual average maximum temperature was 23.33ºC and minimum temperature was 12.84ºC across the country. The highest daily maximum temperature was recorded at Phuntsholing met station with 30.15ºC and the lowest daily minimum temperature was recorded at Haa met station with 4.44ºC. Haa experienced a greater number of days with the minimum temperature below or equal to zero with 141 days (minimum temperature <=0).
The annual average temperature for 2025 is the highest on record, surpassing the previous warmest year 2024 by 0.02 ºC.

1.4 Monsoon Monitoring

Bhutan experiences the summer monsoon from June to September (JJAS). The country 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 country's climate.

1.4.1 Rainfall

During the summer of 2025, cumulative rainfall remained below the long-term average for most of the season. Although brief periods of enhanced rainfall occurred in mid-August and early September, they were insufficient to offset the deficit. Overall, the accumulated rainfall for the JJAS season was below normal, indicating a drier-than-average summer.

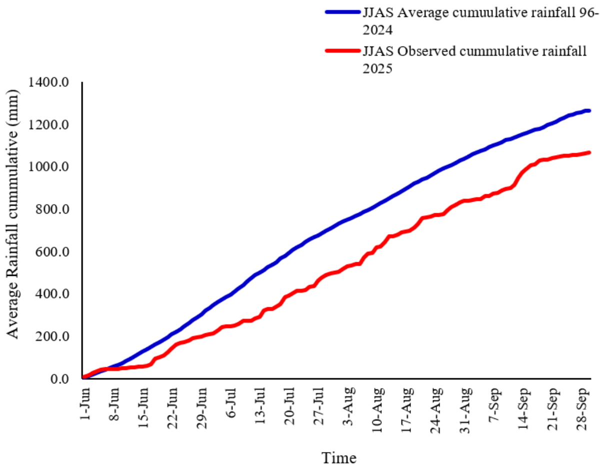


Figure 4: Observed rainfall of 2025 (JJAS) with long term average (1996-2024)

1.4.2 Temperature

During the summer of 2025, the country as a whole observed near-normal average temperatures relative to the long-term average. Minor fluctuations were evident throughout the season, with temperatures generally aligning with climatological conditions.

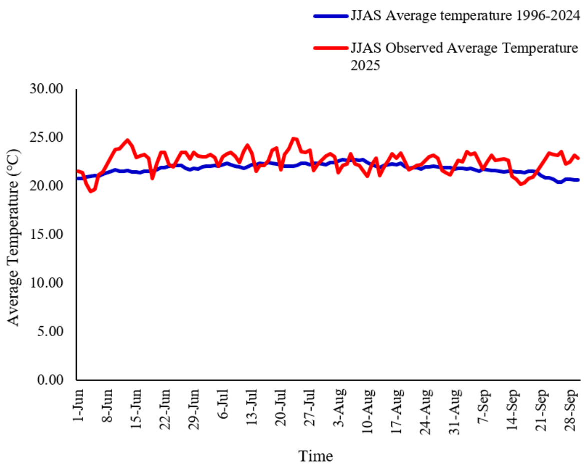


Figure 5: Observed average temperature of 2025 (JJAS) with long term average (1996-2024)

2. ANALYSIS OF TEMPERATURE - 2025

2.1 MAXIMUM TEMPERATURE

2.1.1 Annual average maximum temperature

Figure 6 shows the spatial distribution of annual average maximum temperature (Tmax) across Bhutan in 2025. Tmax is highest in the southern lowlands and valley areas and decreases toward the northern high elevation regions, indicating strong elevation and topographic control on temperature patterns.

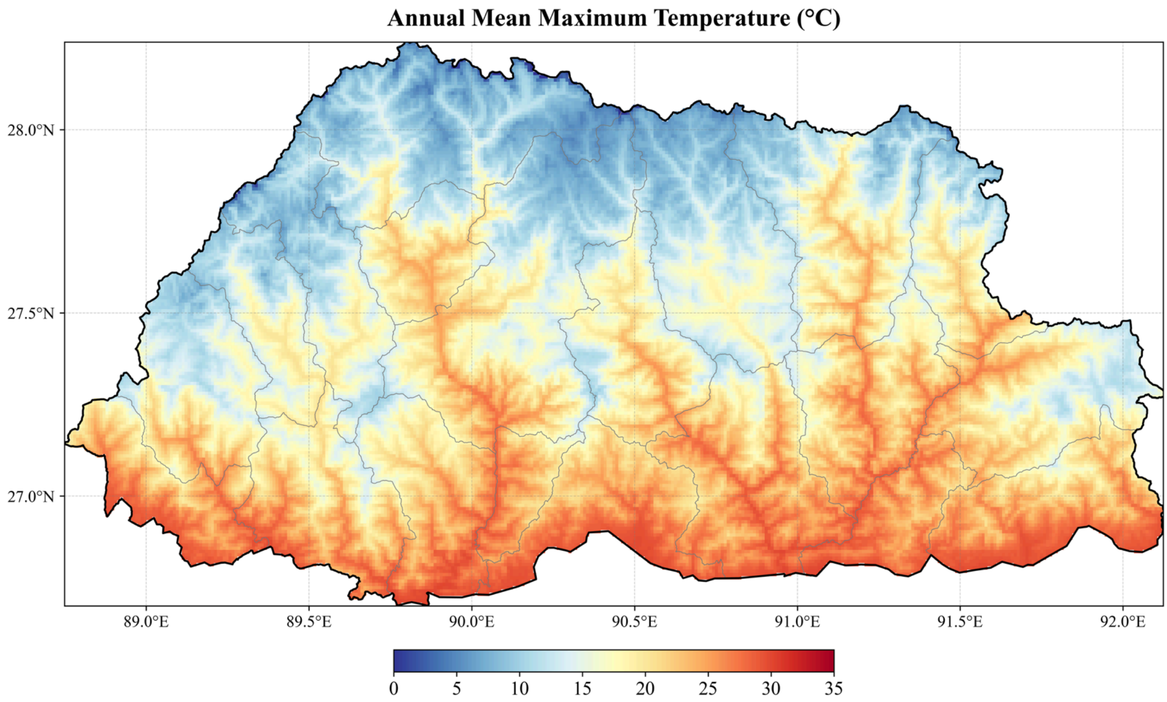


Figure 6: Annual average maximum temperature (Tmax) in Bhutan, 2025 (°C)

2.1.2 Seasonal average maximum temperature

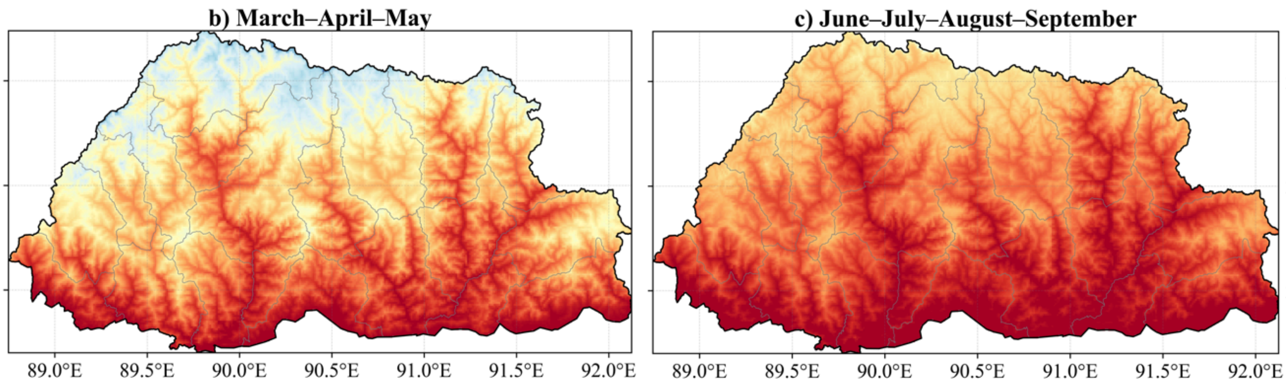
The spatial distribution for average maximum temperature across four seasons is mapped. In Bhutan based on the rainfall and temperature pattern, 12 months in a year are divided into four seasons.

2.1.2.1 Spring/ Pre-monsoon – March to May (MAM)
2.1.2.2 Summer Monsoon – June to September (JJAS)
2.1.2.3 Autumn/Post-monsoon – October to November (ON)
2.1.2.4 Winter Monsoon – December to February (DJF)

2.1.3 Seasonal spatial distribution average maximum temperature

The following maps (Figure 7) show the spatial distribution of seasonal average maximum temperature for the year 2025.

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



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

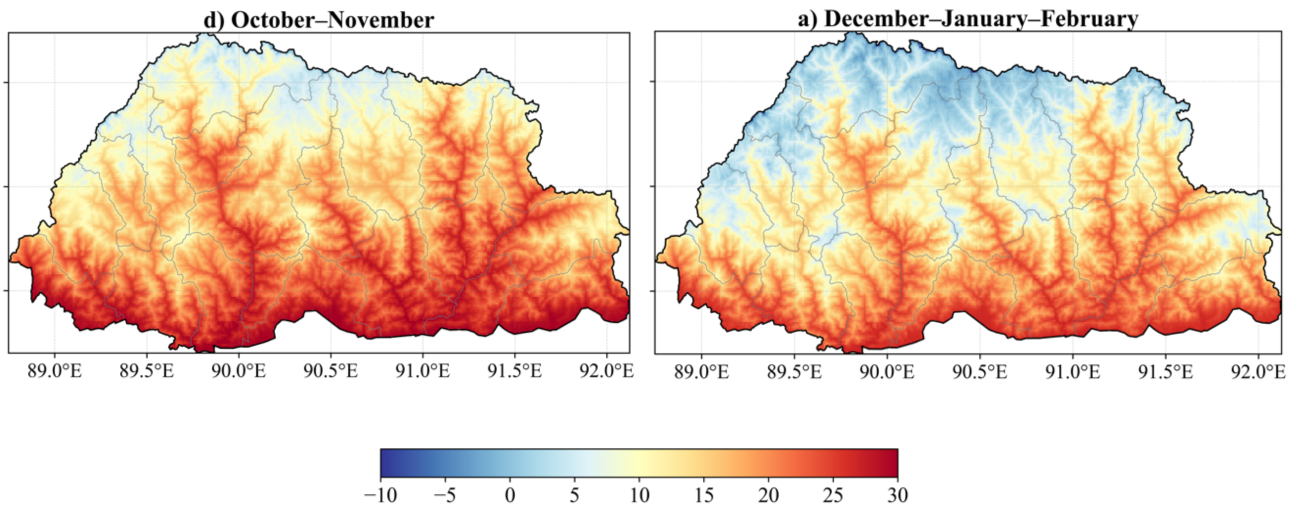


Figure 7: *Spatial distribution of seasonal average maximum temperature for the year 2025*

2.2 Minimum Temperature

2.2.1 Annual average minimum temperature

Figure 8 shows the spatial distribution of annual average minimum temperature (Tmin) across Bhutan in 2025. Tmin is generally higher in the southern lowlands and major valley corridors, including the Sipsu–Phuntsholing belt and the southern districts extending eastward. In contrast, lower Tmin values are concentrated in the northern high elevation regions, particularly around Gasa and adjacent interior mountainous areas. Overall, the 2025 pattern indicates a clear south–north and lowland–highland gradient, reflecting strong control by elevation and topography.

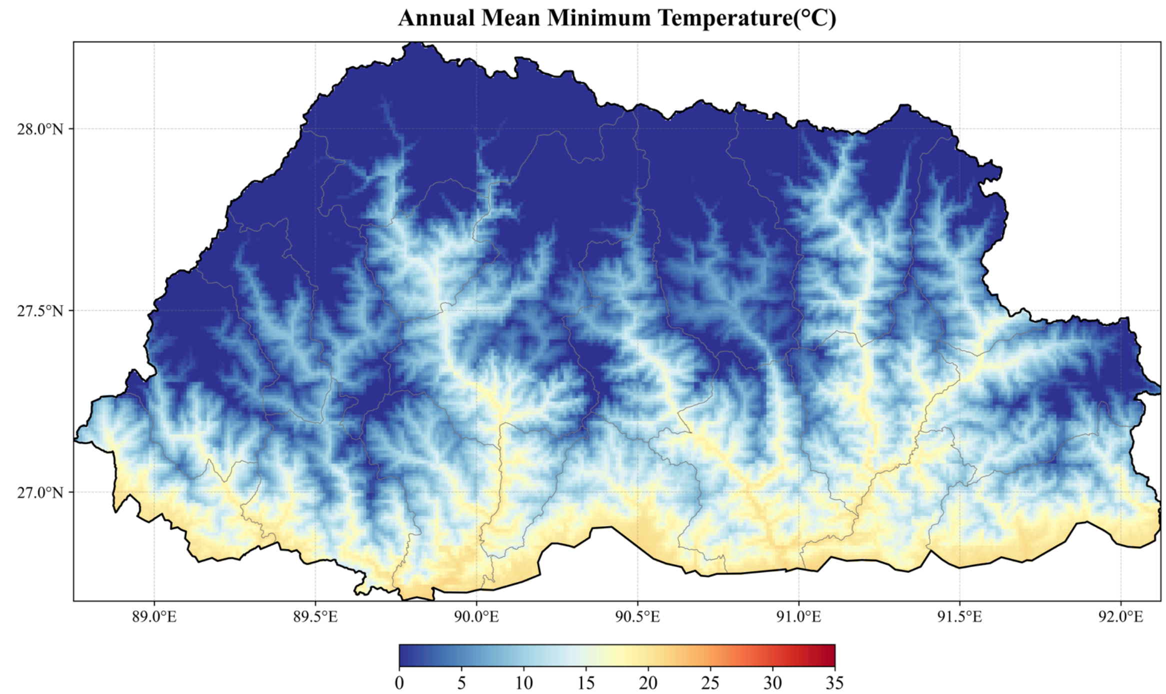
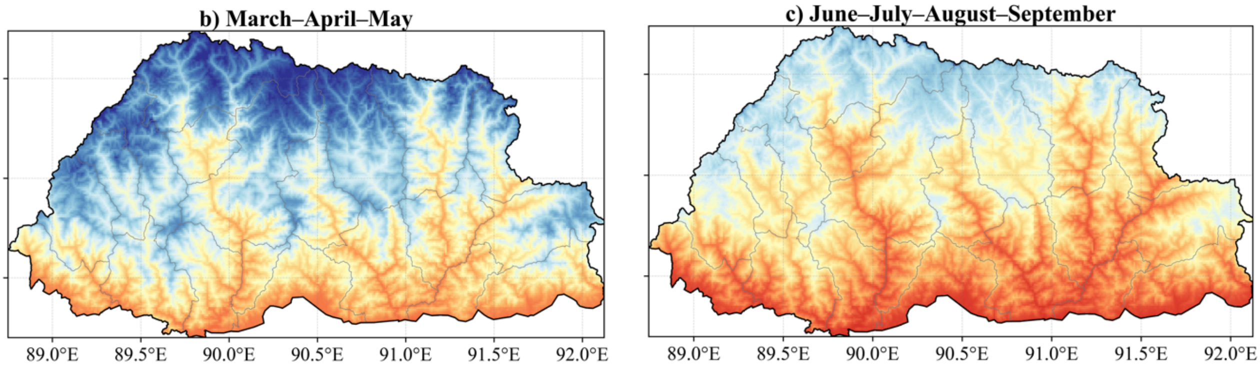


Figure 8: Annual average minimum temperature (Tmin) in Bhutan, 2025 (°C)

2.2.2 Seasonal spatial distribution of average minimum temperature

The following maps (Figure 9) show the spatial distribution of seasonal average minimum temperature for the year 2025.

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



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

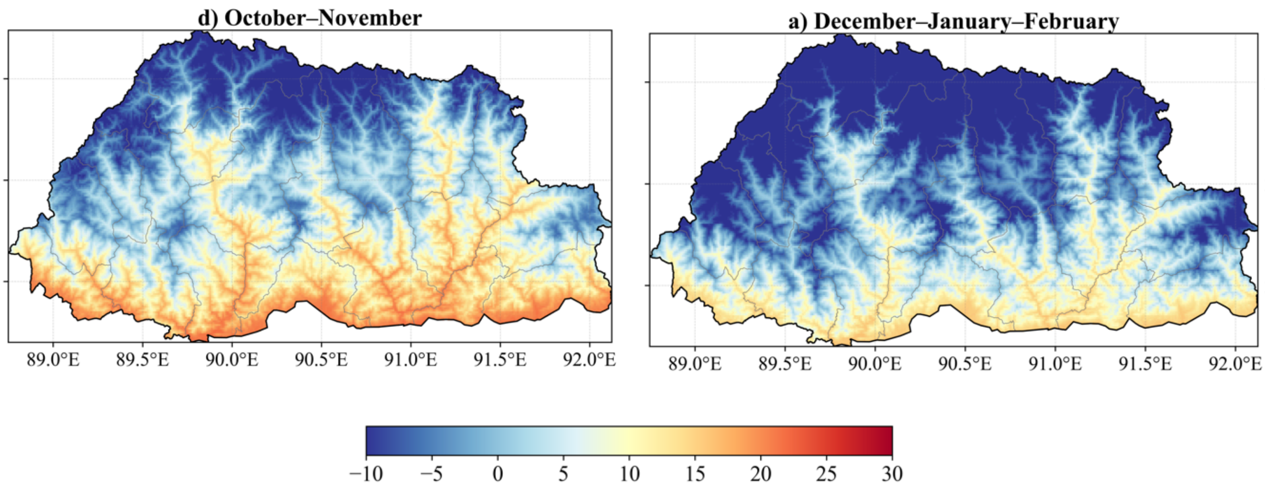


Figure 9: Spatial distribution of seasonal average minimum temperature for the year 2025

3. ANALYSIS OF RAINFALL - 2025

3.1 Annual Accumulated Rainfall

Figure 10 shows the distribution of annual accumulated rainfall in the year 2025.

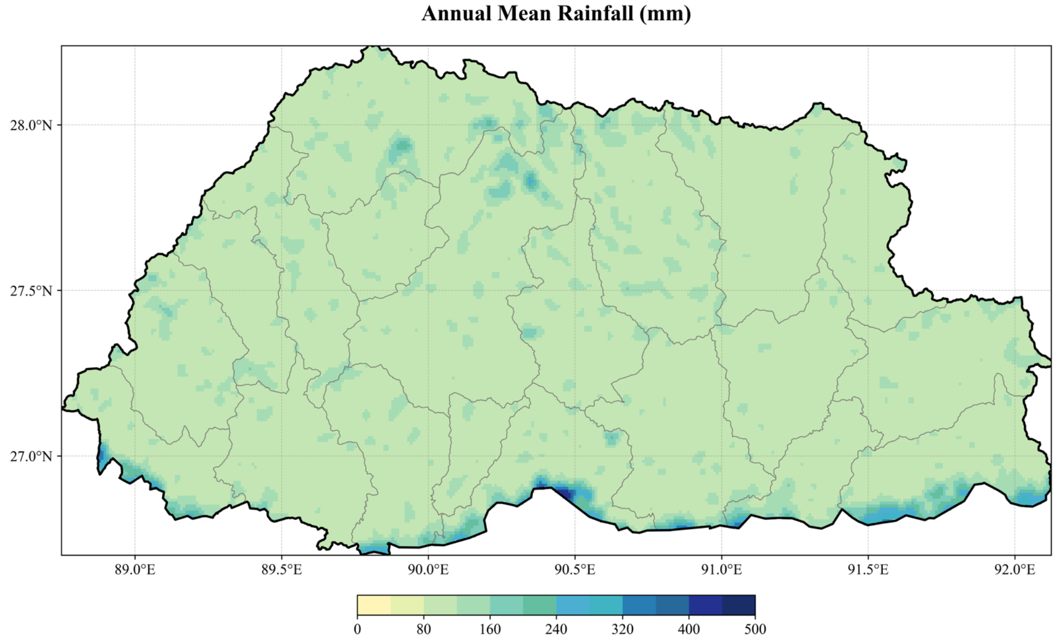
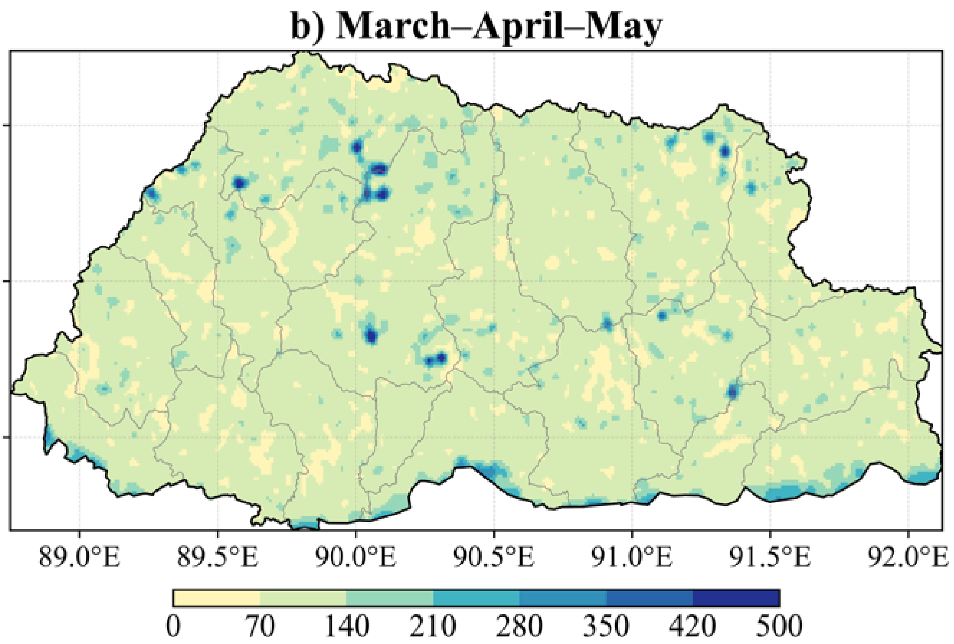


Figure 10: Annual accumulated rainfall for the year 2025

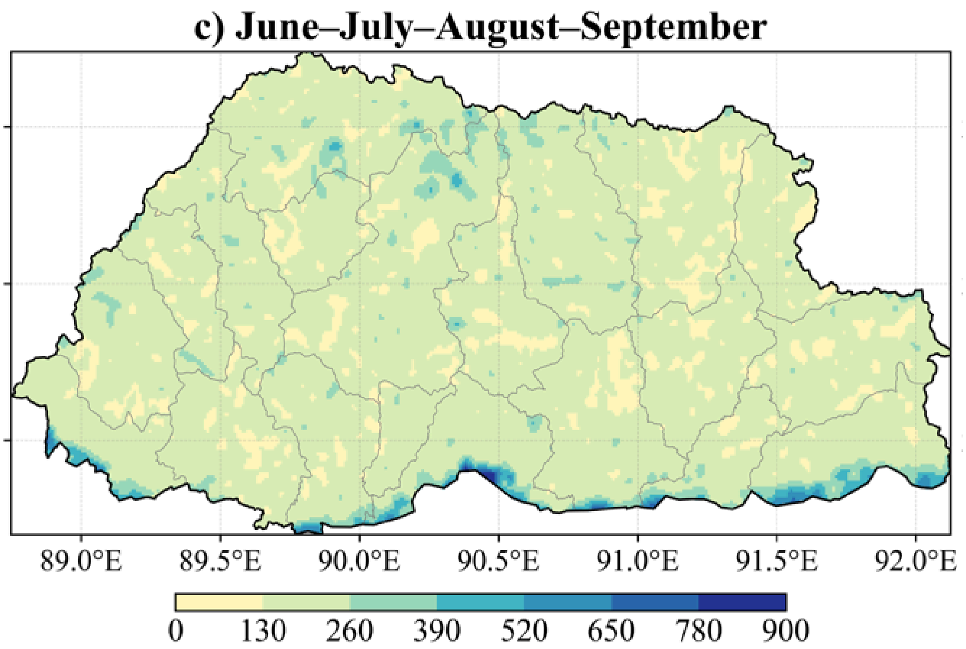
3.2 Seasonal spatial distribution of accumulated rainfall

The following map shows the distribution of seasonal accumulated rainfall.

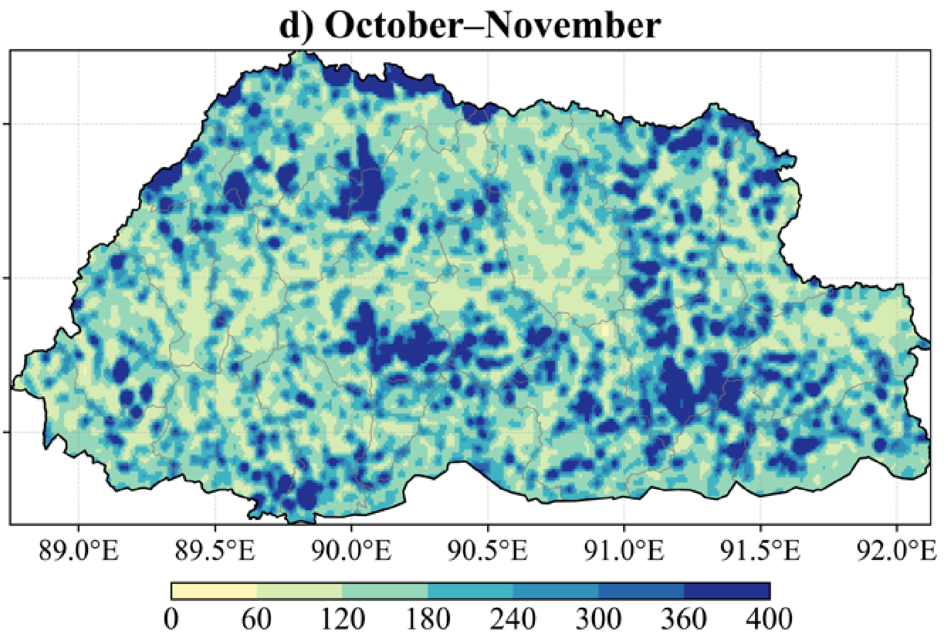
a. Spring/Pre-monsoon (March-May)



b. Summer/Monsoon (June-September)



c. Autumn/Post Monsoon (October-November)



d. Winter/Monsoon (December)

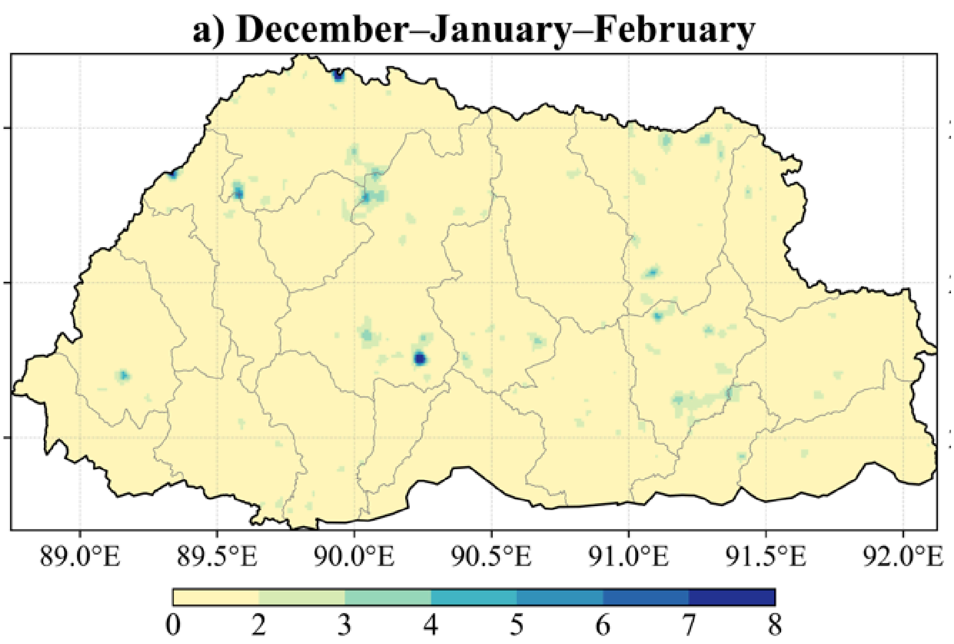
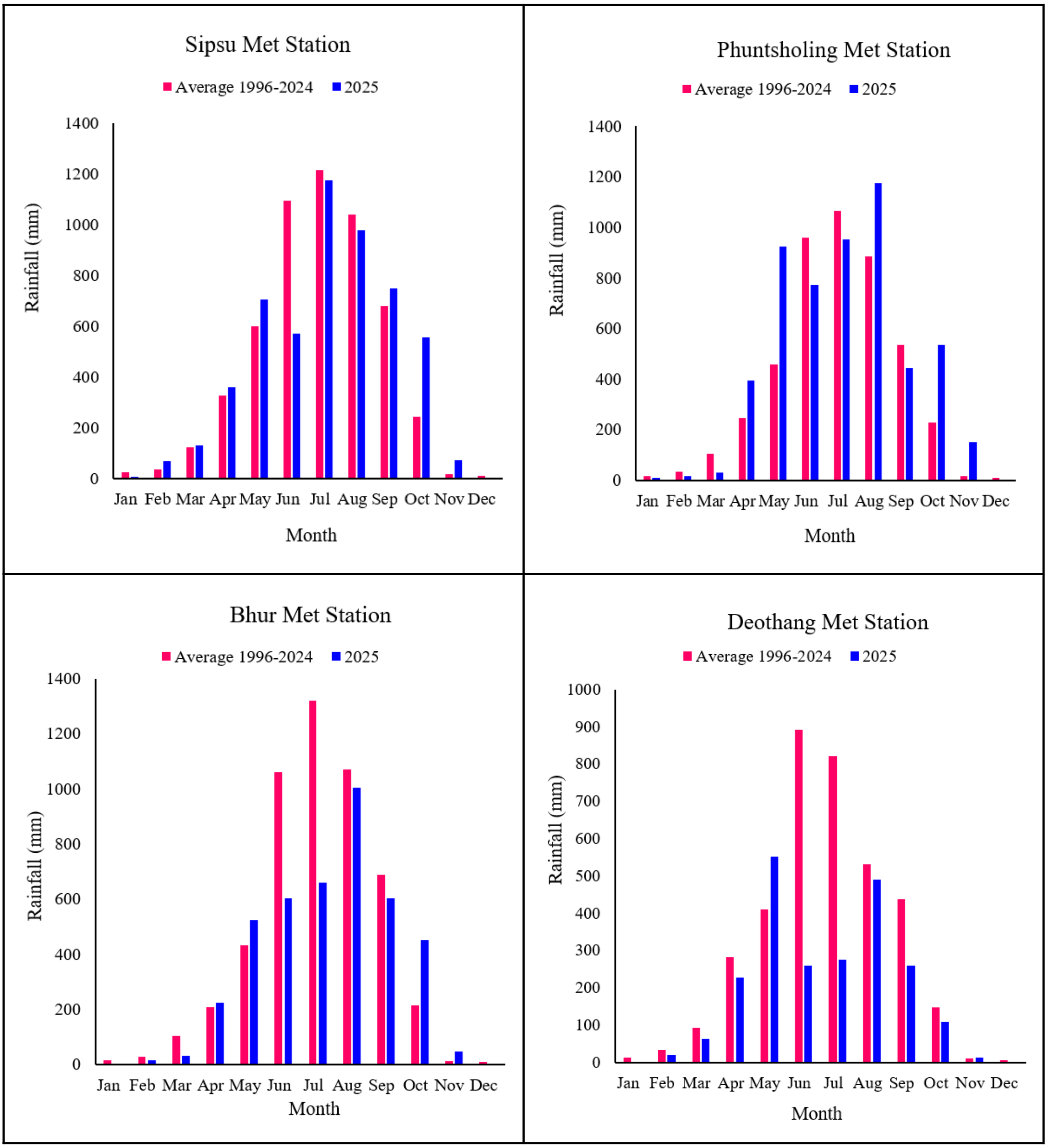
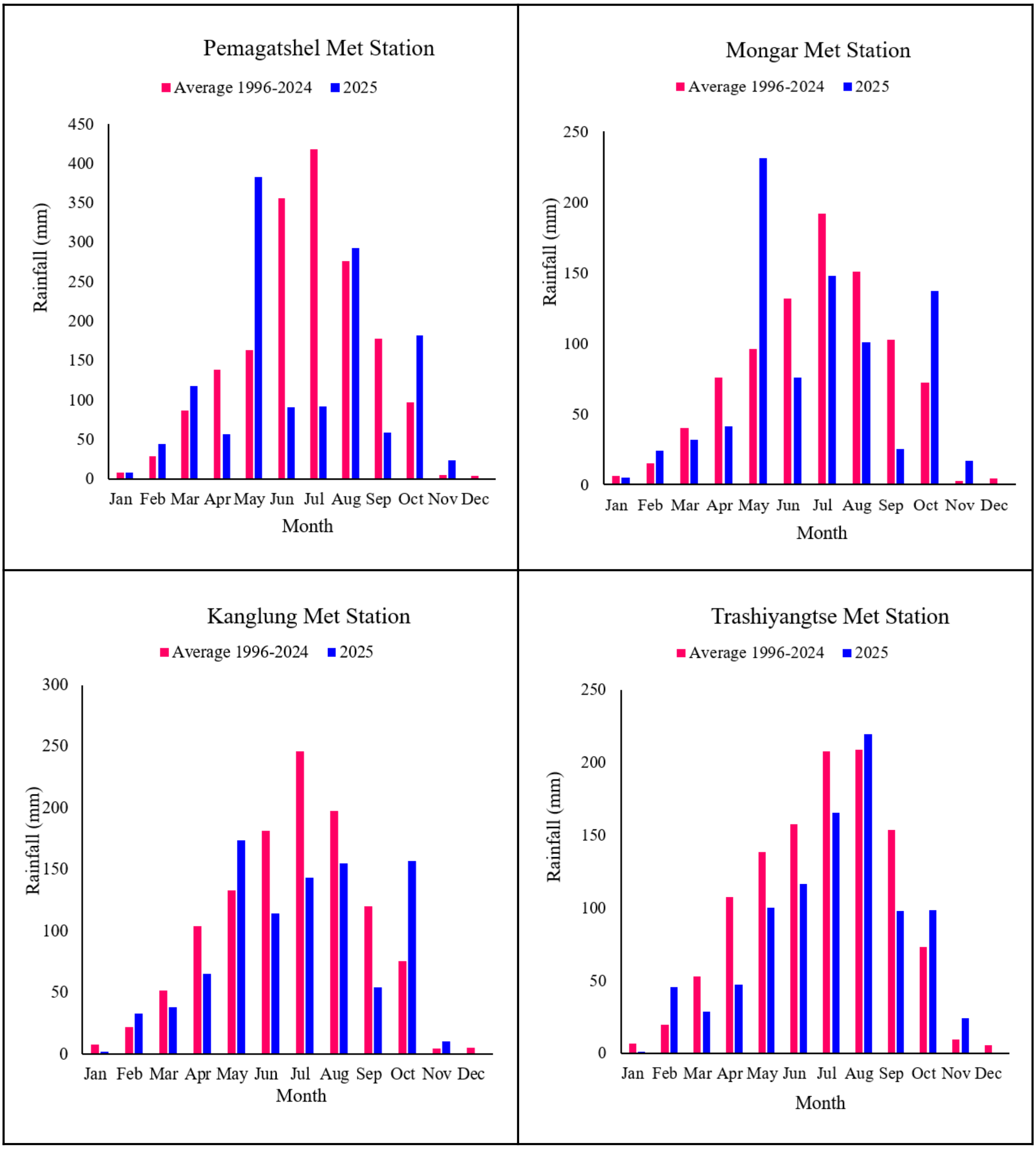


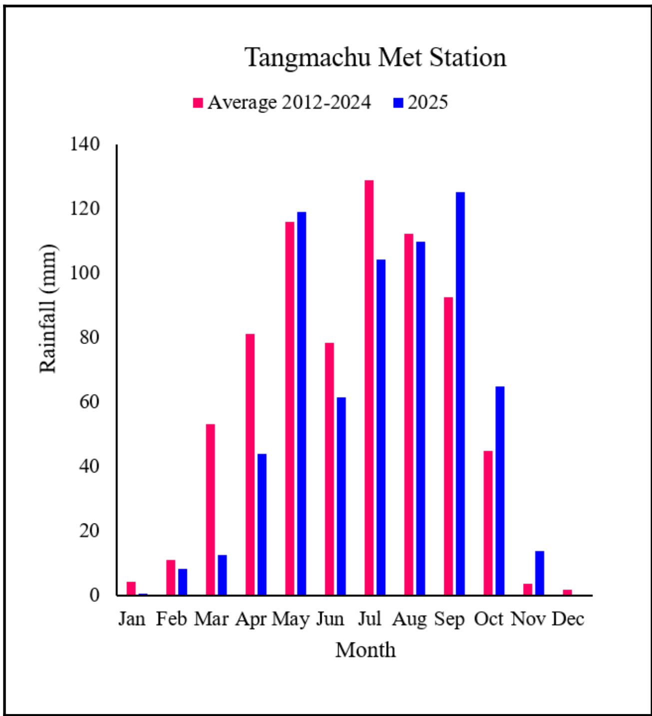
Figure 11: Spatial distribution of seasonal accumulated rainfall for the year 2025

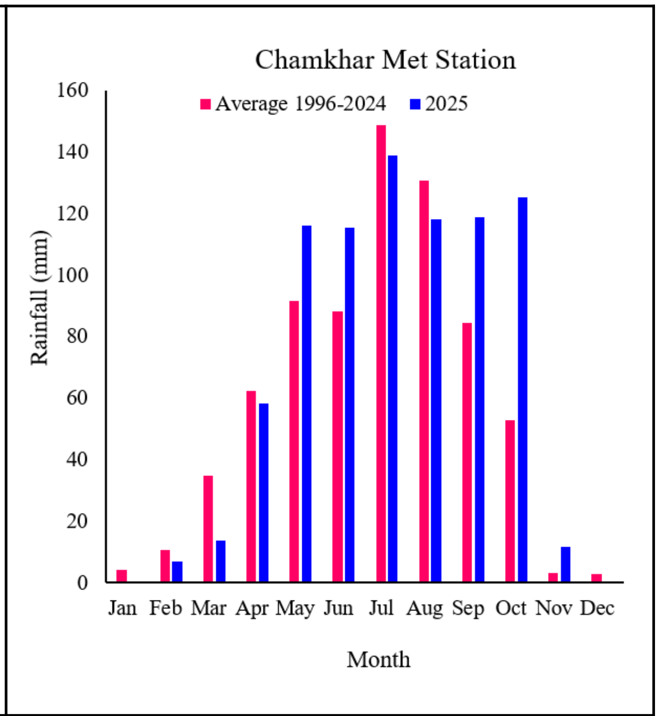
3.3 Comparison of monthly accumulated rainfall against long term average

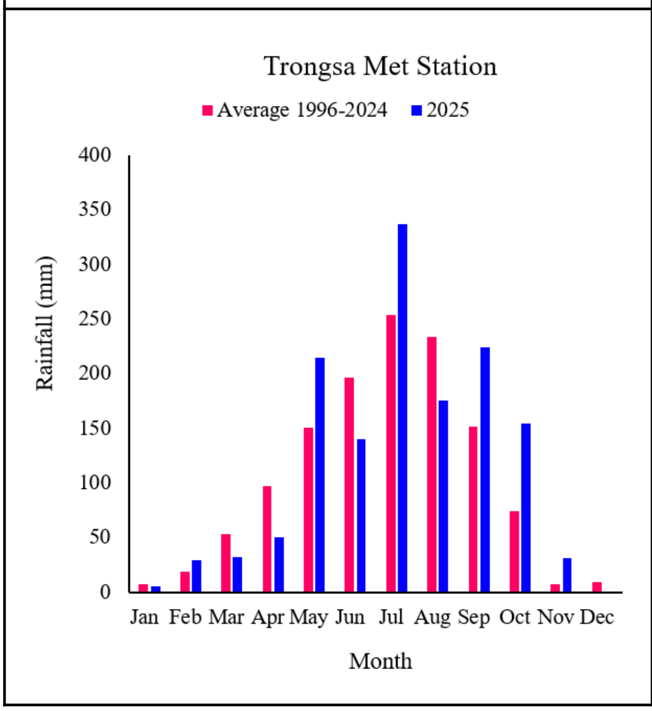
The following figures show the comparison of monthly accumulated rainfall of the year 2025 with their long-term average. Please note that the long-term averaging period in each station varies based on the data availability.

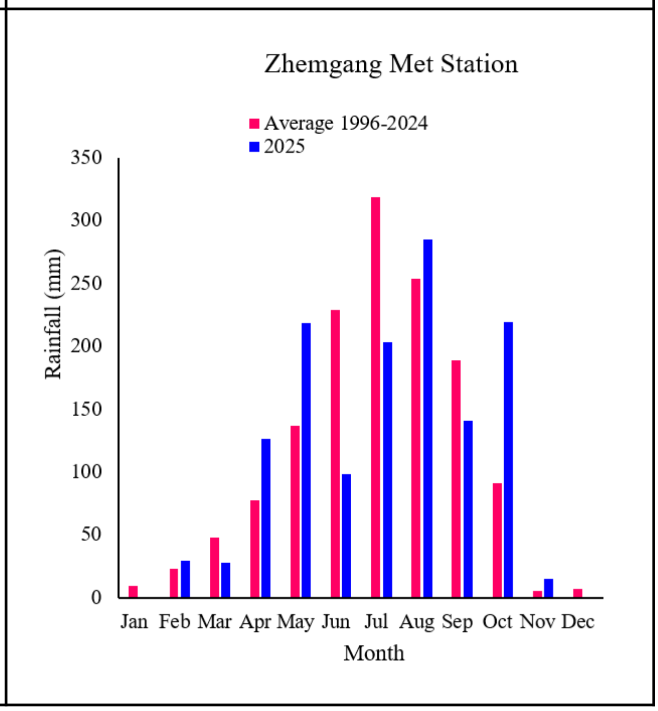


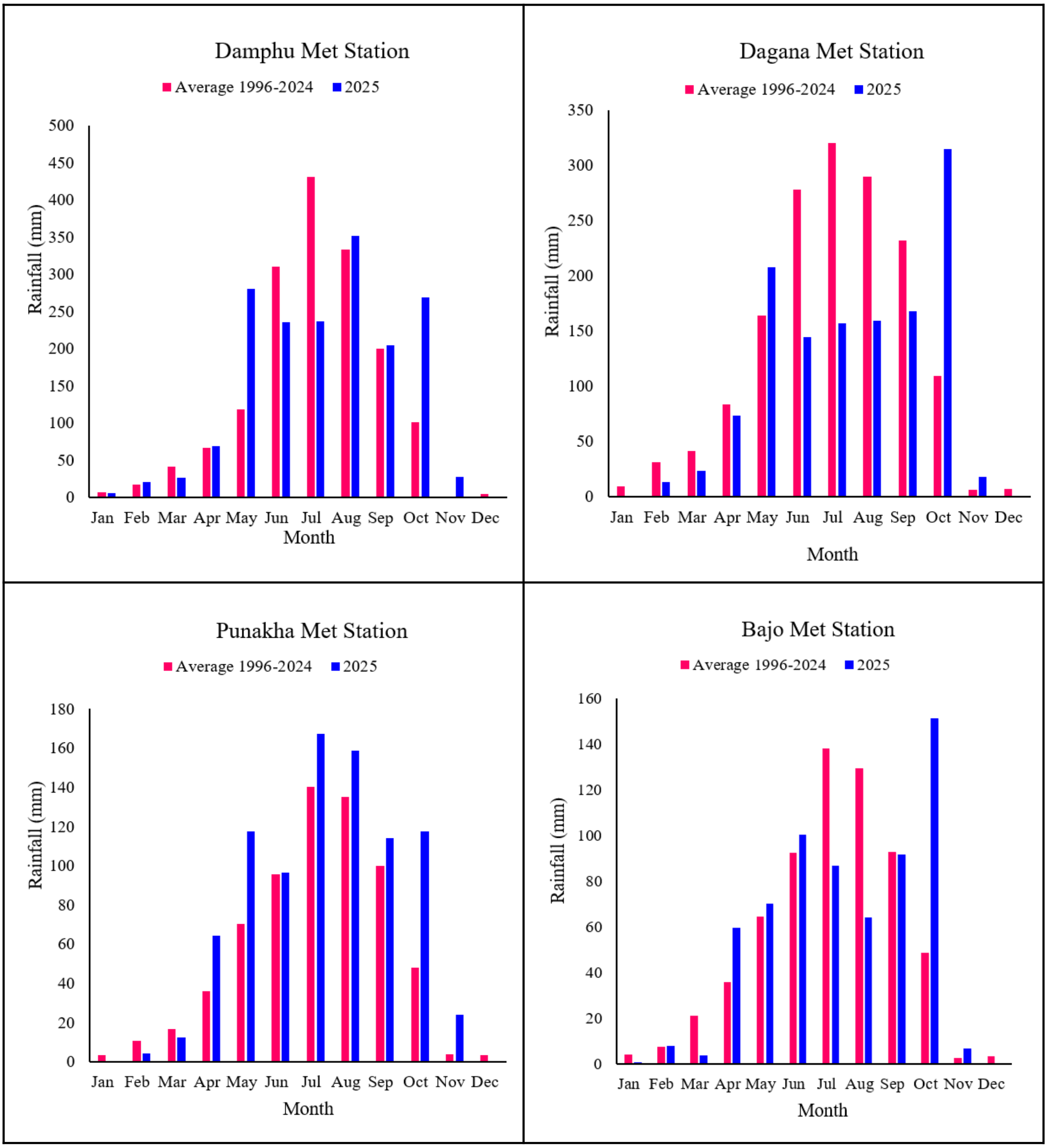

Pemagatshel Met Station
Average 1996-2024
2025
Rainfall (mm)
0
50
100
150
200
250
300
350
400
450
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month
Mongar Met Station
Average 1996-2024
2025
Rainfall (mm)
0
50
100
150
200
250
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month
Kanglung Met Station
Average 1996-2024
2025
Rainfall (mm)
0
50
100
150
200
250
300
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month
Trashiyangtse Met Station
Average 1996-2024
2025
Rainfall (mm)
0
50
100
150
200
250
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month


Tangmachu Met Station
Average 2012-2024
2025
Rainfall (mm)
0
20
40
60
80
100
120
140
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month


Chamkhar Met Station
Average 1996-2024
2025
Rainfall (mm)
0
20
40
60
80
100
120
140
160
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month


Trongsa Met Station
Average 1996-2024
2025
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 1996-2024
2025
Rainfall (mm)
0
50
100
150
200
250
300
350
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month


Damphu Met Station
Average 1996-2024
2025
Rainfall (mm)
Month
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Dagana Met Station
Average 1996-2024
2025
Rainfall (mm)
Month
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Punakha Met Station
Average 1996-2024
2025
Rainfall (mm)
Month
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Bajo Met Station
Average 1996-2024
2025
Rainfall (mm)
Month
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

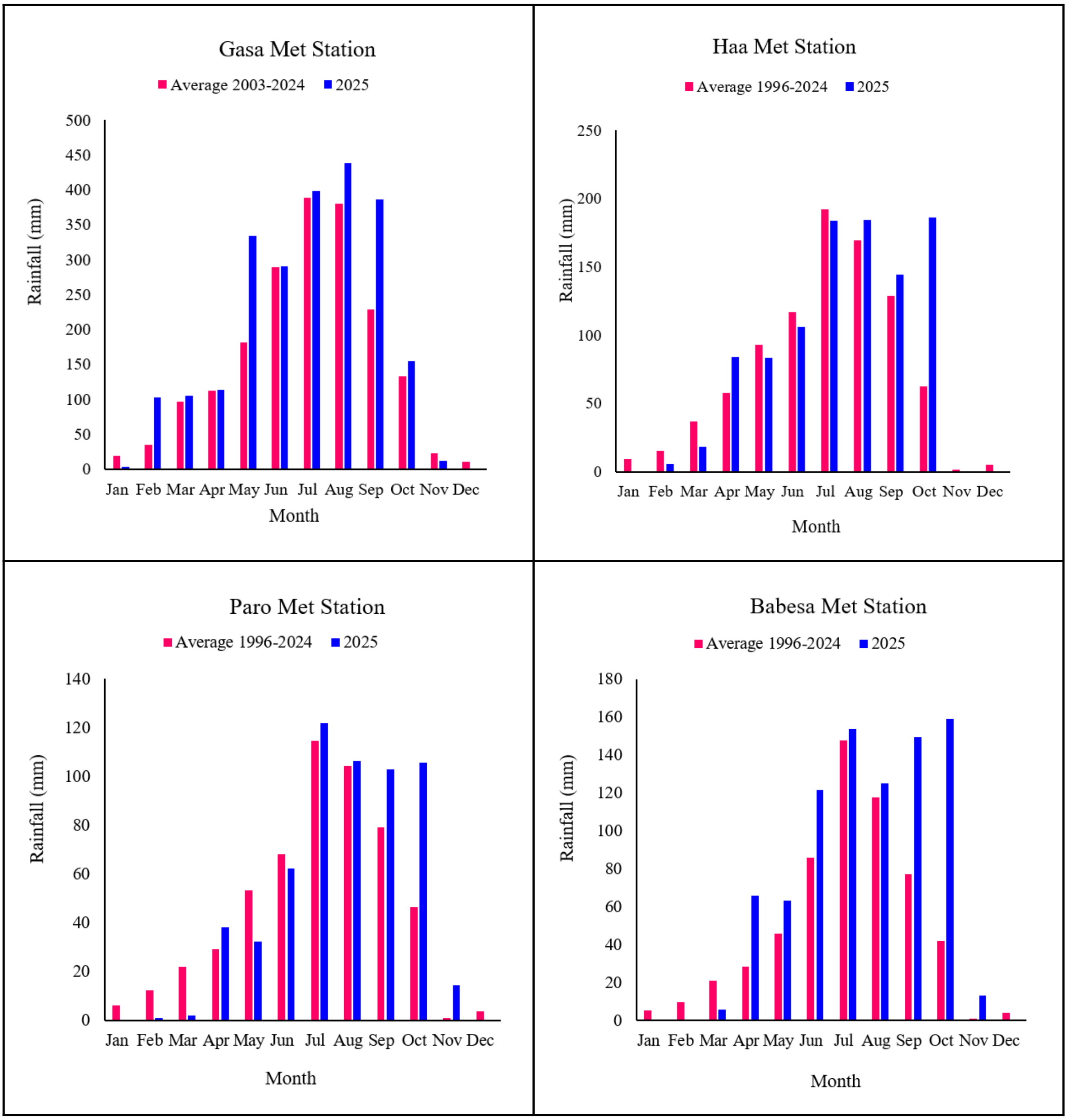


Figure 12: Comparison of total monthly rainfall of observed 2025 with long term average

4. ANNUAL STATISTICS

4.1 Annual statistics for 20 Agrometeorological stations – 2025

Table 1. Annual statistics for 20 Agrometeorological stations

Station	Annual total rainfall (mm)	Annual average maximum temp (℃)	Annual average minimum temp (℃)	Number of days with rainfall>=1mm	Number of days with Tmax>=30	No. of days with Tmin<=0
Sipsu	5385.30	28.69	19.85	175	155	0
Phuentsholing	5402.31	30.15	19.70	170	233	0
Bhur	4165.70	29.45	19.82	137	187	0
Deothang	2268.20	25.85	18.33	112	43	0
Pemagatshel	1348.10	23.74	13.70	98	24	0
Mongar	837.40	23.12	14.76	98	24	0
Kanglung	947.50	23.54	11.05	109	5	0
Trashiyangtse	944.60	23.17	10.13	144	41	22
Tangmachu	664.00	23.64	15.28	101	10	0
Chamkhar	823.90	19.05	8.05	113	0	51
Trongsa	1396.50	20.14	10.03	143	0	3
Zhemgang	1364.90	20.98	11.05	123	0	0
Damphu	1729.40	21.33	13.56	110	0	0
Dagana	1279.20	23.62	14.13	101	5	0
Punakha	877.40	28.82	16.42	101	182	0
Bajo	643.00	26.29	15.68	93	100	0

Gasa	2338.90	16.81	6.91	202	0	49
Haa	997.90	16.95	4.44	138	3	141
Paro	587.00	20.14	6.74	95	5	96
Babesa	857.00	21.08	7.26	97	2	77

5.2 Extreme records for 20 Agrometeorological stations - 2025

Table 2. Annual extremes for 20 Agrometeorological stations

Station	24-hour Rainfall (mm)	Date of occurrence	Maximum temperature (℃)	Date of occurrence	Minimum temperature (℃)	Date of occurrence
Sipsu	302.2	4th October	37	26th September	7.5	25th January
Phuntsholing	385	5th October	37.5	27th September	10.5	31st January
Bhur	196.8	13th September	37	13th June, 13th,24th July, 26th September	9.5	3rd January
Deothang	105	12th August	34	14-15th June, 14th July	9	9th January, 30th December
Pemagatshel	75.2	13th March	32.5	26th, 30th September	3	14th February
Mongar	68.8	11th May	32	13th June, 24th July	5	14th, 22nd January, 14th February
Kanglung	54.2	30th October	30	11th, 13th June, 24th July, 4th, 23rd September	2.5	14th January
Trashiyangtse	31	30th June	33.5	24th July	-2	14th January, 16th December
Tangmachu	36.4	22nd September	36	4th August	5	14th January

Chamkhar	37.1	5th October	28.5	6th August	-7	5th, 13-14th January, 12-13th, 18th December
Trongsa	62.6	4th October	28.5	24th September	-1.5	14th January
Zhemgang	71.4	30th October	29.5	24th July	1	4th January, 14th February
Damphu	105.8	18th June	29	26th September	4	9th, 10th, 14th January
Dagana	158	4th October	30.5	14th June, 26th, 30th September	5.5	8th, 14th January
Punakha	75.2	5th October	39.5	26th July	3.5	16th, 19th December
Bajo	70.6	4th October	35.5	13th June	3	14th January, 19th December
Gasa	132	9th July	27	23rd July	-3	6th, 7th, 9th February
Haa	83.8	4th October	31	2-4th November	-10	14th January
Paro	51.2	30th October	31	1st September	-6	9th, 14th, 15th January, 10th March
Babesa	63.4	27th July	30	11th June, 23rd July	-7	17th 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 over the course of a year is known as the river regime. A flow record of 20-30 years is 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 ice covers over 25-30% of the catchment area, melting conditions dominate the river flow. 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 meltwater 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 intertropical convergence zone, and these are reflected directly in the river regime.

2. EXTREME HYDROLOGICAL EVENTS RECORDED IN 2025

Bhutan experienced some of the most severe and disruptive hydrological events in its recent history in 2025. Unusually intense and incessant rainfall triggered widespread flash floods, devastating landslides, and a critical technical failure at a major hydropower dam, exposing the country's profound vulnerability to climate change. The most significant extreme event of the year was a period of "incessant heavy rainfall" on October 4th and 5th of 2025. This downpour triggered widespread destruction across southern and western Bhutan, caused by a low-pressure system drawing moisture from the Bay of Bengal. The table below compiles some of the extreme hydrological events experienced in 2025.

Sl. No	Flood Event Location	Date of Occurrence	Flood Classification	Causative Factor	Impact and Damages
1	Flash Flood Jomori Hydropower Project, Samdrup Jongkhar	28/5/2025	Flash Flood	Heavy Rainfall	The ongoing hydropower project, located upstream of the Zamtari station, has reported several impacts resulting from the flood, which reached the site at 6:30 pm. The reported damages include: Loss of one ROC machine and one AMW dumper vehicle, submergence of one vehicle along with construction equipment, and erosion of the foundation of a bridge currently under construction for the hydropower project.
2	Flash Flood at Gayza, Gasa	2/6/2025	Flash Flood	Heavy Rainfall	Due to the flash flood, the Punakha-Gasa Secondary National Highway (SNH) at chainage 56 km has been completely washed away, and roadblocks have been reported at Domay Pangchu and Datakha.
3	Flash Flood across Bhutan	5/10/2025	Flash Flood	Heavy Rainfall	Heavy and continuous rainfall was experienced across Bhutan on 5th October, 2025, which caused multiple flooding cases. The flooding event caused widespread destruction in transport infrastructure, hydropower plants, telecommunications, and settlement areas

3. ANNUAL FLOW OF 2025 COMPARED WITH THE HISTORICAL FLOW

The annual average flow, based on recorded data from 1992 to 2023, is compared with the 2024 average for stations across Bhutan. Each station is located in a different basin but does not serve 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 2024) in m^3/s	Average flow 2025 in m^3/s
1	Tamchu	Wangchhu	58.7	57.6
2	Lungtenphu	Wangchhu	21.6	21.6
3	Kerabari	Punatsangchhu	445.5	445.7
4	Wangdirapids	Punatsangchhu	295.5	278.9
5	Yebesa on Mochhu	Punatsangchhu	111.6	94.1
6	Kurjey on Chamkhar	Manas	52.3	49.5
7	Muktirap on Kholongchhu	Manas	63.1	57.9
8	Sumpa on Kurichhu	Manas	173.5	193.5

9	Kurizampa on Kurichhu	Manas	287.5	274.9
10	Panbang on Drangmechhu	Manas	778.1	716.3

4. EXTREME FLOWS RECORDED IN 2025

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	1146.9	9.7
2	Lungtenphu	665.71	177.93	3.2
3	Kerabari	9627.237	3326.9	99.7
4	Wangdirapids	5647.62	2238.6	60.9
5	Yebesa	2223.30	815.2	19.8
6	Kurjey	1354.97	282.5	10.6
7	Muktirap	876.36	352.153	10.5
8	Sumpa	7101.15	1274.6	31.4
9	Kurizampa	8997.70	1990.8	56.1
10	Panbang	21006.1	3534.6	139.8

4. LOCATION MAP OF PRINCIPLE HYDROLOGICAL STATIONS

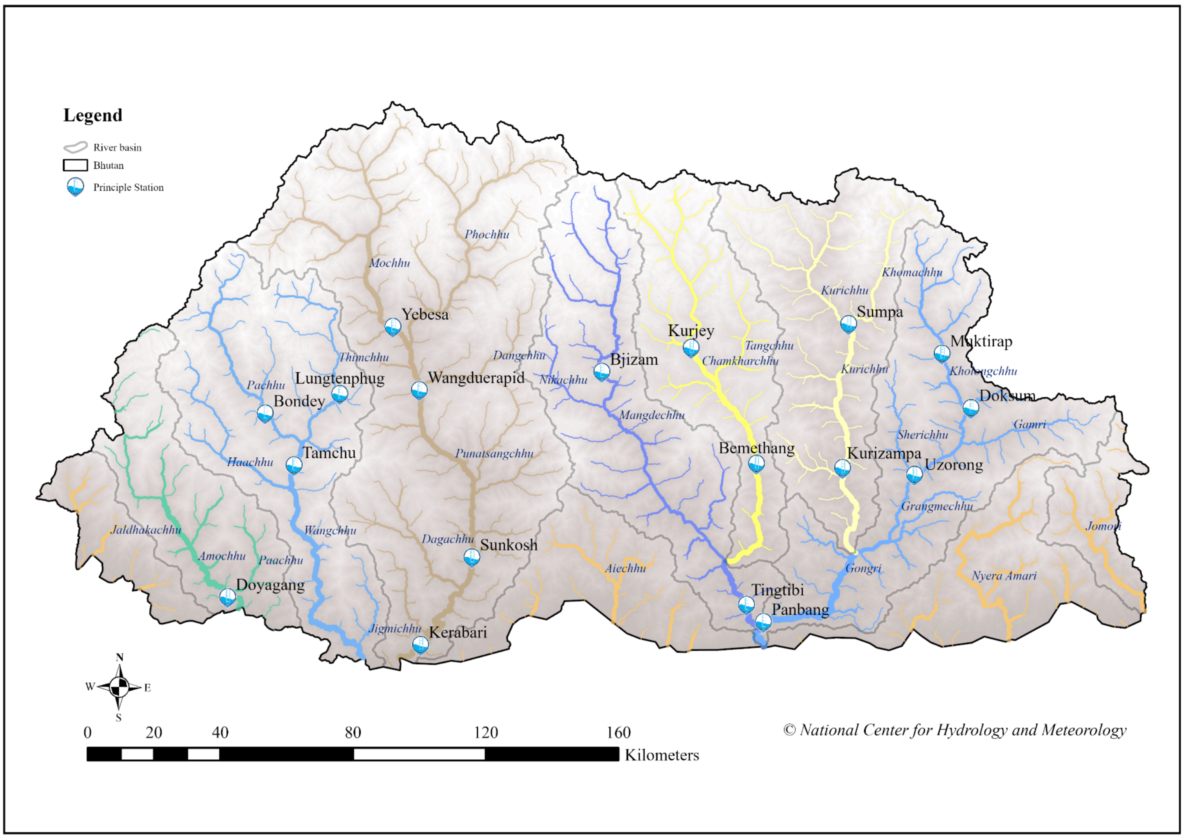


Figure 13: Location of Principle Stations

5. WANGCHU BASIN RIVER FLOW STATUS

5.1 STATION WISE AVERAGE MONTHLY FLOW

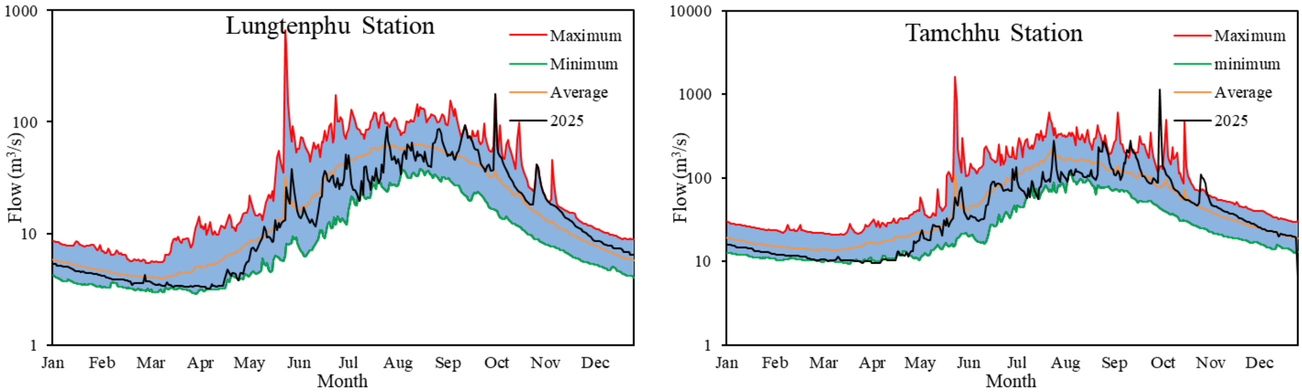


Figure 14: Station's average monthly flow in the Wangchhu basin

6. PUNATSANGCHHU RIVER FLOW STATUS

6.1 STATION-WISE AVERAGE MONTHLY FLOW

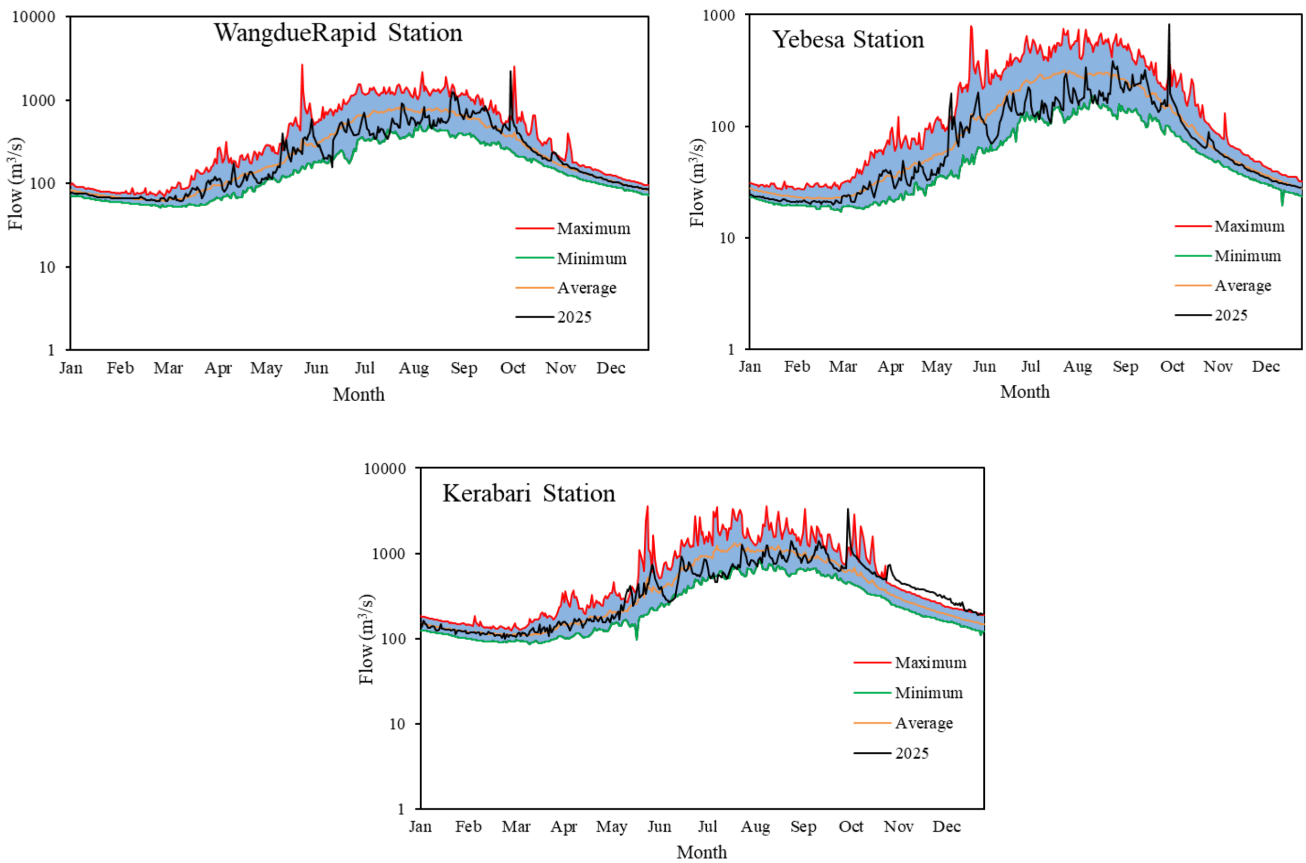


Figure 15: Station's average monthly flow in the Punatsangchhu basin

7. MANAS BASIN RIVER FLOW STATUS

7.1 STATIONWISE AVERAGE MONTHLY FLOW

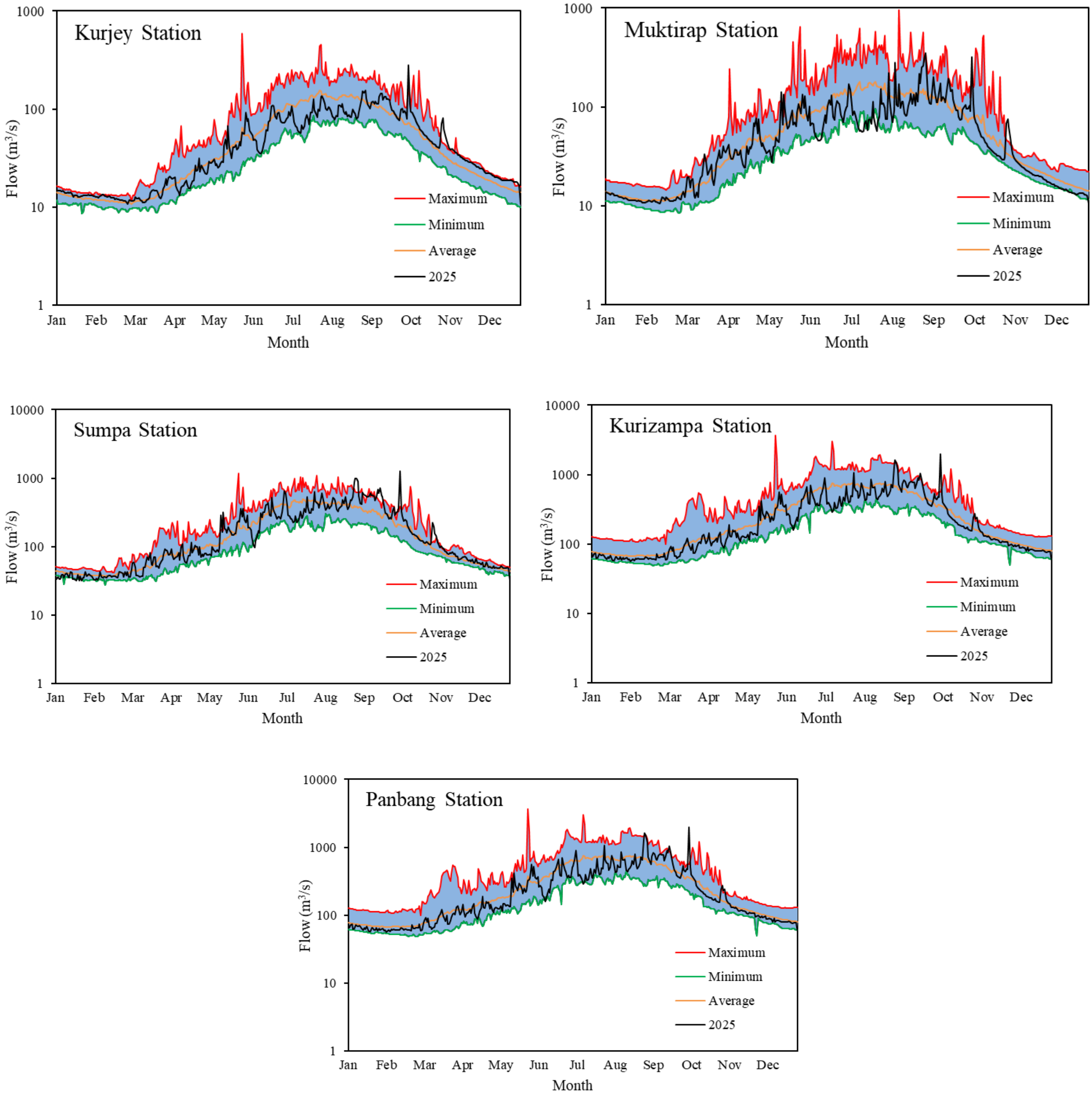


Figure 16: Station's average monthly flow in Manas Basin

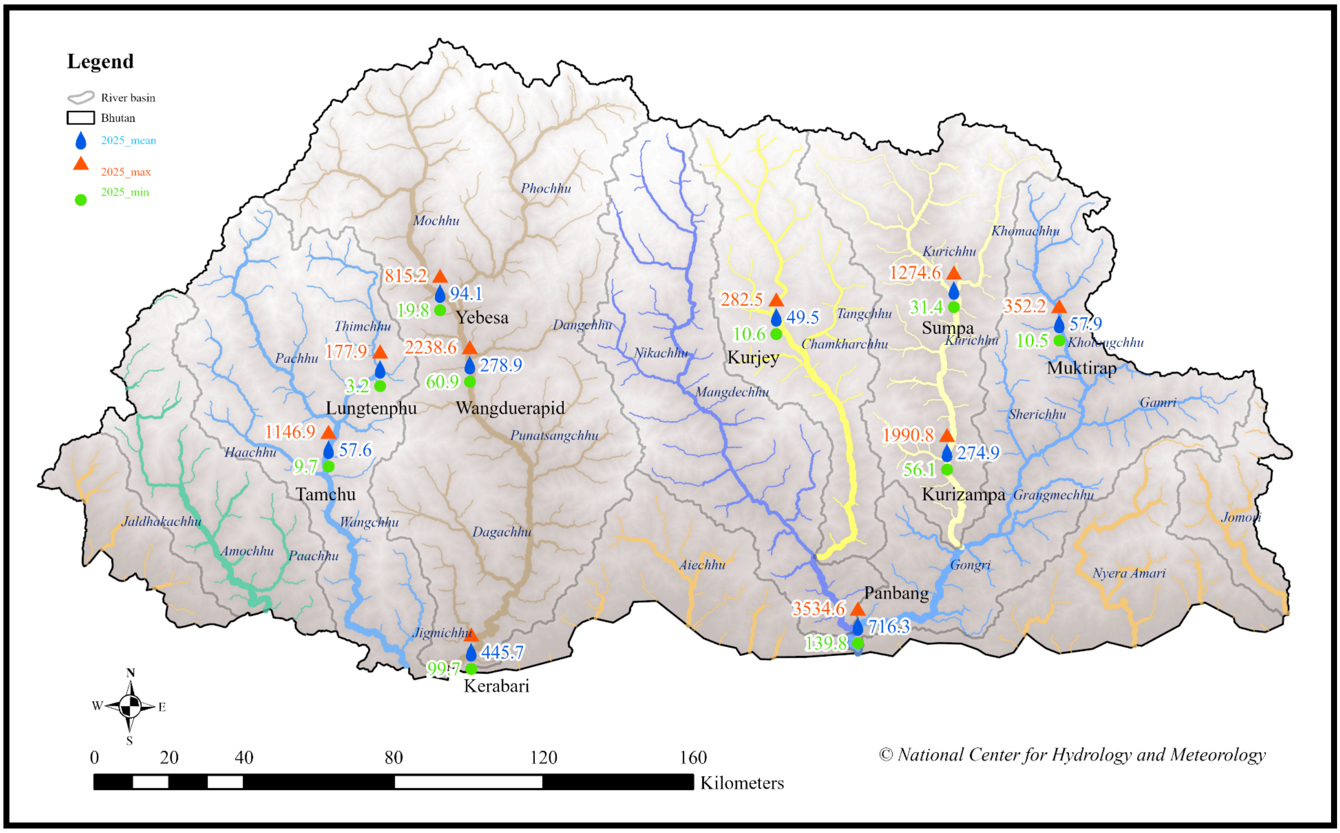


Figure 17: Map showing the status of flow in 2025 across multiple stations

SECTION C: CRYOSPHERE

1. GLACIERS

Bhutan, located in the eastern Himalayas, is home to numerous glaciers that span its northern regions. These glaciers serve as crucial sources of freshwater for the country's rivers, supporting agriculture, hydropower production, and local ecosystems. According to the Bhutan Glacier Inventory (BGI, 2018), the nation has around 700 glaciers, covering roughly 630 km², which represents about 1.6% of Bhutan's total land area. In recent decades, however, these glaciers have been increasingly affected by climate change. Rising temperatures and altered precipitation patterns have caused many glaciers to retreat, reducing both their surface area and ice volume.

Among the 700 glaciers, the Punatsang Chhu basin has the largest number, with 341 glaciers covering 361.07 km², while the Wang Chhu basin has the fewest, with 47 glaciers over 33.38 km². The largest glacier in Bhutan is MMagr16_482 (G090443E28024), located in the Mangde Chhu sub-basin, stretching 15.56 km in length and covering 45.85 km². Figure 14 and Table 5 present the glacier map and the distribution of glaciers by basin and sub-basin in Bhutan.

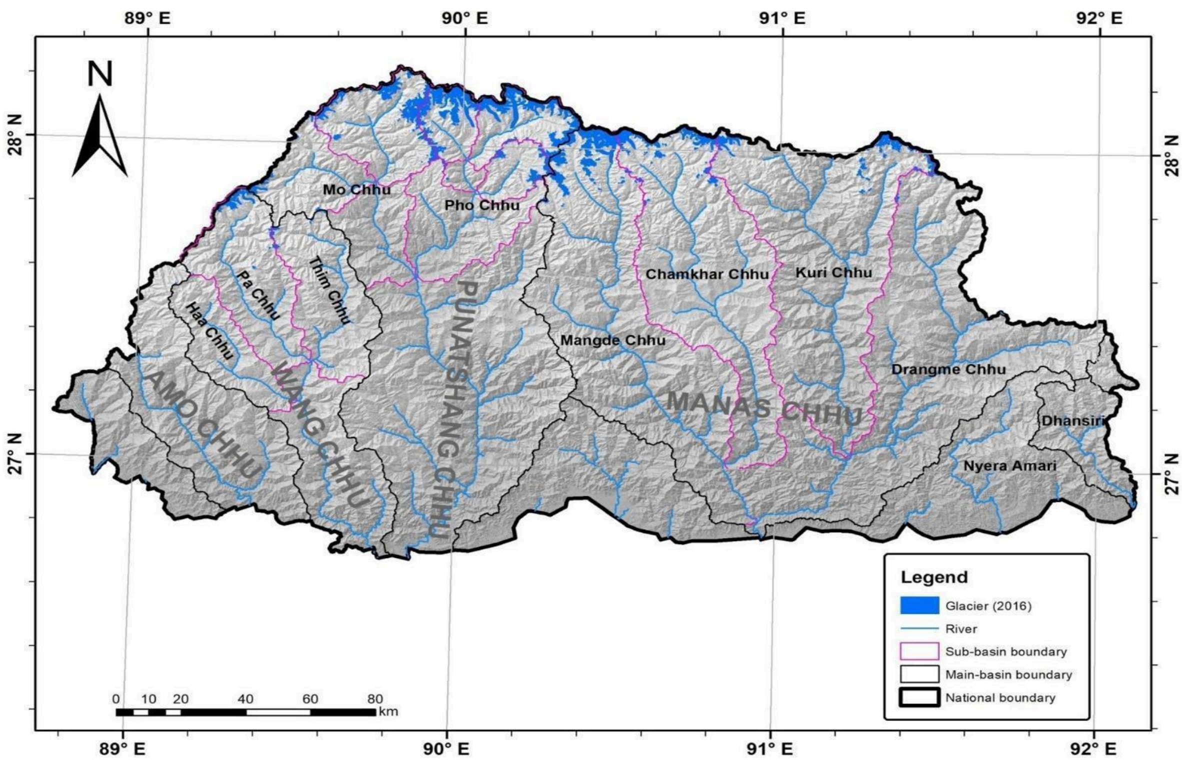


Figure 14: Sub-basin-wise distribution of glaciers of Bhutan. Pink polygons show the sub-basin boundary, dark blue polygons show the glaciers and light blue polygons are rivers of Bhutan

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

Major Basin	Sub-basin	Glaciers (number)	Area (km²)
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

Due to the extensive presence of glaciers in Bhutan's northern regions, the country is home to a large number of glacial lakes. According to the Bhutan Glacial Lake Inventory (BGLI, 2021), 567 glacial lakes have been mapped using updated criteria. While Bhutan boasts numerous glacial lakes, including some of the largest and most scenic, these lakes also pose significant risks to local communities because of the potential for glacial lake outburst floods (GLOFs). In total, these lakes cover an area of 55.04 km². The Manas basin contains the highest number of glacial lakes, with 331 lakes spanning 29.2 km², whereas the Wang Chhu basin has the fewest, with 31 lakes covering just 0.6 km². Figure 15 and Table 5 illustrate the distribution of glacial lakes across the northern regions and their sub-basin-wise breakdown.

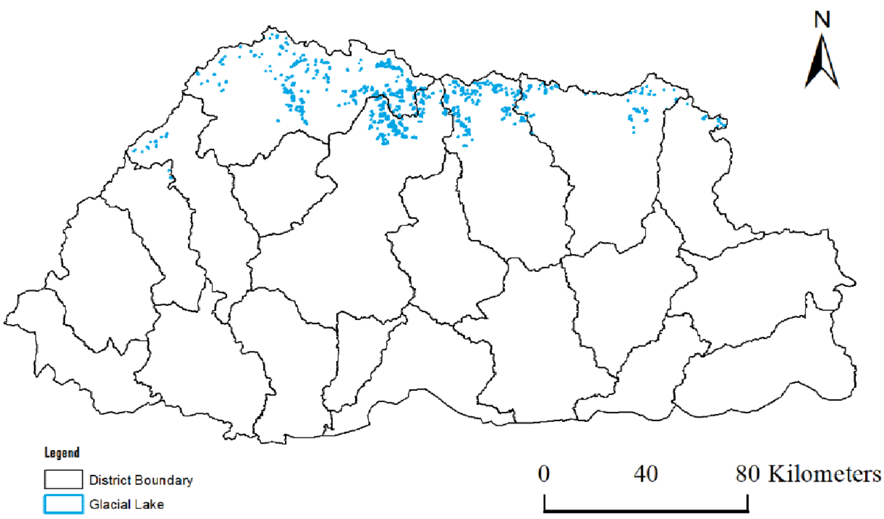


Figure 15: Distribution of glacial lakes in the northern frontiers of the country. Blue polygons are the distribution of glacial lakes and the black polygons are district boundaries

Table 5. 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. FRESHWATER LAKES IN BHUTAN

In addition to glacial lakes, Bhutan is also home to a large number of freshwater mountain lakes distributed across its major river basins and sub-basins. According to the freshwater lake inventory, a total of 2,391 freshwater lakes have been mapped across the country. These lakes cover a total area of 55.56 km², representing about 0.144% of Bhutan's total land area. The Puna Tsang Chu sub-basin contains the highest number of freshwater lakes, with 769 lakes covering 19.22 km², whereas the Nyera Ama Chhu sub-basin has the fewest, with 13 lakes covering 0.11 km². These freshwater lakes are an important component of Bhutan's water resources and provide valuable baseline information for water resource management, hydrological studies, cryosphere research, and long-term monitoring of environmental change. Figure 16 and Table 6 present the distribution of freshwater lakes across Bhutan and their basin and sub-basin-wise breakdown.

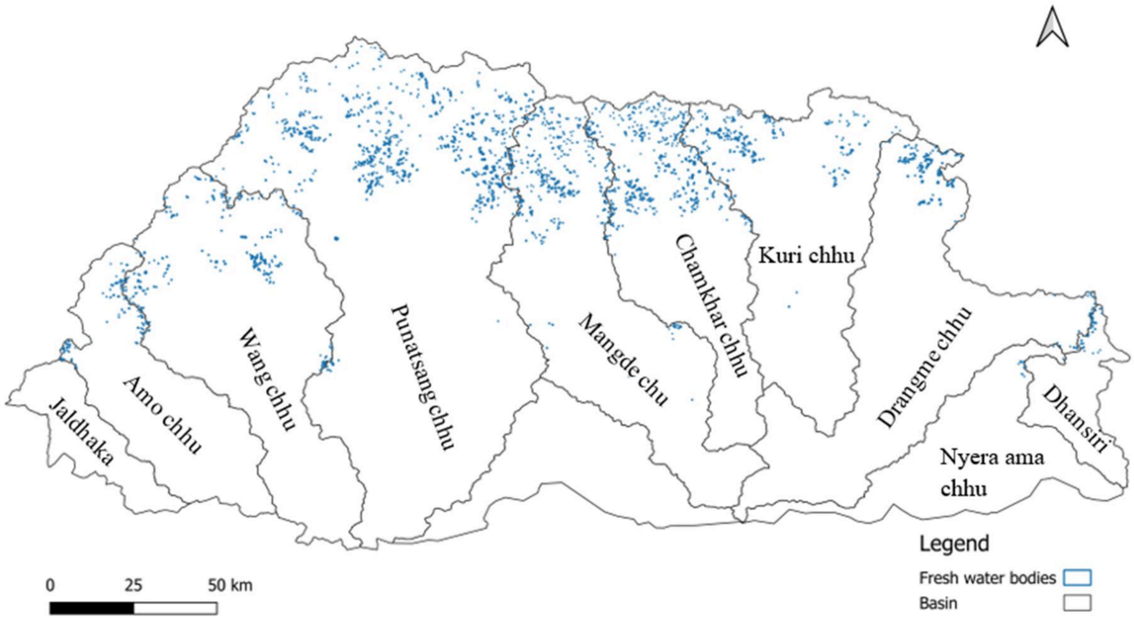


Figure 16. Map showing freshwater lakes in Bhutan

Table 6. Basin wise distribution of glacial Lakes of Bhutan

Major Basin/Sub-basin	**Glacial lakes (number)**	**Area (in km²)**
Amo Chu	94	2.04
Wang Chu	236	5.88
Puna Tsang Chu	769	19.22
Mangde Chhu	374	5.53
Chamkhar Chhu	449	10.57
Kuri Chhu	243	6.51
Drangme Chhu	173	5.12
Nyera Ama Chhu	13	0.11
Dhansiri	40	0.58
Total	**2,391**	**55.56**

4. POTENTIALLY DANGEROUS GLACIAL LAKES (PDGL)

Based on the glacier and glacial lake inventory of Bhutan (2001), the country was initially identified to have 25 potentially dangerous glacial lakes (PDGLs). Subsequent field verification and ground-based assessments of these lakes led to an updated understanding of the actual risks, resulting in a revised count of 17 PDGLs across the country. Among these, the Pho Chhu sub-basin alone has 11 with the highest concentration of potentially dangerous lakes, highlighting the regional variations in GLOF risk. These lakes are closely monitored due to their potential impact on downstream communities, infrastructure, and hydropower installations. Figure 16 and Table 7 present the locations of these 17 PDGLs along with their sub-basin-wise distribution, providing critical information for risk assessment and mitigation planning in Bhutan.

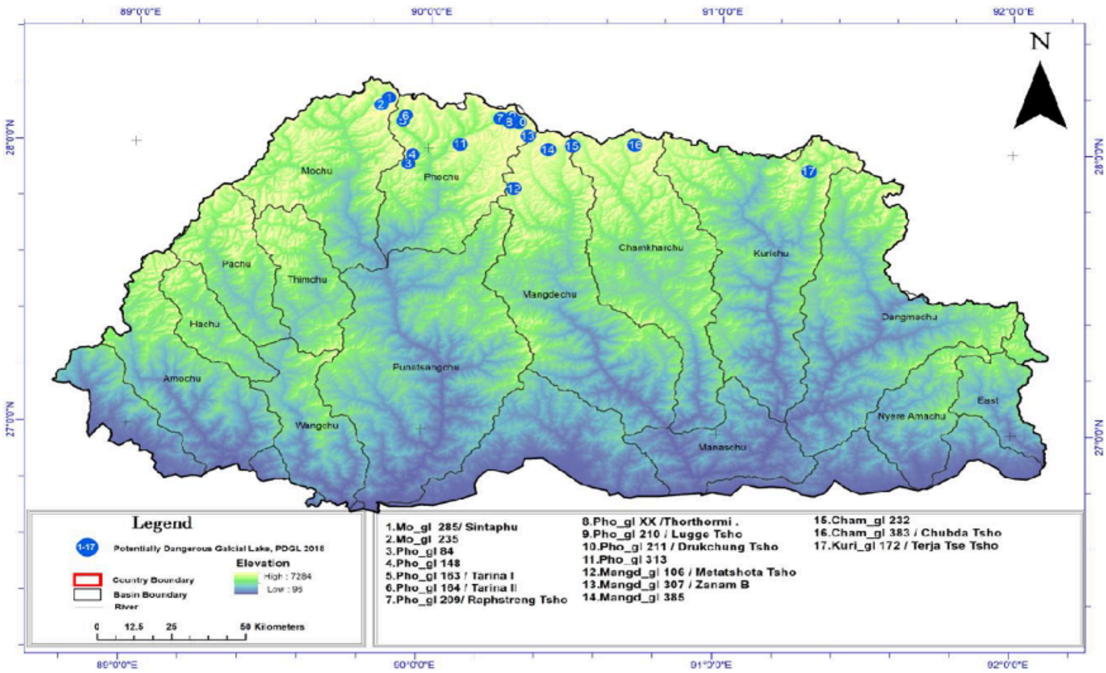


Figure 16: Sub-basin-wise distribution of potentially dangerous glacial lakes of Bhutan

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 (m²)	Volume (m³)	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

5. GLACIER MASS BALANCE

Bhutan has identified three benchmark glaciers for long-term monitoring to understand glacier behaviour since 2003, 2012, and 2022 for Gangju La (headwater of Pho Chhu), Thana (headwater of Chamkhar Chhu), and Shodug (headwater of Thim Chhu) glaciers, respectively. Glacier mass balance monitoring is a key indicator of glacier health, as it represents the net gain or loss of ice over time and provides a direct measure of the glacier's response to climatic conditions. Because glaciers integrate variations in temperature and precipitation, changes in mass balance serve as a sensitive indicator of climate variability and long-term climate change in high-mountain environments. Over the observation periods, all the glaciers have exhibited negative mass balance, indicating continuous glacier ice mass loss. Figure 17 and Table 8 show the location of the three benchmark glaciers and the glacier mass balance data of Gangju La and Thana glaciers over the observation periods.

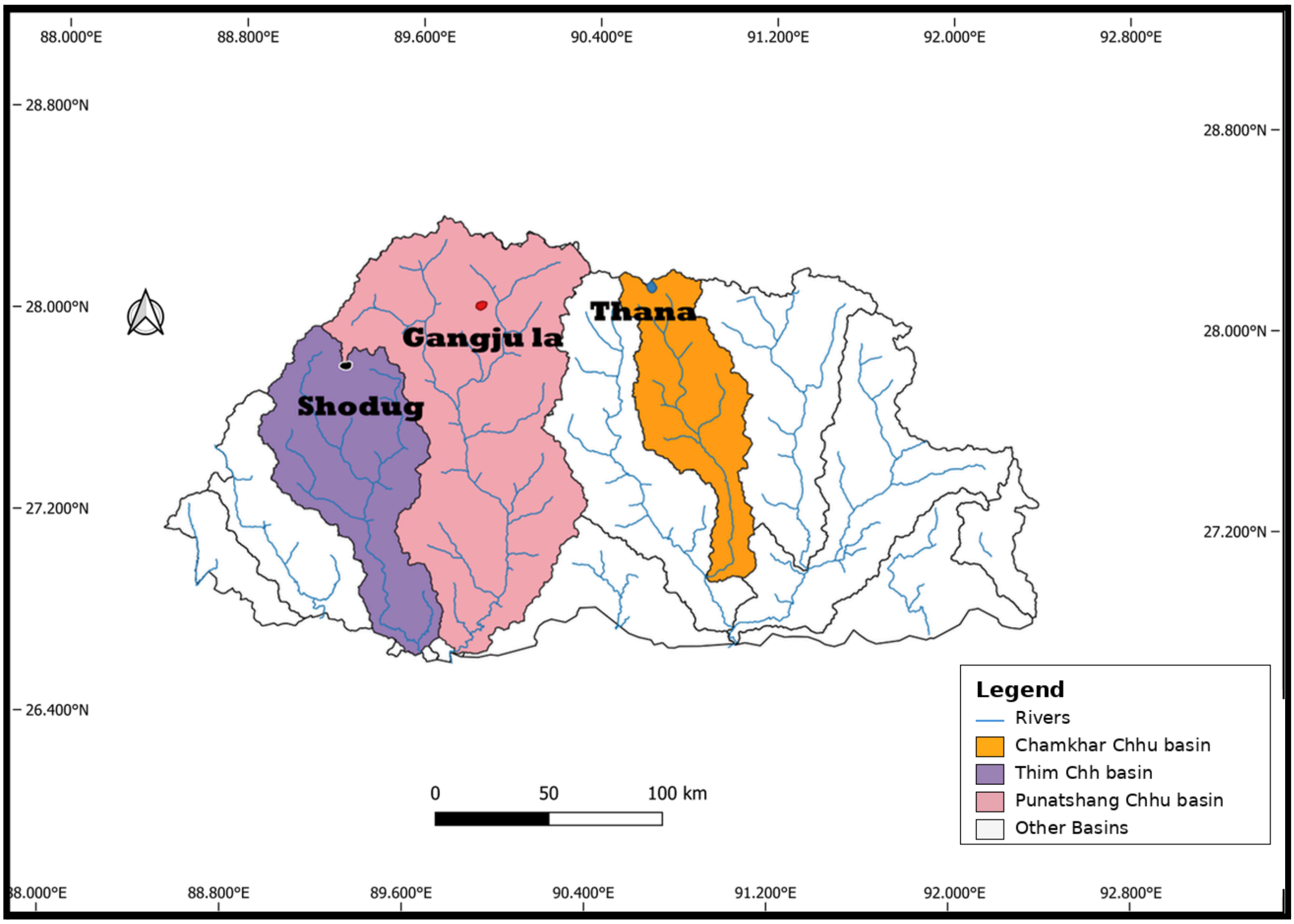


Figure 17: Location map of Three benchmark glaciers in Bhutan

Figure 18 shows the annual glacier mass balance of the three benchmark glaciers, derived using direct field measurements and in-situ geodetic methods over the observation period. The observations reveal that the glaciers experience negative mass balance indicating ice loss. Figure 19 presents the cumulative glacier mass balance, which sums the annual values over time, providing a clear view of the total ice mass loss since the start of monitoring. The cumulative values highlight the long-term glacier retreat and serve as a robust indicator of glacier health and response to climatic conditions.

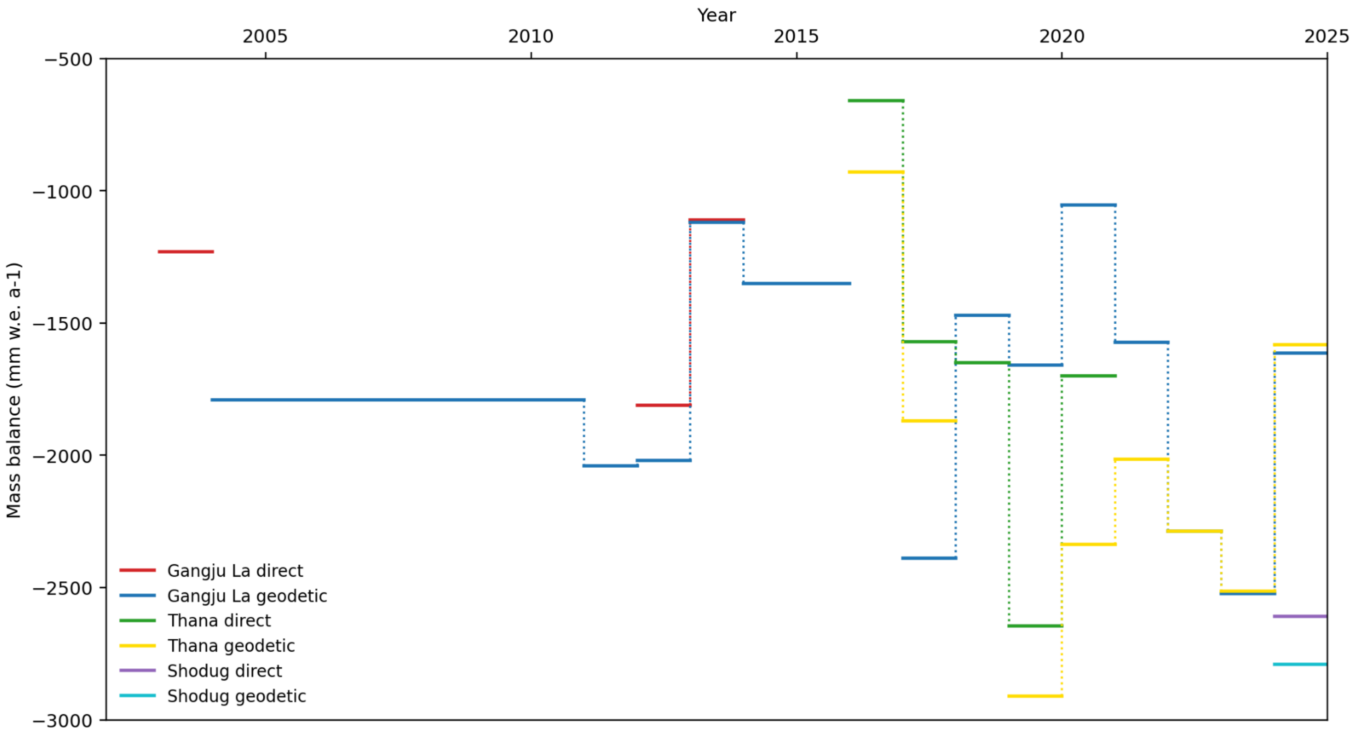


Figure 18: Mass balance of Three benchmark glaciers using different methods

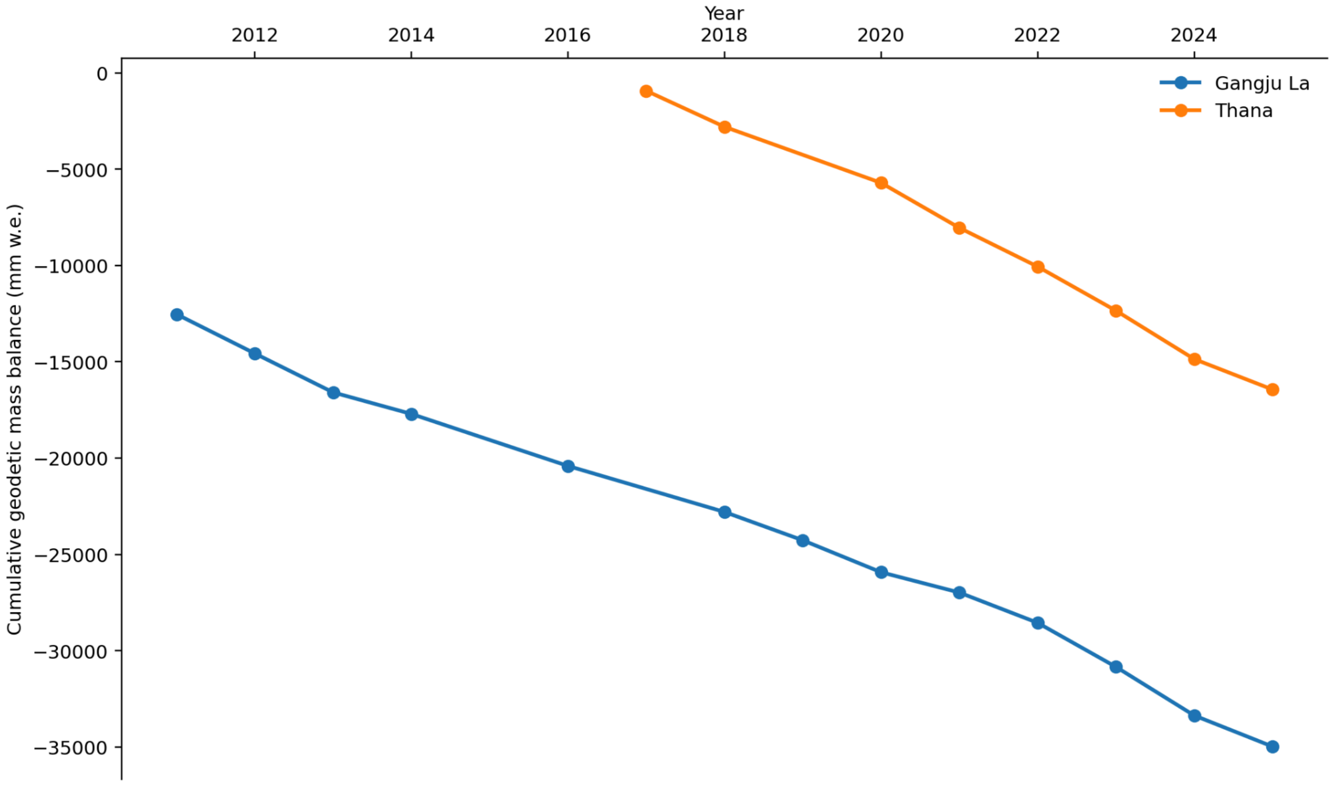


Figure 19: Cumulative Mass balance of Gangju La and Thana glacier

Table 8: Mass Balance details on Gangju La ,Thana and Shodug

	Gangju La (mm w.e. a^{-1})		**Thana (mm w.e. a^{-1})**		**Shodug (mm w.e. a^{-1})**	
Year	**Direct**	**Geodetic**	**Direct**	**Geodetic**	**Direct**	**Geodetic**
2003-2004	-1230					
2004-2011		-1790				
2011-2012		-2040				
2012-2013	-1810	-2020				
2013-2014	-1110	-1120				
2014-2016		-1350				
2016-2017			-660	-930		
2017-2018		-2390	-1570	-1870		
2018-2019		-1470	-1650			
2019-2020		-1660	-2645	-2910		
2020-2021		-1054	-1699	-2336		
2021-2022		-1572		-2014		
2022-2023		-2288		-2287		
2023-2024		-2522		-2513	-2608	-2791
2024-2025		-1614		-1582		

6. GLACIER MASS BALANCE MEASUREMENT IN BHUTAN: A JOINT INITIATIVE OF NCHM AND ICIMOD

To strengthen glacier monitoring in Bhutan, the National Centre for Hydrology and Meteorology (NCHM), in collaboration with the International Centre for Integrated Mountain Development (ICIMOD), initiated seasonal glacier mass balance measurement in 2025. This initiative complements NCHM's ongoing annual glacier mass balance monitoring programme on the benchmark glaciers of Gangju La, Thana, and Shodug. While annual mass balance reflects the net gain or loss of glacier ice over a hydrological year, seasonal mass balance measurement helps distinguish winter accumulation from summer ablation and provides a better understanding of short-term glacier response to climatic conditions. Seasonal monitoring is particularly important in Bhutan because glaciers are influenced by both the Indian Summer Monsoon and the Winter Westerlies, which together create a complex seasonal pattern of glacier mass gain and loss.

Under this joint initiative, Shodug Glacier, located in the headwaters of Thim Chhu, was selected as the priority site for seasonal monitoring due to its relative accessibility and existing field infrastructure.

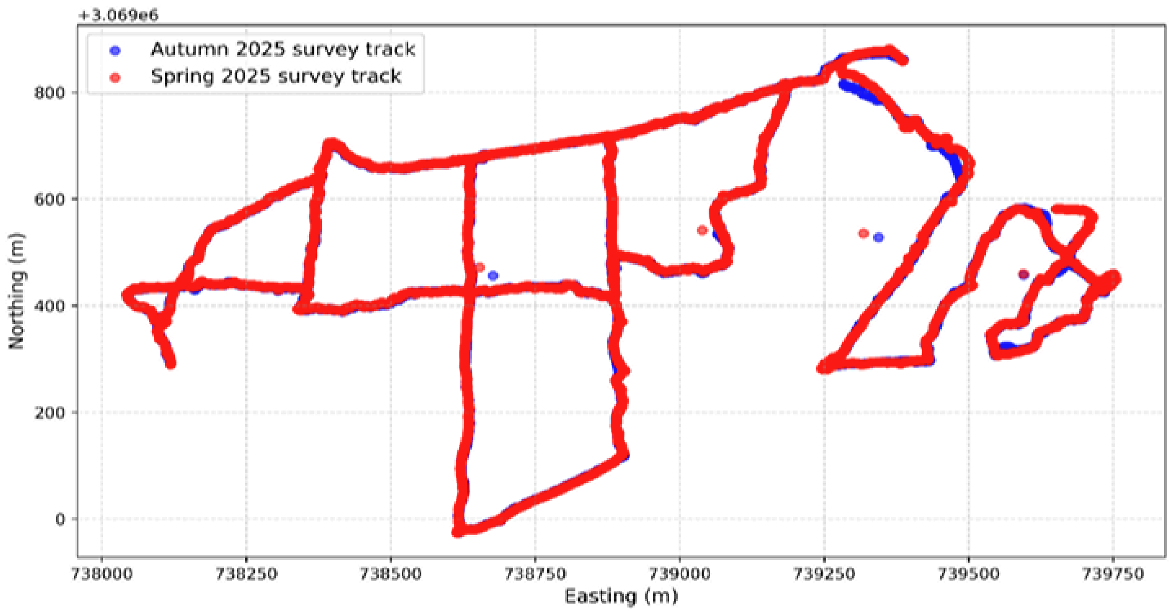


Figure 15: dGPS survey tracks (points) on Shodug glacier in Spring and Autumn 2025

7. PERMAFROST

Permafrost is subsurface earth material that remains at or below 0°C for at least two consecutive years. It is one of the least understood components of the cryosphere in Bhutan, despite its importance for slope stability, water availability, and mountain hazards. To strengthen understanding of permafrost conditions in the country, the National Centre for Hydrology and Meteorology (NCHM), in collaboration with the International Centre for Integrated Mountain Development (ICIMOD), carried out near-surface ground temperature monitoring in Redrukzhi, Laya. A total of 19 near-surface ground temperature sensors were deployed in the headwaters of the Mo Chhu sub-basin, with particular focus on the area affected by the 2021 landslide event in Laya. This activity marks an important step in strengthening permafrost research in Bhutan and provides a basis for long-term monitoring of ground thermal conditions in high mountain environments.

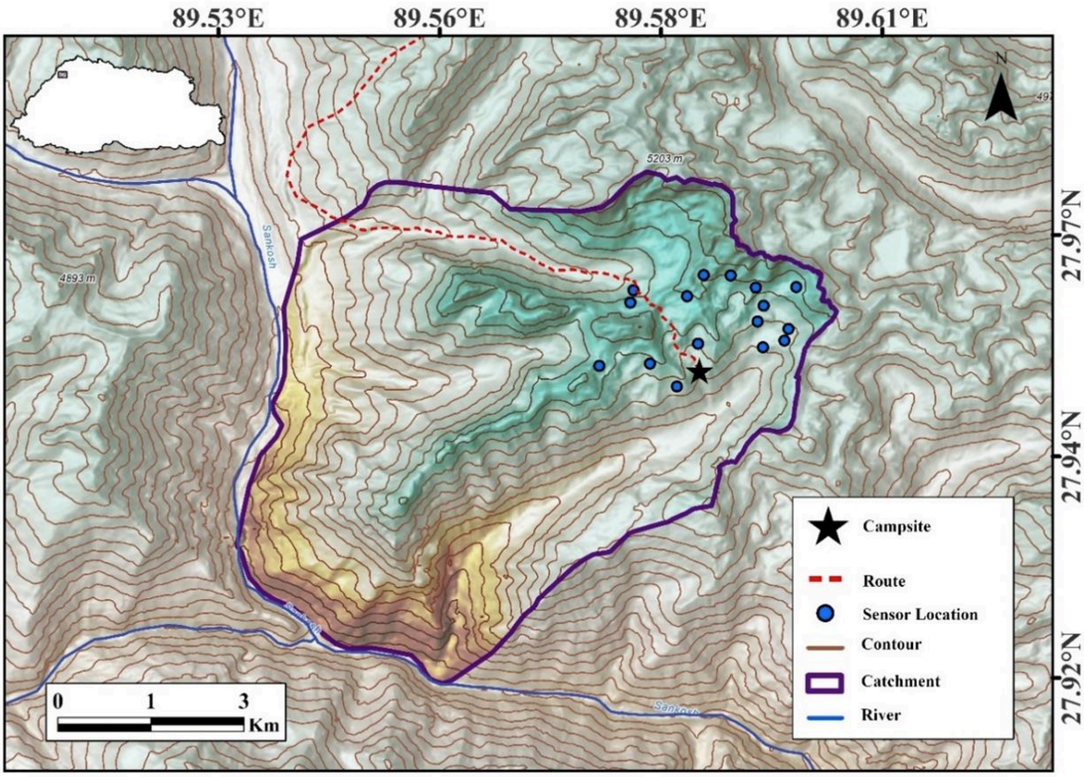


Figure 16: Location of temperature sensors (blue circles with black outline) installed at Ridrukzhi,, Laya.

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