



**Rainfall and Temperature Forecast of Bhutan
for
Winter Monsoon
(December 2022 – February 2023)**

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Table of Contents

1. Background.....	3
2. SASCOF-24 consensus on prevailing conditions	3
2.1 ENSO Conditions over the Pacific Ocean	3
2.2 Conditions over the Indian Ocean	3
3. Regional Outlook for DJF 2022/23 Precipitation and Temperature over South Asia....	4
4. Winter Seasonal Outlook from International and Regional Climate Centres	5
4.1 WMO Lead Centres	5
4.2 Copernicus Climate Change Service.....	6
4.3 International Research Institute for Climate and Society (IRI)	6
4.4 APEC Climate Center	7
4.5 European Centre for Medium-Range Weather Forecasts (ECMWF).....	7
4.6 UK Met Office	8
4.7 JMA.....	8
4.7 Climate Predictability Tool (CPT).....	9
5. Consensus Winter Monsoon outlook DJF 2022/23 for Bhutan	10

1. Background

Seasonal forecasting and climate predictions are important adaptation measures to climate variability and change. Regional Climate Outlook Forums (RCOFs) were created to bring together countries having common climatological characteristics and to produce a joint assessment of the state of the regional climate. Thus, South Asian Climate Outlook Forum (SASCOF) came into existence in 2010 with specific focus on the information needs of countries affected by the monsoon climate in South Asia.

Seasonal forecasts generally consist of an outlook of precipitation and temperature for a particular region. The seasonal forecast of Bhutan is prepared with inputs from global and regional prediction centres, and national climate data. The final outlook is also based on the consensus outlook of the South Asian Climate Outlook Forum (SASCOF), products from World Meteorological Organization (WMO) Global Producing Centres (GPCs) of Long-Range Forecast, various other international sources and the prevailing global climate conditions such as El Niño Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) affecting the monsoon. The summer monsoon outlook has to be used and interpreted along with the extended, medium, daily weather forecasts and other advisories released by the Centre.

2. SASCOF-24 consensus on prevailing conditions

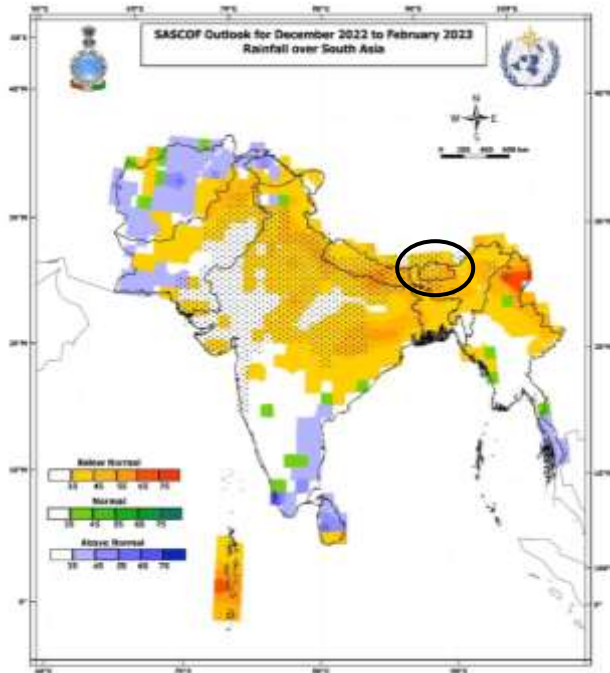
2.1 ENSO Conditions over the Pacific Ocean

The El Niño/Southern Oscillation (ENSO) is a global climate conditions having significant influence on the variability of the monsoon precipitation and the surface temperatures over South Asia. The Nino3.4 Sea Surface Temperature anomaly for the last 12 months indicates that the La Niña conditions were prevailing from November 2021 to October 2022. Currently, La Niña conditions are prevailing over the Pacific. The latest forecasts from global climate models indicate a strong probability for La Niña conditions likely to continue during the winter season (DJF 2022/23).

2.2 Conditions over the Indian Ocean

The Sea Surface Temperature (SSTs) of the Indian Ocean also influence the monsoon of the region. A positive (negative) Indian Ocean Dipole (IOD) is associated with a stronger (weaker) than normal monsoon. The Dipole Mode Index (DMI) for the last 12 months indicates that the neutral IOD conditions were observed over the Indian Ocean from November 2021 to April 2022 but the DMI was the negative side of its normal. The negative DMI value strengthened from May to July 2022 to develop a negative IOD which weakened from August to October 2022. At present, neutral IOD conditions are present over the Indian Ocean. Currently, the SST conditions over the equatorial Indian Ocean suggest neutral Indian Ocean Dipole (IOD) conditions. Forecasts from global climate models indicate a strong probability of neutral IOD conditions persisting during the winter season (DJF 2022/23).

3. Regional Outlook for December 2022 to February 2023 (DJF 2022/23) Season Precipitation and Temperature over South Asia



A regional climate outlook for December 2022 to February 2023 season precipitation and temperature over South Asia was prepared based on assessment of the prevailing large-scale climate indicators, experimental and operational long-range forecasts based on statistical and dynamical models generated by respective NMHS and various other climate Centres of the world.

Figure 1: Consensus Outlook for DJF 2022/23 precipitation over South Asia

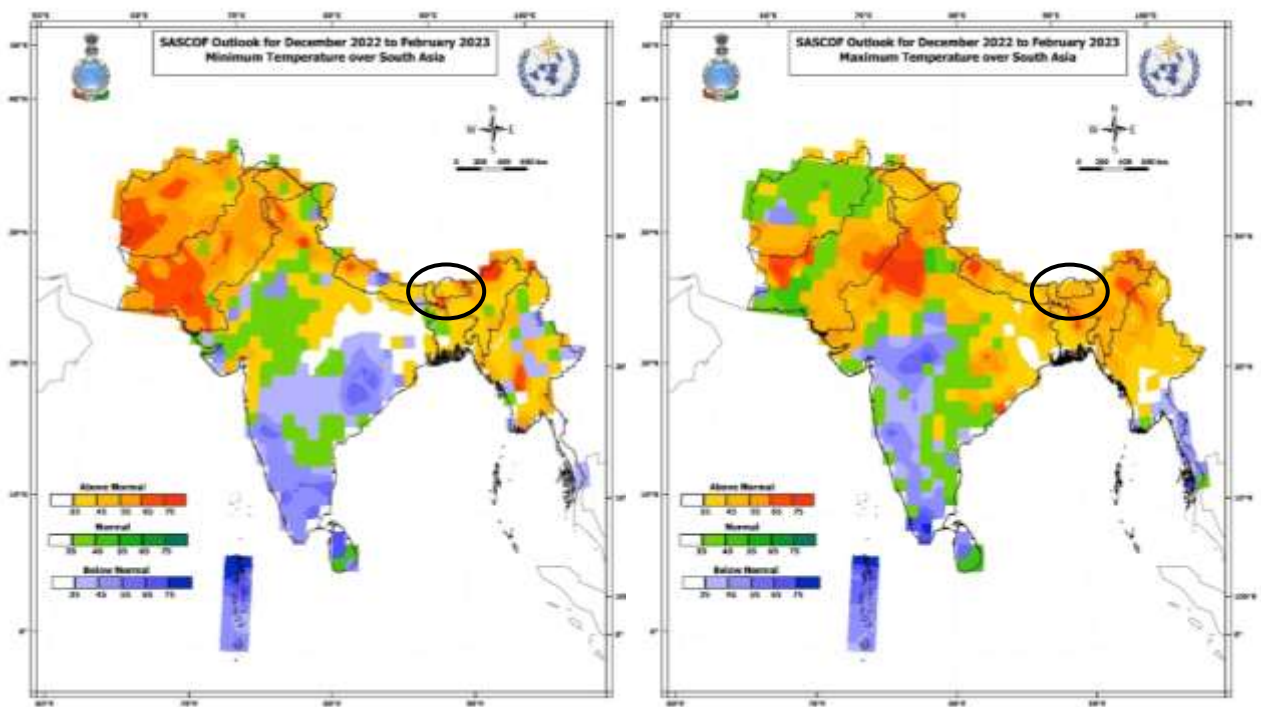


Figure 2: Outlook for DJF 2022/23 minimum (left) and maximum temperature (right) over South Asia

The outlook suggests that during the winter season December 2022 to February 2023 (DJF 2022/23) season, below-normal precipitation is likely over many regions of South Asia like parts of north, northwest, along the foothills of the Himalayas, and the northeastern part of South Asia. Above normal precipitation is likely over the extreme northwest region and some regions of the southern part of South Asia (**Figure 1**).

The consensus outlook on minimum temperatures for December 2022 to February 2023 season indicates that above normal minimum temperatures are likely over many areas of the north, northwestern, northeast, and along the plains of the Himalayas. However, below normal minimum temperatures are likely over some areas of central and southern parts of the region. The rest of the region is likely to experience normal rainfall or have climatological probabilities (**Figure 2**).

The consensus outlook on maximum temperatures for December 2022 to February 2023 season suggests that normal to above normal maximum temperatures are most likely over north, northwest, northeast regions and along the Himalayas. Below normal maximum temperatures are likely over parts of the central and southern region (**Figure 2**).

Since the rainfall and temperature during the winter season depicts strong intra-seasonal variability, it is recommended to follow the extended and medium range forecast besides seasonal forecast for better planning.

4. Winter Seasonal Outlook from International and Regional Climate Centres

4.1 WMO Lead Centres

Probabilistic multi-model ensemble forecast of all the GPCs of WMO forecast show below normal rainfall and above normal temperature during DJF 2022/23 over Bhutan.

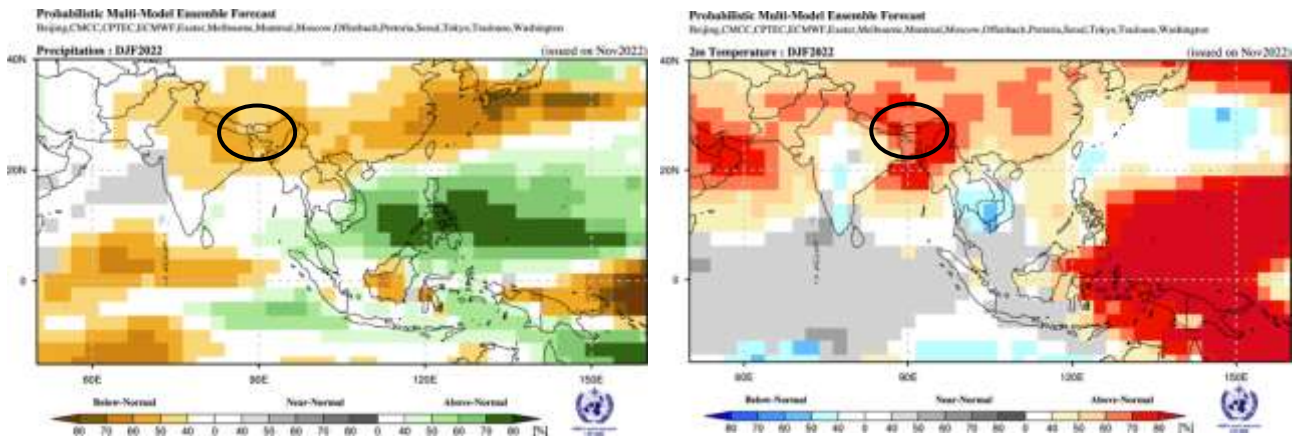


Figure 3: DJF 2022/23 precipitation (left) and temperature (right) forecast from WMO GPCs

4.2 Copernicus Climate Change Service

According to C3S forecast, there is high probability of below normal rainfall and above normal temperature during DJF 2022/23 over Bhutan.

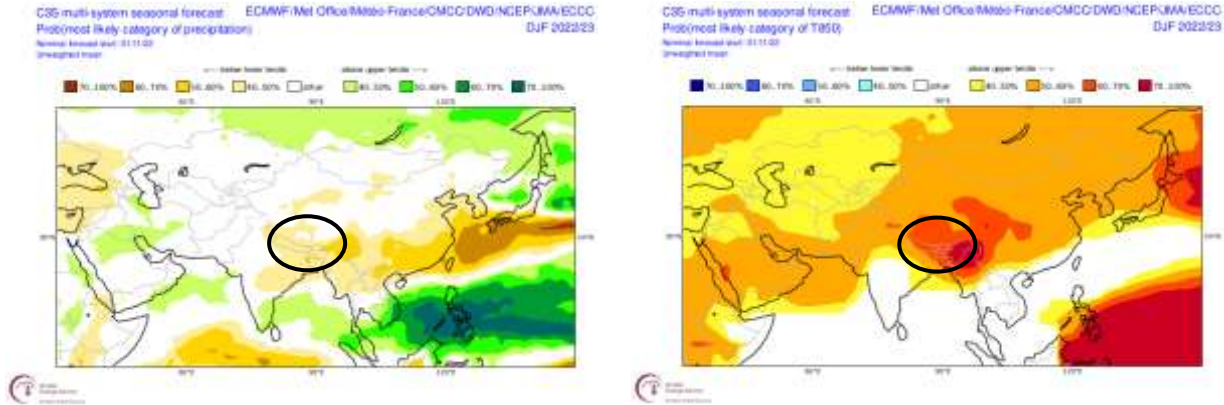


Figure 4: DJF 2022/23 precipitation (left) and temperature (right) forecast from C3S

4.3 International Research Institute for Climate and Society (IRI)

The IRI forecast indicates below normal rainfall over most of the areas and above normal temperature during DJF 2022/23 over Bhutan.

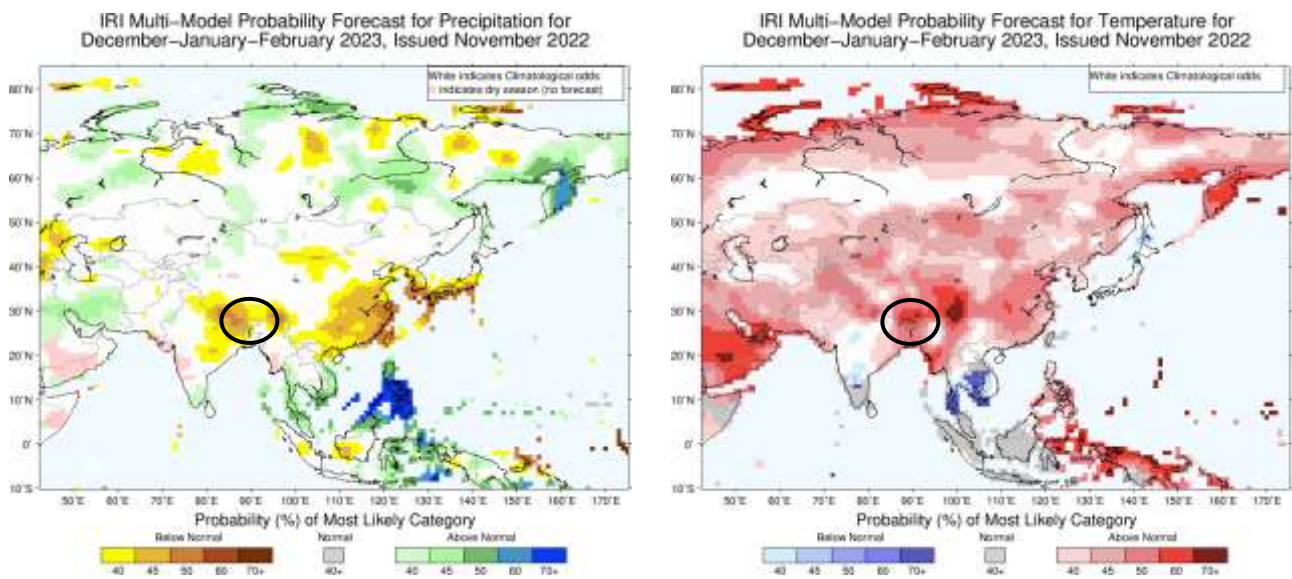


Figure 5: DJF 2022/23 precipitation (left) and (right) forecast from IRI

4.4 APEC Climate Center

The APEC Climate center forecast indicates below normal rainfall and above normal temperature during DJF 2022/23 over Bhutan.

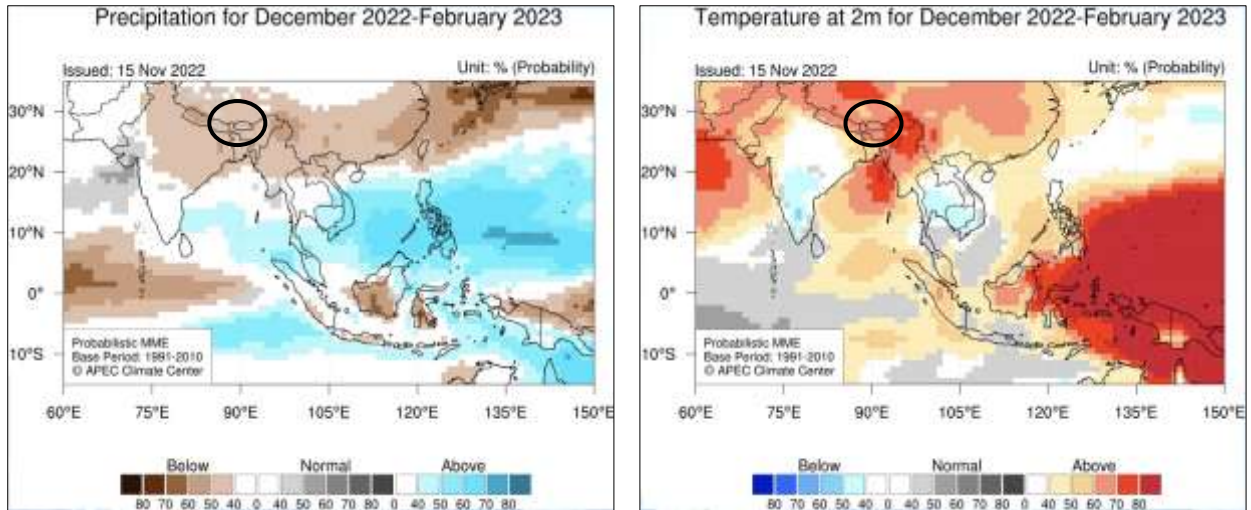


Figure 6: DJF 2022/23 precipitation (left) and temperature (right) forecast from APCC

4.5 European Centre for Medium-Range Weather Forecasts (ECMWF)

The ECMWF forecast indicates climatological probability for rainfall and above normal temperature during DJF 2022/23 over Bhutan.

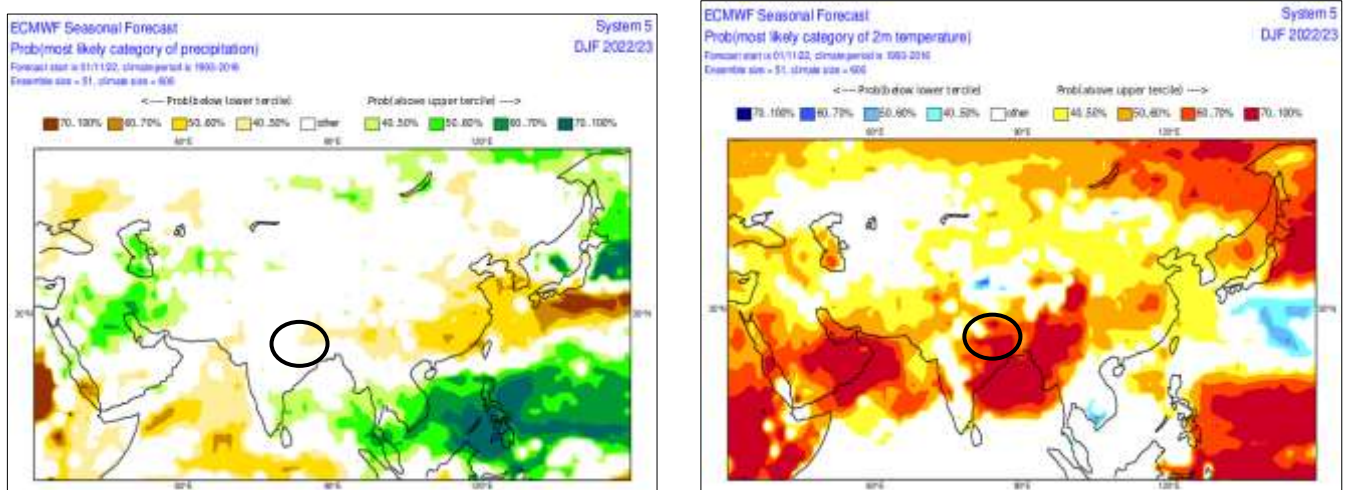


Figure 7: DJF 2022/23 precipitation (left) and temperature (right) forecast from ECMWF

4.6 UK Met Office

According to UK Met office forecast, there is high probability of below normal rainfall and above normal temperature during DJF 2022/23 over Bhutan.

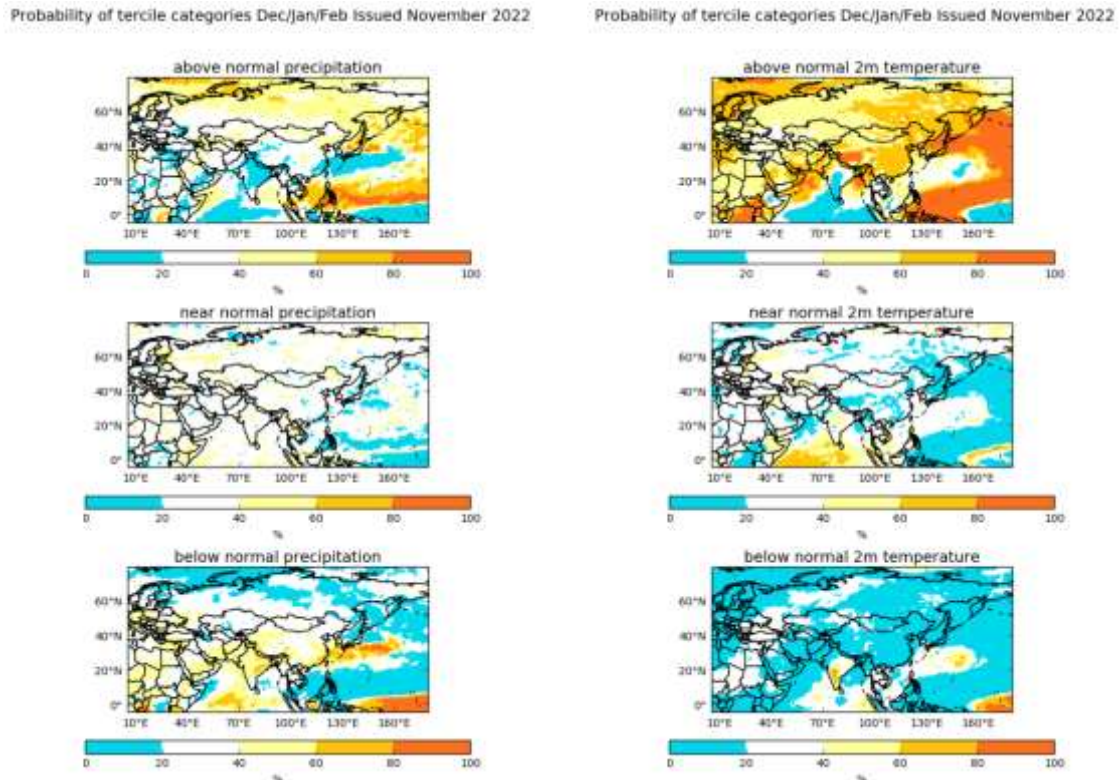


Figure 8: DJF 2022/23 precipitation (left) and temperature (right) from UK Met office

4.7 JMA

According to JMA forecast, there is high probability of below normal rainfall and above normal temperature during DJF 2022/23 over Bhutan.

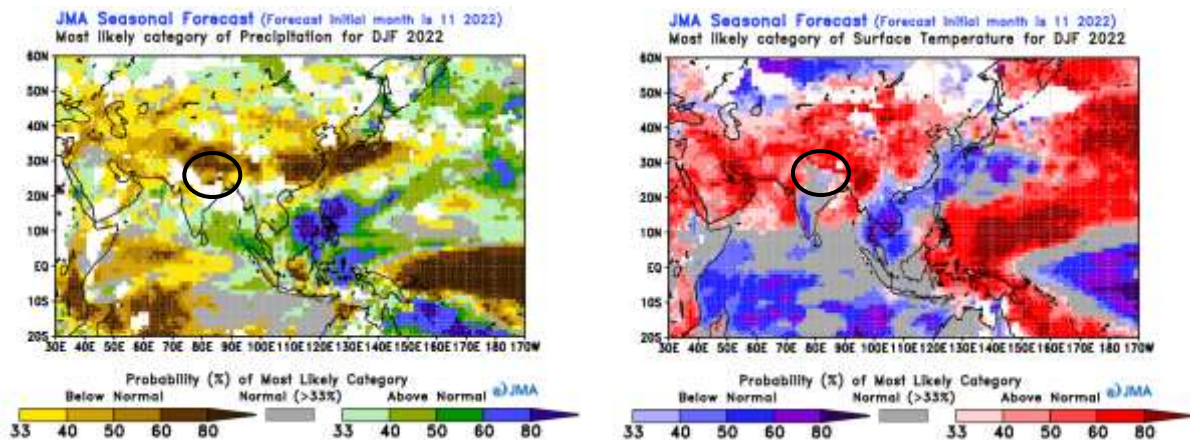


Figure 9: DJF 2022/23 precipitation (left) and temperature (right) from JMA

4.7 Climate Predictability Tool (CPT)

The CPT forecast indicate below to slightly near normal rainfall during DJF 2022/23.

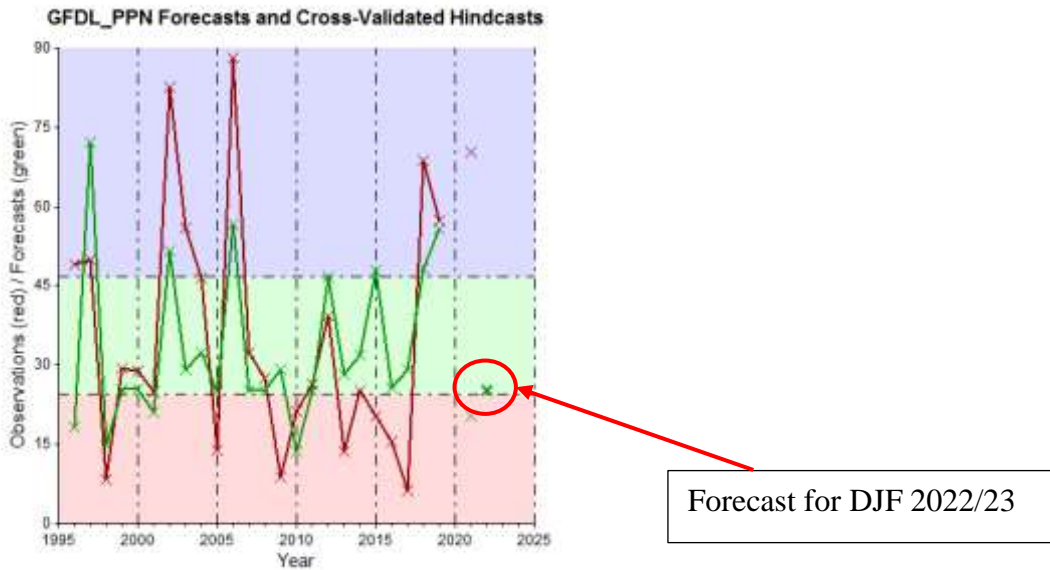


Figure 10: DJF 2022/23 Precipitation forecast from CPT

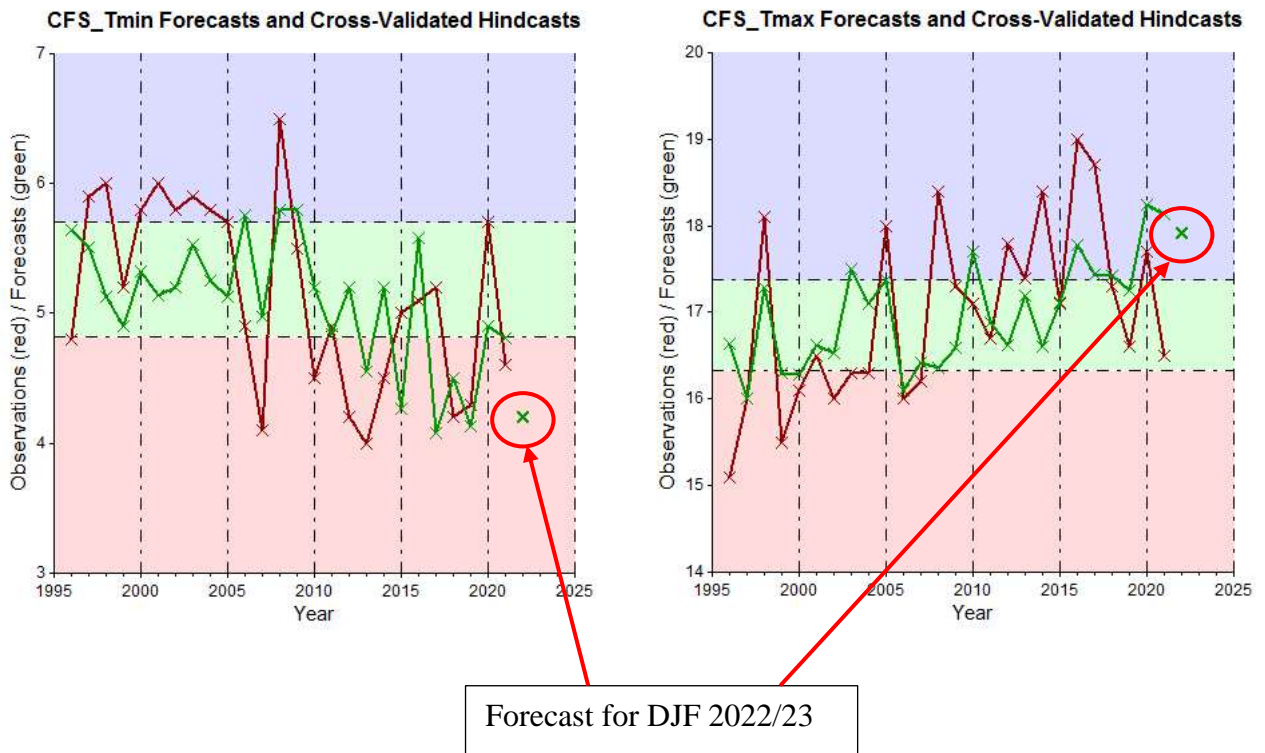


Figure 11: DJF 2022/23 minimum (left) and maximum temperature (right) forecast from CPT

5. Consensus Winter Monsoon outlook DJF 2022/23 for Bhutan

ENSO La Nina and negative IOD conditions are likely to prevail during this season. The final outlook of summer season over Bhutan is based on the forecast products from various sources.

Table 1: Summary of results from various sources

SI No.	Indicators	Precipitation	Minimum Temperature	Maximum Temperature
1	SASCOF	Below normal	Above	Above
2	GPCs	Below normal	Above normal	
3	C3S	Below normal	Above normal	
4	IRI	Below normal	Above normal	
5	APEC	Below normal	Above normal	
6	ECMWF	Climatological Probability	Above normal	
7	UK Met	Below normal	Above normal	
8	JMA	Below normal	Above normal	
9	CPT	Below to slightly near normal	Below normal	Above normal