



**Rainfall and Temperature Forecast of Bhutan
for
Winter Monsoon
(December 2023 – January 2024)**

**Meteorological Services Division
National Centre for Hydrology and Meteorology
Royal Government of Bhutan
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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 must be used and interpreted along with the extended, medium, daily weather forecasts and other advisories released by the Centre.

2. SASCOF-27 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 El Niño conditions (warmer than normal SSTs over the equatorial Pacific) are prevailing over the Pacific region. The latest global model forecasts indicate El Niño conditions to continue during the winter season (DJF).

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. Currently, positive IOD conditions are prevailing over the region and the latest global model indicate the weakening of a positive IOD and turn to neutral conditions during this winter season (DJF).

3. SASCOF-27 Outlook for DJF 2023/24 Winter Monsoon over South Asia

A regional climate outlook for December, 2023 to February, 2024 season over South Asia was prepared based on assessment of the prevailing large-scale climate indicators, experimental models developed during capacity-building workshops of previous SASCOF sessions, statistical and dynamical long-range forecasts of NMHSs in the region and various other climate centres of the world. Factors such as ENSO and IOD are considered for the SASCOF outlook.

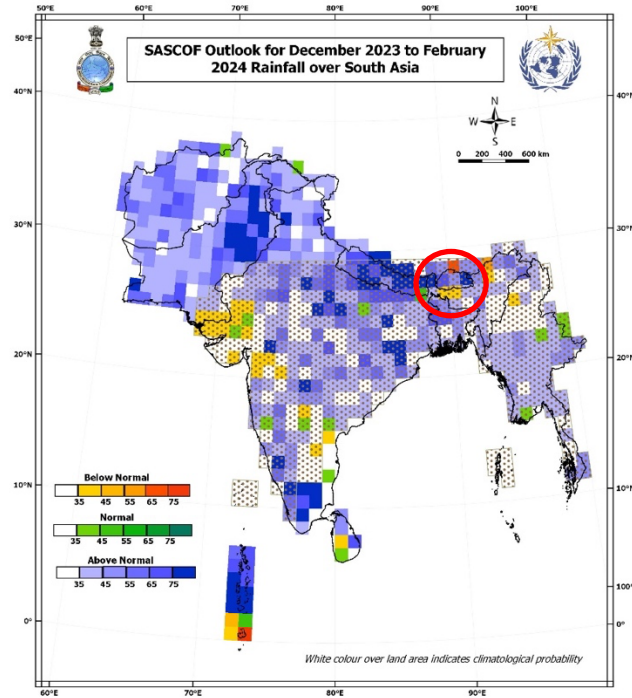


Figure 1: Outlook for DJF 2023/24 2023 rainfall over South Asia (left),

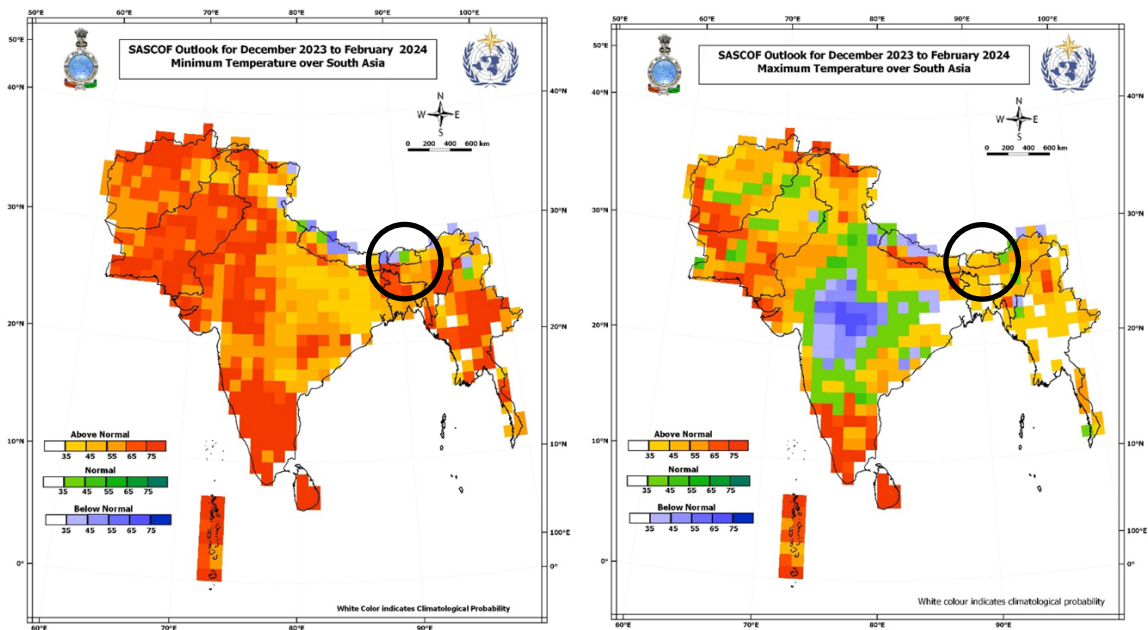


Figure 2: Outlook for DJF 2023/24 minimum temperature (left) and maximum temperature (right) over South Asia

The Figure 1 shows grid wise most likely tercile probability category for each 1x1 degree grids. As depicted in Figure 1, the outlook indicates that during the winter season DJF 2023/24, the rainfall is most likely to be above normal over most parts of South Asia. The above normal rainfall is expected over the north, northwestern, along the foothills of the Himalayas, and the northeastern region of South Asia. Below normal is likely over the parts of the western region and some regions of the northeast and southern part of South Asia. The remaining regions are likely to experience normal rainfall or climatological probabilities.

The outlook on minimum temperatures for DJF 2023/24 (Figure 2) is likely to be normal over most of the South Asia region except northern part of the Himalayan region. The outlook on maximum temperatures for DJF 2023/24 (Figure 2) is likely to be above normal over most of the region except north, northwest, south, northeast regions and along the Himalayas. Below normal maximum temperature is likely over parts of the central and foothills of Himalaya.

Since the rainfall and temperature during winter season depicts strong intra-seasonal variability, it is recommended to follow the extended range and medium range forecast besides the seasonal forecast for the 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 above normal rainfall and above normal temperature during DJF 2023/24 over Bhutan.

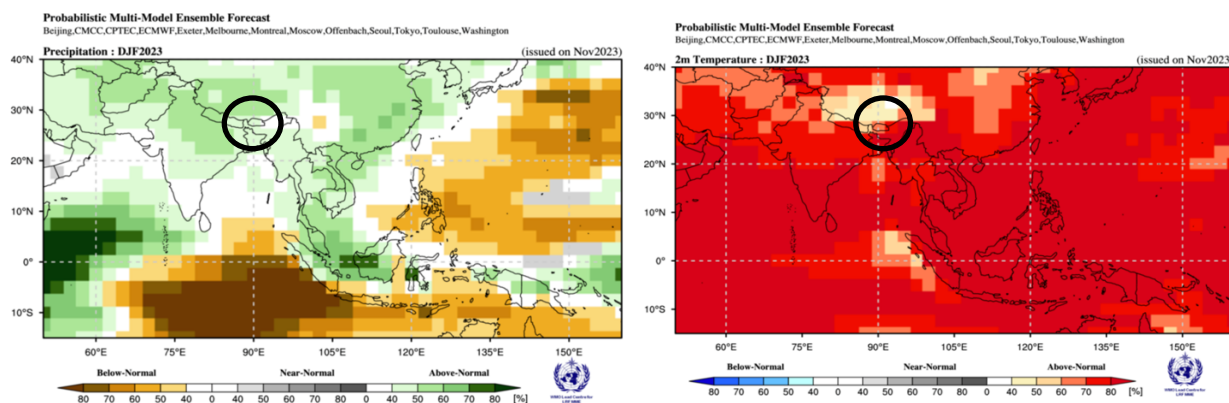


Figure 3: DJF 2023/24 precipitation (left) and temperature (right) forecast from WMO GPCs

4.2 International Research Institute for Climate and Society (IRI)

The IRI forecast indicates below normal rainfall and above normal temperature during DJF 2023/24 over Bhutan.

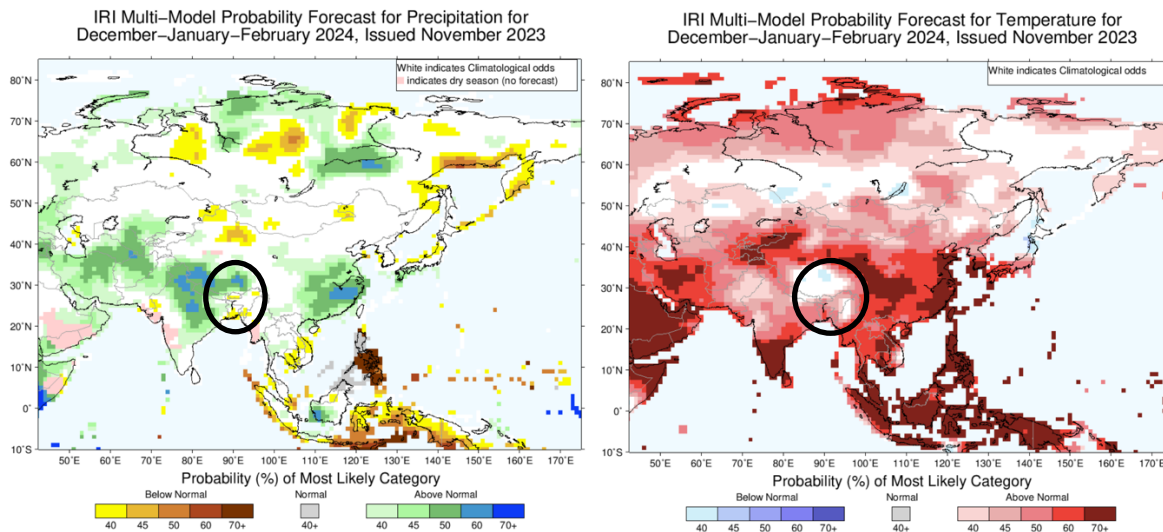


Figure 4: DJF 2023/24 precipitation (left) and temperature (right) forecast from IRI

4.3 APEC Climate Center (APCC)

The APCC forecast indicates above normal for rainfall and above normal temperature during DJF 2023/24 over Bhutan.

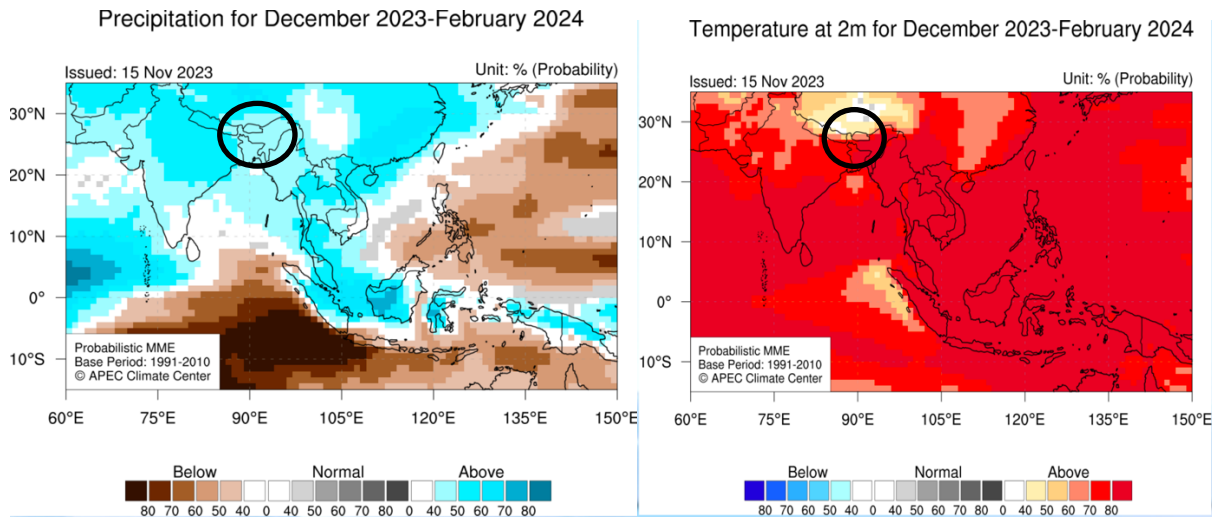


Figure 5: DJF 2023/24 precipitation (left) and temperature (right) forecast from APCC

4.4 Copernicus Climate Change Service (C3S)

According to C3S forecast, there is above normal rainfall and above normal temperature during DJF 2023/24 over Bhutan.

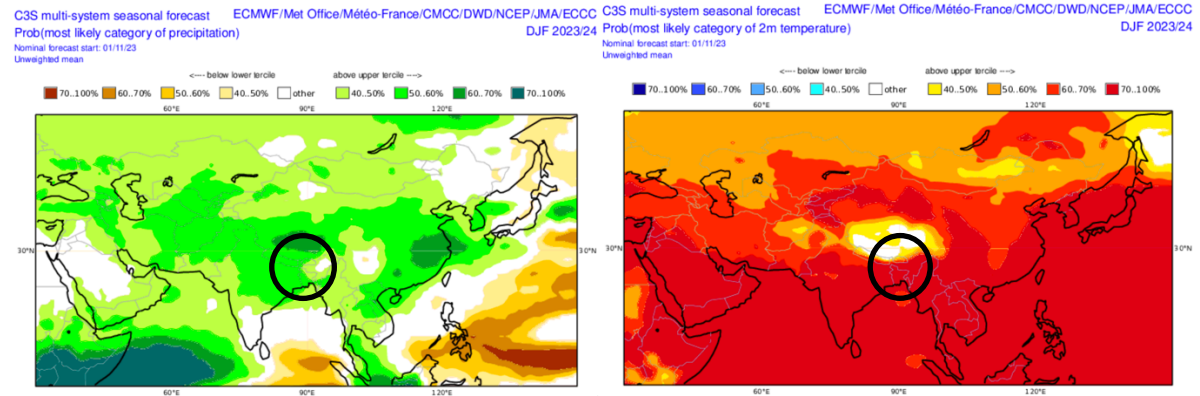


Figure 6: DJF 2023/24 precipitation (left) and temperature (right) forecast from C3S

4.5 Japan Meteorological Agency (JMA) forecast

The JMA forecast indicates above normal for rainfall and normal temperature during DJF 2023/24 over Bhutan.

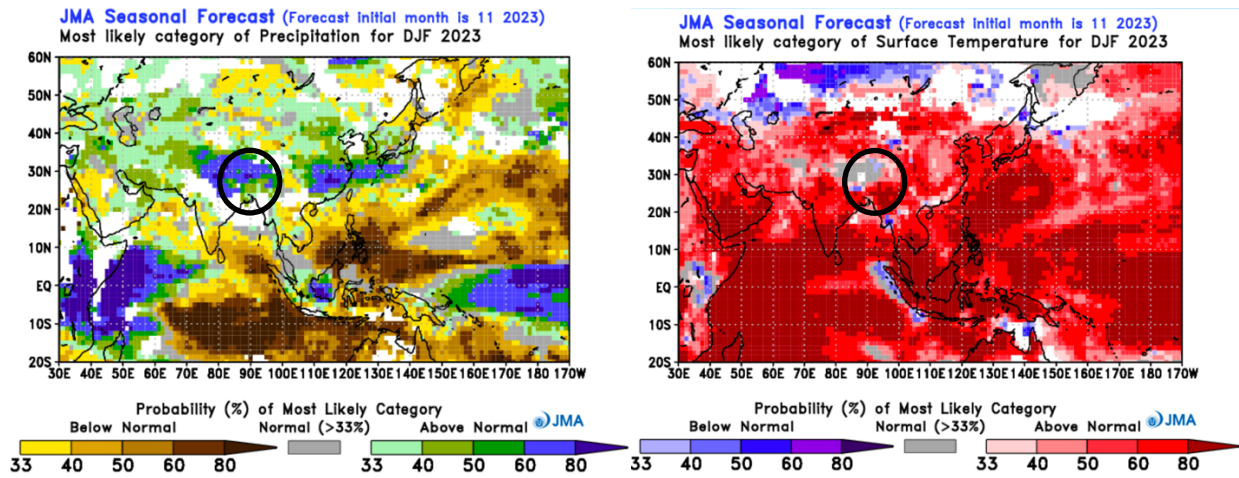


Figure 7: DJF 2023/24 precipitation (left) and temperature (right) forecast from JMA

4.6 North American Multi Model Ensemble (NMME) forecast

The NMME forecast indicates slightly above normal rainfall in the western part of the country, and normal rainfall over the remaining regions and above normal temperature during DJF 2023/24 over Bhutan.

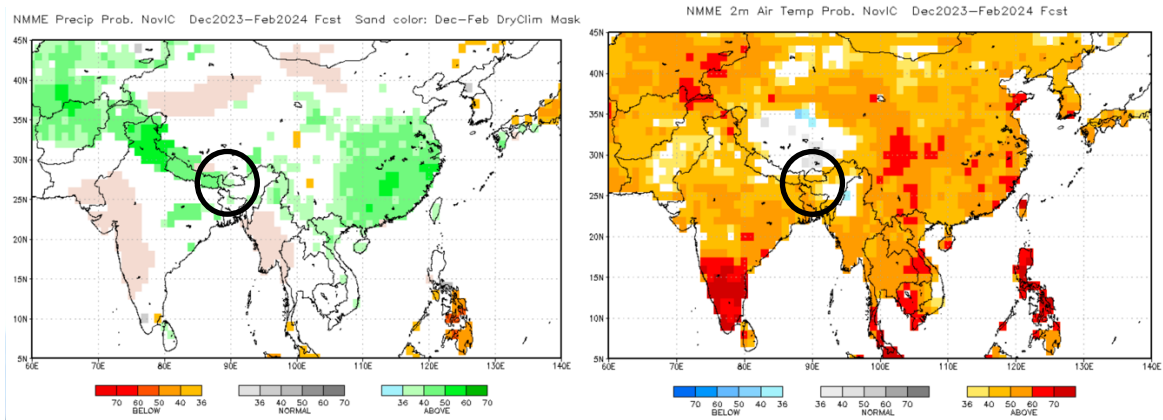


Figure 8: DJF 2023/24 precipitation (left) and temperature (right) forecast from NMME

4.7 Forecast from NCHM using Climate Predictability Tool (CPT)

The CPT forecast indicate normal rainfall, above normal maximum temperature and below normal minimum temperature during DJF 2023/24.

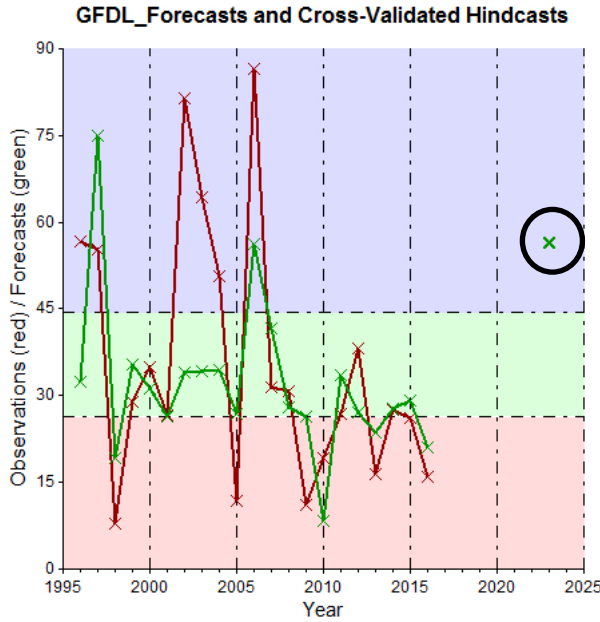


Figure 9: DJF 2023/24 Precipitation forecast from CPT

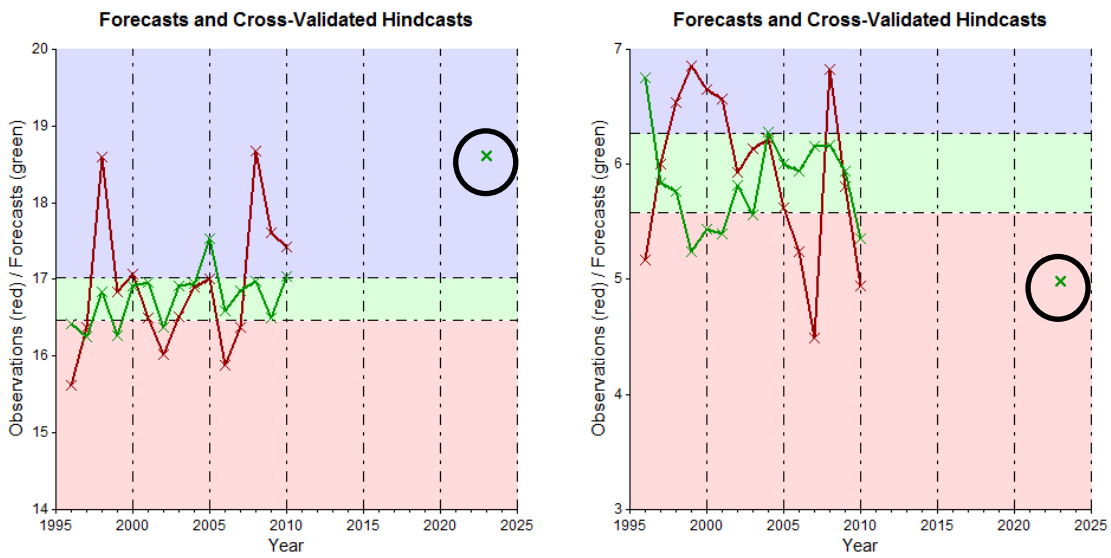


Figure 10: DJF 2023/24 minimum (left) and maximum temperature (right) forecast from CPT

5. ENSO and IOD outlook DJF 2023/24

ENSO El Nino and weakening positive IOD conditions are likely to prevail during this season.

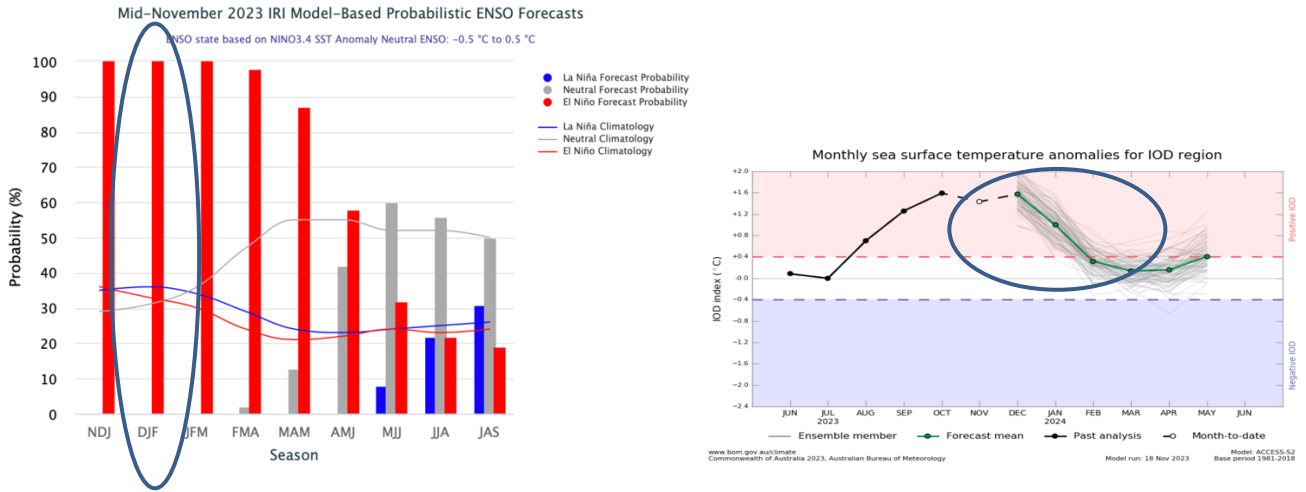


Figure 11: El Nino condition (left) and IOD condition (right)

The final outlook of winter season DJF 2023/24 over Bhutan is based on the forecast products from various sources.

SI No.	Indicators	Precipitation	Maximum Temperature	Minimum Temperature
1	CPT	Above normal	Above normal	Below normal
2	GPCs	Above normal	Above normal	
3	IRI	Below Normal	Above normal	
4	APEC	Above normal	Above normal	
5	C3S	Above normal	Above normal	
6	JMA	Above normal	Normal	
7	NMME	Above normal to CP	Above normal	
8	SASCOF	Above normal	Above normal	Normal to slightly above normal
9	ENSO	El Nino		
10	IOD	Positive to Neutral		

Table 1: Summary of results from various sources