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**El Niño Southern Oscillation (ENSO) and
Indian Ocean Dipole (IOD) Bulletin**

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Highlights

Currently, Moderate El Niño conditions are prevailing over equatorial Pacific and the sea surface temperatures (SSTs) are above average over most of the equatorial Pacific Ocean. The latest MMCFS forecast indicates moderate to strong El Niño conditions are likely to continue during the upcoming season.

At present, positive IOD conditions are observed over the Indian Ocean and the latest MMCFS forecast indicates positive IOD conditions are likely to continue until the end of this year.

1. Current Sea Surface Temperature (SST) Conditions over Pacific and Indian Oceans

During September 2023, warmer than normal SSTs were observed over most of the equatorial Pacific Ocean (Fig.1a). Warmer than normal SSTs were also observed over most of the northern extra-tropical regions. Compared to the previous month, there is an increase in the warming of SSTs in the central equatorial Pacific Ocean (Fig.1b), along with some cooler SST anomalies observed over the western and eastern equatorial Pacific Ocean.

In September 2023, Warm SST anomalies were observed over the Arabian Sea and western equatorial Indian Ocean (Fig.1a). However, cold SST anomalies were also observed over north Bay of Bengal and south equatorial Indian Ocean. Compared to the previous month, warming of SSTs were observed over north Arabian Sea and cooling of SSTs were observed over north Bay of Bengal and most parts of equatorial Indian Ocean. (Fig. 1b).

1.1. El Niño Southern Oscillation (ENSO) conditions over the Pacific Ocean

The monthly time series of Niño3.4 SST anomalies for the last 12 months from October 2022 to September 2023 is shown in Fig.2a. The La Niña conditions were prevailing till early this year with maximum strength in October 2022. Thereafter ENSO neutral conditions were observed over the Pacific Ocean from February to May 2023 and Weak El Niño conditions developed during June and July 2023. However, moderate El Niño conditions developed during August 2023. At present strong El Niño conditions are prevailing over equatorial Pacific Ocean. The positive subsurface temperature anomalies are observed over most parts of the equatorial Pacific Ocean with maximum strength close to surface along the eastern Pacific Ocean (Fig.2 b). The negative subsurface temperature anomalies are observed over west-central equatorial Pacific Ocean below the

1.2. Indian Ocean Dipole (IOD) conditions over the Indian Ocean

The monthly time series of Dipole Mode Index (DMI) for the last 12 months from October 2022 to September 2023 is shown in Fig.2c. The negative DMI value weakened from October 2022 to December 2022. The DMI has remained within the average and neutral IOD conditions were observed between January and July 2023. However, positive IOD conditions developed during August 2023 and continued in September 2023. The positive subsurface temperature anomalies (Fig. 2d) were seen over the western and central equatorial Indian Ocean with a strong magnitude in between 20°C isotherm and thermocline depth and negative subsurface anomalies were seen over the western and eastern equatorial Indian Ocean near and below the thermocline depth.

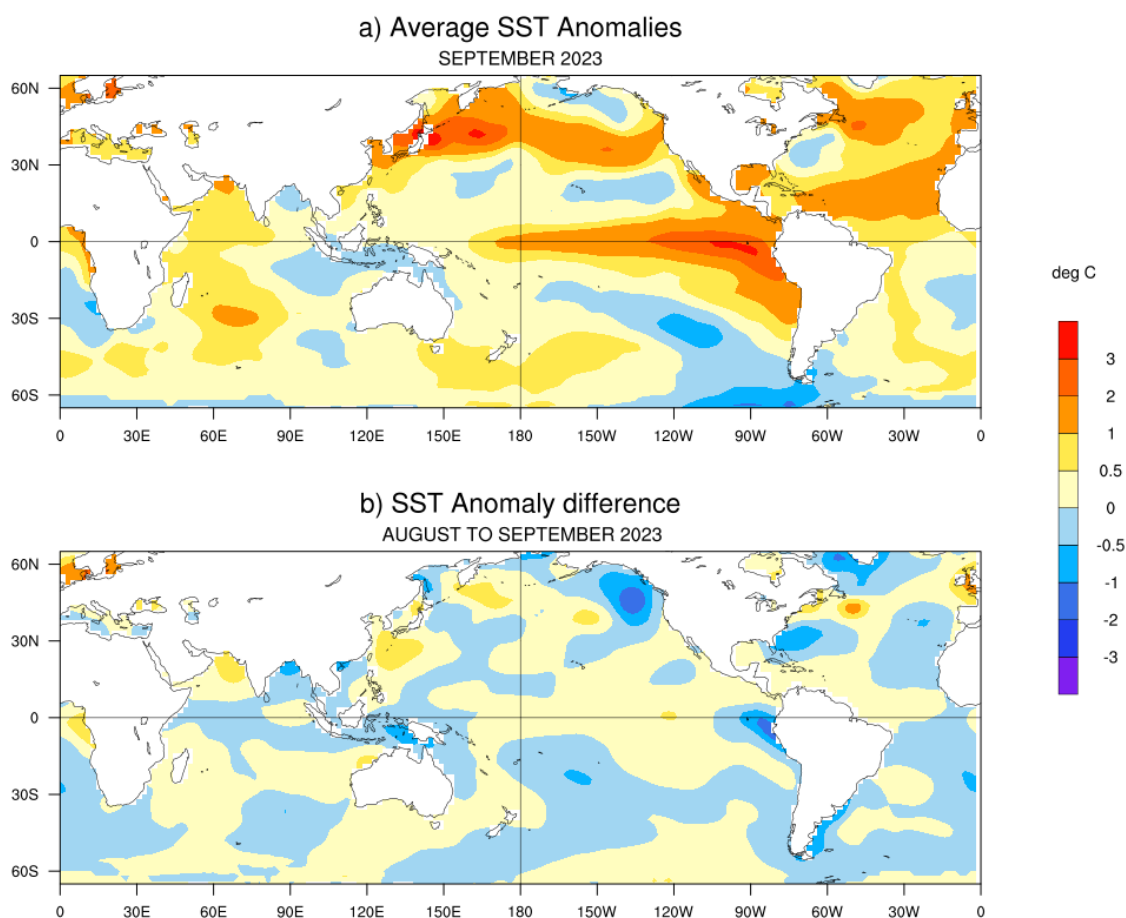


Fig.1: (a) Sea surface temperature (SST) anomalies ($^{\circ}\text{C}$) during September 2023 and **(b)** changes in the SST anomalies ($^{\circ}\text{C}$) from August 2023 to September 2023. SSTs were based on the ERSSTv5, NOAA, and anomalies were computed with respect to 30-year (1991-2020) long term mean.

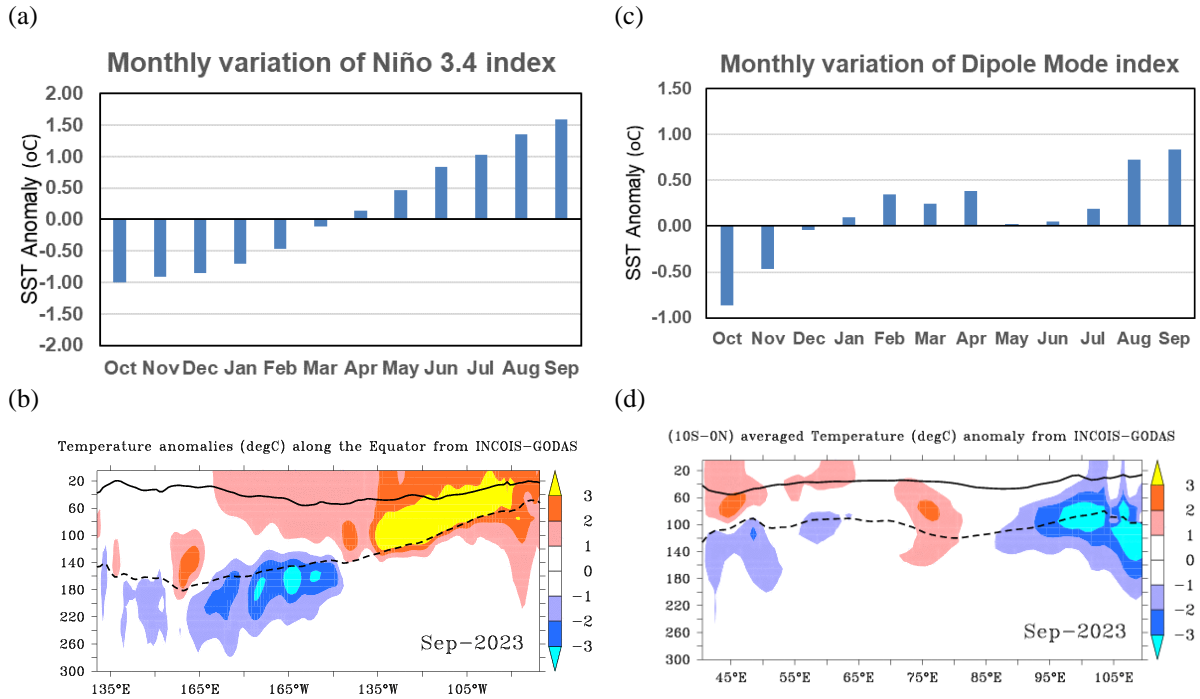


Fig.2: (a) Monthly variation of Niño 3.4 SST index for the last 12 months and (b) Depth-longitude section of ocean temperature anomalies in the equatorial (5°S-5°N) the Pacific Ocean for the month of September 2023. (c) Same as (a) but for Dipole Mode Index (DMI). (d) Same as (b) but for the tropical Indian Ocean (10°S-Eq). The anomalies in (a) and (c) were computed using the base period of 1991-2020 (Data Source: ERSSTv5, NOAA). The solid dark line in (b) and (d) is the 20°C isotherm and the dashed line is thermocline depth (Data Source: INCOIS-GODAS).

2. ENSO & IOD Forecast

The SST forecast was prepared using the high-resolution Monsoon Mission Coupled Forecast System (MMCFS) (AGCM T382L64; ~38 km and OGCM 25 km in tropics) based on the 2023 September initial conditions. The initial conditions for the model runs were obtained from ESSO-INCOIS and ESSO-NCMRWF analysis. Probability density function (PDF) bias correction was applied on the forecasts of Niño3.4 index (Fig.4a) and DMI (Fig.4b) based on hindcasts for the period 1999-2008 and anomalies were calculated based on 1991-2020 climatology.

The 3-month season averaged SST anomaly forecast (Fig.3) indicates that positive SST anomalies are likely over most parts of the central and eastern equatorial Pacific Ocean for the entire forecast period. Currently, the sea surface temperatures (SSTs) are above average over most of the equatorial Pacific Ocean and strong El Niño conditions are prevailing. The latest MMCFS Plume forecast (Fig.4a) indicate that El Niño conditions are likely to continue until the first quarter of next year. The probability forecast for ENSO indicates the enhanced probability for El Niño conditions (Fig.5a) during all the forecasted seasons. IMD is closely monitoring the El Niño conditions and monthly updates are provided as per observed changes in the Pacific Ocean.

The positive IOD conditions are prevailing over the Indian Ocean. As per the latest MMCFS forecast a positive IOD conditions likely to continue during the upcoming season (Fig.4b). The probability forecast for IOD (Fig.5b) indicates the probability of the positive IOD during October–December 2023 season.

MMCFS SST Anomaly Forecast :Sep 2023 IC

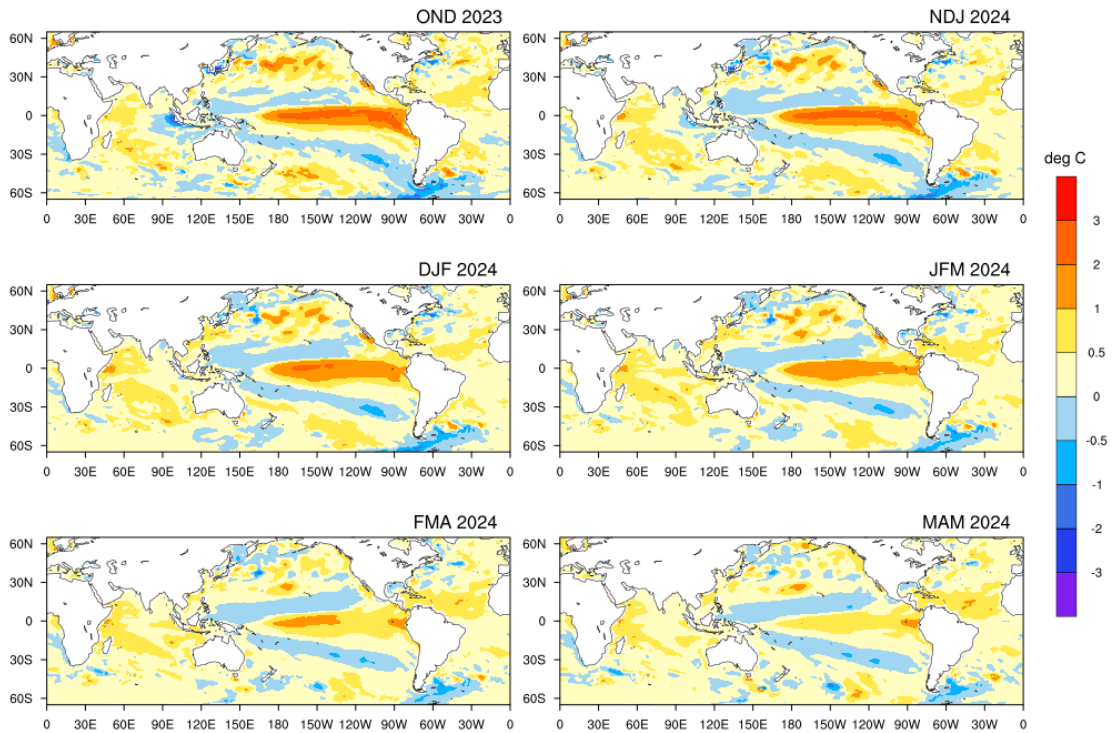


Fig.3: Forecasted Seasonal mean SST anomalies for three monthly (a) October to December (OND 2023), (b) November 2023 to January 2024 (NDJ 2024), (c) December 2023 to February 2024 (DJF 2024), (d) January 2024 to March 2024 (JFM 2024), (e) February 2024 to April 2024 and March 2024 to May 2024. (Model bias correction base period: 1999-2008; Climatology base period:1991-2020).

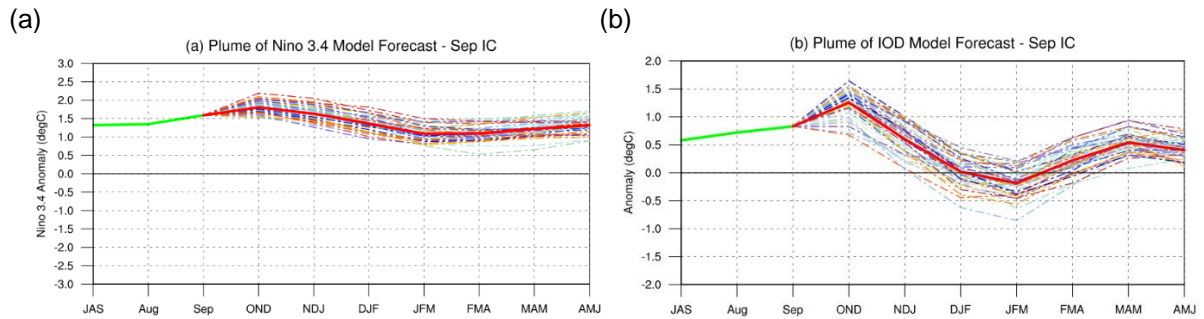


Fig.4: Plume of (a) Niño 3.4 SST index, (b) Indian Ocean Dipole Mode Index forecasted by high-resolution MMCFS. The forecasts were PDF corrected for bias and variance. The solid green line is the observed SST anomaly (ERSSTv5, NOAA) and the solid red line is the ensemble mean SST anomaly forecast of 43 members (MMCFS). The individual ensemble member forecasts are shown in light dotted lines of different colours.

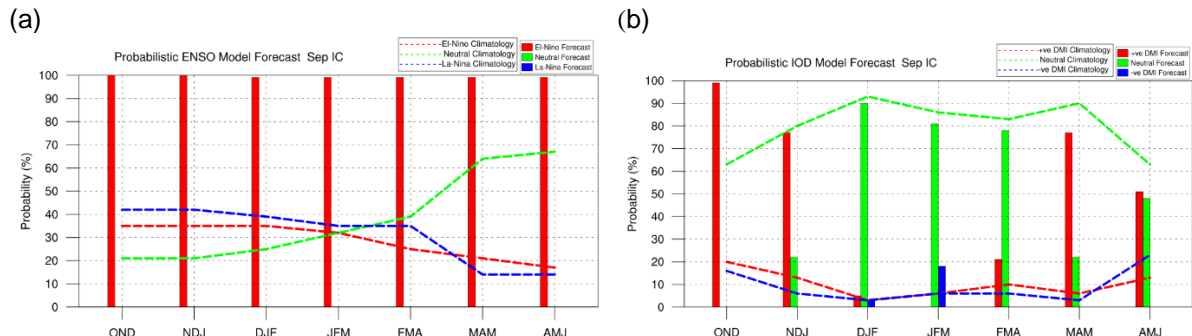


Fig.5: Probability forecast along with climatological probabilities of (a) Niño 3.4 and (b) Indian Ocean Dipole Mode Index from high-resolution MMCFS. The data source for Climatology probabilities: NOAA Extended Reconstructed SST V5. Criteria used for Probabilistic ENSO Forecast: La Niña ≤ -0.5 , Neutral <0.5 to >0.5 , El Niño ≥ 0.5 . Criteria used for Probabilistic DMI Forecast: negative DMI ≤ -0.4 , Neutral <0.4 to >0.4 , positive DMI ≥ 0.4 .