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

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Highlights

The strength of El Niño conditions weakened since beginning of the year and currently weak El Niño conditions are observed over equatorial Pacific. The latest MMCFS forecast indicates that El Niño conditions are likely to weaken further during the upcoming season and turn to ENSO neutral thereafter. The model also indicates likely development of the La Niña conditions during the latter part of the monsoon season.

At present, neutral Indian Ocean Dipole (IOD) conditions are prevailing over the Indian Ocean. The latest MMCFS forecast indicates that the neutral IOD conditions are likely to develop during the monsoon season.

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

During April 2024, warmer than normal sea surface temperatures (SSTs) were observed across the central and east-central Pacific Ocean and the northern & southern extra-tropical Pacific region (Fig.1a). However, cooler than normal SSTs were observed over a small region of eastern equatorial Pacific and some parts of Southern Pacific Ocean. As compared to March 2024, negative SST anomalies were observed over central and eastern equatorial Pacific region and positive SST anomalies were observed over the western parts of the Pacific Ocean (Fig.1b).

In April 2024, warmer than normal SSTs were observed over most parts of the Indian Ocean (Fig.1a) including Bay of Bengal and Arabian Sea. As compared to March 2024, cool SSTs were observed over western Indian Ocean and warm SSTs were observed over eastern equatorial Indian Ocean, Bay of Bengal and some part of north Arabian Sea (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 May 2023 to April 2024 is shown in Fig.2a. ENSO neutral conditions observed over the Pacific Ocean in May 2023 but turned to weak El Niño conditions during June-July 2023. The El Niño conditions strengthened to moderate level during August 2023 and further to strong El Niño

during the latter part of 2023. The El Niño conditions after peaking to its maximum intensity during November – December 2023, started to weaken thereafter. Currently weak El Niño conditions are observed over equatorial Pacific.

The weak positive subsurface temperature anomalies are observed over most parts of the central and western Pacific Ocean near and above 20°C isotherm (Fig.2 b). The negative subsurface temperature anomalies are observed over central and eastern equatorial Pacific Ocean both near and below the thermocline depth (Fig.2 b).

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 May 2023 to April 2024 is shown in Fig.2c. After remaining neutral for most part of the first half of 2023, the Indian Ocean Dipole (IOD) conditions switched to a positive phase in August 2023, lasted until January 2024. In February, the IOD conditions weakened from positive to neutral, and currently continue to be in the same level. The positive subsurface temperature anomalies (Fig. 2d) were seen over the western equatorial Indian Ocean with highest magnitudes between 20°C isotherm and thermocline depth. Some negative subsurface anomalies were seen over the eastern equatorial Indian Ocean with highest magnitude near and below the thermocline depth.

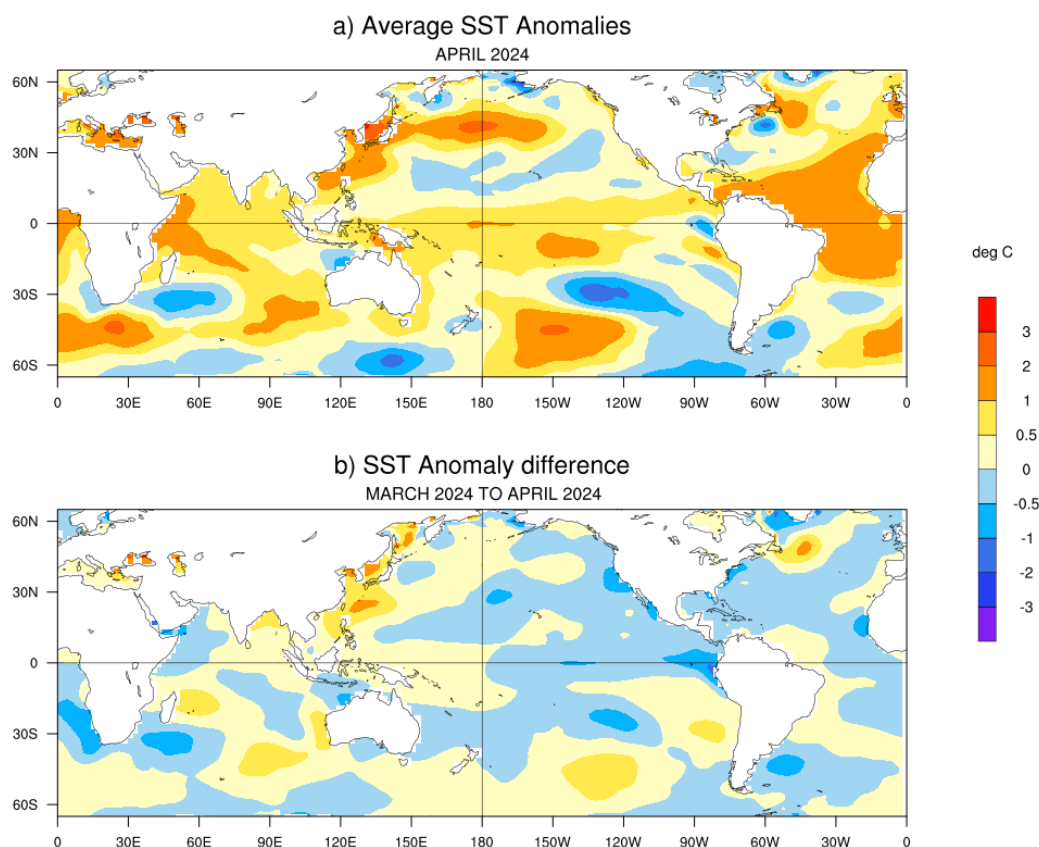


Fig.1: (a) Sea surface temperature (SST) anomalies ($^{\circ}\text{C}$) during April 2024 and **(b)** changes in the SST anomalies ($^{\circ}\text{C}$) from March 2024 to April 2024. SSTs were based on the ERSSTv5, NOAA, and anomalies were computed with respect to 30-year (1991-2020) long term mean.

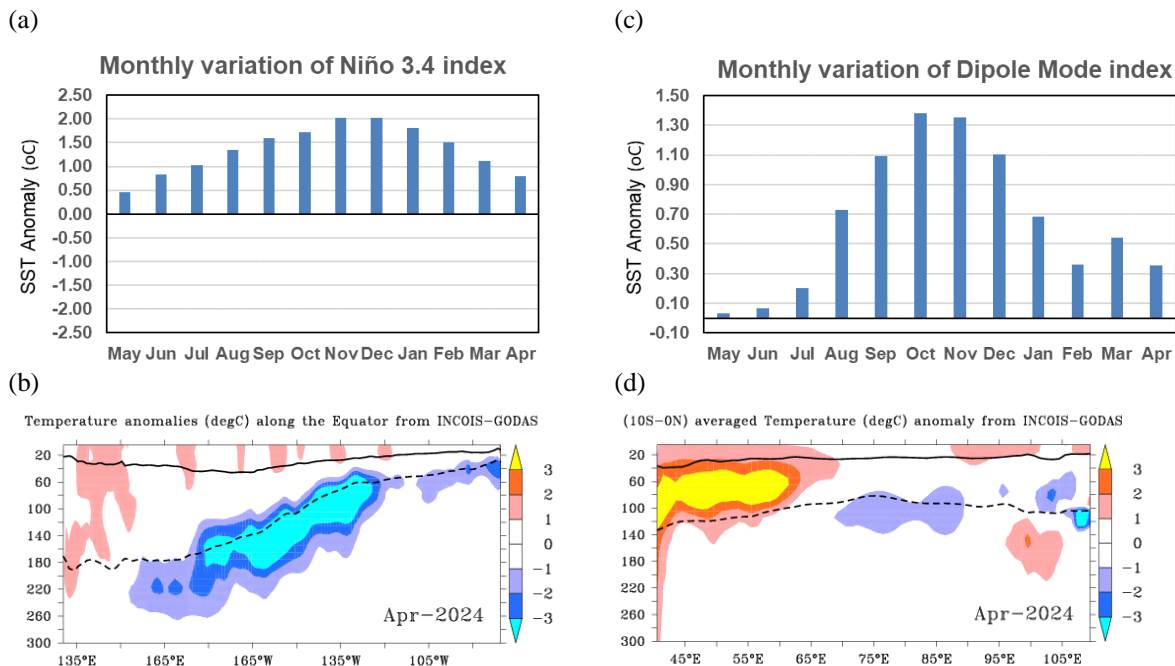


Fig.2: (a) Monthly variation of Niño 3.4 SST index for the last 12 months and (b) Depth-longitude section of sub surface temperature anomalies in the equatorial (5°S-5°N) Pacific Ocean for the month of April 2024. (c) Same as (a) but for Dipole Mode Index (DMI). (d) Same as (b) but for the tropical Indian 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 2024 April 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.

Currently, the sea surface temperatures (SSTs) are warmer than normal over most of the equatorial Pacific Ocean and weak El Niño conditions are prevailing. The 3-month season-averaged SST anomaly forecast (Fig. 3) indicates that cooler-than-normal SSTs are likely over eastern equatorial Pacific Ocean during the upcoming season and expected to strengthen thereafter. The latest MMCFS Plume forecast (Fig.4a) indicates that neutral ENSO conditions are likely during MJJ season and turn to La Niña thereafter. The probability forecast indicates enhanced probability of La Niña conditions (Fig.5a) around JAS 2024 season. IMD is closely monitoring the El Niño conditions and monthly updates are provided as per observed changes in the Pacific Ocean.

Neutral IOD conditions are currently prevailing over the Indian Ocean. The 3-month season-averaged SST anomaly forecast (Fig. 3) indicates that warmer-than-normal SSTs are likely over most parts of the Indian Ocean. As per the latest MMCFS Plume forecast, the neutral IOD conditions are expected to persist during the southwest monsoon season (Fig.4b). The probability forecast also indicates enhanced probability of neutral IOD conditions during JJA 2024.

MMCFs SST Anomaly Forecast :Apr 2024 IC

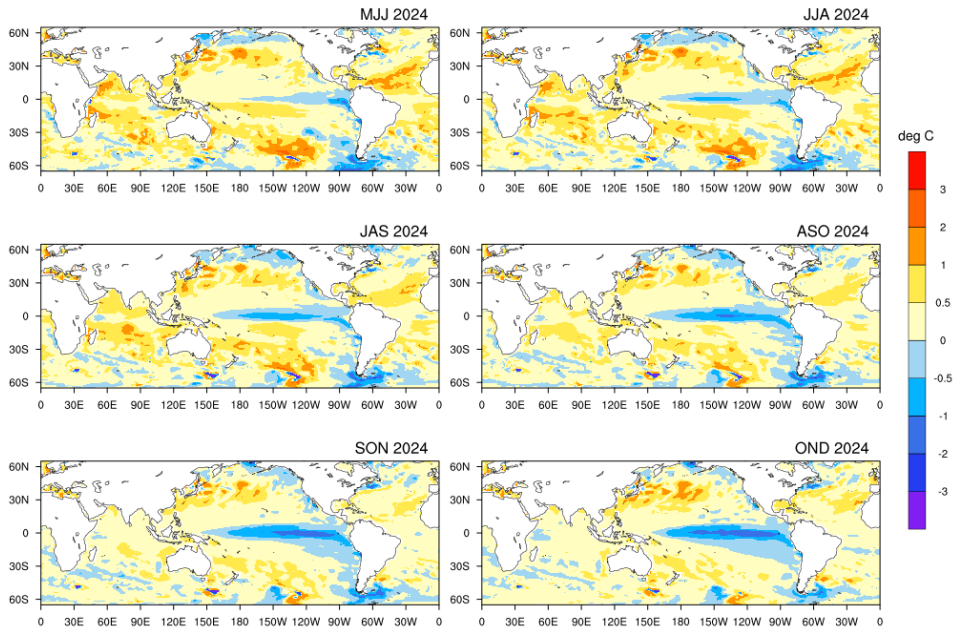


Fig.3: Forecasted Seasonal mean SST anomalies for three monthly (a) May 2024 to July 2024 (MJJ 2024) (b) June 2024 to August 2024 (JJA 2024), (c) July 2024 to September 2024 (JAS 2024) and (d) August 2024 to October 2024 (ASO 2024) (e) September 2024 to November 2024 (SON 2024) and (f) October 2024 to December 2024 (Model bias correction base period: 1999-2008; Climatology base period:1991-2020).

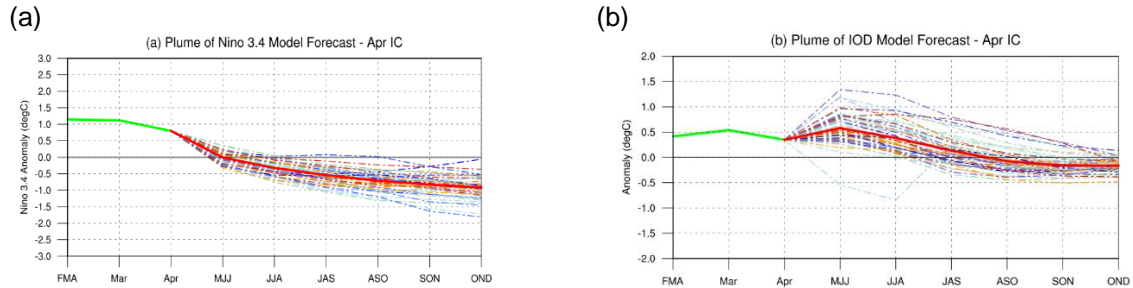


Fig.4: Plume of (a) Niño 3.4 SST index, (b) Indian Ocean Dipole (IOD) Mode Index forecasted by high-resolution MMCFs. The forecasts were PDF corrected for bias and variance. The solid green line is the observed SST anomaly (ERSSTv5, NOAA) and the solid red line is the ensemble mean SST anomaly forecast of 48 members (MMCFs). The individual ensemble member forecasts are shown in light dotted lines of different colours.

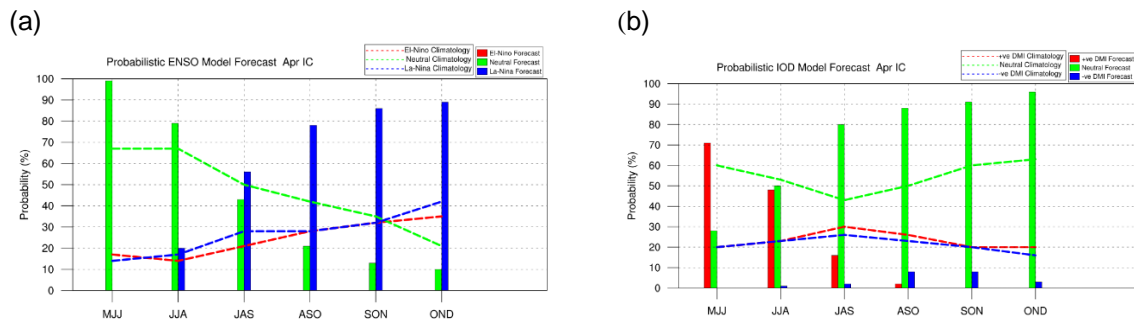


Fig.5: Probability forecast along with climatological probabilities of (a)Niño 3.4 and (b) Indian Ocean Dipole (IOD) Mode Index from high-resolution MMCFs. The data source for Climatology probabilities: NOAA Extended Reconstructed SST V5. Criteria used for Probabilistic ENSO Forecast: La Niña ≤ -0.5 , 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 .