Basic Concepts of ENSO & IOD

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भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT
Mean Seasonal Cycle of SST over Pacific Ocean

- **January-March**
- **April-June**
- **July-September**
- **October-December**

**Equatorial Upwelling**
- Northern trade winds
- Southern trade winds
- Warm surface water
- Cool water upwells from below

**Ekman Current**
- Warm surface water

**Thermocline**
- 120°E
- 80°W

**INDIA METEOROLOGICAL DEPARTMENT**
El Niño and La Nina

- El Niño is a phenomenon of anomalous warming of the central and east equatorial Pacific Ocean with a quasi periodicity of 2-7 years.

- La Nina is just the opposite phase of El Niño and is associated with anomalous cooling over the equatorial Pacific Ocean.

- Tend to develop during the period April-June and reach their maximum strength during December-February.
- Typically persist for 9-12 months, though occasionally persisting for up to 2 years.
- Recur every 2 to 7 years, although the average is about once every 3-4 years.
Peak El Niño occurs about Christmas season...

- “Christ Child (in Spanish)”
- “The Boy”
- “The Little One”
- La Niña
- “The Girl”

Dead seabirds—mostly Peruvian boobies—appeared along the northern Chilean coast in late June. Other birds include Guanay cormorants, blue-footed boobies, and Peruvian pelicans.
Evolution of 1997-1998 El Nino
SEA LEVEL ANOMALY (surface, cm) and OCEAN TEMPERATURE ANOMALY (color, C)
What is the SO (Southern Oscillation)?

Southern Oscillation:
- the atmospheric component of El Nino
- a global wave pattern
- an oscillation in surface air pressure between the tropical eastern and the western Pacific Ocean waters.
- The strength of SO is measured by the Southern Oscillation Index (SOI) defined as the normalized difference in surface pressure between Tahiti, French Polynesia and Darwin, Australia (Tahiti minus Darwin)
- SOI is a measure of the strength of the trade winds, which have a component of flow from regions of high to low pressure.
- High SOI (large pressure difference) is associated with stronger than normal trade winds and La Niña conditions, and low SOI (smaller pressure difference) is associated with weaker than normal trade winds and El Niño conditions.
- El Niño episodes are associated with negative SOI, i.e below (above) normal pressure over Tahiti (Darwin).
ENSO: EN and SO together: Refers to whole cycle of warming and cooling.

El Niño: the ocean part: Warm phase of ENSO:
   El Niño - Southern Oscillation

La Niña: is the cold phase of ENSO:
   Cool sea temperatures in tropical Pacific

ENSO events have been going on for centuries (records in corals, and in ice layers in glaciers in South America)

ENSO arises from air-sea interactions in the tropical Pacific
The prevailing easterly trades converge over Indonesia in conjunction with the Asian monsoon, producing widespread convection. Additionally, warm water "piles up" in the western Pacific, due to the easterly winds. Further east, the SE trades and equatorial easterlies in the eastern and central Pacific produce upwelling of cool water along the equator and coast of South America.

During El Niño, the easterlies relax, reducing the amount of upwelling and allowing the western warm water to move eastward. As time goes on, the warm pool in the western Pacific grows and expands eastward toward the central Pacific. Once the warmest water reaches the International Date Line, anomalous convection appears in that region, accompanied by a weakening of the equatorial easterlies.

This pattern typically may be preceded or followed by a warming that causes the ITCZ to move farther south than normal, which contributes to enhanced rainfall across Ecuador and northern Peru, producing the "years of abundance (periods of extreme wetness along the normally very dry Peruvian coast)."

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a. The typical wind and water circulation pattern.
b. The circulation pattern during an El Niño event.
ENSO Impacts on Global Climate
Monitoring of ENSO

- Monitoring of ENSO conditions primarily focuses on SST anomalies in the 4 geographic regions of the equatorial Pacific.
- SST anomalies equal to or greater than 0.5°C (0.9°F) in the Niño 3.4 region (comprising portions of Niño regions 3 and 4, from 170°E to 120°W longitude) are indicative of ENSO warm phase (El Niño) conditions, while anomalies less than or equal to –0.5°C (–0.9°F) are associated with cool phase (La Niña) conditions.
- Niño 3.4 SST anomalies are averaged over the three months ending with the current month, and that value is called the Oceanic Niño Index (ONI). If the ONI exhibits warm or cool phase conditions for at least five consecutive values, it officially becomes an El Niño or La Niña event.
In general, ENSO has inverse relationship with Indian summer monsoon. During the warm phase of the ENSO (El Nino), monsoon is weaker than normal and during the cold phase of the ENSO (La Nina), monsoon is stronger than normal. The intensity of the events also decides the amount of impact.
MONSOON – ENSO Concurrent Relationship (JJAS): Correlation Coefficient
El Nino Vs Monsoon

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- In general, Indian SW monsoon is weaker than normal during the El Nino years.
- No one to one association between EL Nino and ISMR.
- However there is stronger inverse relationship between El Nino and rainfall during later half of the monsoon season (particularly with September rainfall).

- During 1951-2014, there were 14 El Nino years.
- 8 El Nino years - deficient (less than 90%) season rainfall
- 4 El Nino years 90 to 100%
- 2 El Nino years it was above 100% (which includes 1997 one of the strongest El Nino years of the last century).
- No El Nino years was associated with the excess monsoon rainfall
During El Nino years, in general, most parts of the country except northeast India receive below normal rainfall anomalies. The impact is more over northwest India and central India.
The Indian Ocean Dipole (IOD) also known as the Indian Nino is a coupled ocean and atmosphere phenomenon characterised by an irregular oscillation of sea-surface temperatures in which the western Indian Ocean becomes alternately warmer and then colder than the eastern part of the ocean (Saji et al. 1999).

A positive IOD - cooler (warmer) than normal water in the tropical (western) eastern Indian Ocean

The dipole begins to be evident in early to mid-summer, reaches its peak in late fall to early-winter, then rapidly decays during the boreal spring.

The IOD affects the climate of India and other countries that surround the Indian Ocean basin.


Figure 4. The dipole mode index (DMI) defined (Saji et al 1999) as the difference in SST anomalies between western (50°E-70°E) and eastern (90°E-110°E) Indian Ocean. The DMI is normalized by its standard deviation and smoothed by a 5-month running mean before plotting.
Climatology of low level winds, SST & OLR over Indian Ocean

Figure 1. Climatology of winds (vectors in m/s), SST (°C, color shaded) and outgoing longwave radiation (OLR, contours in Wm⁻²) over the Indian Ocean.
The composite anomaly pattern of the SST and low level winds over the Indian Ocean associated with IOD

Coevolution DMI (black bars) and strength of equatorial zonal winds anomalies (grey bars) from the year before, to the year following a typical dipole mode event

Correlation between the DMI and rainfall
IOD Mechanism

- The intensity of the SST dipole mode and the strength of the zonal wind anomaly over the Equator are strongly dependent on each other.
- Significant anomalies appear around June, intensify in the following months and peak in October.
- Cool SST anomalies first appear in the vicinity of the Lombok strait by May-June, accompanied by moderate southeasterly wind anomalies in the southeastern tropical Indian Ocean.
- In the following months, the cold anomalies intensify and appear to migrate towards the Equator along the Indonesian coastline, while the western tropical Indian Ocean begins to warm up.
- Zonal wind anomalies (easterlies) along the Equator and alongshore wind anomalies off Sumatra intensify together with the SST dipole.
- A dramatically rapid peaking of these features occurs in October, followed by a rapid demise. The changes in the state of the climate system, brought about by the seasonal monsoonal reversals, that are responsible for the demise of the dipole mode event. However, after the boreal autumn, until the next spring, weakening winds both along the Equator and along the coast diminish the importance of ocean dynamics in the regulation of SST.
- In a normal summer monsoon season, the westerly winds along the Equator accumulate warmer water along this coast through downwelling equatorial and coastally trapped Kelvin waves. This process counters the cooling tendencies by evaporation, coastal upwelling and oceanic heat advection brought about by the strong alongshore winds off this coast.
- In a year with a dipole mode event, abnormally extended trade winds with an easterly component along the Equator, by preventing the intrusion of the equatorial current, allow the cooling processes to dominate off Indonesia. This cooling is further enhanced as entrainment processes associated with the coastal winds become more effective due to the shallower thermocline.
IOD and Monsoon

- Dipole mode is strongly dependent on the state of the system set up by the monsoonal circulation, and therefore the variability of the monsoons would significantly affect this mode.

- Dipole mode shares certain common features, like the biennial tendency with the monsoonal variability. Also, easterly anomalies along the Equator as well as reduced convection in the OTCZ are well-known features of strong monsoons.

- No significant statistical correlation of the DMI with rainfall over Indian region (Saji et al. 1999).

- However, the IOD plays an important role as a modulator of the Indian monsoon rainfall and influences the correlation between the ISMR and ENSO (Ashok et al. 2001).

- The IOD and the ENSO was found to be complementarily affected the ISMR during the last four decades (Fig. 8). Whenever the ENSO-ISMIR correlation was low (high), the IOD-ISMIR correlation was high (low).
Current Status and Prediction of ENSO and IOD
During the last four weeks, SSTs were above average across the equatorial Pacific with maximum around the International Date Line. Between January to April, the SSTs were near normal to cooler than normal over NINO1+1 region. The SSTs were warmer than normal since September 2014 over other NINO regions except over NINO3 region where SSTs turned to near normal in the early part of April. Currently conditions have reached weak El Nino level.
ENSO Forecast – IMD- IITM CFS: March IC
Latest forecasts from most of the ENSO prediction models indicate about 70% probability for the weak El Nino conditions to persist till the monsoon season.
Evolution of ONI Series during previous El Nino years

The years most analog to 2015 is 1991 (91%) & 2004 (86%)
### El Nino Vs Monsoon

In general, Indian SW monsoon is weaker than normal during the El Nino years. During the period 1951-2014, there were 14 El Nino years and during 8 of these years ISMR was below normal indicating that there is no one to one association between EL Nino and ISMR. However there is stronger inverse relationship between El Nino and rainfall during later half of the monsoon season (particularly with September rainfall)

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*ISMR = Indian Summer Monsoon Rainfall
Composite Rainfall Anomaly: El NINO Years

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**8-Sep-15**

[Image of two maps showing precipitation anomaly over Asia, with color codes indicating rainfall anomaly.]
Indian Ocean Dipole: IMD-IITM CFS

IOD forecast: A negative IOD in the tropical Indian Ocean during 2015 monsoon season.
The snow-covered area over NH was close to normal during Dec, 2014 to Feb 2015 and below normal in March, 2015. Over Eurasia, slightly above normal snow cover area was observed in Dec 14 & Jan 15 and below normal snow cover area was observed in recent 2 months. The March snow-covered area over NH was 7th lowest & that over Eurasia was 9th lowest during the last 49 years. **NH snow cover during winter and spring has a general negative relationship with the subsequent Asian summer monsoon.**
Thanks for the Attention