

# **The oceanic conditions in the Indo-Pacific region during the summer monsoon season of 2023**

**18<sup>th</sup> March 2024**

**Annual Monsoon Workshop,  
Indian Meteorological Society, Pune Chapter**



**Francis P. A.**  
**Indian National Centre for Ocean Information Services**  
Ministry of Earth Sciences, Govt. of India  
Hyderabad-500090



# **Outline of the talk**

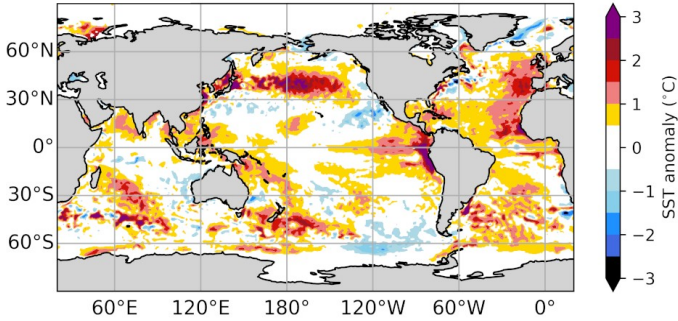
**Part-1 : The Evolution of El Nino in 2023**

**Part-2 : ENSO Status and Outlook for 2024**

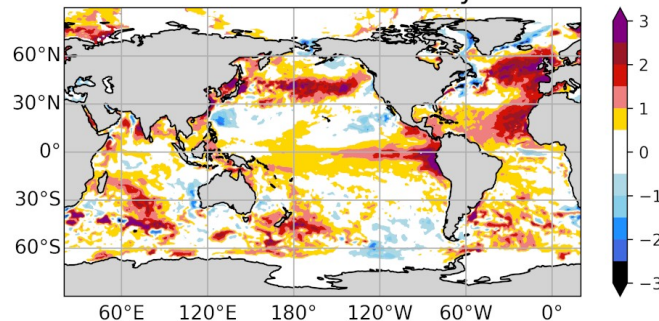
**Part-3: Evolution of pIOD in 2023**

# Evolution of SST in the Indo-Pacific region during summer monsoon season of 2023

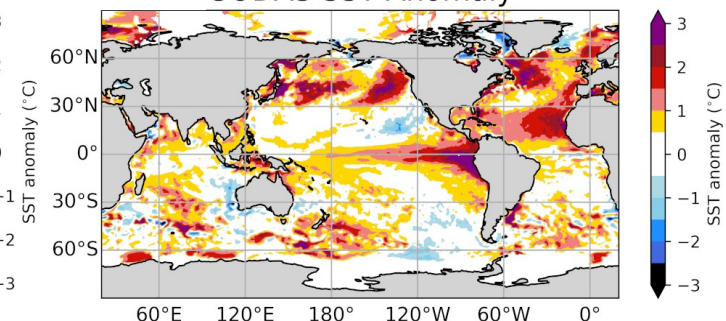
MAY ODAS SST Anomaly



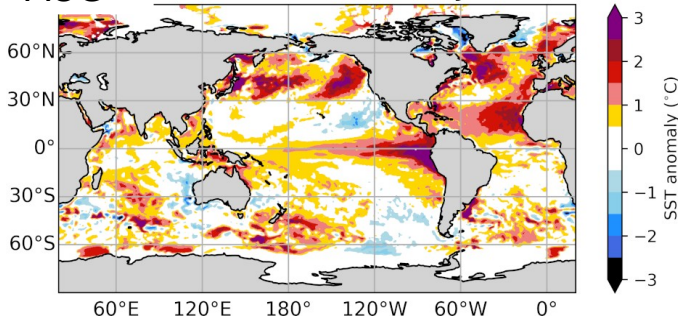
JUN GODAS SST Anomaly



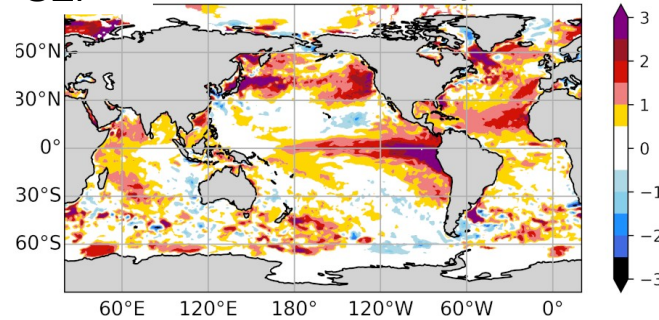
JUL GODAS SST Anomaly



AUG GODAS SST Anomaly

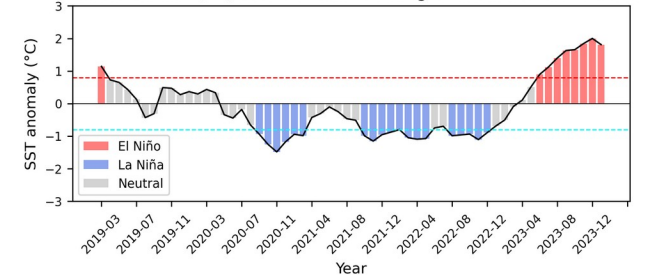


SEP GODAS SST Anomaly

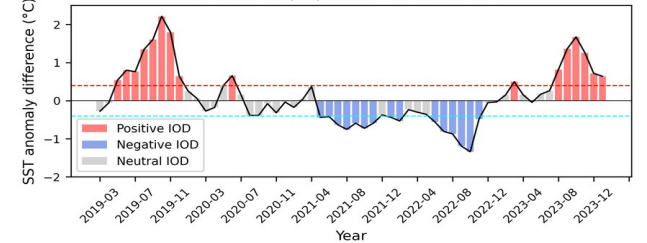


El Niño co-evolved with monsoon, which the positive IOD appeared in the second half of the monsoon season.

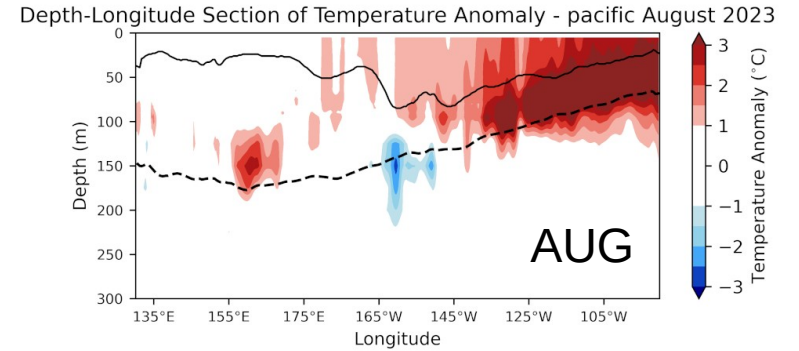
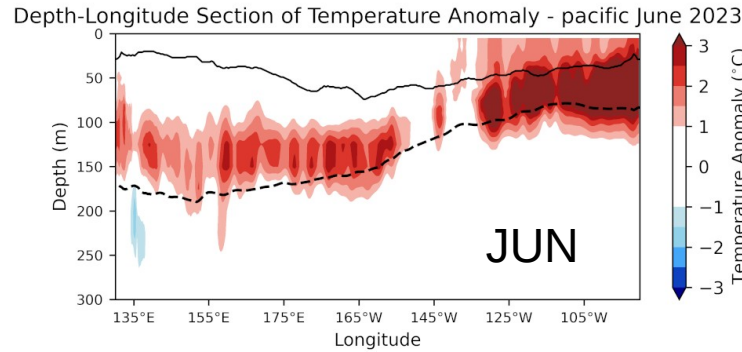
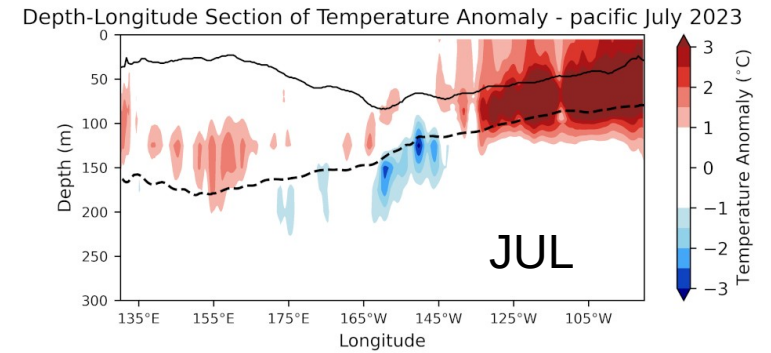
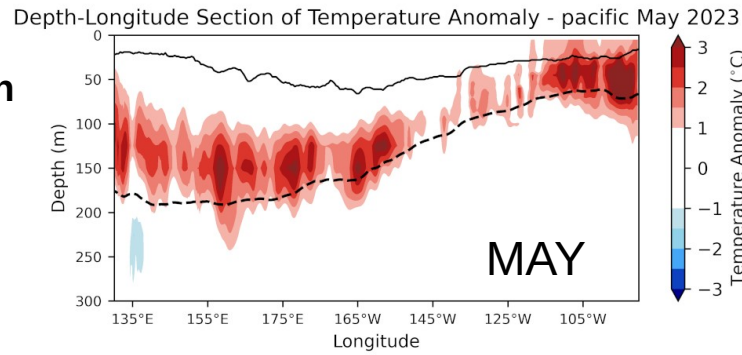
SST anomalies (°C) over the Niño 3.4 region from INCOIS-GODAS



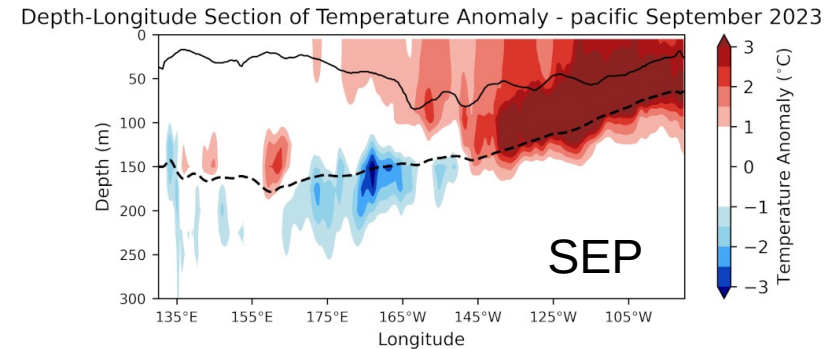
IOD index (°C) from INCOIS-GODAS



**Data: INCOIS- Global Ocean  
Data Assimilation System**



- Subsurface temperature anomalies in the equatorial Pacific also shows the evolution of El Nino conditions from May/June 2023.
- Very strong warm anomalies near thermocline region in the eastern Pacific persisted throughout the monsoon season.

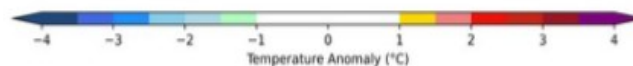
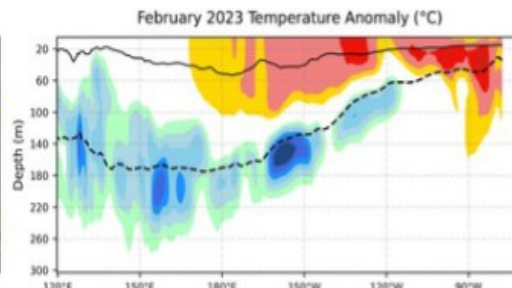
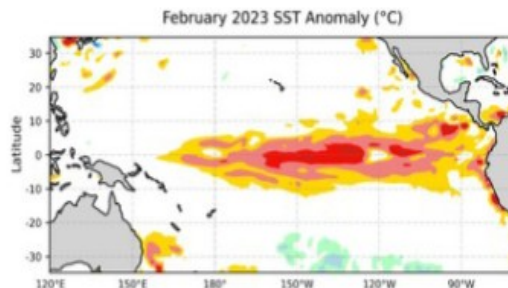
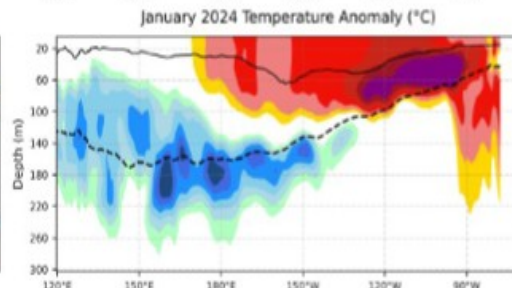
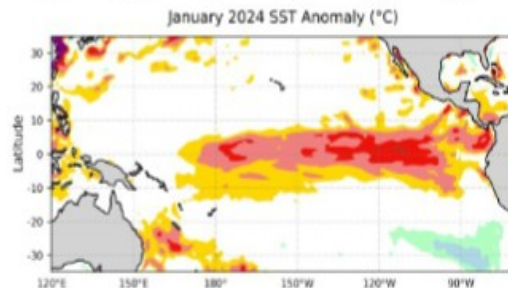
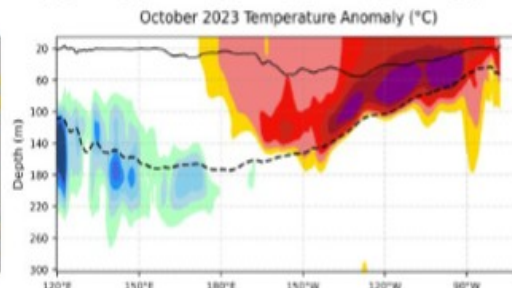
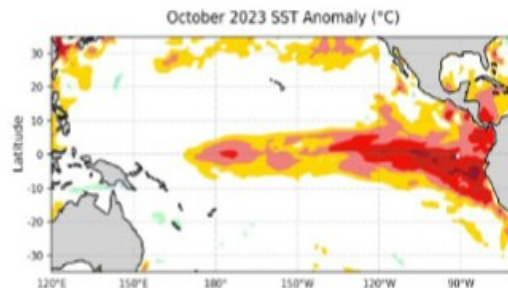
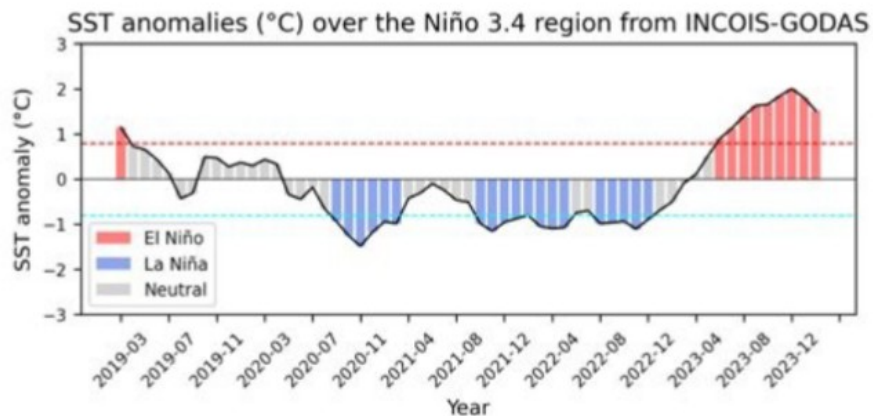




**El Niño outlook for the year 2024**

**Highlights:**

- The warm sea surface temperature anomaly signature started to relax with rapid cooling in the eastern Pacific, indicating a possible ending of the ongoing El Niño.
- A gradual weakening of the current El Niño, transitioning to a neutral phase around May-July (with a probability of ~55%), followed by a transformation into a La Niña pattern by fall 2024 (with a probability of ~70%) is predicted.



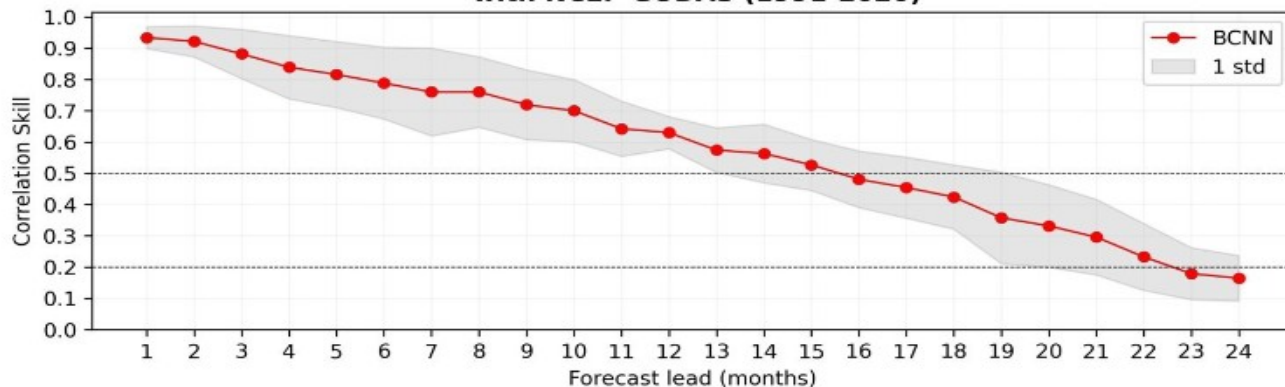
# Bayesian Convolutional Neural Network\* (BCNN) model

- The prediction approach relies on the fact that ENSO is connected to slow oceanic variations and their atmospheric coupling, indicating the potential for early forecast.
- The training dataset is expanded by incorporating historical runs (1850-2014 period) from the CMIP5 (11 models ) and CMIP6 (14 models).
- To mitigate systematic errors in the BCNN reflecting those of the CMIP samples, fine-tuning of the CMIP pre-trained model was conducted through another training approach utilising SODA reanalysis predictors spanning from 1871 to 1980.
- Separate BCNN models were set up for each season and each lead time.

Table 1. Details of data used for the BCNN model.

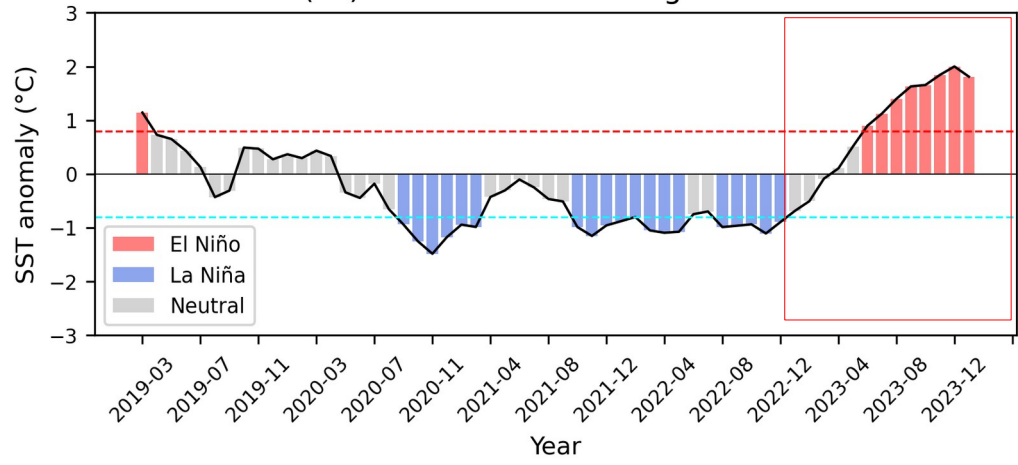
	Data	Period
Training dataset	CMIP5 historical run (11 models)	1850-2005
	CMIP6 historical run (14 models)	1850-2014
Training dataset (Transfer Learning)	Reanalysis (SODA)	1871-1980
Validation dataset	Reanalysis (GODAS)	1990-2020
Operational forecast dataset	INCOIS GODAS	2024 onwards

All season Nino 3.4 correlation skill of BCNN predictions with NCEP GODAS (1991-2020)



\*Ham, YG., Kim, JH. & Luo, JJ. Deep learning for multi-year ENSO forecasts. Nature 573, 568–572 (2019). <https://doi.org/10.1038/s41586-019-1559-7>

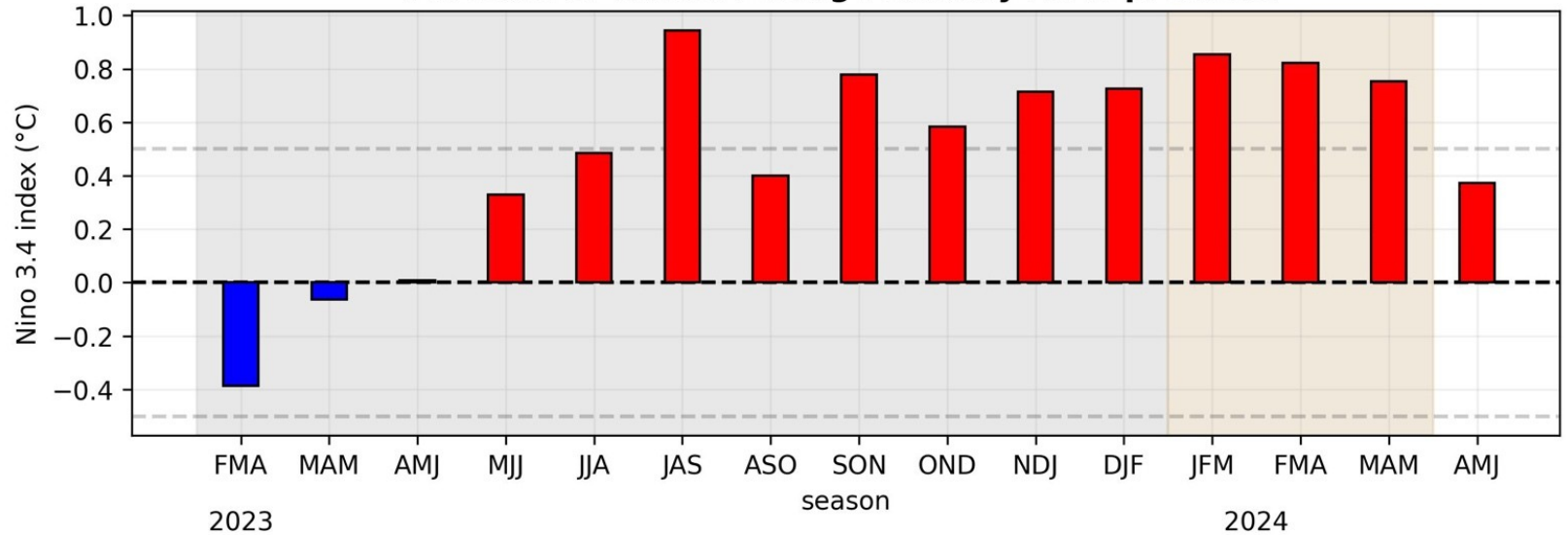
SST anomalies (°C) over the Niño 3.4 region from INCOIS-GODAS



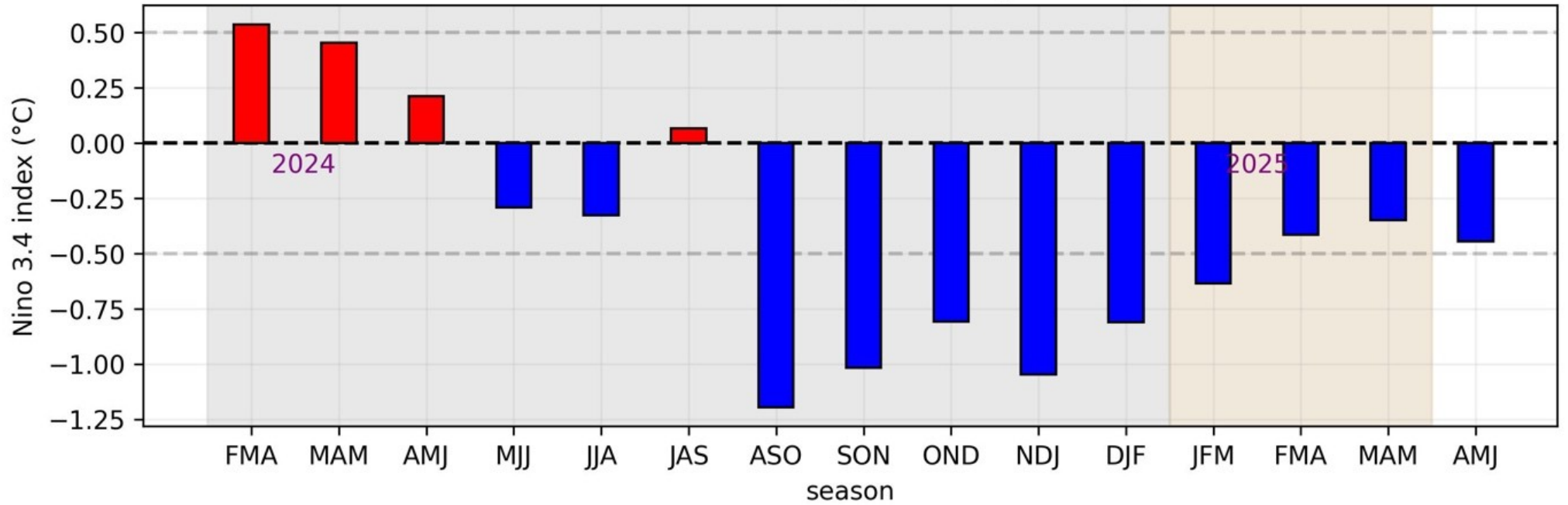
Prediction of 2023 El Niño Event by the BCNN method.

I/C: February 2023 (INCOIS-GODAS)

Forecast of Niño3.4 using February 2023 predictor



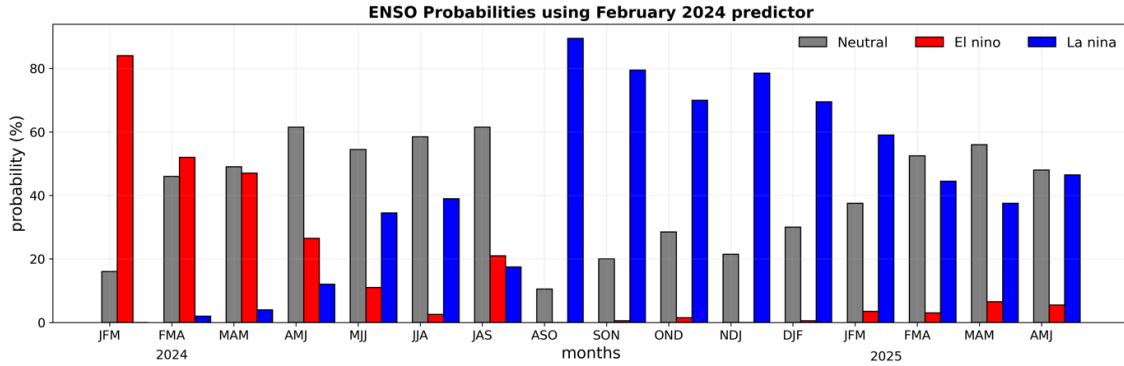
## Forecast of Nino3.4 using February 2024 predictor



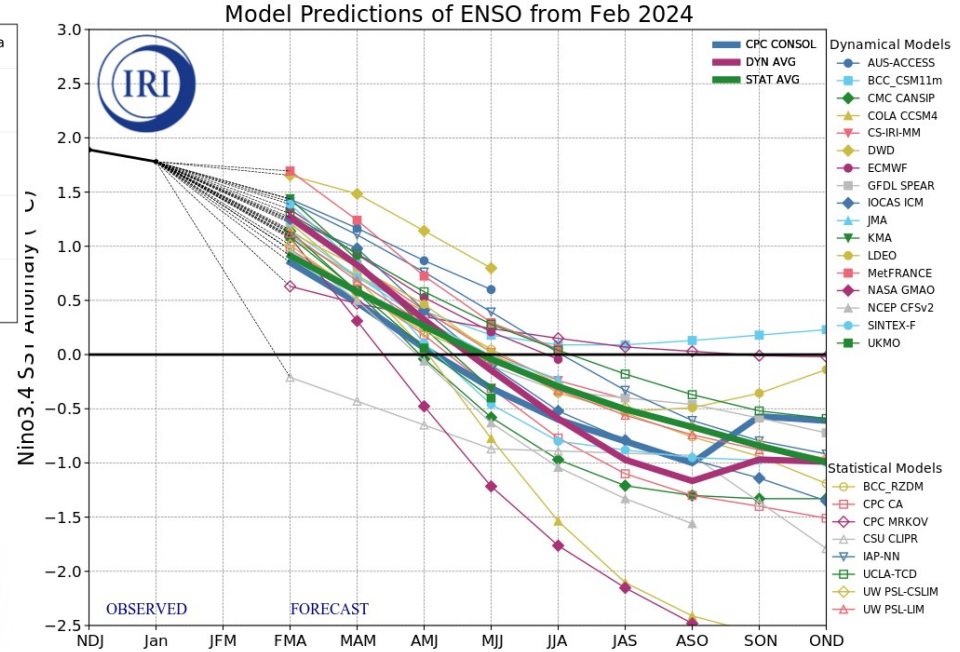
El Niño conditions to be treated by April/May 2024, neutral conditions to be prevailed in the first half of Monsoon season and La Niña conditions can be expected from August/September 2024.



# INCOIS ENSO Prediction

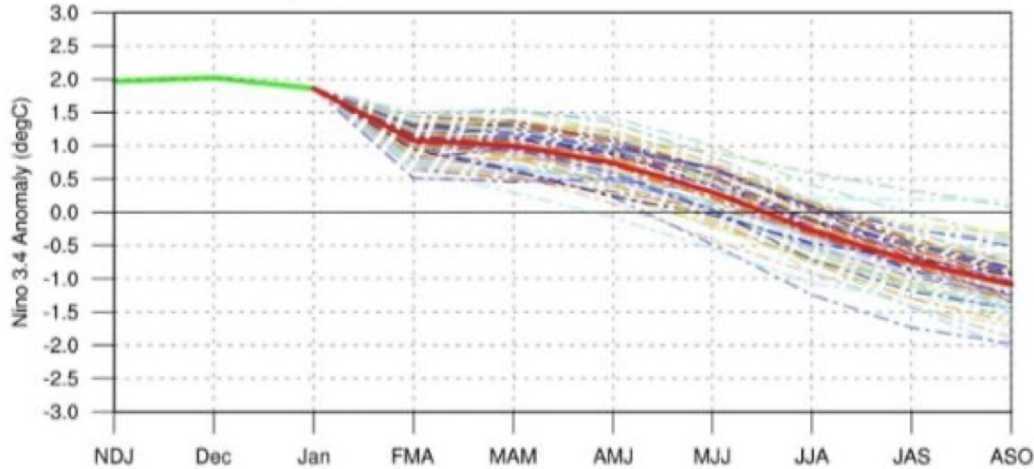


# Global ENSO Predictions

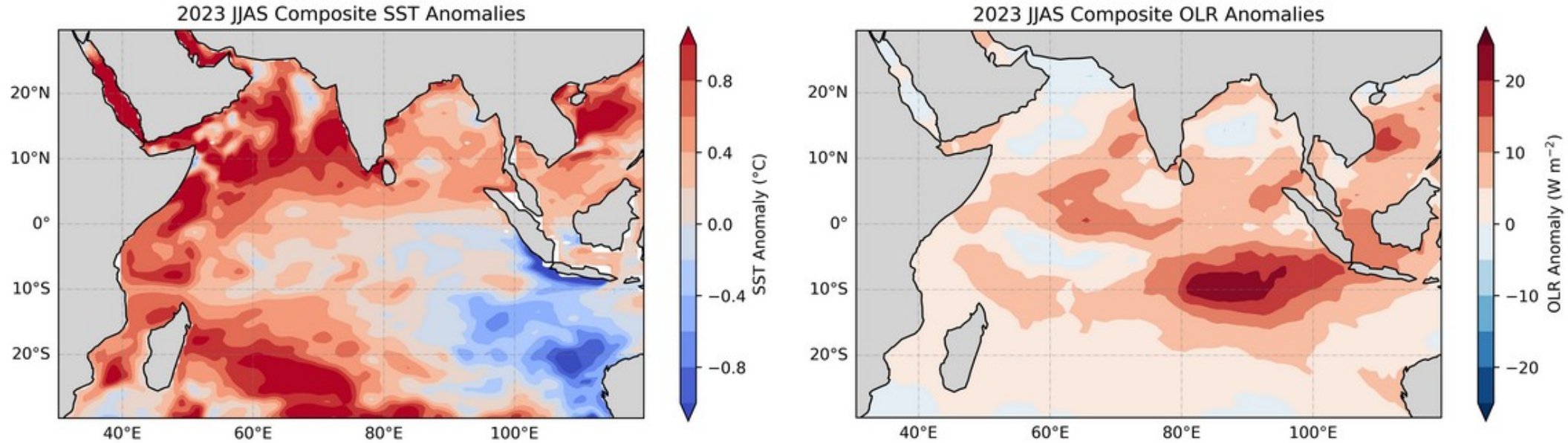


# IMD ENSO Prediction

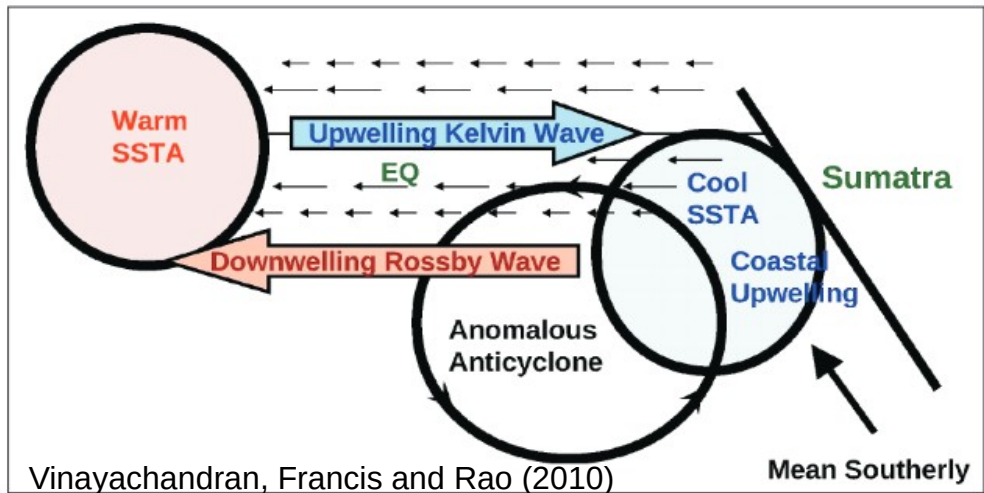
(a) Plume of Nino 3.4 Model Forecast - Jan IC



## Evolution of positive IOD in 2023



June-September mean SST and OLR anomaly in the Indian Ocean depicts a clear signal of positive IOD with below normal SST anomaly in the eastern equatorial Indian Ocean and above normal SST anomaly in the western equatorial Indian Ocean. Convection was suppressed over the eastern equatorial Indian Ocean.



## Initiation of positive IOD events

- Easterly wind burst at equatorial Indian Ocean
  - Upwelling Kelvin & Downwelling Rossby waves at the equator
  - Enhanced upwelling in the eastern equatorial Indian Ocean due to combined action of upwelling Kelvin Waves and coastal upwelling along the Sumatra coast- leading to below normal SST anomalies
  - Cooling prohibited in the western equatorial Indian Ocean due to deeper isothermal layers with the arrival of downwelling Rossby Waves
- Easterly wind bursts is associated with a suppression of convection due to an anomalous anticyclone over the eastern equatorial Indian Ocean.
  - This could be due to prevailing El Nino conditions (Annamalai et al 2003, convection over the South China Sea (Kajikawa et al 2001 or severe cyclones over the Bay of Bengal (Francis et al. 2007)

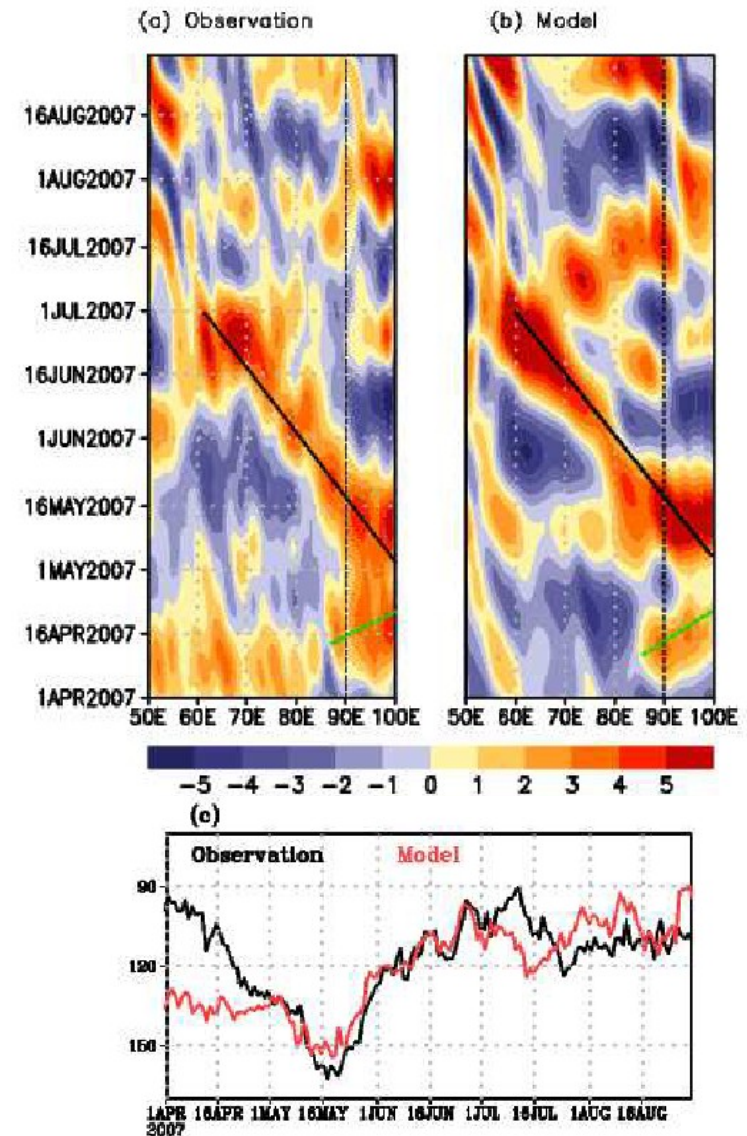


# Anomalous warming of the western equatorial Indian Ocean in 2007: Role of ocean dynamics

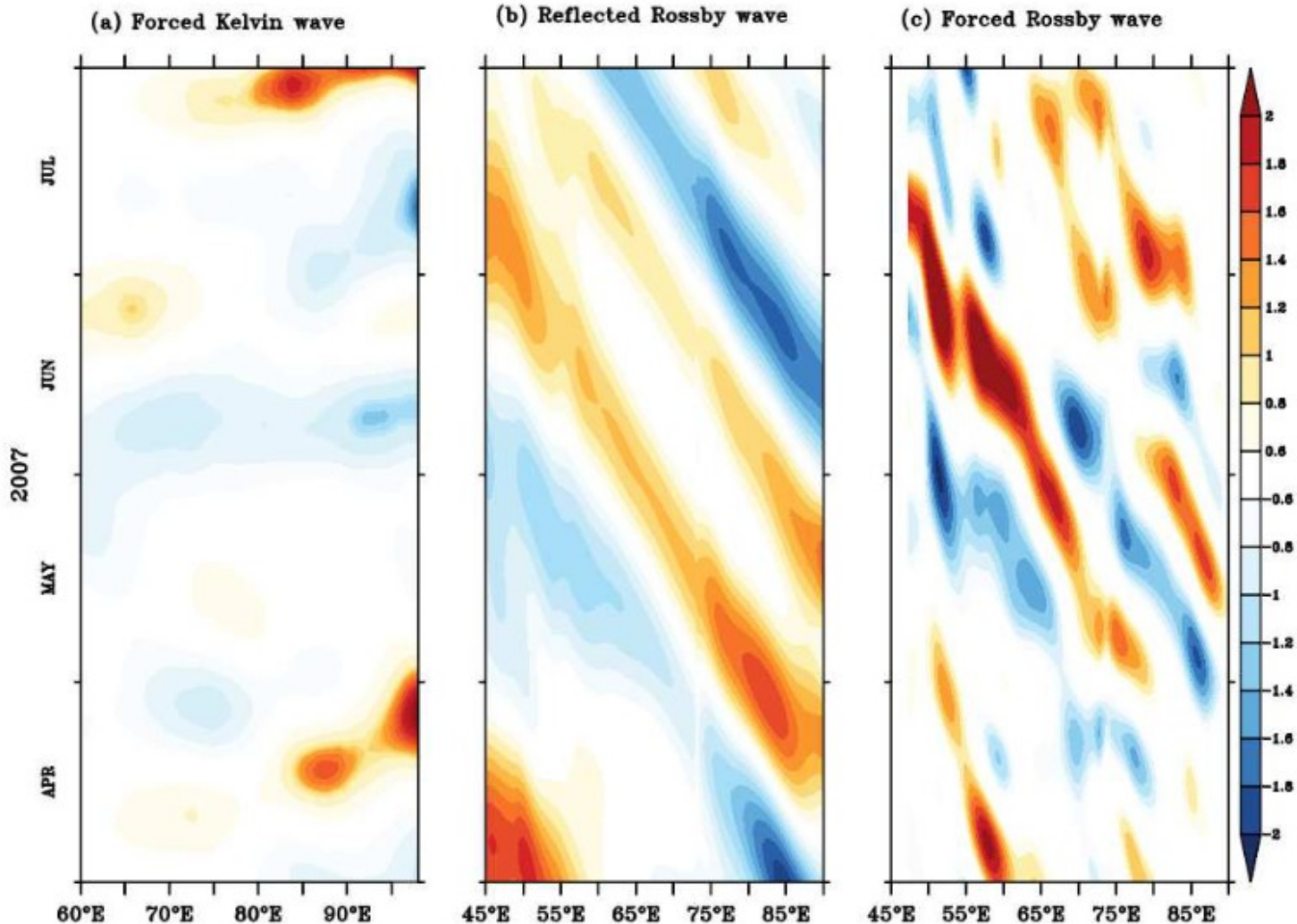
John B. Effy<sup>a,b</sup>, P.A. Francis<sup>a</sup>, S.S.V.S. Ramakrishna<sup>b</sup>, Arnab Mukherjee<sup>a</sup>

Recently, Effy et al (2020) showed that the anomalous warming in 2007 was associated with the arrival of two consecutive downwelling Rossby waves,

- one reflected from the eastern boundary after the arrival of a downwelling Kelvin wave as a response to a westerly wind burst at the equator and
- another as a direct response to the easterly wind burst at the equatorial Indian Ocean



# Simulations from a LCS model for 2007



- It is difficult to differentiate the signals of two Rossby Waves with observation or with OGCMs, particularly when the signals are superimposed.
- Simulations from LCS model was used to extract the signals of the Rossby waves.
- Effy et al (2019) suggested that there is a possibility for the development of a positive IOD with a westerly wind burst at the equatorial Indian Ocean!



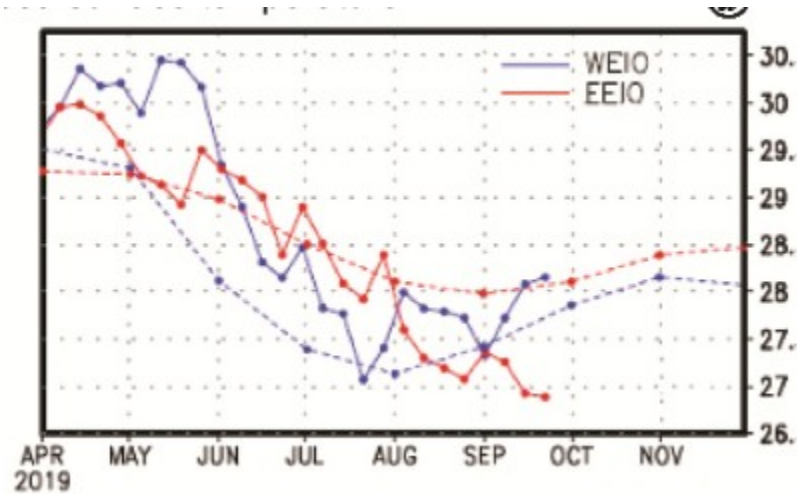
## RESEARCH ARTICLES

## Summer monsoon of 2019: understanding the performance so far and speculating about the rest of the season

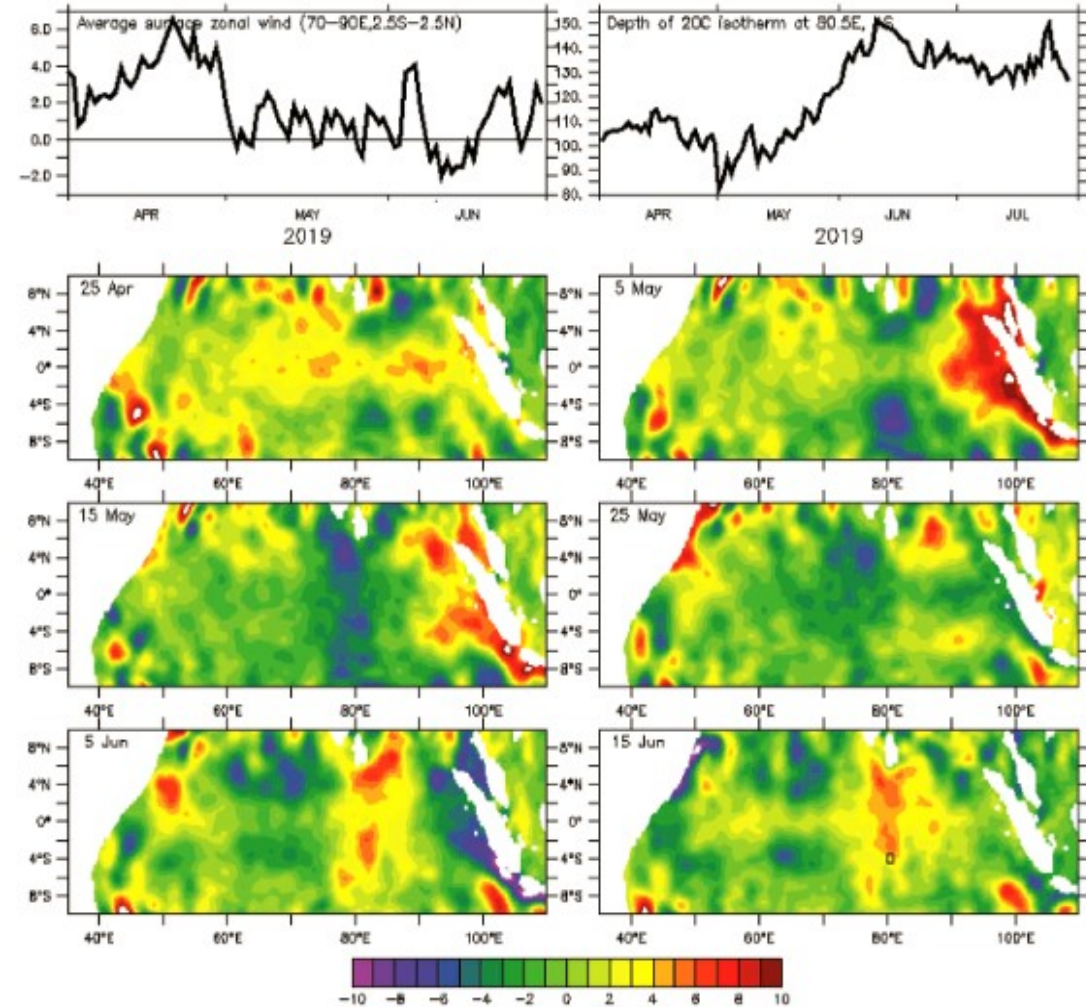
Sulochana Gadgil<sup>1\*</sup>, P. A. Francis<sup>2</sup> and P. N. Vinayachandran<sup>1</sup>

<sup>1</sup>Centre for Atmospheric and Oceanic Sciences, Indian Institute of Science, Bengaluru 560 012, India

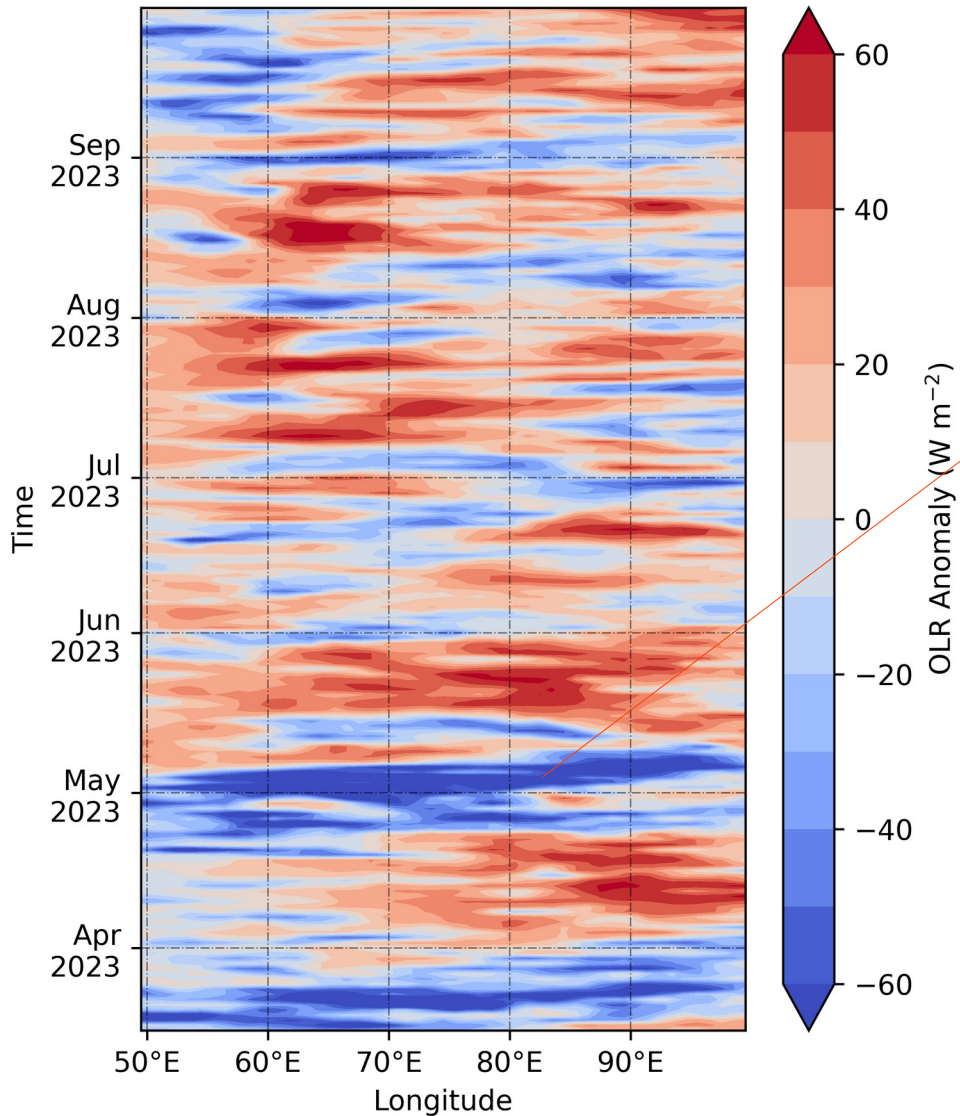
<sup>2</sup>Indian National Centre for Ocean Information Services (Ministry of Earth Sciences, Government of India), Hyderabad 500 090, India



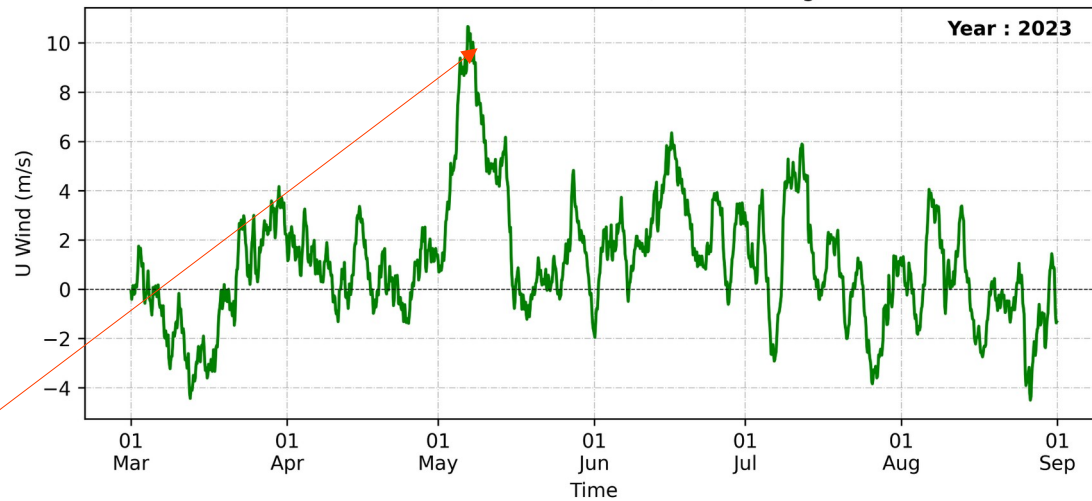
The understanding gained on the role of westerly wind bursts has helped us to make an educated guess on the evolution of Monsoon in 2019.



OLR Anomaly (5S to 5N avg)



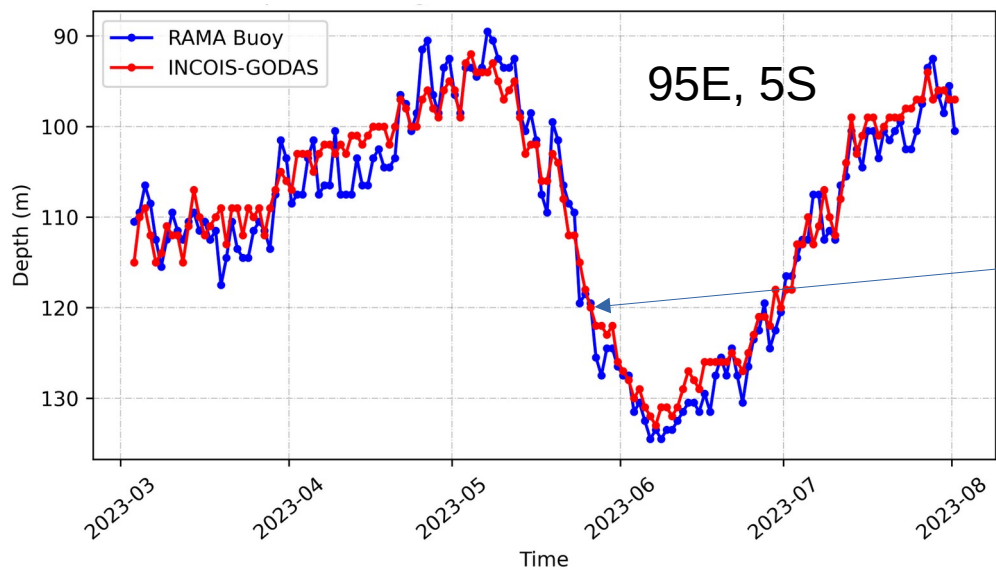
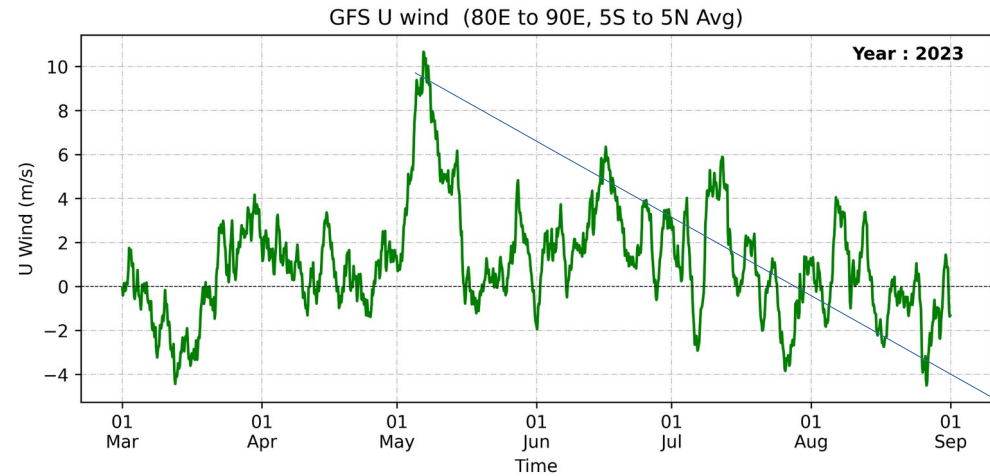
GFS U wind (80E to 90E, 5S to 5N Avg)



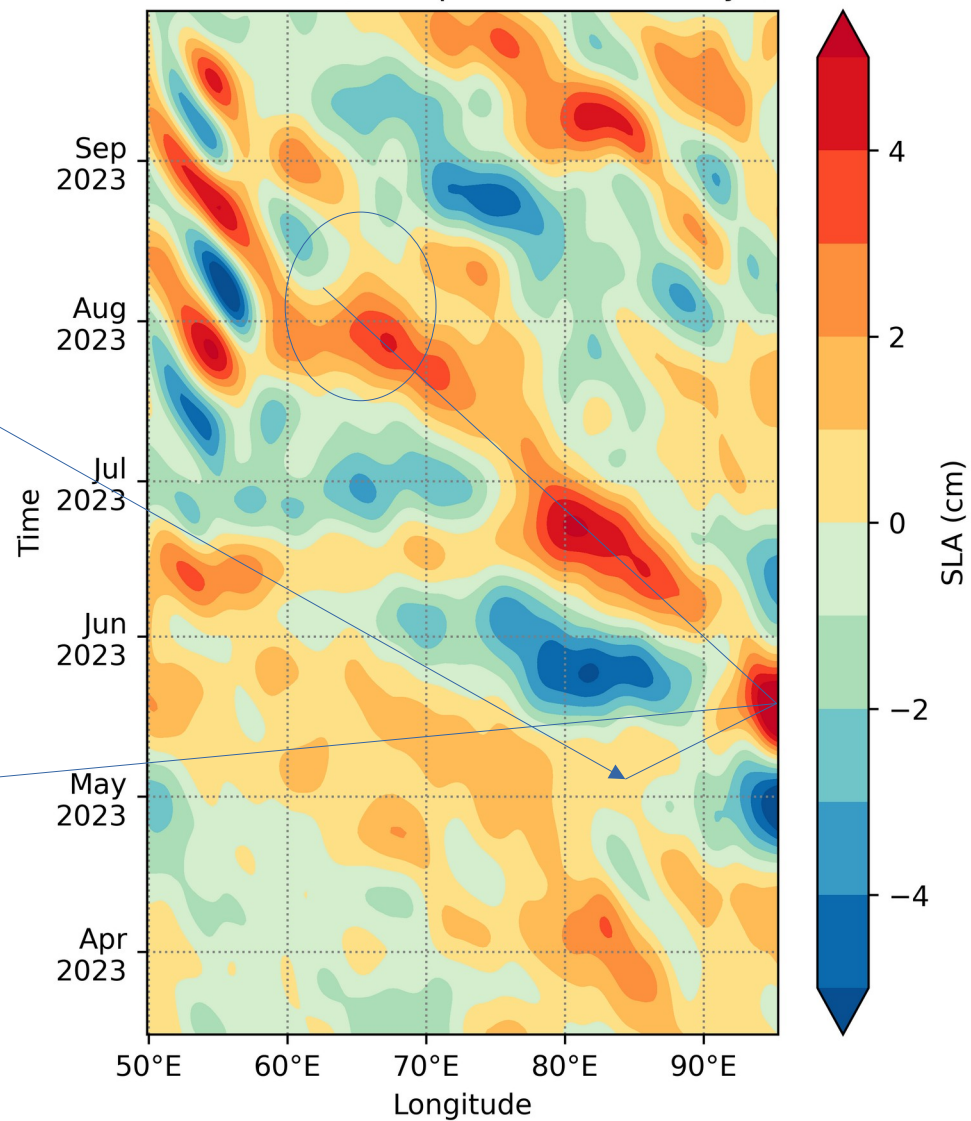
Westerly wind burst was associated with an eastward propagating OLR anomaly patch in the equatorial Indian Ocean.

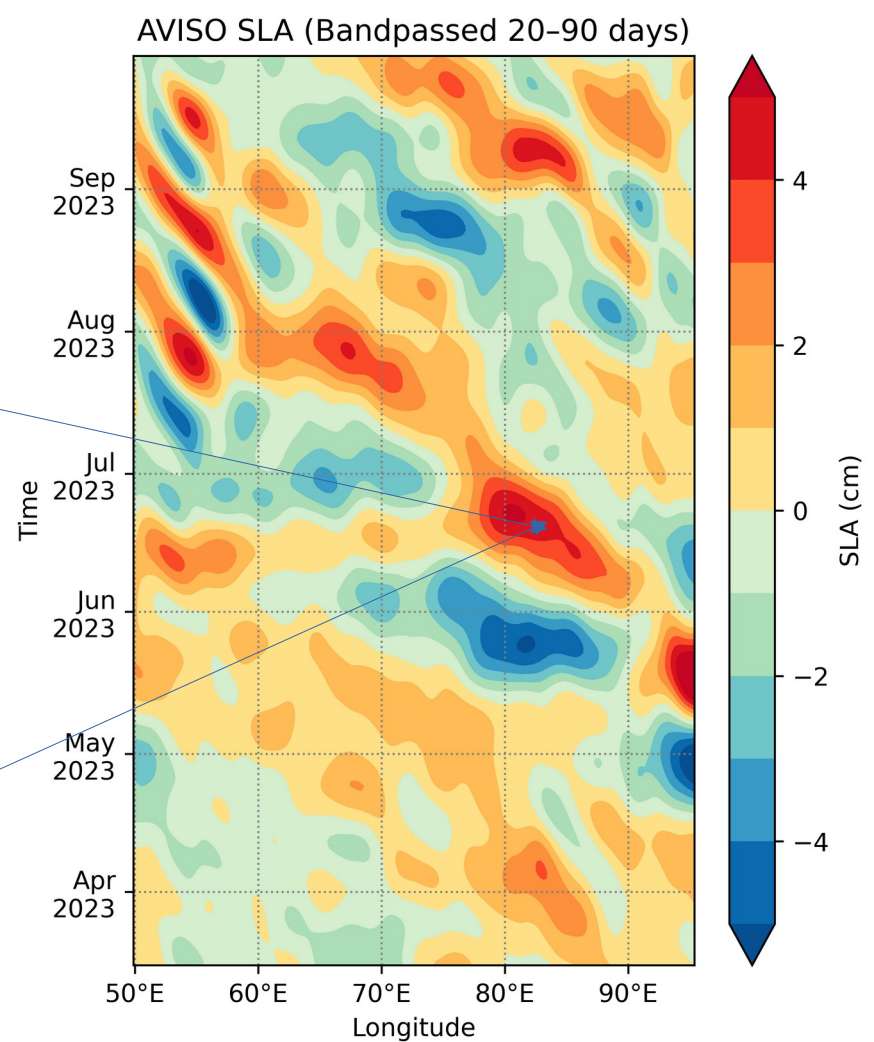
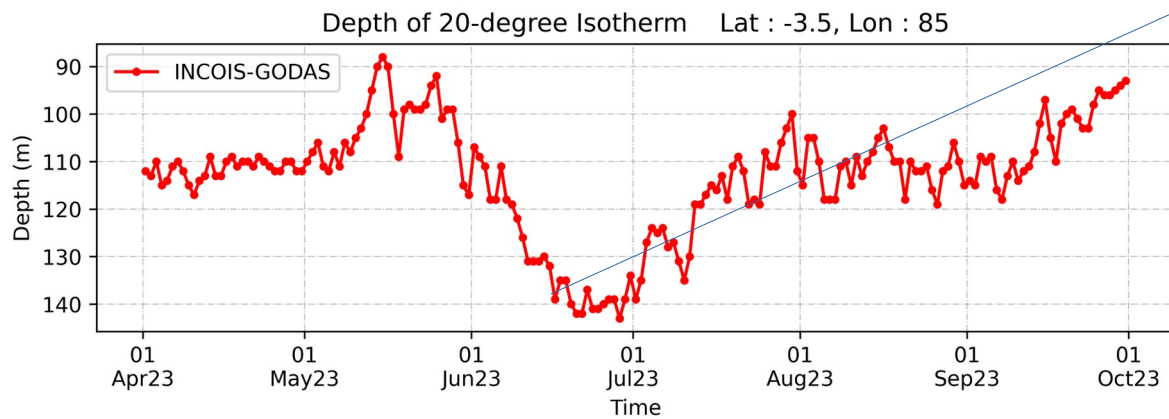
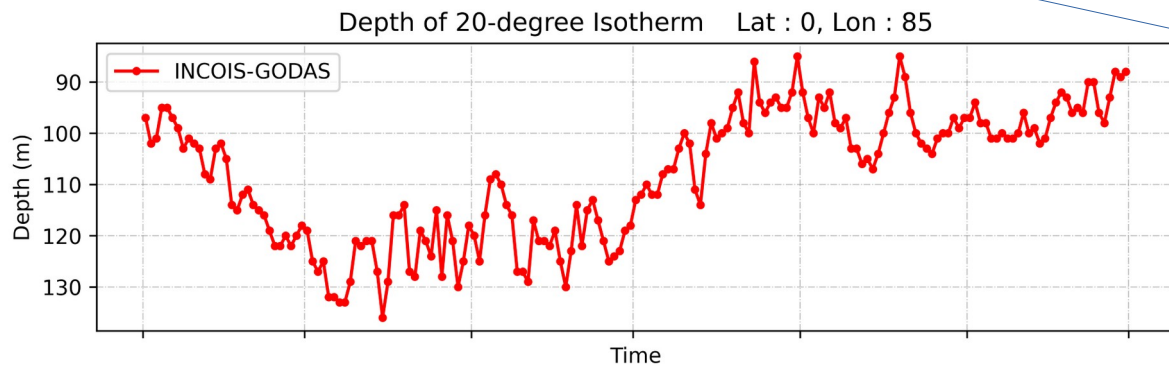
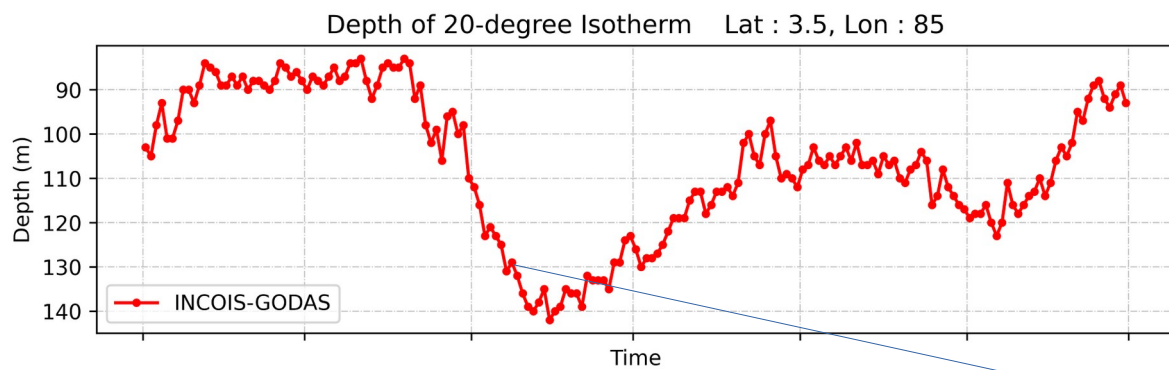


# 2023 Case



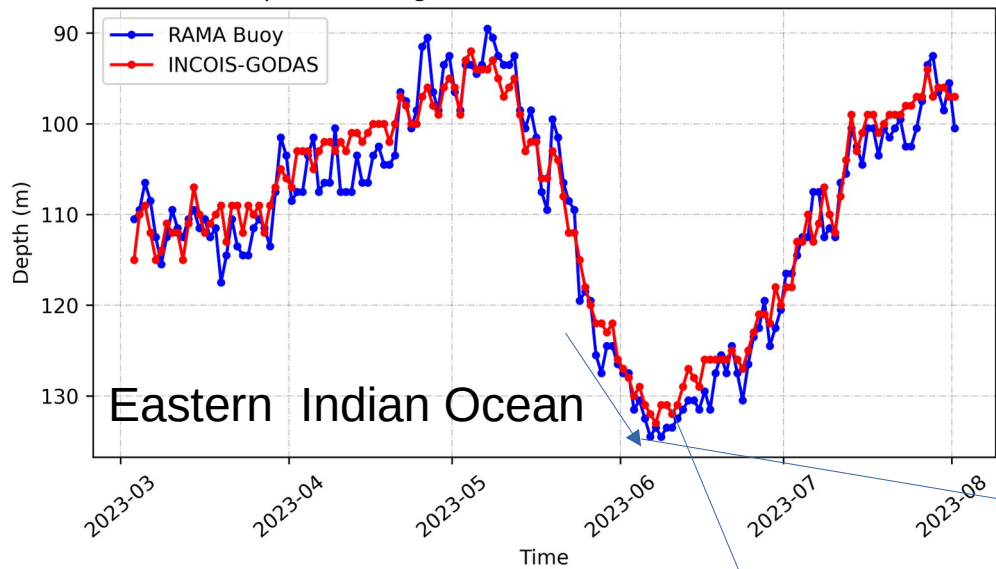
# AVISO SLA (Bandpassed 20-90 days)



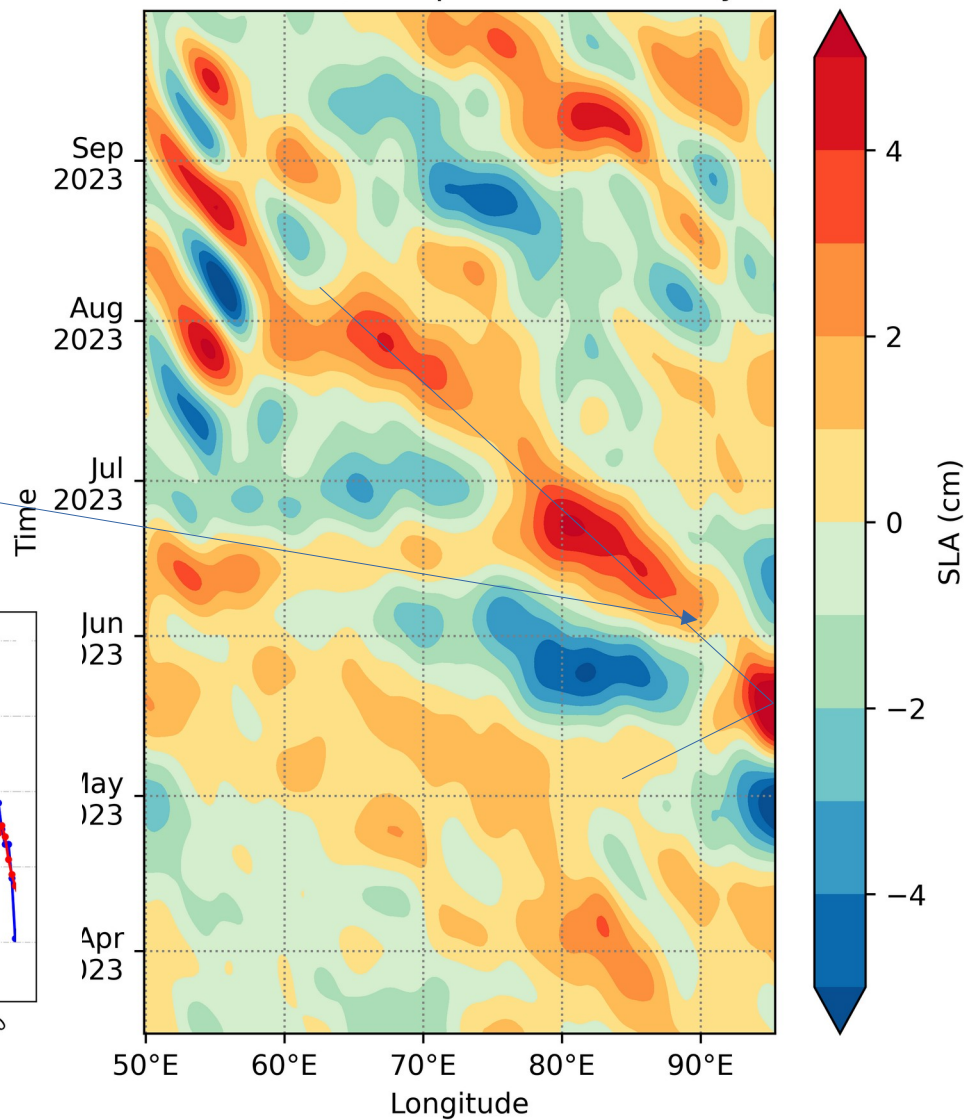


Signals of Downwelling Rossby Wave

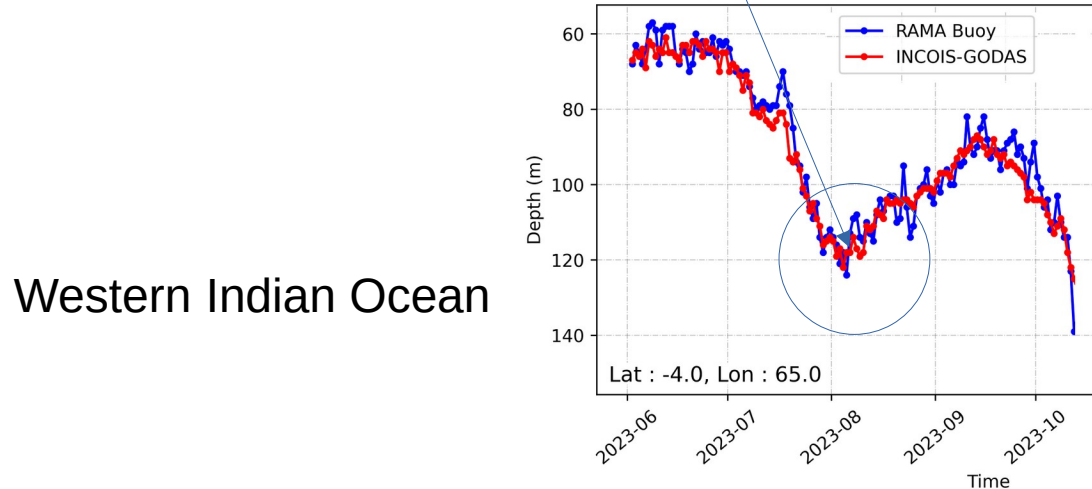
Depth of 20-degree Isotherm Lat : -5.0, Lon : 95.0



AVISO SLA (Bandpassed 20-90 days)



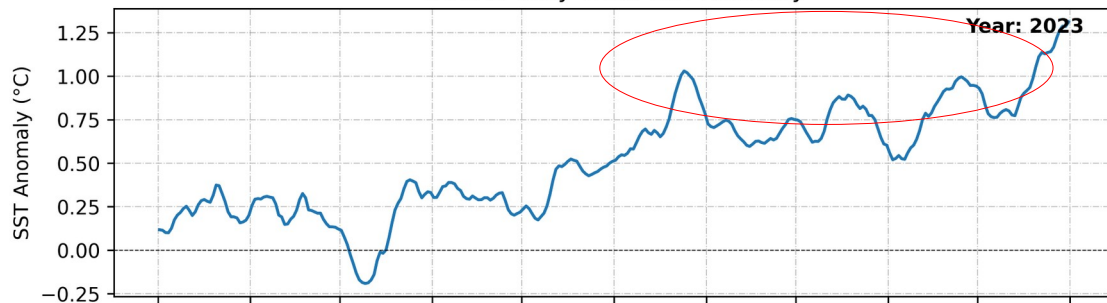
Depth of 20-degree Isotherm



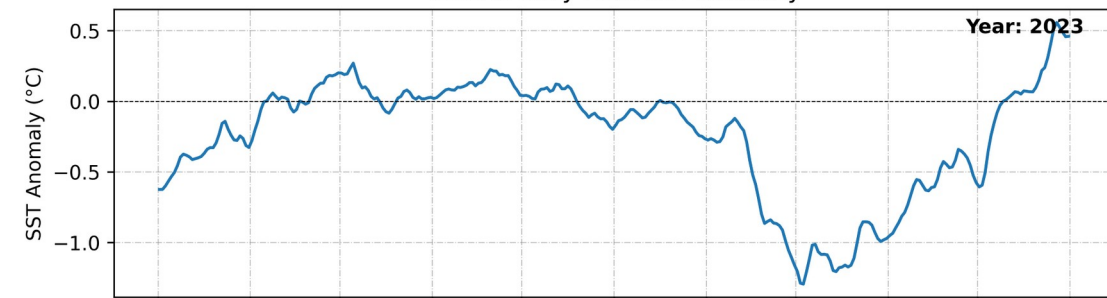


# Evolution of SST in the Indian Ocean

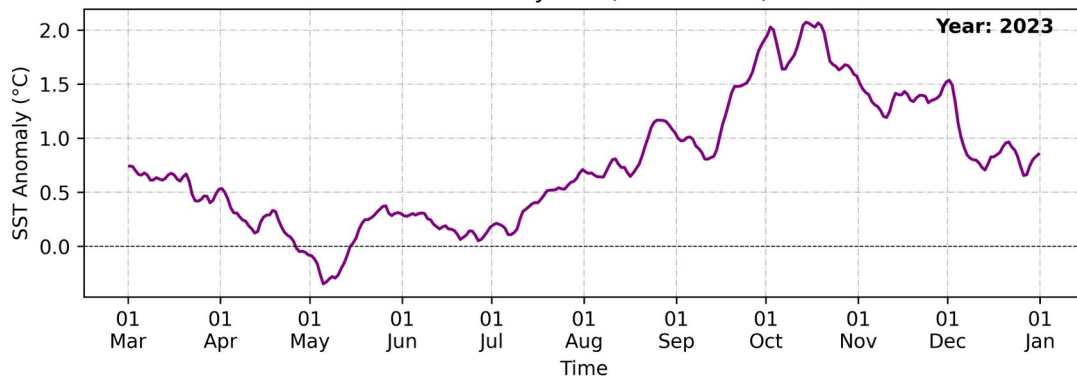
GODAS daily WEIO SST Anomaly



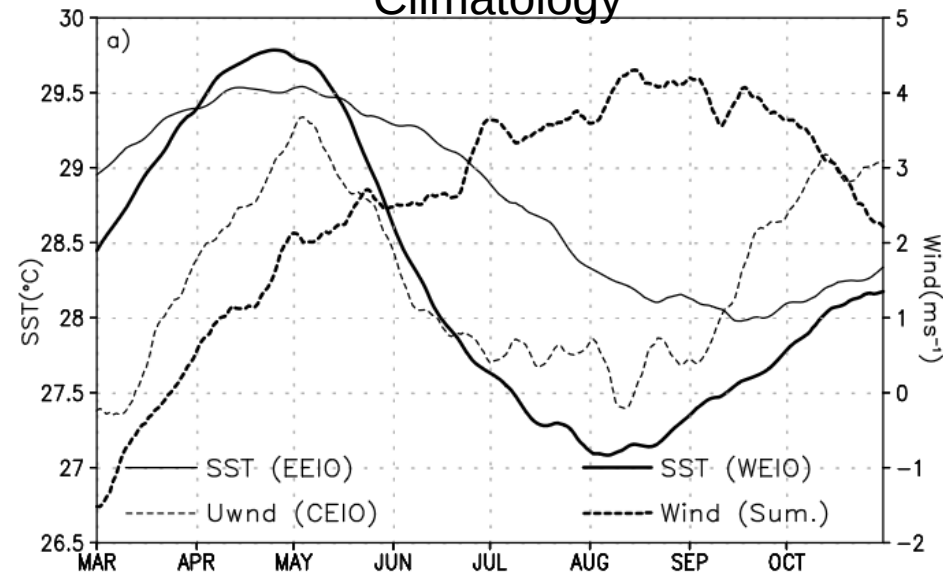
GODAS daily EEIO SST Anomaly



GODAS daily DMI (WEIO - EEIO)



## Climatology



- Significant cooling in the EEIO (which is a characteristic feature of pIOD) appeared only by early September in 2023.
- Though the WEIO was warmer than usual in the monsoon season in 2023, SST anomalies became substantial by early August.

## Concluding Remarks

- The ocean dynamics responsible for the triggering of positive IOD events can be initiated even with westerly wind bursts in the equatorial Indian Ocean.
- In general, such pIOD events co-evolve with monsoon and signals of EEIO cooling appear towards the end of the monsoon season only.
- The evolution of pIOD in 2023, 2019 and 2007 suggest that a close monitoring of the Indian Ocean conditions during late spring/early summer is very important.

**Thank You.**

[francis@incois.gov.in](mailto:francis@incois.gov.in)