Annual to decadal variability in the Indian Ocean

J.S. Deepa, C. Gnanaseelan, Sandeep Mohapatra, Amol Vibhute, A. Parekh, Rashmi Kakatkar, Subrota Halder, J.S. Chowdary

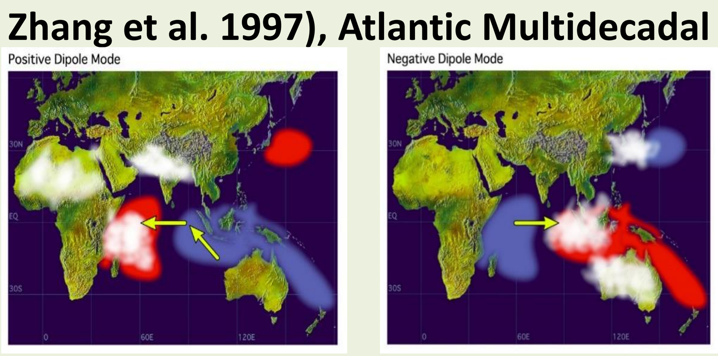
Short Term Climate Variability and Prediction

Indian Institute of Tropical Meteorology, Pune-411 008, India

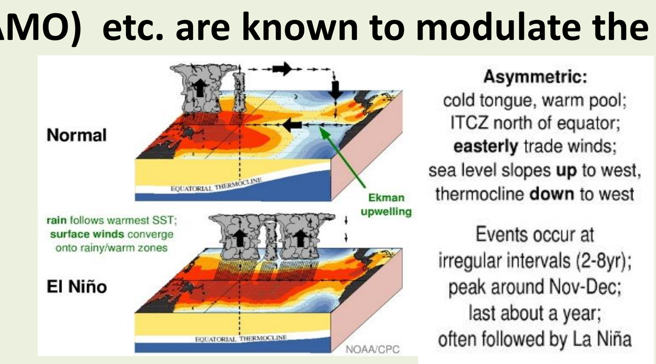
Background/Motivation:

❖The Indian Ocean, which is a region of prominent interannual to decadal variations, is characterized by a number of low lying islands and highly populated coastal zones. Therefore, the interannual to decadal time scale variabilities over the Indian Ocean has important social, economic and environmental consequences on the rim countries.

❖Dominant global climate modes such as Indian Ocean Dipole (IOD) (Saji et al. 1999), El Niño Southern Oscillation (ENSO), Pacific Decadal Oscillation(PDO)/Interdecadal Pacific Oscillation(IPO) (Mantua et al. 1997, Zhang et al. 1997), Atlantic Multidecadal Oscillation (AMO) etc. are known to modulate the Indian Ocean variability in the annual to decadal timescales.



(Image source: JAMSTEC)



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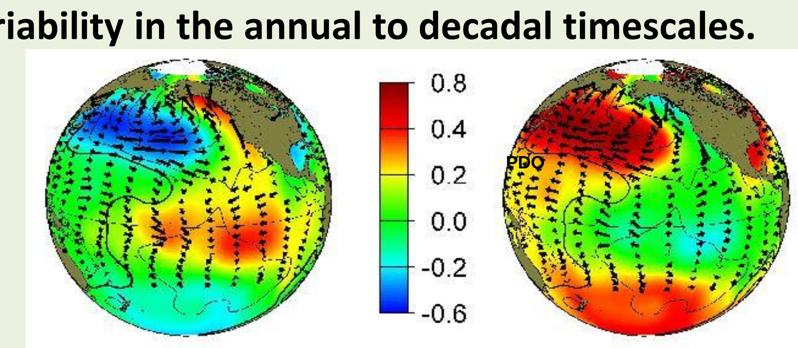

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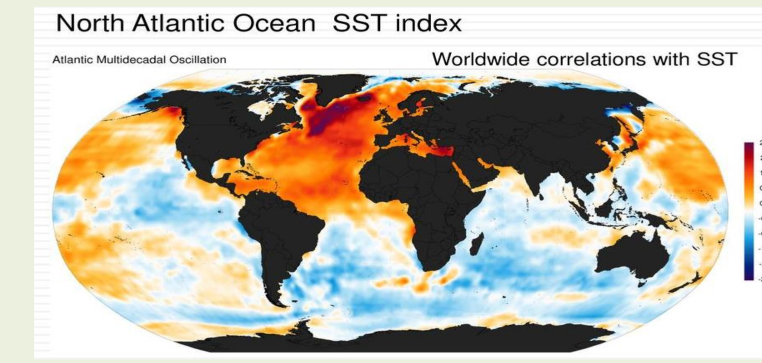


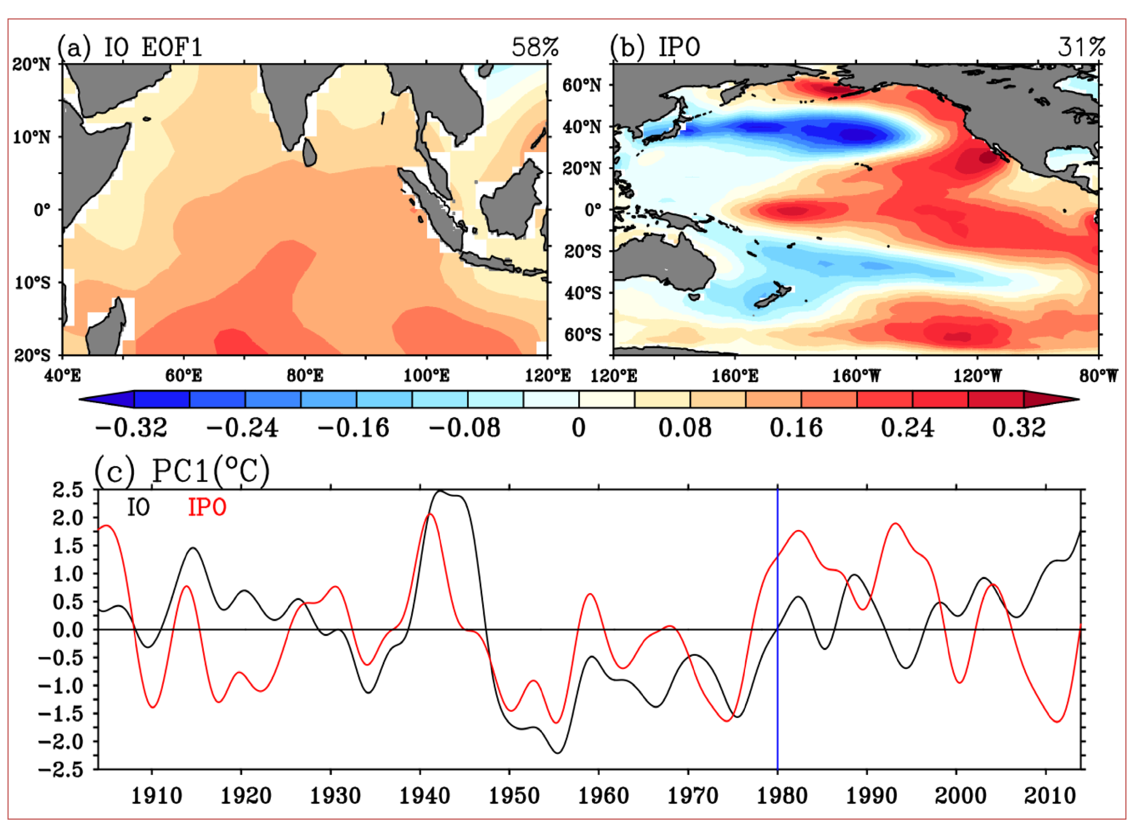
(Image source: wikipedia)

❖Explicit studies on Indian Ocean climate variability are lesser in number compared to that of the Pacific (e.g. Alexandar 2010; Mantua et al. 1997) and Atlantic Oceans (e.g. Liu 2012, Li et al. 2016).

❖Our work in the direction of understanding Indian Ocean climate variability in the interannual to decadal timescales is presented .

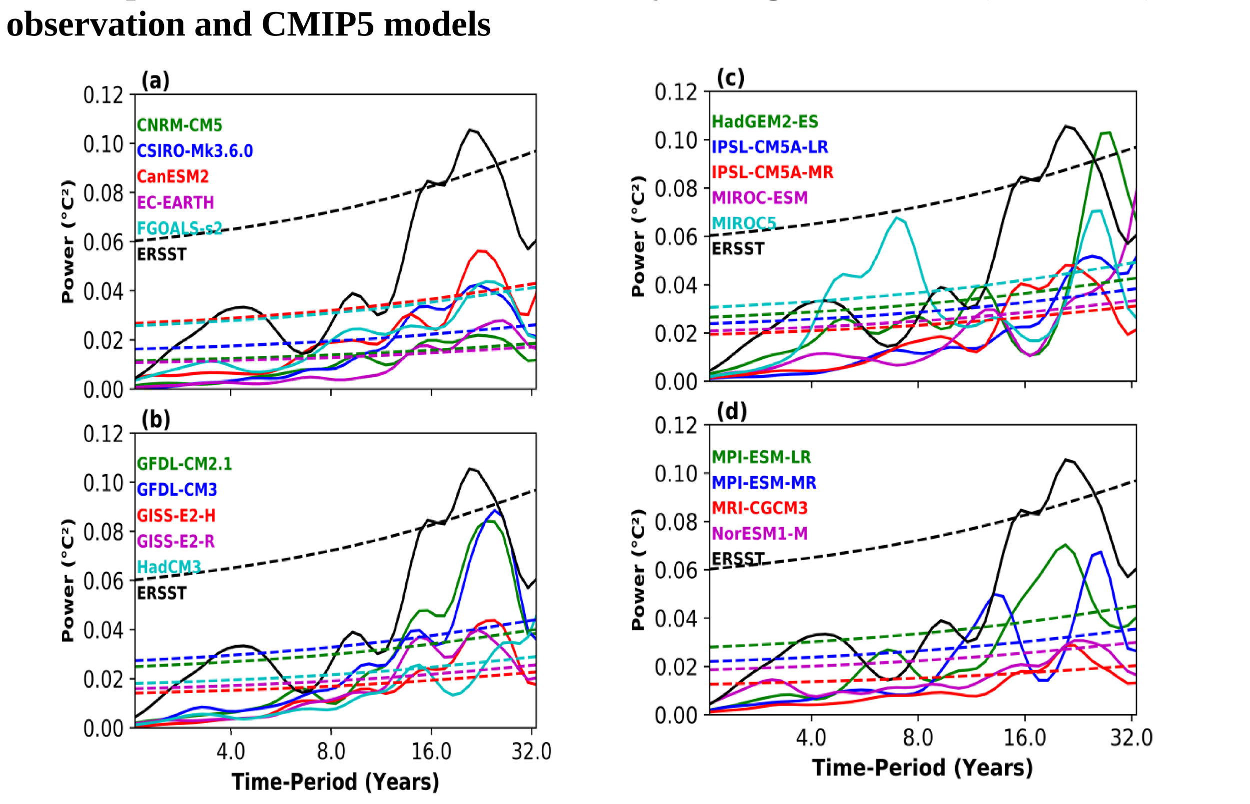
Discussion

Leading mode of decadal variability of SST over Indian Ocean and Pacific Ocean

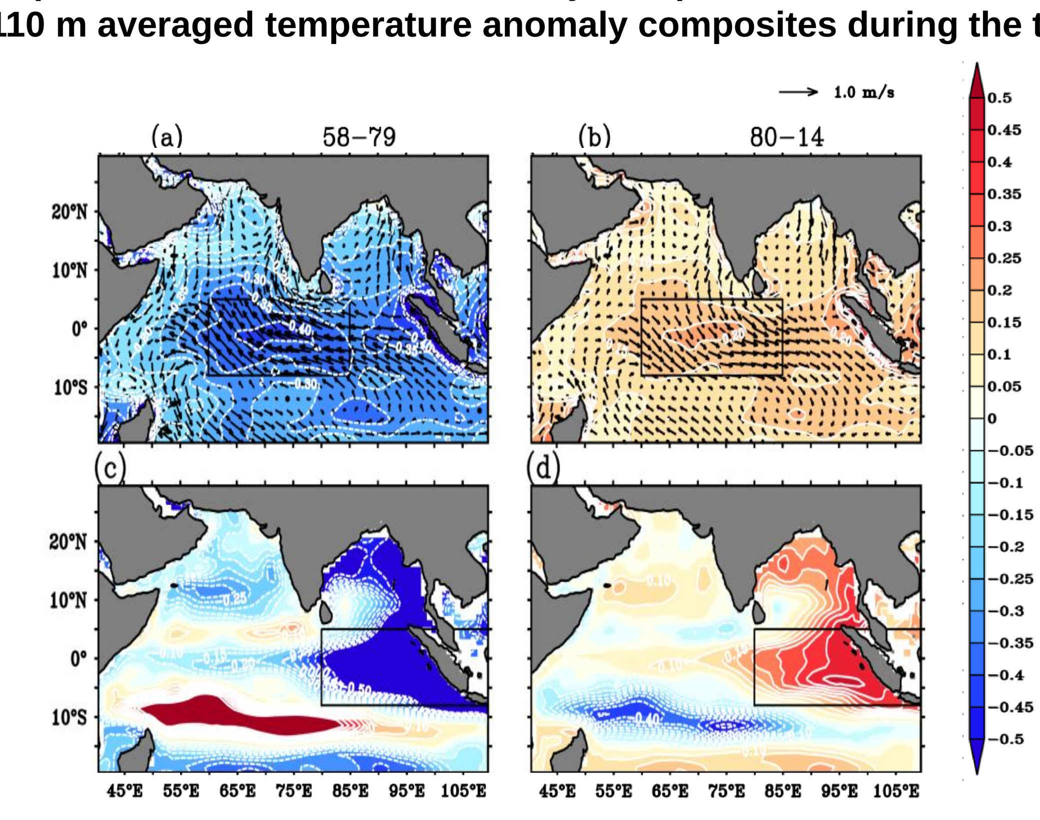


In the well observed period, decadal SST over the Indian Ocean exhibits epochal variability with negative SST anomalies in the epoch-1 (1958-1979) and positive SST anomalies in the epoch-2 (1980-2014)

Power spectrum of detrended SST anomaly averaged over TIO (1861-2004) from observation and CMIP5 models



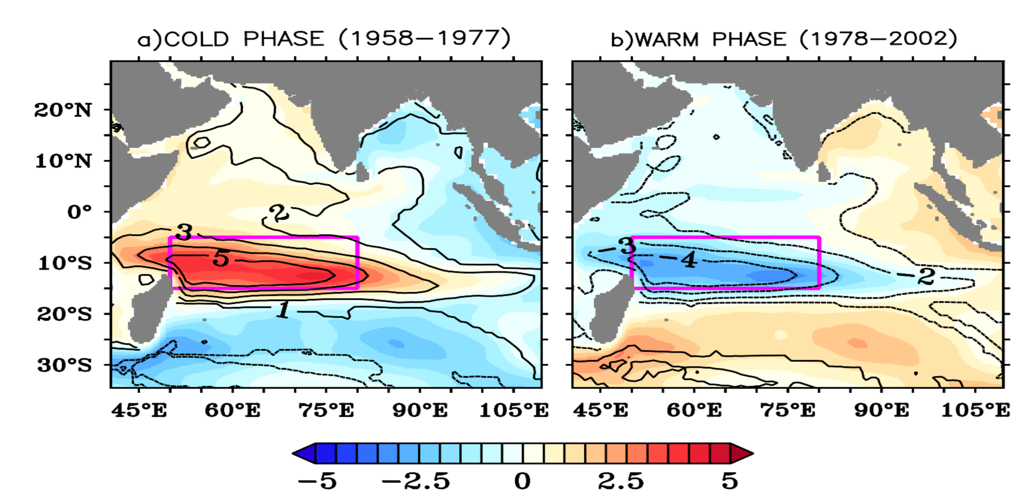
The spatial structure of SST anomaly composites, with overlaid winds and 50-110 m averaged temperature anomaly composites during the two epochs

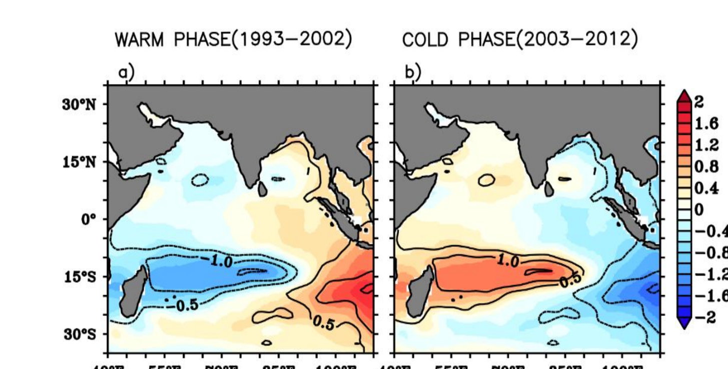


The highlighted boxes based on prominent signals for SST and subsurface temperature are 60°E-85°E, 8°S-5°N and 80°E-110°E, 8°S-5°N respectively.

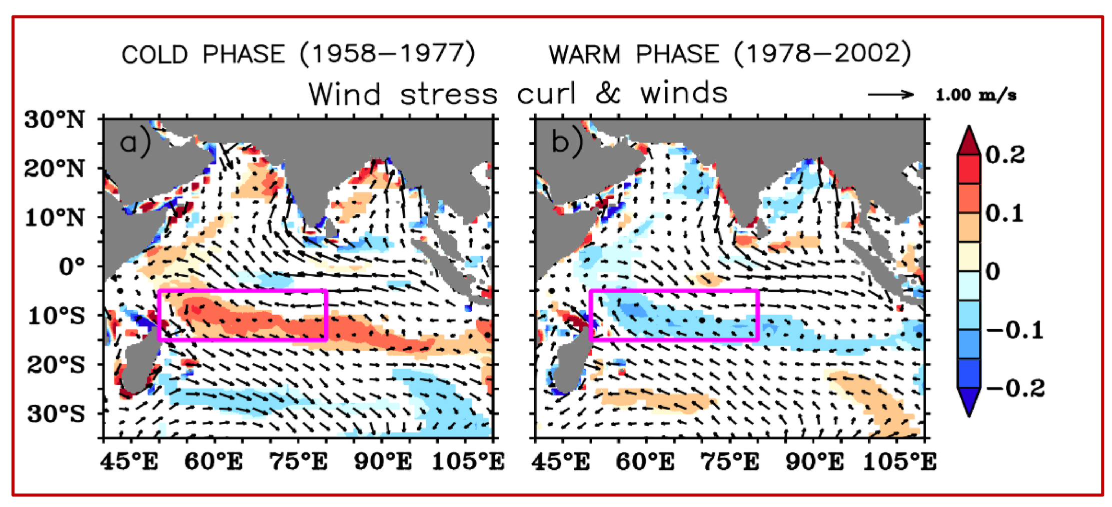
- Equatorial easterly wind anomalies in epoch-1 contribute to thermocline tilt anomalies with shallower thermocline in the EEIO, while equatorial westerly wind anomalies in epoch-2 lead to opposite thermocline tilt anomalies with deeper thermocline in the EEIO.
- It is important to note the close association between the subsurface pattern seen especially in the EEIO and the SST pattern during these epochs.

The Indian Ocean SLA composites during the cold and warm phases of PDO





The Indian Ocean sea level patterns have undergone extreme phase change as PDO shifts from cold to warm phase.

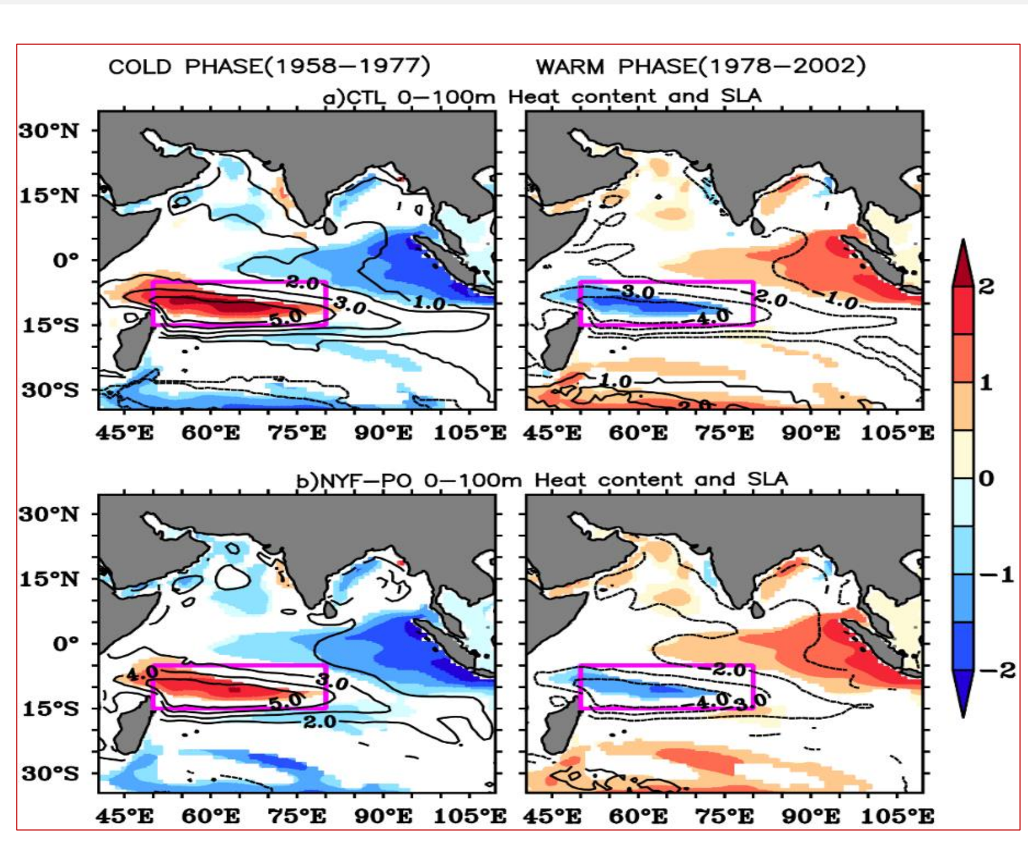


The positive (negative) curl during the cold (warm) phase induces downward (upward) Ekman pumping and deepening (shallowing) of the thermocline, which propagates westward as downwelling (upwelling) Rossby waves and amplify (weaken) the sea level in the TRIO region.

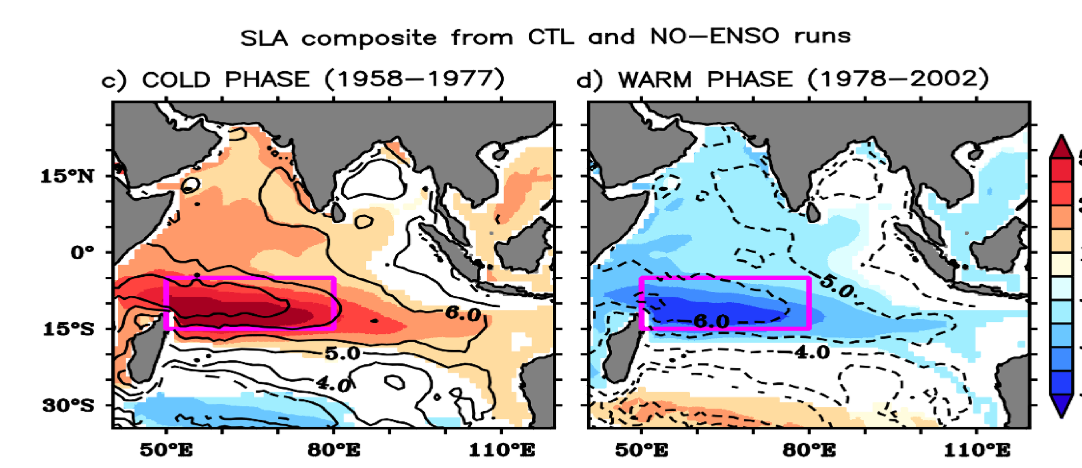
Ocean model sensitivity experiments

CTL	IAF over full region
NYF-PO	NYF over Pacific Ocean and IAF everywhere else
NYF-EIO	NYF (of surface wind only) over the equatorial Indian Ocean (EIO; 40E-100E, 10S-5N) and IAF everywhere else
NO-ENSO	ENSO related wind components are suppressed from monthly mean winds

Model details: Modular Ocean Model version 5 (MOM5)
Global model with 1°× 1° horizontal resolution and 50 vertical levels

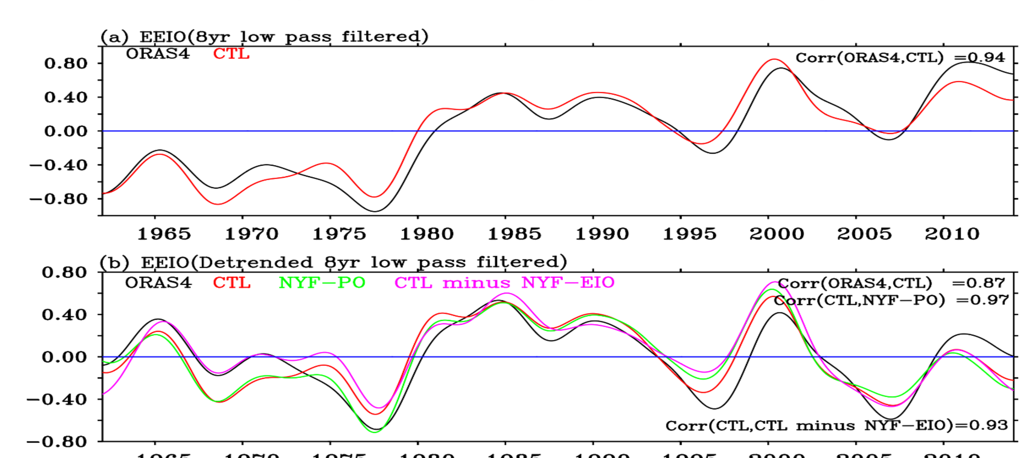


The upper ocean heat content anomalies in NYF-PO is found to be weaker than that of CTL but the SLA in both NYF-PO and CTL are similar. This strongly suggests the role of local winds modulated by PDO through atmospheric teleconnection on the decadal SLA variability in the TRIO region.

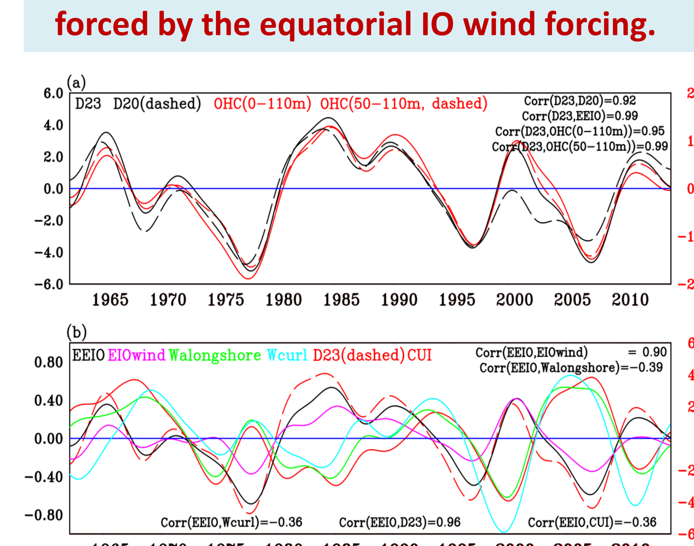


SLA patterns over TRIO region got amplified when the ENSO effects from winds are suppressed, indicating the major role of PDO

8-yr low pass filtered temperature anomaly(°C) over EEIO averaged for 50-110 m and detrended temperature anomaly(°C) from model experiments



- The observed subsurface temperature along EEIO in CTL and NYF-PO are found to be consistent, ruling out the possibility of any significant Pacific influence on the study region through oceanic pathways.
- Also, the EEIO subsurface variability in CTL and CTL minus NYF-EIO are similar suggesting that the EEIO subsurface temperature is mainly forced by the equatorial IO wind forcing.

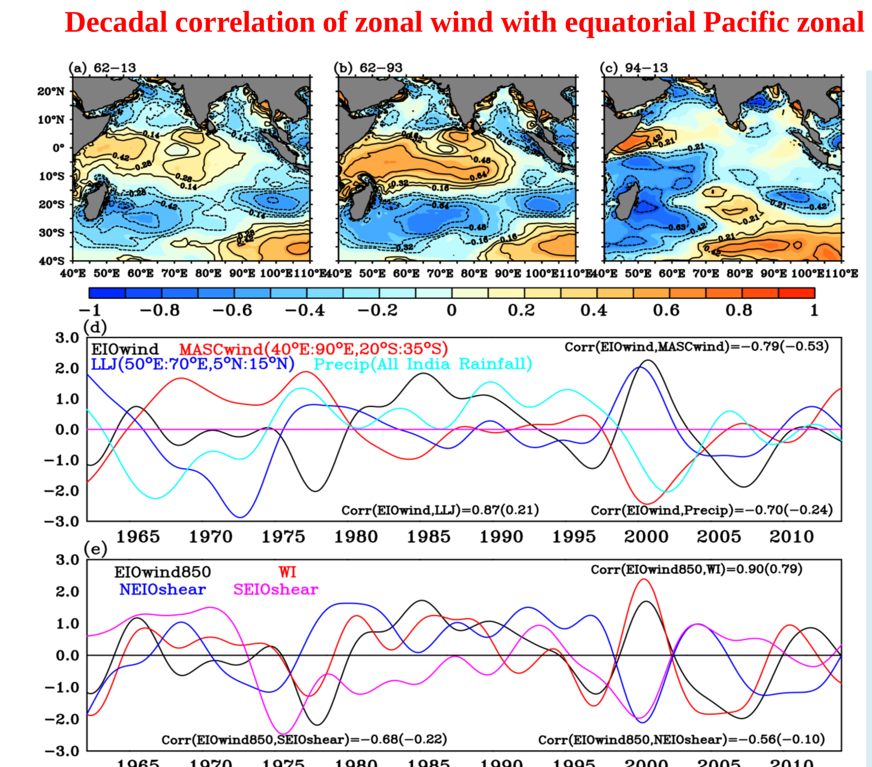


(a) 8yr low pass filtered detrended D23 anomaly (m), D20 anomaly (m) and upper 110m oceanic heat content anomaly (10^8 J/m^2) and 50-110m oceanic heat content (10^8 J/m^2) averaged over 80°E-110°E, 8°S-5°N

(b)Detrended 8yr low pass filtered EEIO subsurface temperature anomaly (°C), EIO (averaged over 40°E to 100°E, 5°S to 5°N) wind anomaly (m/s, EIOwind), alongshore wind anomaly (m/s, Walongshore), coastal upwelling index (m^3s^{-1} per 100m coastline, CUI), D23 anomaly (10^{-1} m, 80°E-110°E, 2°S-2°N,) and wind stress curl anomaly (10^{-8} N/m3, Wcurl) averaged over 80°E to 110°E, 15°S to 25°S.

- Wind induced thermocline along the equator (D23, averaged over 2°S-2°N) shows a pattern similar to that of EEIO subsurface temperature.
- Along with EIO winds, both alongshore winds and Coatal upwelling index (CUI) consistently contribute to the EEIO subsurface temperature variability with maximum impact observed since the mid 1990s.
- The major contributors for the decadal variability in EIO winds are found to be the decadal variability in the Mascarene high, the low level jet, and the large scale off-equatorial circulations.

Decadal correlation of zonal wind with equatorial Pacific zonal wind



Decadal variability in Mascarene high, LLJ and off equatorial circulations (anticyclonic and cyclonic circulations respectively during the decades of equatorial easterlies and westerlies) closely associated with monsoon rainfall over India are the primary factors for the decadal modulation of EIO winds especially in the post mid 1990s.

The wind forcing is found to be driving the decadal and multidecadal variability in the subsurface temperature as compared to the remote forcing from the Pacific Ocean through ITF via oceanic pathways.

References

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