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Heat distribution in the tropical Indian Ocean in the prolonged La-Nina years during 1958–2017

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Introduction

- Prolonged La-Niña events are those which persists more that 24-months (Allan and D’Arrigo 1999;Reason et al. 2000; Allan et al. 2003) has significant effect on the north Indian Ocean (IO) heat content and sea-level.

- Heat content and sea-level in the north Indian Ocean is analysed for the pro-longed La-Niña years viz., 1973–1976, 1983–1986, 1998–2001 and 2010–2012.

- The prolonged La-Nina induced wind forcing found responsible for the warming seen in the eastern IO all the way up to Bay of Bengal.

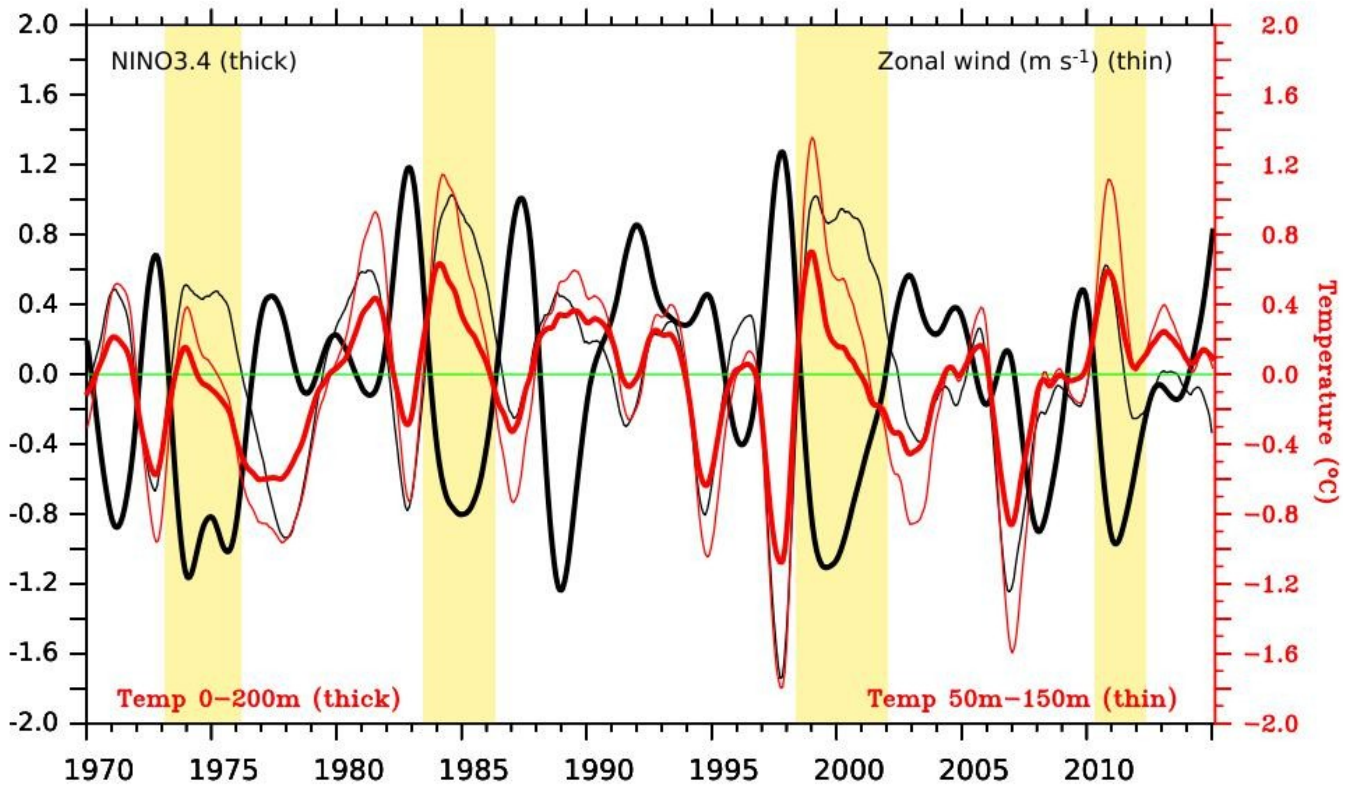
- Effect of co-occurrence of the Indian Ocean Dipole events during these period are also studied.

Data:

1. ORAS4 reanalysis during 1958–2017.

2. Surface winds (10 m) from ECMWF Reanalysis (ERA) for 1958–2017.

25-months running mean of Nino3.4, vertical temperature average (5°S-5°N,90°E-100°E) and zonal wind (5°N-5°S,60°E-100°E) anomalies



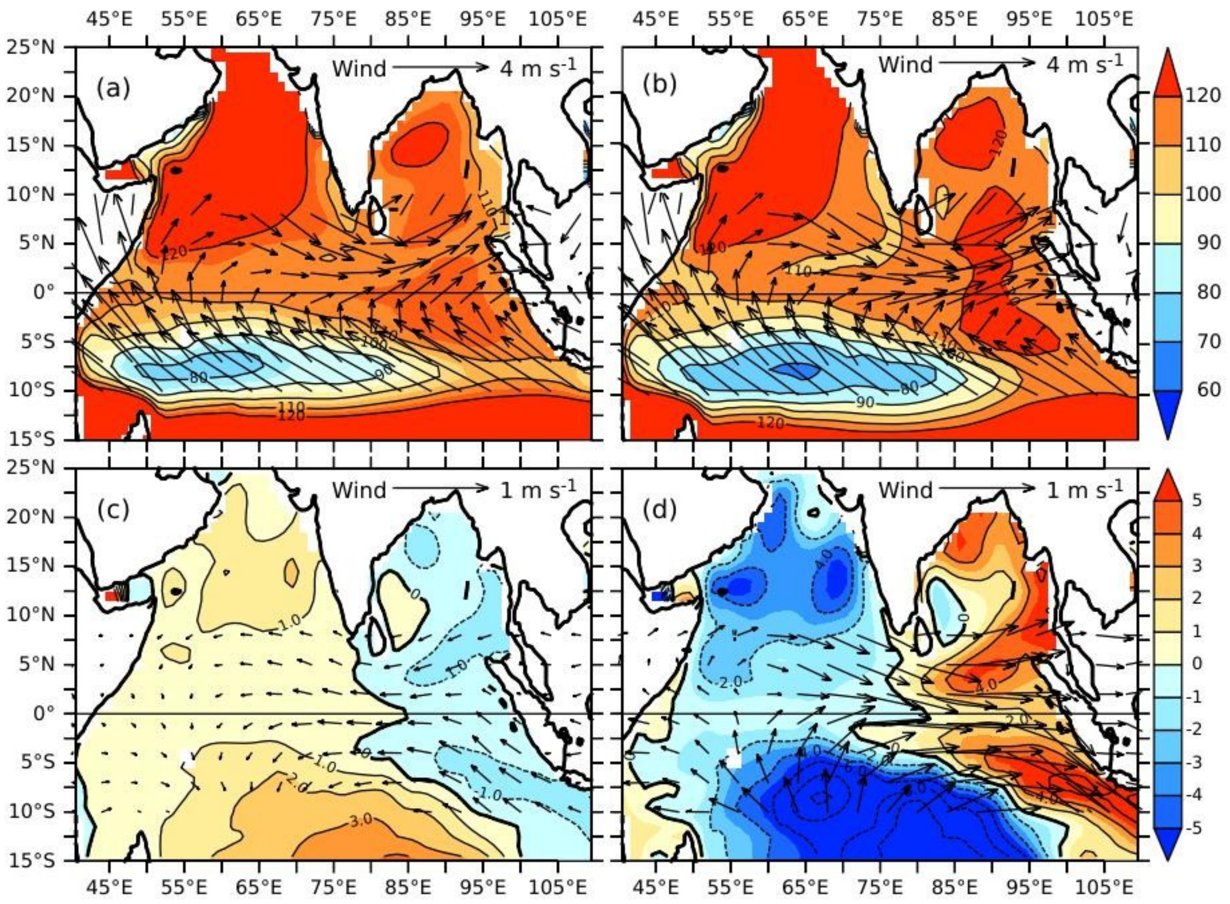
1. The La-Nina events of 1973–1976, 1983–1986, 1998–2001, 2010–2012 are chosen.

2. Warming is evident during the prolonged La-Nina times.

3. Warming decays after a certain period during the prolonged La-Nina times.

4. Westerlies are prominent in the eastern equatorial Indian Ocean during prolonged La-Nina times and linked with the warming and decay during the same.

D20 composites with and without the prolonged La-Nina events

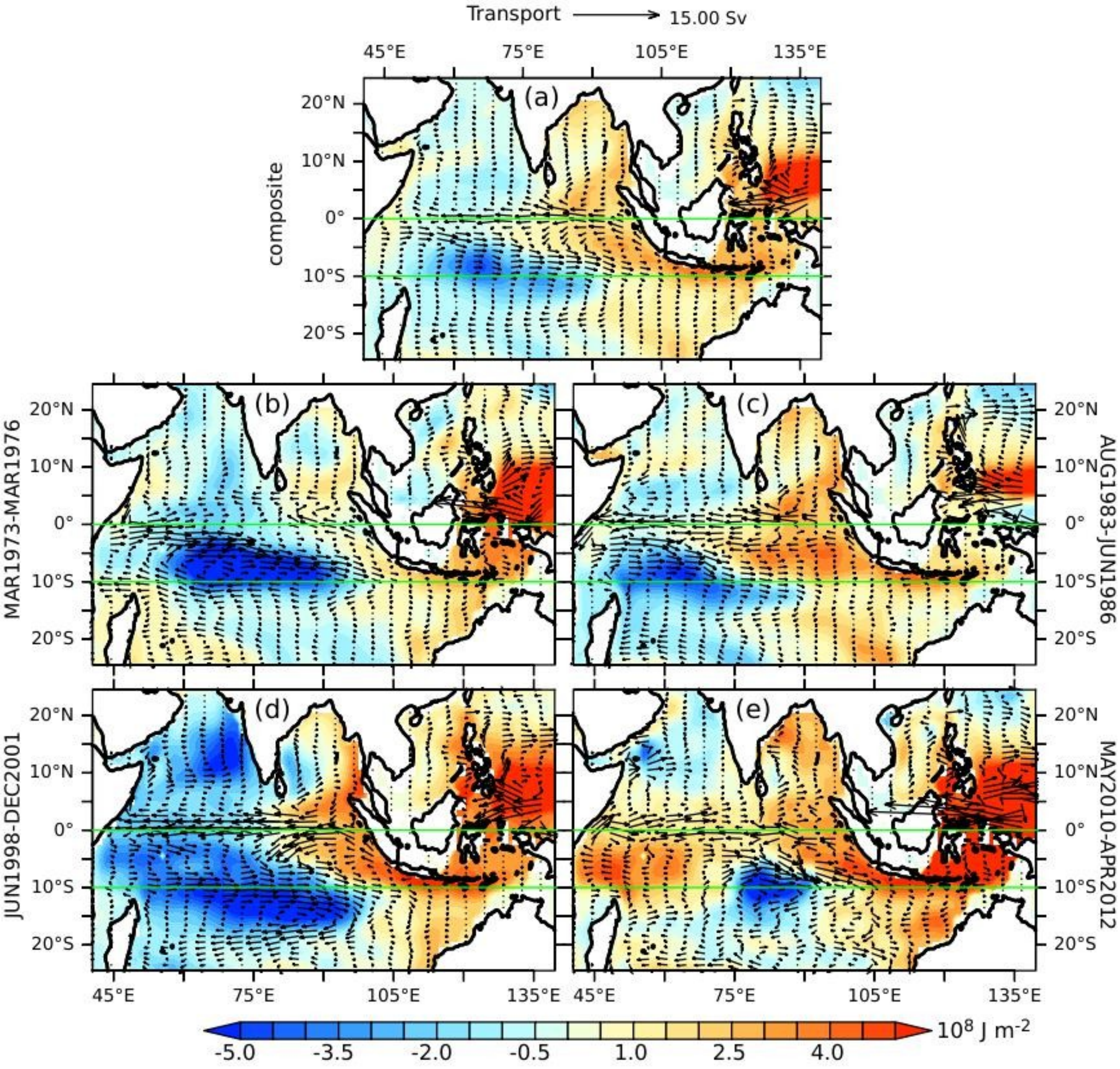


1. A an east-west thermocline gradient is seen during the prolonged La-Nina years in the eastern Indian Ocean during 1958–2017.

2. Thermocline deepens for most of the regions in Bay of Bengal.

3. The TRIO region extends eastward during these times.

4. Westerlies enhances during these times.



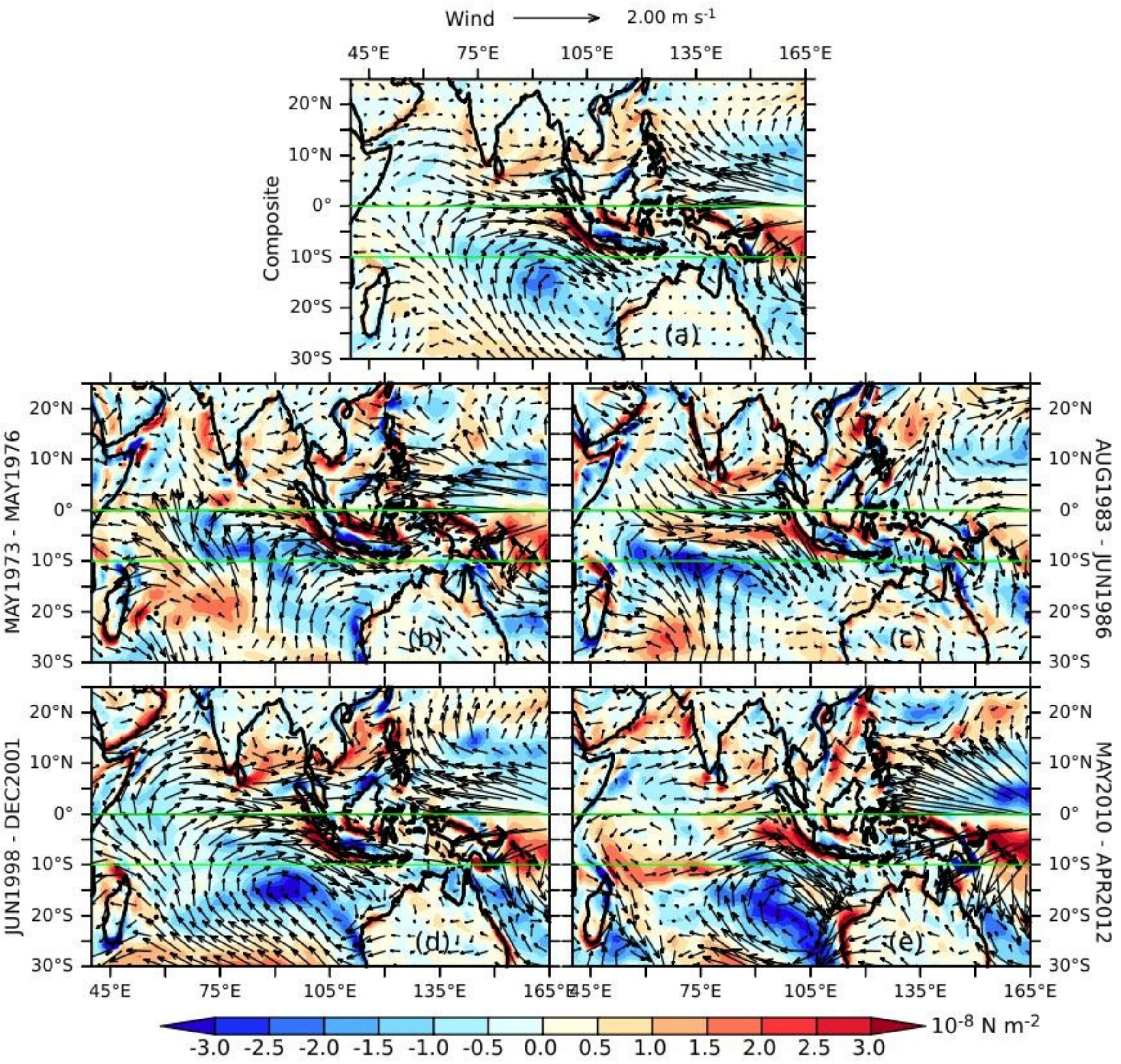
Heat content anomalies during the prolonged La-Nina times

1. Warming is seen in the eastern part up to Bay of Bengal in the heat content during the prolonged La-Nina.

2. Most of the warming is confined to the 50m—150m depth range.

3. Volume transport shows prominent cross-equatorial flow along near the eastern boundary of the Indian Ocean.

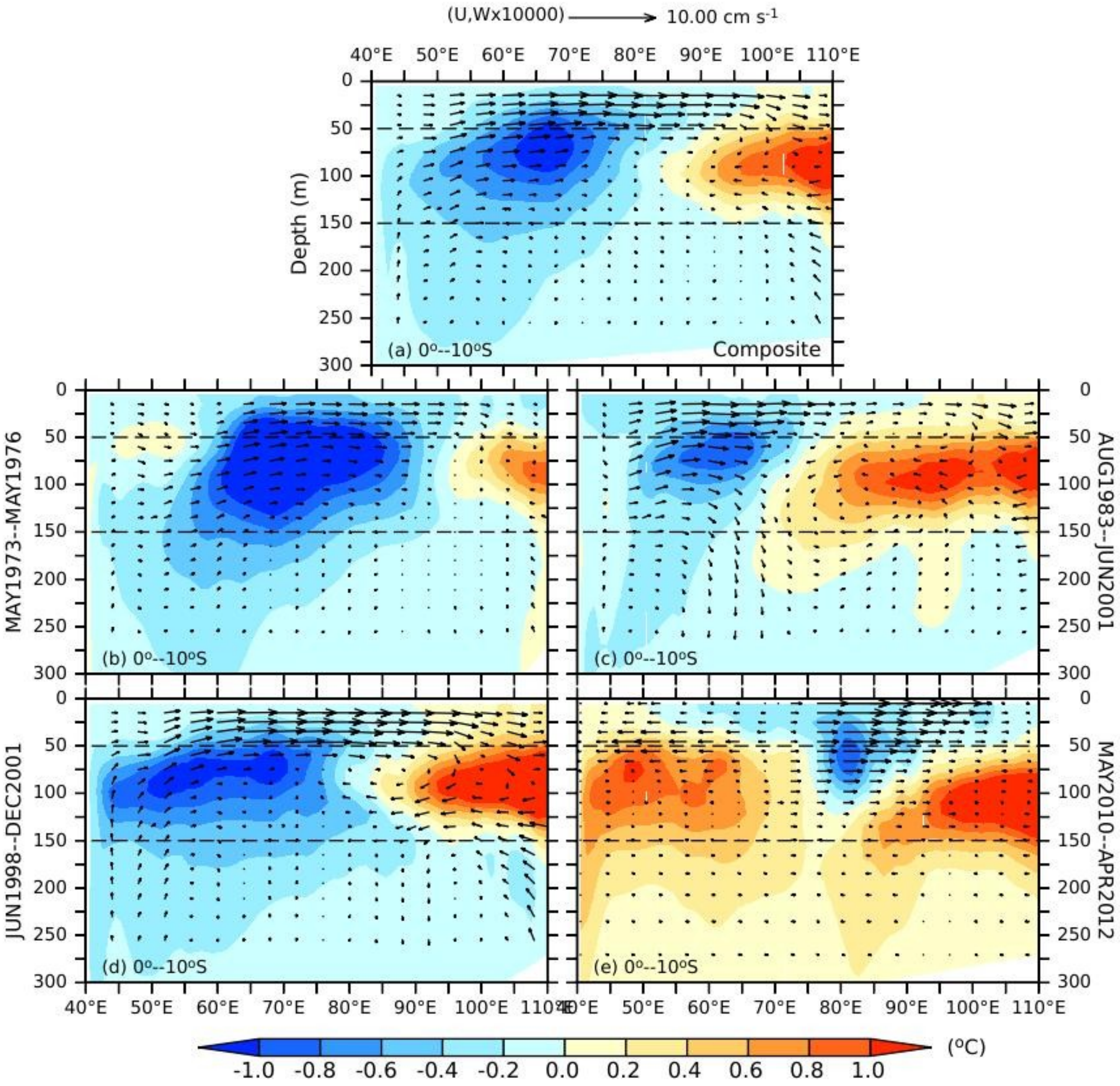
4. More intense cooling is happens in the TRIO region only during the prolonged La-Nina times.



Composites of the wind-stress curl anomalies during the prolonged La-Nina times.

1. The westerlies in the EEIO exhibits a positive curl along the eastern boundary of the IO which promotes warming through downwelling there.

2. The cyclonic wind patterns south of 10^{o}S exhibits negative wind-stress curl which promotes cooling by forcing westward propagating upwelling Rossby waves there.



Composites of vertical temperature anomaly profiles during the prolonged La-Nina times.

1. Downwelling along with strong warming are seen in the eastern IO during prolonged La-Nina times.

2. Strong cooling is observed only during the prolonged La-Nina times.

3. Strong eastward transport is seen during the prolonged La-Nina times which cools down the mixed layer in the eastern IO as a result a decay phase in the warming is seen during the prolonged La-Nina events.

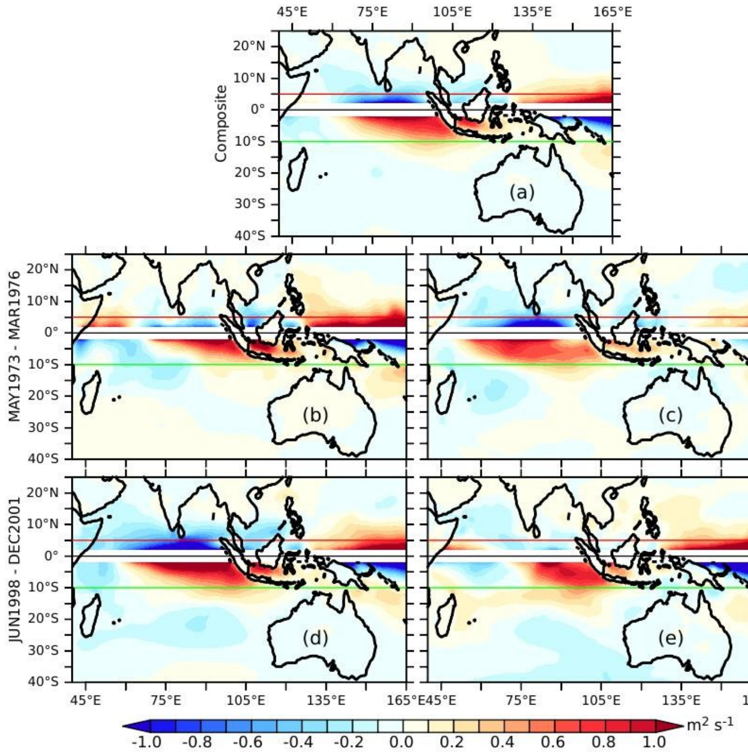


Fig1: Meridional Ekman transport (MET) anomalies during the prolonged La-Nina times.

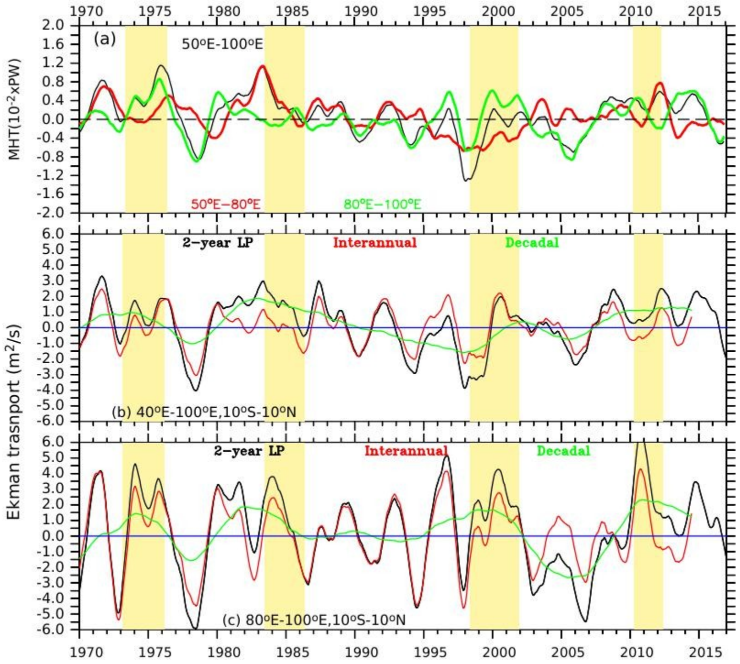
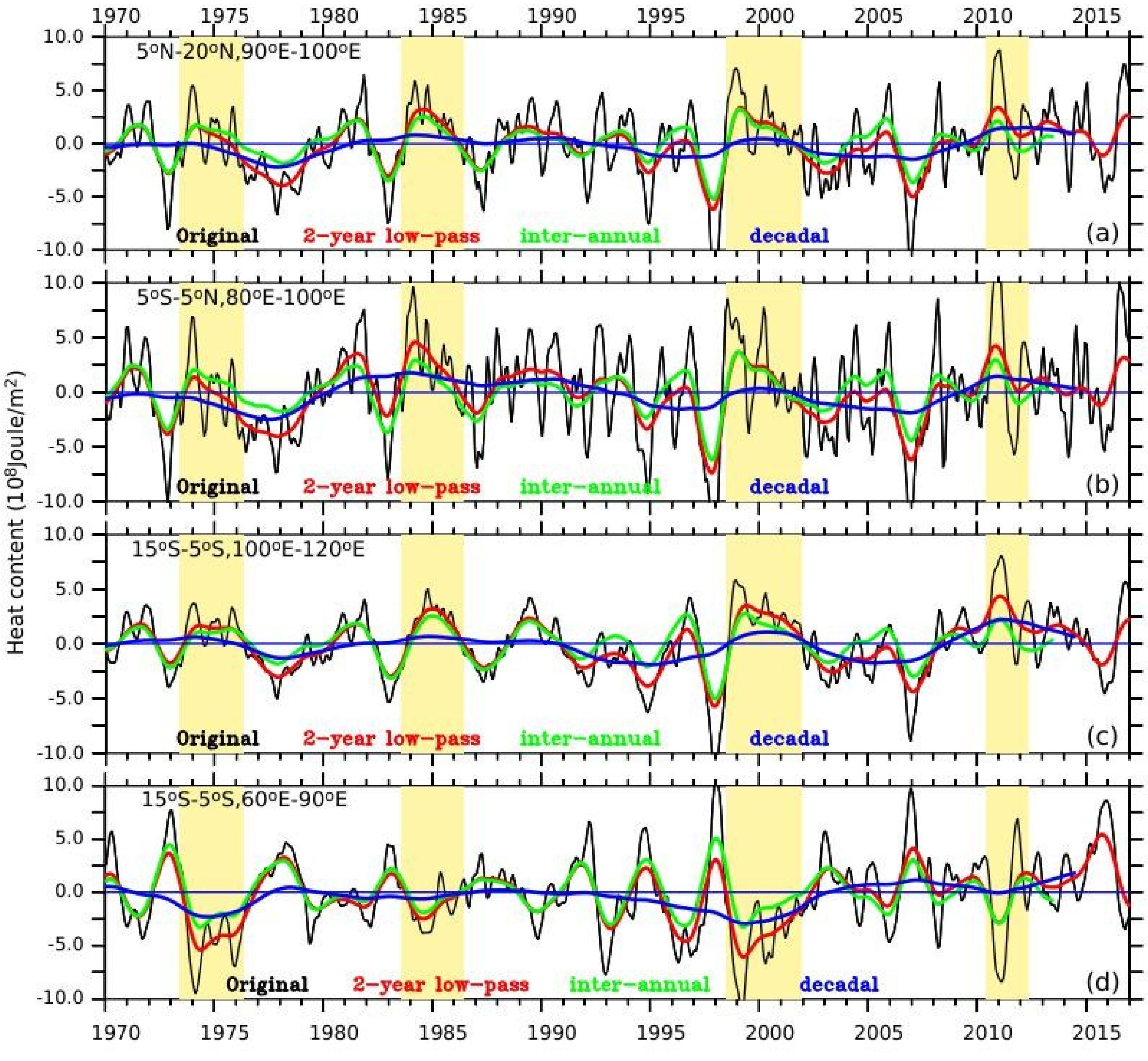


Fig2: Time series of Meridional Heat Transport (MHT) and Meridional Ekman Transport (MET) over chosen spatial domain.

1. Strong convergence for MET is seen along the equator during the prolonged La-Nina times.

2. Northward net transport is evident in the eastern IO for the MET.

3. MHT also shows strong northward cross-equatorial transports during these prolonged La-Nina times.



Time series of heat content anomaly averaged over different spatial domains (BOB, EEIO, SEIO, TRIO)

1. Warming is seen during the prolonged La-Nina years in the 50m—150m heat content along the eastern IO region.

2. A strong cooling is evident for the TRIO regions during these prolonged La-Nina times.

3. Wherever La-Nina (El-Nino) coincides with a negative (positive) IOD year enhanced warming (cooling) is seen in the eastern IO. TRIO region opposite is seen during these time.

Summary:

1. The east-west themocline and subsurface temperature gradients observed in the equatorial IO are associated with the prolonged La-Nina events.

2. The intense cooling in the TRIO region and its eastward extension of TRIO region are the characteristics of these prolonged La-Nina events.

3. The anomalous subsurface warming in 50m—150m depth range, sea-level rise and thermocline deepening in the Bay of Bengal are also happens due to these prolonged La-Nina events.

4. The upper ocean heat-content in the eastern and southeastern Indian Ocean shows the dominance of the inter-annual variability but in the recent years the decadal variability also have comparable strength. In TRIO region opposite is seen.

The equatorial IO winds and OHC response in the recent years (La Nina period 2010-12) is different from the previous such events highlighting the possible change in IO processes during the recent years and is consistent with recent study (Sandeep et al. 2020).