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A possible new role of Indian Ocean in causing the recent global warming hiatus

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Introduction

Recent studies have documented a slowdown in the warming rate, apparently termed as ‘hiatus’ in annual mean global surface temperature. In the recent decade (2002-2012), sea surface temperature over the tropical Pacific Ocean has shown cooling trend despite a continued rise in SST over the tropical Indian Ocean. Strong cooling in Pacific Ocean is attributed to this hiatus in global warming (Kosaka and Xie (2013).

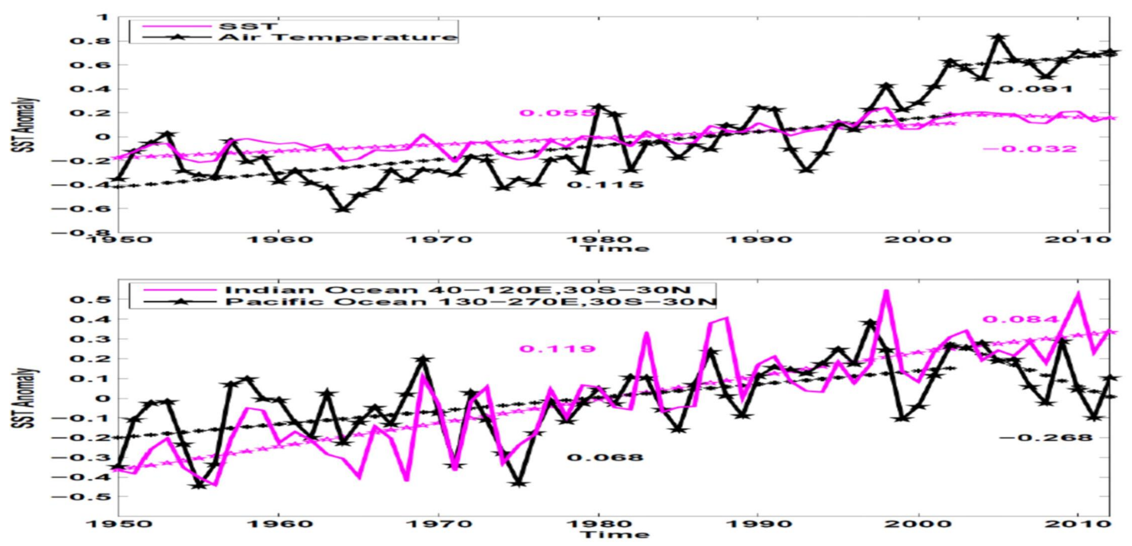
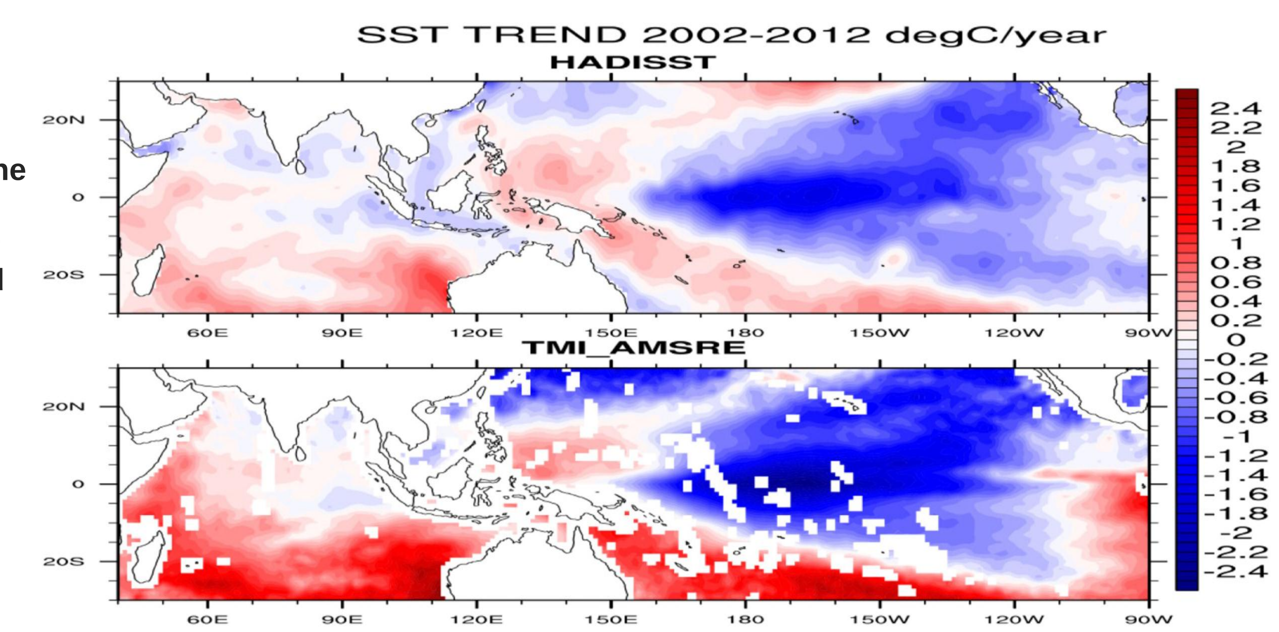


Fig. Time series of (a) annual mean global sea surface temperature (°C;magenta) and 2mair temperature (°C; black) (b) SST (°C) averaged over the tropical Indian Ocean (40°E-120°E,30°S-30°N; magenta) and tropical Pacific Ocean (130°E-90°W, 30°S-30°N; black) for the period 1950 to 2012, along with linear trend (dashed line) calculated for two different periods (1950–2002 and 2002–2012).Slope of each trend line is labeled in respective line color.

- Global surface air temperature and global SST show a consistent warming for the period 1950-2002;No significant warming in SST in the recent decade (2002-2012)
- Indian Ocean warming has slowed down (0.084 °C/d from 0.119 °C/d); Warming trend over the Pacific Ocean is reversed (−0.268 °C/d from 0.068 C/d).



- Eastern and central parts of the Pacific Ocean contribute mainly to basin wide cooling trend observed in the tropical Pacific Ocean.
- Indian Ocean shows warming trend in the western equatorial and the southern tropical Indian Ocean.

Results

- Sudden drop in correlation indicates significant changes in teleconnection
- The Indian Ocean SST is found to be more conducive for convection in the recent decades and it could impact the Pacific Ocean climate by modulating Walker circulation (McPhaden et al., 2011; Luo et al., 2012; Rao et al.,2012; England et al., 2014).

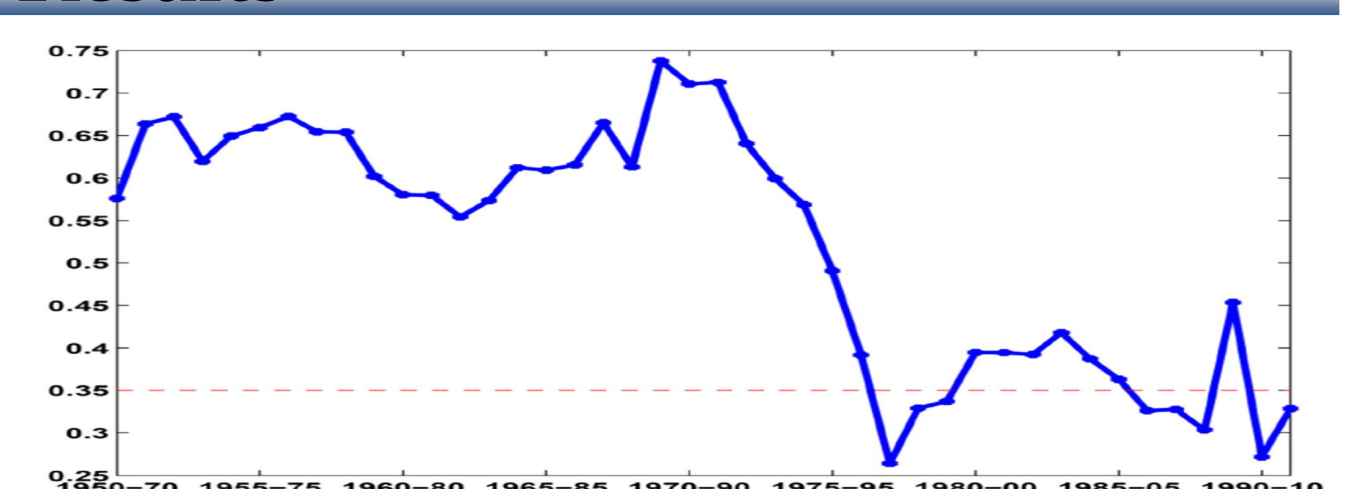


Fig. Twenty one year running correlation between the two detrended SST time series obtained by averaging over the tropical Indian Ocean (40°E-120°E,30°S-30°N) and tropical Pacific Ocean (130°E-90°W, 30°S-30°N. Dashed red line in indicates where correlation is 90% significant. X-axis denotes 21 year running window chosen.

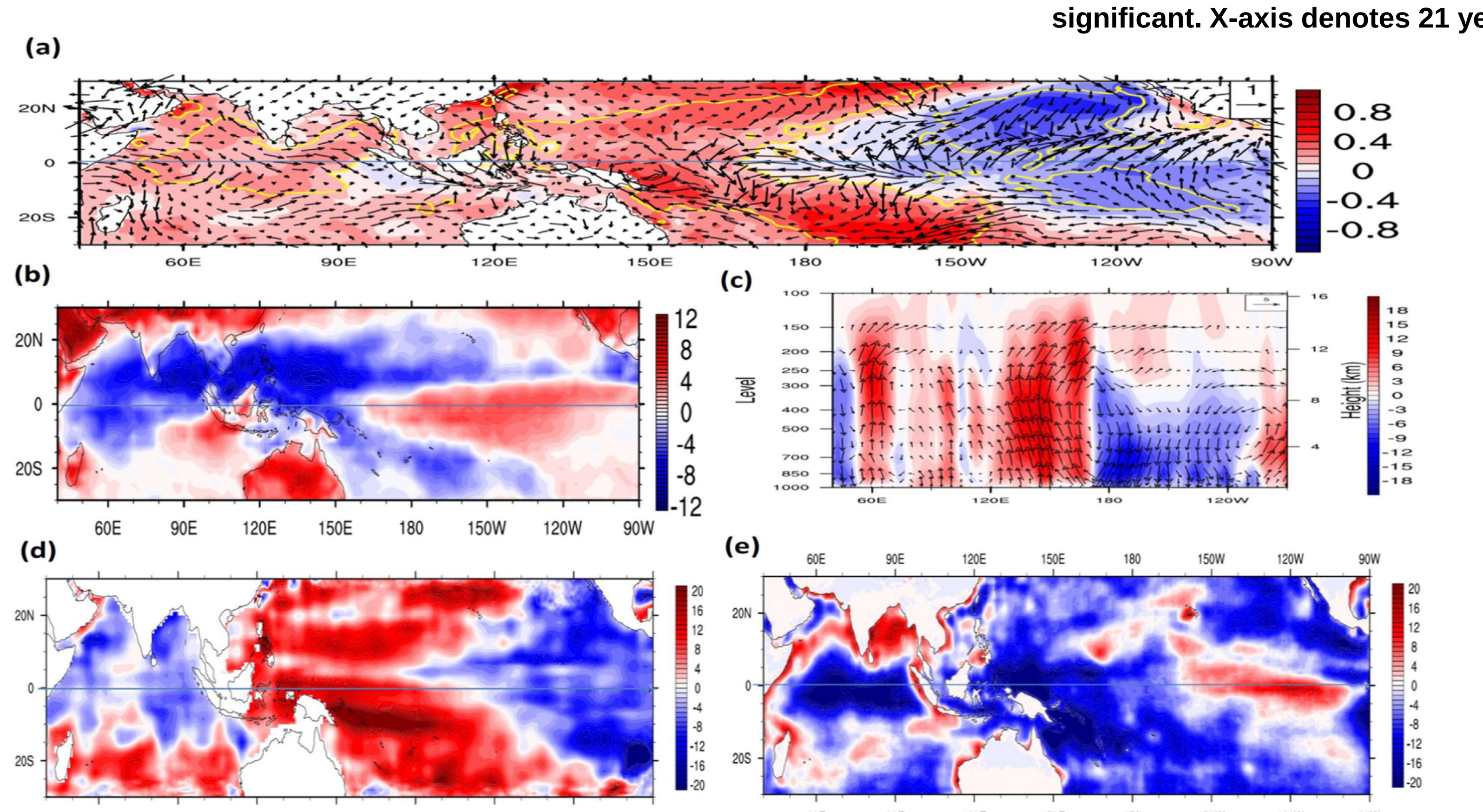
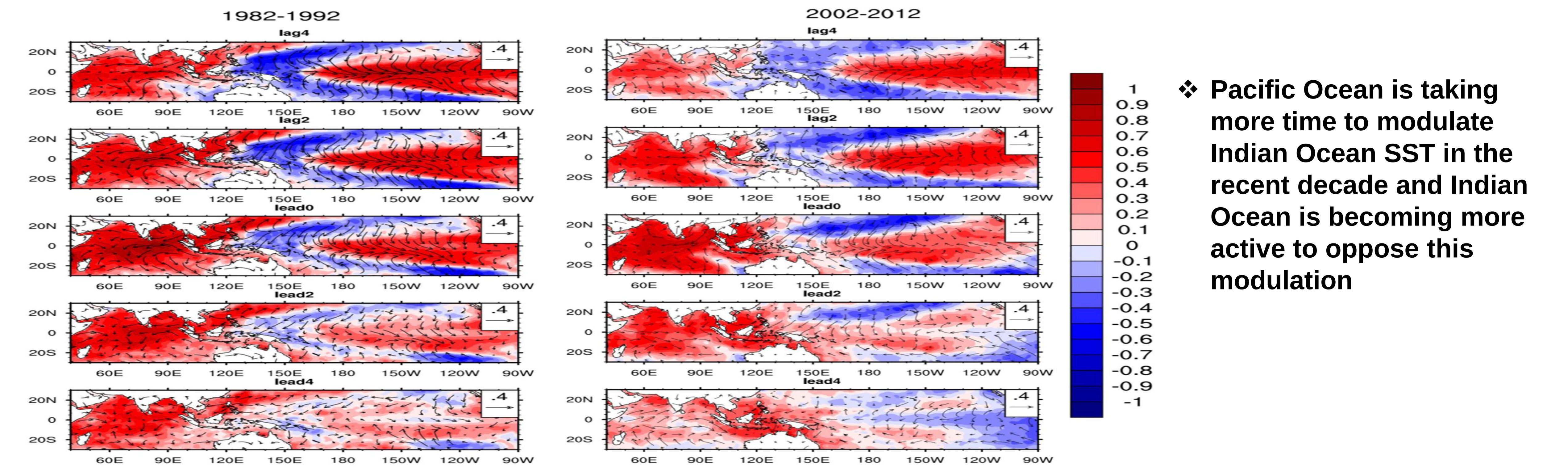


Fig. Difference between hiatus period (2002−12) and pre-hiatus period (1982−92) in (a)mean SST (°C) overlaid by winds (m/s), (b) OLR (W/m2), (c) walker circulation averaged over 5°S-5°N (omega multiplied by a scale factor=−5 ∗ absolute value of (average of u/average of omega)), (d) 20 °C isothermal depth (d20) and (e) net surface heat flux. Yellow line in (a) indicates where difference in SST is 90% significant

- Significant change in mean SST with strong warming in the Indian Ocean and the western Pacific Ocean and cooling in the eastern Pacific Ocean. 20 °C isotherm depth difference signature similar to SST difference
- Reduced OLR over the Indian Ocean and the west Pacific indicator of enhanced convective activity and a dominant heat source in the equatorial region.
- Increase in net surface heat flux in the equatorial eastern Pacific Ocean extending to the central Pacific Ocean

Results (contd.)



- Pacific Ocean is taking more time to modulate Indian Ocean SST in the recent decade and Indian Ocean is becoming more active to oppose this modulation

Fig. Lead lag correlation of monthly SST and wind anomalies wrt a reference time series obtained by averaging the SST anomalies over the Indian Ocean

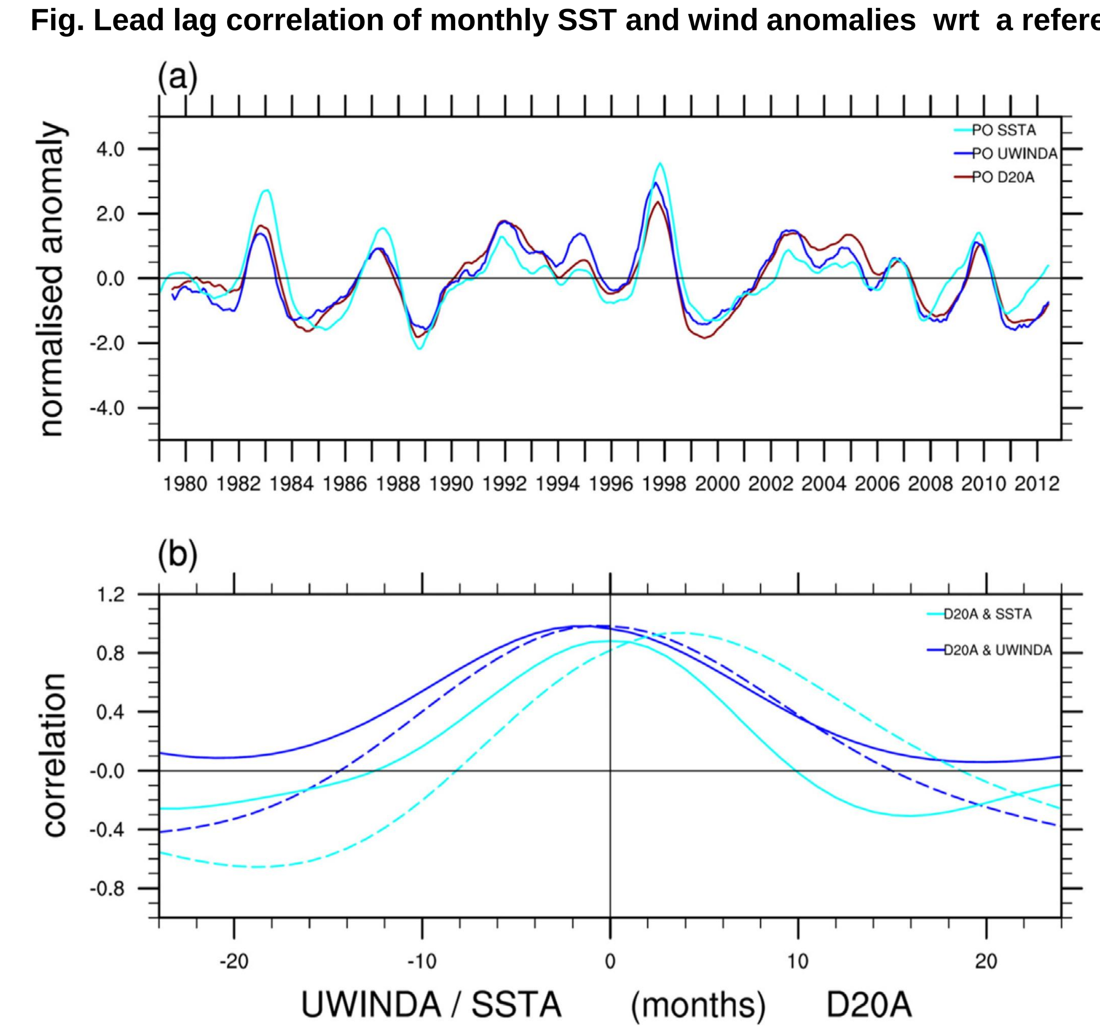


Fig (a) Normalized time series of detrended anomalies of zonal wind averaged over Niño 4 region and SST and d20 averaged over Niño 3 region, (b) lead-lag correlation of d20 with SST and d20 with zonal wind. Dashed (Solid) line denotes pre-hiatus (hiatus) period.

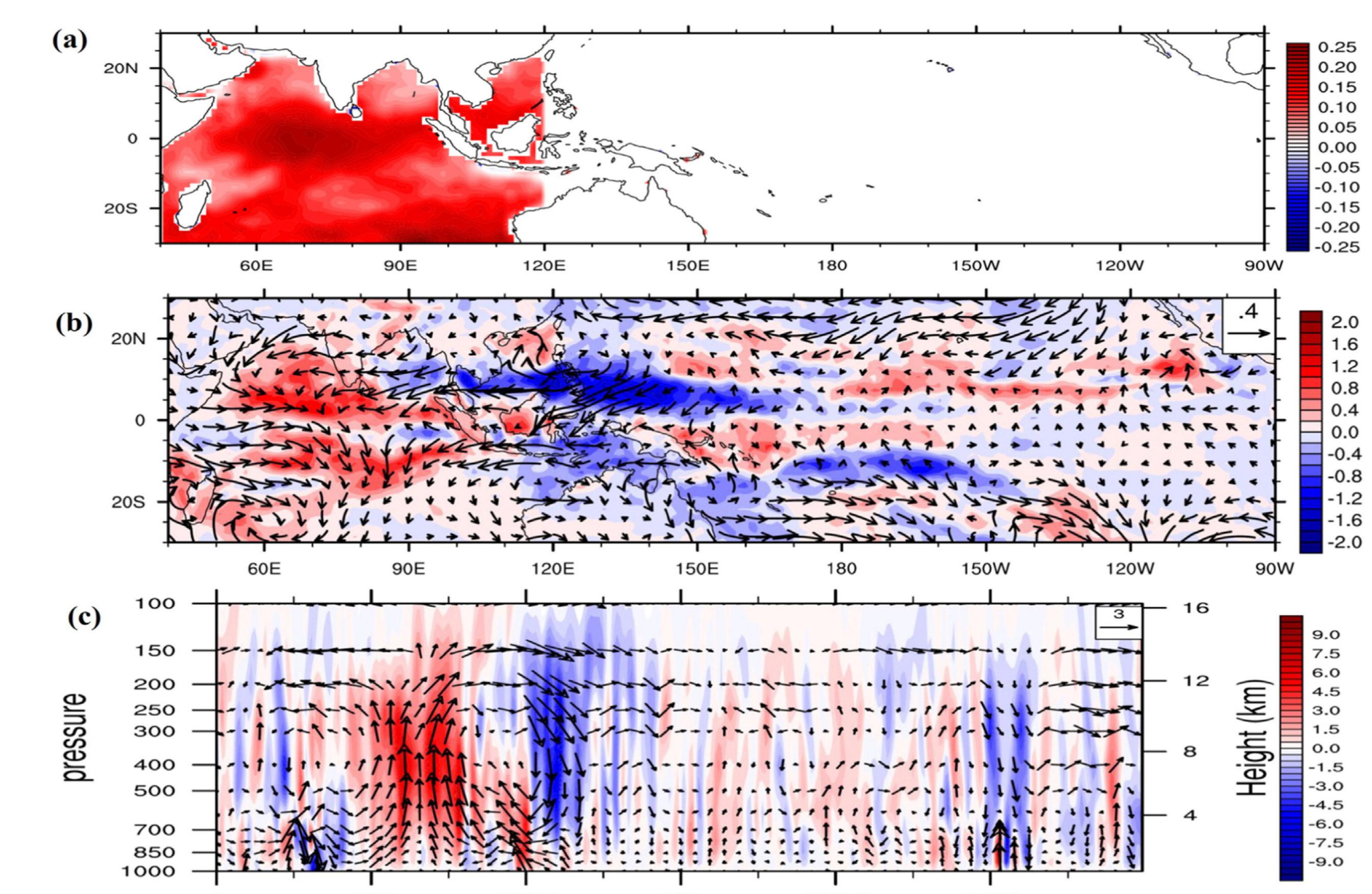


Fig. The difference between the control run (CTL) and Indian Ocean non-warming (IONW) run of ECHAM 5 AGCM. (a) SST; (b) Wind vector (m/s) at 2 m height and precipitation (shaded; units: mm/day) (c)Walker circulation averaged over 5°S-5°N (vertical velocity is shaded).

- Increased (decreased) precipitation anomaly over the Indian Ocean (Maritime continent)
- Strengthened easterlies over western Pacific Ocean in response to the Indian Ocean warming

Conclusions

- Indian Ocean warming partly controlling the Pacific Ocean cooling by enhancing the surface anomalous easterlies over western central Pacific Ocean.
- Anomalous easterlies along the western equatorial Pacific force Ekman divergence; excites upwelling Kelvin waves
- Strong easterly zonal wind anomaly over Niño 4 region shoals 20 °C isothermal depth anomaly in the eastern Pacific after two months and this shoaling in 20 °C isothermal depth cools SST in the eastern Pacific Ocean.

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