Global Warming Hiatus Simulated in HadGEM2-AO

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The increase rate of the observed global surface air temperature has reduced in recent decades, although the green house gases concentrations continuously increase. This phenomenon is called hiatus or warming pause. The previous study shows possibility that the warming pause might be linked to La Niña-like conditions and relatively common phenomenon while the global warming continues (Eastering, 2009; Meehl et al., 2011; Kosaka and Xie, 2013). Trenberth and Fasullo(2013) argued that global warming is one side of the long-turn changes in Pacific by that the deeper ocean gains a large amount of heat from the upper ocean. We investigated the characteristics of the warming pause in global warming scenario by HadGEM2-AO (Baek et al., 2013). The RCP8.5 experiment performed by the HadGEM2-AO was run for 95 years(2006-2100) and the radiative forcing of the experiment reached to 8.5W/m^2 by 2100 which means very high baseline emission scenario as a result of additional anthropogenic gases in atmosphere.

2. Global Warming Pause

Observed Rate Change of Global Warming

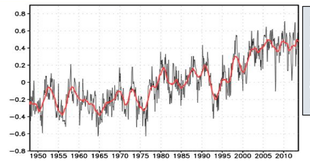

Fig. 1. Time Series of global averaged surface air temperature (black) and its 2 year moving average (red) of NCEP-NCAR Reanalysis data.

- ✓ Observed global averaged surface air temperature increases with increasing in atmospheric carbon dioxide concentration.
- ✓ Temperature slowed down for recent decade although continuously increasing in carbon dioxide concentration.

Global Warming Hiatus in Future

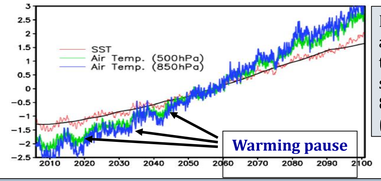

Fig. 2. Time Series of global averaged sea surface temperature (red) and surface air temperature at 850hPa (blue) and 500hPa (green) .

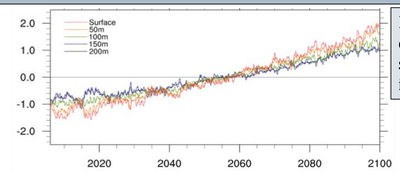

Fig. 3. Global averaged ocean temperature from surface to 200m of 50m interval.

- ✓ Global averaged sea surface temperature has several warming pause decades in global warming scenario in future.
- ✓ Global averaged sea surface temperature has same increasing patterns as global averaged air temperature at 850 hPa and 500 hPa (left), but has opposite pattern as the deeper layer below 100 m (right).
- ✓ It means that the deeper layer gains heat from the upper layer during warming decades. (Meehl et al., 2011; Trenberth and Fasullo, 2013)

Warming Hiatus under Global Warming

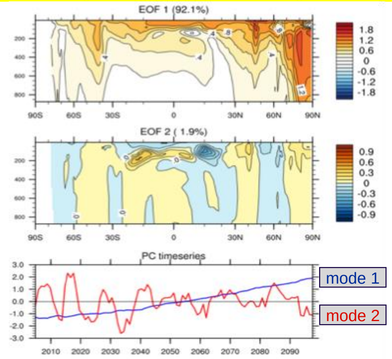

Fig. 4. The first and second EOF modes for annual zonal mean ocean temperature and their PC time series.

- ✓ The results of the empirical orthogonal function (EOF) analysis of zonal averaged ocean temperature show that the first mode indicates the global warming for whole period, and the second mode is decadal fluctuations which are related to global warming pause decades.
- ✓ Surface and subsurface layer and high-latitude layer in north hemisphere is more warming during global warming (first mode).
- ✓ Surface ocean temperature decreases against the deeper layer temperature under 100m increases for the hiatus decades (second mode).

3. La Niña and Warming Hiatus

La Niña and Warming Hiatus

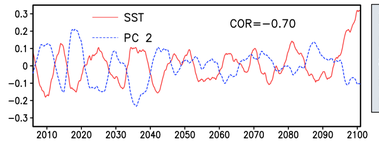

Fig. 5. Time Series of PC2 (blue) and global averaged annual sea surface temperature anomalies (red).

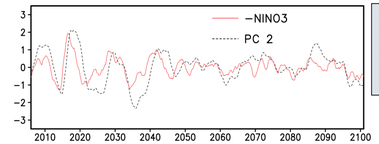

Fig. 6. Time Series of PC2 (black) and La Niña index (Nino3 index multiplied by -1) (red).

- ✓ PC time series of EOF second mode (PC2) has opposite phase with global averaged sea surface temperature anomalies (fig. 5), and in phase with La Niña index (fig. 6)

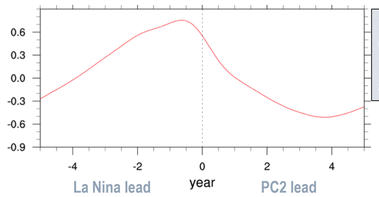

Fig. 7. Lead – lag Correlation Coefficient between La Niña index and PC2 time series.

- ✓ PC2 has peak after about 7 months of occurrence of La Niña.

Lead-lag Regression Coefficient

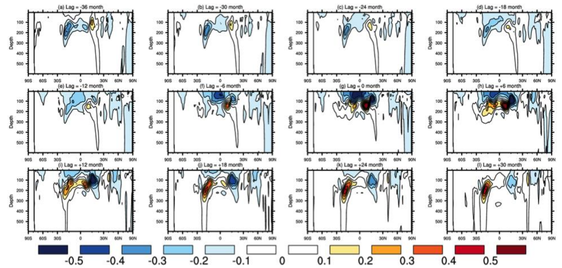

Fig. 8. Lead-lag regression coefficient of La Niña index on zonal averaged ocean temperature.

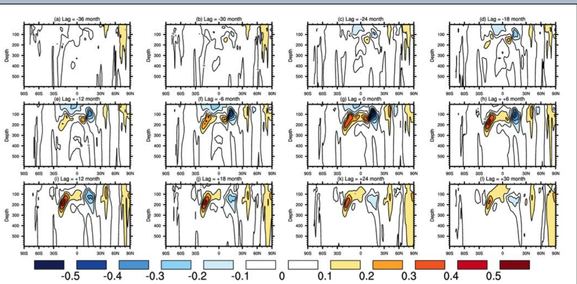

Fig. 9. Same fig. 8 but PC time series.

- ✓ Heat of the layer from 100m to 200m in low-latitude transports southward and then into deeper ocean during around La Niña events and global warming pause decades.

5. Conclusion

We investigated the characteristics of the warming pause simulated in HadGEM2-AO. The EOF analysis of zonal averaged ocean temperature shows the cold anomalies appear in equatorial upper ocean during hiatus period. The result indicates that La Niña events are related to the global warming hiatus. During hiatus period, heat transports subsurface layer into deeper ocean. The results of this study will be useful to understanding warming pause in recent decade.

References

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