# 5B.10 Decadal change in the tropical Pacific Ocean

Hye-Rim Kim and Soon-Il An
Department of Atmospheric Sciences, Yonsei University
Seoul, Korea

## 1. Introduction

The long-term accumulation of the worldwide meteorological, oceanic, and biological observations revealed the existence of the decadal change in the global climate system. The instrumental observations, for example showed the significant decadal change, especially in the North Pacific (Nitta and Yamada 1989; Trenberth and Hurrel 1994), while the role of the tropical Pacific was also stressed as a pivot of the decadal change (e.g., Cane 1998). On the other hand, Chang et al. (2001) and Giese et al. (2002) argued that the decadal variation associated with the late 1970s climate shift could be originated from the south Pacific. A coupled GCM also simulated the decadal ENSO-like variation that was originated from the south Pacific (Luo et al. 2003). In addition, the relatively longer proxy data covering the recent 86 years showed a decadal thermal advection staring from the southwestern Pacific and reaching to the eastern equatorial tropical Pacific as a form of the large-scale oceanic waves (Holland et al. 2006). It is hard to identify the origin of the decadal variation or the decadal variation may be generated in any place by a different mechanism. Since the origin of the decadal variation remains in debate and a lot of studies are necessary to explore this problem, we do not aim to show the origin of the decadal variation. Whereas we would analyze the life cycle of the decadal variation appeared in the tropical Pacific Ocean.

## 2. Results

Here, we use the SODA-POP global ocean assimilation data, which spans from 1958 to 2001. To isolate the decadal variation from the raw data, the annual cycle has been removed, and the 7-year running average has been taken to remove the considerable interannual variability.

To describe the oceanic thermal advection, we first show the spatial patterns of Pacific-basin-averaged ocean temperature anomalies in the vertical section at four year intervals from 1961 to 1998 (Fig. 1). In the early 1960s, the maximum warm core is located at 10S and around 270m depth. For a decade, this warm core slowly moves to the equator as well as to upward, and thus the maximum warm core is observed at the equator and around 170m depth during the late 1960s – the early 1970s. After that, the one branch originated from this warm core moves to surface and the other branch goes to the subtropical north Pacific and slightly downward. During this separation, the intensity of the warm core becomes weaker. During the early 1980s, almost opposite pattern to that in the early 1960s is observed such that the cold core in the south-to-equatorial Pacific and warm core in the north Pacific are appeared. During the late 1980s to the early 1990s, the cold core moves to the upper equatorial ocean, and the warm core in the north Pacific disappears. Interestingly, the north to south movement of anomalies is also observed in near the surface. This movement is obviously related to the movement of the subsurface temperature anomalies. However, it is unclear whether it is related to the thermal advection or the atmospheric teleconnection.

Together with the meridional propagation, the thermal advection in the zonal section is shown in Fig. 2. From the early 1960s to the late 1970s, the warm water in the subsurface (100 to 250 m depth) at the western Pacific and the cold water in the surface at the central-to-eastern Pacific are observed as similar to the ocean condition during La Nina. On the other hand, during the early 1980s to the late 1990s, the situation is reversed such that the cold water in the subsurface western Pacific and the warm water in the surface eastern Pacific are observed. At the same time, the steep east-west slope of the equatorial thermocline (approximated by the 20C isotherm) is replaced with relatively flat since the late 1970s. Interestingly, during the transition period (1977 ~81), both the surface temperature and subsurface temperature anomalies are small.

The time series of the anomalous wind stress curl in the southwestern Pacific, the subsurface temperature anomalies over the tropical western

---

* *Corresponding author address*: Soon-Il An, Yonsei University, Department of Atmospheric Science, Yonsei University, Seoul, 120-749, Korea. E-mail: sian@yonsei.ac.kr

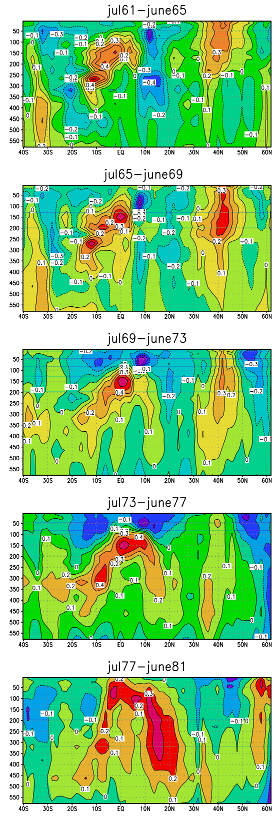


Fig. 1 Meridional cross section of zonal-mean ocean temperature anomalies. The zonal-mean is taken over the Pacific basin. Each panel shows four-year averaged quantities, and the period used for the average indicates at the top of each panel.

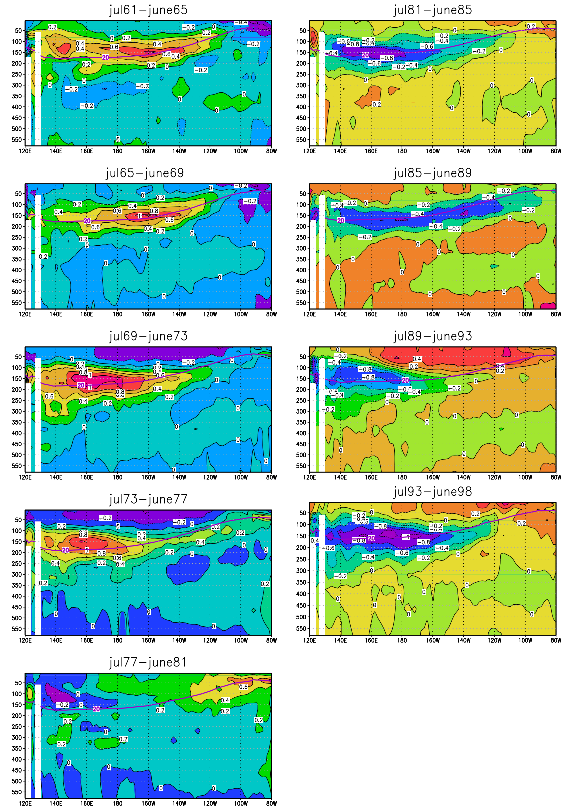


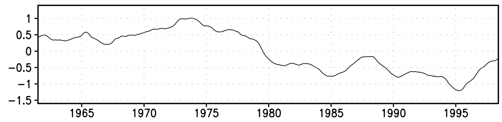
Fig. 2 As in Fig. 1 except the zonal cross section along the equator

Pacific, and the anomalous zonal wind stress over the equatorial Pacific are shown in Fig. 3. A well matching between the anomalous wind stress curl in the southwestern Pacific and the subsurface temperature anomalies over the tropical western Pacific manifests that the subsurface temperature anomalies are presumably caused by the wind stress curl in the corresponding area (Chang et al. 2001). The zonal wind stress anomalies over the equatorial Pacific show an increasing tendency, indicating the weakening trend of the trade wind. The weakening of the trade wind is dynamically consistent with the flatting of the thermocline slope in the equatorial Pacific since the late 1970s.

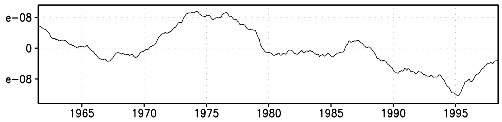
The evolution features in above figures are similar to the general El Nino life cycle. For instance, before a transition, the warm water in the subsurface western Pacific is accumulated (Wyrtki 1975). During the transition, the accumulated warm water in the subsurface transports to eastward along the mean thermocline and the temperature at the surface in the eastern Pacific becomes warmer. After the transition the contrast between the cold subsurface water in the western Pacific and the warm surface water in the eastern Pacific is intensified, and the trade wind over the equatorial Pacific becomes weaker and the thermocline slope becomes relatively flat like the El Nino condition (see Fig. 3c; i.e. Bjerknes 1969). In this regard, the mechanism attributing to ENSO evolution may be responsible for this decadal change as well.

The ocean model experiment forced by the wind stress curl associated with this decadal change is performed (not shown here). The results demonstrate that rather than the equatorially confined wind stress curl, the off-equatorial wind stress curl plays an important role of generating the warm water accumulation, which is different from the ENSO. In ENSO case, the intensified convective heating over the central Pacific and its resultant zonal wind stress is the main mechanism for the accumulation of the warm water in the equatorial western Pacific. However, the warm water accumulation in this case is done by the wind stress curl anomaly in the southwestern Pacific, and it is unclear what causes this wind stress curl anomaly. Thus, the comprehensive

(a) filtered temperature anomaly within 130−170E,5N−5S,100−250m



(b) filtered curl anomaly within 160E−150W,EQ−20S



(c) filtered zonal windstress anomaly along equator,120E−120W

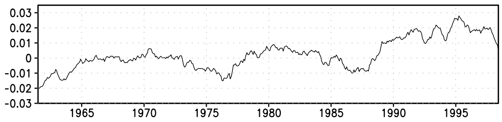


Fig. 3 Time series of (a) the anomalous wind stress curl in the southwestern Pacific, (b) the subsurface temperature anomalies over the tropical western Pacific, and (c) the anomalous zonal wind stress over the equatorial Pacific.

picture presenting the coupled atmosphere and ocean process for the decadal change in the tropical Pacific is not yet completed. The further study needs to be done.

## 3. Summary

Using the SODA-POP ocean assimilation data, the decadal evolution in the tropical Pacific Ocean spanning from 1961 to 1998 is analyzed. During the pre-1980, the ocean temperature anomalies in the meridional cross section were positive in the subsurface southwestern Pacific and negative in the surface layer of the tropical Pacific. This more or less stationary pre-1980's pattern reversed after early 1980s. Rather than gradual changing, an abrupt phase transition occurred between 1977 and 1981. During the transition period, the trade wind becomes weaker, and the warm subsurface water in the western Pacific moved toward the surface layer of the eastern equatorial Pacific as well as toward the subsurface in the northwestern Pacific. The transition mechanism resembles the recharge-oscillator hypothesis on the ENSO such that the warm water is accumulated in the western Pacific before the ENSO starts and the weakening of the trade wind may be related to the triggering mechanism.

## Reference

Cane, M. A., 1998: Climate change: A role for the tropical Pacific. *Science*, **282**, 59-61.

Chang, P., B. S. Giese, L. Ji, H. F. Seidel, 2001: Decadal change in the south tropical Pacific in a global assimilation analysis. *Geophy. Res. Lett.*, **28**, 3461-3464.

Giese, B. S., S. C. Urizar, and N. S. Fuckar, 2002: Southern Hemisphere origins of the 1976 climate shift. *Geophy. Res. Lett.*, **29**, doi: 10.1029/2001GL013268.

Holland, C. L., R. B. Scott, S.-I. An, and F. W. Taylor, 2006: Propagating decadal sea surface temperature signal identified in modern proxy records of the tropical Pacific. *Clim. Dyn.*, doi: 10.1007/s00382-006-0174-0.

Luo, J.-J., S. Masson, S. Behera, P. Delecluse, S. Gualdi, A. Navarra, and T. Yamagata, 2003: South Pacific origin of the decadal ENSO-like variation as simulated by a coupled GCM. *Geophy. Res. Lett.*, **30**, doi: 10.1029/2003GL018649.

Nitta, T., and S. Yamada, 1989: Recent warming of t ropical sea surface temperature and its relationship to the Northern Hemisphere circulation. *J. Meteor. Soc. Japan*, **67**, 375-383.

Trenberth, K. E., and J. W. Hurrel, 1994: Decadal atmosphere-ocean variations in the Pacific. *Clim. Dyn.*, **9**, 303-319.

Wyrtki, K. 1975: El Nino -- The dynamic response of the equatorial Pacific Ocean to atmospheric forcing. *J. Phys. Oceanogr.*, **4**, 91-103.