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Relationship between Oceanic Variability over the Equatorial Pacific and Atmospheric Large Scale Variability over Midlatitude Using Wind Anomaly Index

Kyoung-Min Lee and Jai-Ho Oh

Dept. of Envir. Atmos. Sci., Pukyong National University, Busan, Korea

1. Introduction

It is likely that the large-scale variation over the North Pacific influences not only on the Pacific Ocean but on the oceanic ecosystems. There are a number of studies on the low frequency variability known as the Pacific Decadal Oscillation (PDO) and the stock size of many important commercial species (e.g., FAO 1997a, b Klyashtorin, 2000). Consequently, it is very interesting to understand the mechanism of how the atmospheric circulation influences the midlatitude Pacific Ocean (PO). It has been known that the midlatitude atmosphere mainly responds to remote themal forcing in the tropical oceans (Bjerknes1966, 1969; Wallace and Gutzler, 1981; Horel Wallace, 1981). The hypothesis that the variation of tropical PO induces responses in the extratropical North Pacific via an altered atmospheric circulations excited by tropical SST forcing has been noted by many studies (e.g., Trenberth and Hurrell, 1994), although the prominent SST anomalies observed in the tropical Pacific are coincident with pronounced opposite anomalies in the extratropical PO (Lau, 1997).

A recent study suggested that the variability of atmospheric circulation in the Eurasia might be the source of the decadal PDO-like variability in the extratropical PO distinguished from the El Nino-Southern Oscillation (ENSO) (Frauenfeld and Davis, 2002). They also recommended that it is necessary to considering the atmospheric circulation in entire Northern Hemisphere (NH) to understand the variability in the extratropical PO. Considerable efforts have been expended to illustrate the influence of air-sea interactions on atmospheric variability. Meanwhile, Lau (1997) found that the atmospheric circulation plays a role of bridge between oceanic anomalies in the tropical sector and those in the midlatitudes "The Atmospheric Bridge".

The air-sea interaction is one of important factors not only to determine the development of synoptic system at the Northeast Asia where the pacific jet is located but also to modulate the global climate system. The atmospheric variation (as like Pacific Decadal Oscillation) is effects on maritime resource (Mantua et al., 1997). In this article a simple index called Wind Anomaly Index (WAI) has been introduced to explain the variability in the PO based on consideration of the interaction between the atmospheric circulation over the multitude PO and sea surface temperature (SST). In the midlatitude PO, SST anomaly might be induced by altered surface energy fluxes between atmosphere and water, vertical turbulent mixing from the deep ocean, and vertical and horizontal motion (Alexander, 1992). Consequently, surface wind strength may play a key role to the formation of negative (positive) SST anomalies in the PO. Emery and Hamilton (1985) showed such a relation between surface wind change and SST anomaly.

2. Data and methods

2.1. Data

The SST data used in this analysis are on a 2.5° X 2.5° grid from the NCAR/NCEP reanalysis data for 20°N-60°N and 120°W -120°E were extracted for 1953-1999. The atmospheric wind data consist of monthly NH 200 hPa and 1000 hPa for 1953-1999 derived from 'the NCAR/NCEP reanalysis' (Kalney et al., 1996). And we used following several climatic indices computed by NCAR, CPC (Climatic Prediction Center), JISAO (Joint Institute for the Study of Atmosphere and Ocean).

(1) NCEP/NCAR reanalysis monthly data
 - Zonal wind at 200, 500, 850 and 1000hPa
 - Sea Surface Temperature
(2) North Pacific Index: NCAR
(3) Southern Oscillation Index: CPC
(4) Artic Oscillation Index: CPC
(5) Pacific Decadal Oscillation Index: JISAO
(6) Pacific North American Index: JISAO

In this research, we attempted to explain variability over North Pacific with a newly defined index, Wind Anomaly Index (WAI), which has been introduced to consider interaction between the atmospheric circulation and sea surface temperature (SST) anomalies. And we performed wavelet and periodic analysis for the analysis of climatic variations. And, we compared to other variables and several indices such as the Southern Oscillation Index and Pacific Decadal Index using WAI.

2.2. The definition of WAI and hypotheses

WAI is a simple index to represent atmospheric variations and air-sea interaction. When WAI has positive (negative) values means zonal winds become stronger(weaker) than normal. Then SST is lower(higher) than normal on the experimental region. WAI is defined as the ratio of the number of points where the zonal wind is stronger than the domain average for the target period (1953-1999)to the total number of data points in the target domain. WAI is an index within 0 to 1. WAI becomes 0, when the wind speed is weaker than the average at all data point. in target region. By the same manner WAI becomes 1, when the wind speed is stronger than the average at all data point. Otherwise WAI is remained within 0 and 1 (Eq. 1~3).

$$WA_{ij} = \frac{Area \quad of\ positive \quad monthly \quad wind \quad anomaly}{Area \quad of\ total \quad experimental \quad region} \qquad \text{-----(1)}$$

$$\overline{WA} = \frac{\sum_{j=1}^{N}\sum_{i=1}^{M} WA_{ij}}{T} \qquad \text{-----(2)}$$

i : months
j : years (N= 1, 2, 3, ... , number of experimental year)

$$WAI = WA_{ij} - \overline{WA} \qquad \text{-----(3)}$$

This original WAI has reasonably explained the variation of sst, however, it does not count the impact of air-sea interaction. The cold northerly wind may cause the cooling of sst in addition to the cooling effect by deepening mixed layer, while the warm southerly wind may cancel the cooling effect by deepening mixed layer. In this study WAI has been modified to include the surface heat exchange with the atmosphere by adding 1 when the wind direction is located within NW to NE (cold advection), and subtract 1 when the wind direction is located within SW to SE (warm advection). For easterly and westerly the original definition has applied by assuming the impact of air advection on the air-sea interaction is not significant. As a result the new WAI has a value -1 to 2.

In Air-Sea interaction the anomaly of sea surface temperature (sst) might be explained by two physical processes in the ocean. One is air-sea interaction and the other is variation of mixed layer depth. The surface of ocean will loose (gain) heat to the atmosphere when the atmosphere is colder (warmer) than the ocean. At same time the deepening of mixed layer in the ocean will cause cooling the mixed layer by mixing with colder deep ocean water.

3. Results

There is negative correlation between Twelve months

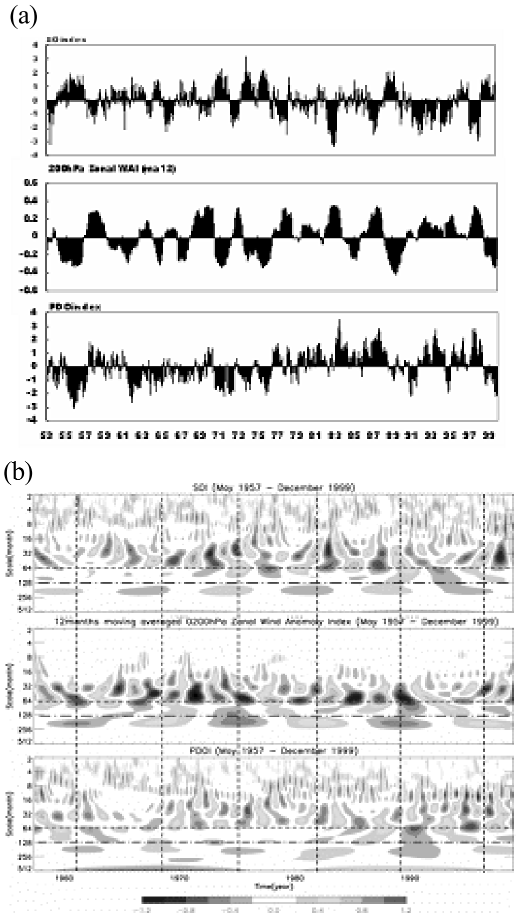

Fig. 1. Time series(a) of SOindex, 12months moving averaged WAI(200hPa) and PDOindex. Real parts of Wavelet transform(b) of SOindex, 12months moving averaged WAI(200hPa) and PDO index.

moving averaged SOI and 200hPa WAI (r=-0.631) and between SOI and 1000hPa WAI (r=-0.304) in significant condition(P-value < 0.005). And between PDOI and zonal WAI (200 and 1000hPa) cases show positive correlation(r=0.518, r=0.399). 200hPa zonal WAI reveals more higher correlation coefficients with SOI than the 1^{st} result of empirical orthogonal function with SOI(r=-0.418). In other cases it shows relatively lower correlation coefficients with AOI(200hPa: r=-0.147; 1000hPa: r=-0.159), NPI(r=0.214, -0.196) and PNAI(r=-0.181, 0.274). We perform periodic analysis for all indices (SOI, WAI, and POI) using real parts of wavelet coefficients. That results remarkable interannual (about 32months scale; red dot line) and interdecadal variations (longer than 120months, black dashed line) in figure 1. Lag correlation coefficient is -0.65 (+2months) between 200hPa WAI and SOI. And 1000hPa WAI shows -0.41 (+3months) with SOI. In other words SOI leads 200hPa WAI and 1000hPa WAI (in order), and then PDOI in longer than decadal variation(Fig. 1, right panels).

4. Discussion and conclusion

WAI might be very useful because it can represent the atmospheric circulation condition with a simple index number and this WAI can be easily compared to other indices such as the Southern Oscillation Index (SOI), the Pacific Decadal Oscillation Index (PDOI). Zonal wind and SST does not negatively correlated in North Pacific always. WAI can be used to represent midlatitude atmospheric circulation. The wind variations in the upper and lower atmospheric levels are in phase with one month lag. WAI plays an important role in linking to equatorial variation (SOI) and midlatitude (PDOI). WAI variability can be considered as a useful tool to indicate the variability over the Pacific region, particularly at the central Pacific and the Aleutian regions. It may explain 'the Atmospheric Bridge' phenomena in Pacific. North Pacific boundary regions show weak correlation with Equatorial variations. Equatorial variations (SOI) leads midlatitude atmospheric variation (WAI), and then PDOI in larger than decadal variation. Above analysis indicates that WAI is very useful tool to study the climate variation over oceanic sectors surrounding the Korean peninsula. In further researches, We will investigate meteorological variations and relationship between atmosphere and maritime resources using the estimated data more long time scale and seasonal variations.

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