IS THE FUNDAMENTAL OSCILLATION OF ENSO/MONSOON SYSTEM BIENNIAL?

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1. Introduction

The global climatic change of several years has become of great interest to many researchers, recently. It is seriously needed to apply the physical understanding of the global climatic change with this time scale to the long time forecast. Some climatic valuables such as the precipitation, zonal wind component, and sea surface temperature (SST) are already inspected, and several dominant interannual components are observed mainly in the tropical region from the eastern Indian Ocean to central Pacific (Landsberg 1963; Trenberth and Shin 1984; Rasumusson et al. 1990; Barnett 1991; Ropelewski et al. 1992). Also, the study on spatial distribution and time evolution of the components are advancing (Rasumusson et al. 1990; Barnett 1991; Ropelewski et al. 1992). The most dominant periods of these interannual fluctuations are about two years and five years (Rasumusson et al. 1990; Barnett 1991). The relationship between the year to year change and the annual cycle is also discussed enthusiastically (cf. Philander et al. 1984; Lau and Sheu 1988; Barnett 1991), and the year to year change component, especially the two-year period fluctuation, is known to have a relatively strong phase preference with the annual cycle (cf. Barnett 1991). Therefore, the tropospheric quasi-biennial component is expected to have periods of two years, in precise (Lau and Sheu 1988). Meehl(1987, 1993) and Yasunari (1992) support the idea, and explain the relation between the annual cycle and the mechanism of the fluctuation treated exactly biennial, not the quasi-biennial.

This study concerns the punctual biennial oscillation (BO) components, and compares the cases of when the period rhythm is clear and unclear. The purposes of this study are to examine the consistency of the BO rhythm, and to expose the important factors for the BO stableness. The term ENSO/monsoon system refers to the climate system from the eastern tropical Indian Ocean to the central tropical Pacific where the tropical biennial fluctuation is apparent (Barnett 1983,1991). Some studies also show that the warm ENSO event and Asian monsoon are closely related to each other (Yasunari 1990; Masumoto and Yamagata 1991).

2. Data

We used the following six data to detect the biennial feature. 1) Sea water temperature (SWT) along the 137°E that was observed by Ryoufu-maru belonging to Japan Meteorological Agency. 2) Snow and ice cover data compiled by the National Oceanic and Atmospheric Administration / National Environmental Satellite Data Information Service. 3) All-India summer (June to September) monsoon seasonal rainfall (Parthasarathy et al. 1991). 4) Wind stress (WS) on the tropical Pacific (30°N-30°S, 120°E-70°W) produced by Florida State University basing on ship reports. 5) Southern Oscillation index (SOI), which is the normalized sea level pressure difference between the maritime continent (Darwin) and the central tropical Pacific (Tahiti), made from Monthly Climatic Data for the World. 6) Global monthly sea surface temperature compiled by United Kingdom Meteorological Office.

3. Results and discussion

To extracts the biennial progress from the several climatic variables related to the ENSO/monsoon system, a high-pass filter, the simplest method for the purpose, were applied (Fig. 1). The signs were decided positive or negative by whether the values of a sample year exceeded the both values before and after the year, and we adopted the signs succeeding more than two. To simplify the figure, the signs were made consistent with the BO progress of SWT in northern winter. Hereafter we adopted the season of northern hemisphere. The climatic variables strongly related to ENSO were examined on the monsoon year presented by Yasunari (1991), a year from June to May with ENSO maturing winter, and the same high-pass filter was applied to these annual mean values. For example, we see the year from 1982 to 1983. The SWT of the western tropical Pacific in winter of 1981-82 was higher than in the years before and after. In the following spring, snow cover area on Central Asia that gave a major effect on following Asian summer monsoon (Morinaga 1992) was greater than the years before and after. In the next summer, the precipitation over Indian subcontinent was small as expected from the previous snow cover area. Namely, it indicates the weak monsoon. In the fall, westerly WS anomalies over the western tropical Pacific were stronger than the years before and after. In the next winter, the SWT in the western tropical Pacific became lower than the years before and after as expected by the mixing and dragging effects of the previous strong westerly anomaly. The steps of the next year were the aforementioned but in the opposite order. The results of filtered annual mean values of the ENSO variables were as follows; both SOI and the SST in the western equatorial Pacific were small, while the SST in the central equatorial Pacific was large with comparing to the years before and after. The sign of the SST in the equatorial Pacific is adjusted with the sign of SOI. The SST in the eastern equatorial Pacific had no clear BO rhythm. The pattern reversed in the following monsoon year. BO progressed with obvious consistency in climate system including the middle latitude. The frequency of the listed BO rhythm was large dominantly in SOI, snow cover area on Central Asia, and SST in the central equatorial Pacific, but the BO rhythm of SST in the eastern equatorial Pacific was not clear. It was also

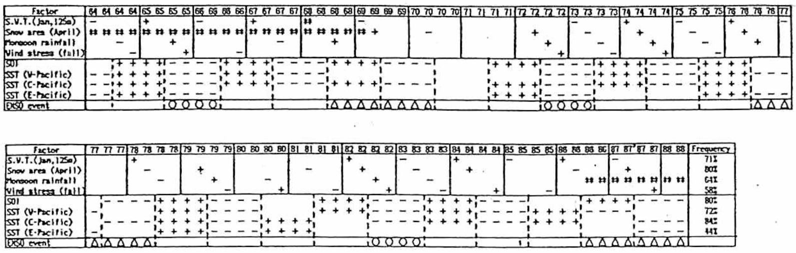


Fig.1 (left)
The signal of BO progress. About each factor and the details, refer to 3.Results and discussion of the text. The symbol ○ indicates the duration of BO-ENSO and △ indicates that of LF-ENSO.

apparent that ENSO did not always occur on the monsoon year with a strong BO pattern.

A time and space composite pattern on SST and WS anomalies field with dominant BO pattern were shown below (Fig. 2). Then the time and space composite pattern were made from the deviation from the average of the previous and following year. The composite years were 1964, '66, '73, '75, '78, and '83, with referring to Fig.1. Since seasonal phase preference was strong, the composite figure was shown for each season. Here, the wind stress anomaly was normalized. Note that an ENSO-like pattern process was dominant (cf. Rasumusson and Carpenter 1982). The details of the process were omitted for the convenience, but some phenomena important to the turnover from positive to negative in anomaly pattern was indicated below. The cold water anomaly that had spread in hook-shape over western tropical Pacific turned over in winter (cf. Hanawa et al. 1989). Then the anticlockwise eddy of WS anomalies spread in the western tropical Pacific, though the clockwise eddy spread in previous spring. The eddy seems to play a major role to warm water converge and diverge under the eddy through the Ekman pumping. Certainly, the cold region spread in the central through eastern tropical Pacific reduced in the following spring. Wind flow of Asian winter monsoon to tropical region seems to be closely related to this eddy (cf. Masumoto and Yamagata 1991).

The monsoon years were divided into two types according to the appearance of BO rhythm. The criterion of the selection was the ENSO event. The years were divided into the cases with ENSO event occurrence in BO rhythm (BO-ENSO) and with longer frequency mode (LF-ENSO) (Tomita and Yasunari 1993). The composite time series of interannual anomalies of SST in the central equatorial Pacific and SOI (Fig. 3) show that ENSO terminated in the following year of the occurrence in BO-ENSO. On the other hand, in LF-ENSO, ENSO terminated in two years after the occurrence. For either type of ENSO, the occurrence and termination season concentrated in the first half of the calender year. The figure also shows that the BO rhythm stableness greatly depends on the situation of SST and Southern Oscillation during Y(0) to Y(+1), i.e., winter to spring. The difference between the two types of ENSO, namely the keeping precise BO rhythm or not, was examined on Y(0) to Y(+1) winter with composite figure such as Fig. 2. The eddy that is the opposite direction of Fig.2 winter appeared in the western tropical Pacific in Y(0) to Y(+1) winter of BO-ENSO. On the other hand, the Y(0) to Y(+1) winter of LF-ENSO had no eddy. The eddy seems to affect greatly on ENSO termination. Also the eddy seems to provide a switch to change the monsoon year anomaly.

In BO rhythm of the climatic variables shown in Fig.1, the rhythm of snow cover area on Central Asia and SWT did not coincide with each other in LF-ENSO occurrence. For a stable BO rhythm, the appearance of eddy in winter western tropical Pacific and the snow cover area on Central Asia during winter to spring were important.

The snow cover area on Central Asia is closely related to the EU pattern of winter atmospheric circulation (Morinaga 1991), and the relation between the PNA pattern corresponding to the ENSO event and this EU pattern is considered as one of the most important factor to keep the stable BO rhythm, but more study is needed for a confirmation.

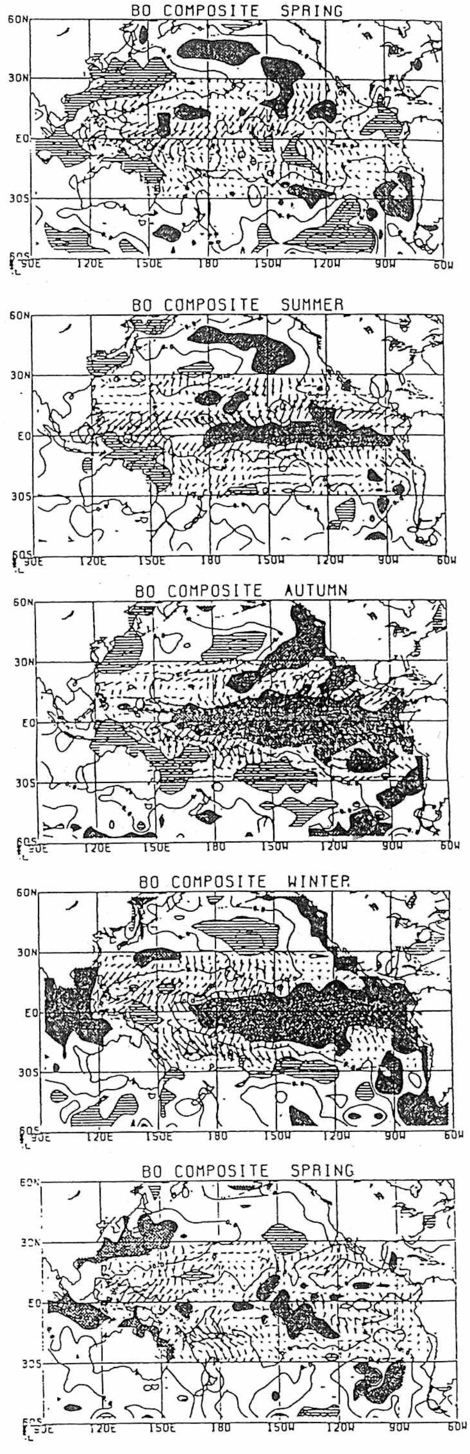
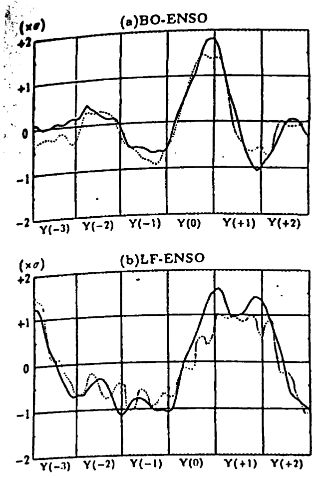


Fig.2
The seasonal composites of SST and wind stress anomali for BO negative phase. Each anomaly was calculated as t difference from the mean of the average of both the for and after years. The contour interval is 0.5℃. Areas ov 0.5℃(under -0.5℃) are shaded lightly (darkly). The size the arrow indicates the normalized value.



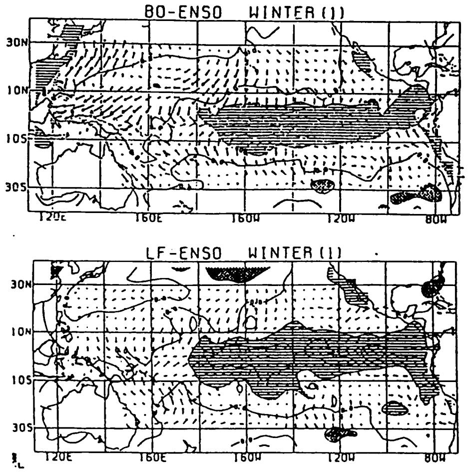


Fig.3 (left)
The composite time series of normalized anomalies of SST (5N-5S, 160E-120W, solid line) and -1×SOI (dashed line) for (a) BO-ENSO and (b) LF-ENSO. Y(0) indicates the occurrence year of ENSO.

Fig.4 (right)
The seasonal composites of SST and wind Stress anomalies in WINTER(1) from Y(0) to Y(+1) of Fig.3. Hatching, contour interval, and the size of the arrow are same as Fig.2.

4. Summary

This study points out that the eddy that appears in wind stress anomaly field on western tropical Pacific in northern winter is an important factor that keeps BO rhythm constant. Also, BO rhythm disturbance observed in spring snow cover area on Central Asia is suggested to trigger the BO rhythm disturbance in the whole ENSO/monsoon system. The BO progress indicated this study, however, has a remarkable consistency with that indicated by Barnett (1991) and so on.

Reference

Barnett, T.P., 1983: Interaction of the monsoon and Pacific trade wind system at interannual time scales. Part I: The equatorial zone. *Mon. Wea. Rev.*, **111**, 756-773.

Barnett, T.P., 1991: The interaction of multiple time scales in the tropical climate system. *J. Climate*, **4**, 269-285.

Hanawa, K., Y. Yoshikawa and T. Watanabe, 1989: Composite Analyses of Wintertime Wind Stress Vector Fields with Respect to SST Anomalies in the Western North Pacific and the ENSO Events Part II. ENSO composite. *J. Meteor. Soc. Japan*, **67**, 833-845.

Landsberg, H.E., J.M. Mitchell, Jr, H.L. Crutcher and F.T. Quinlan, 1963: Surface signs of the biennial atmospheric pulse. *Mon. Wea. Rev.*, **91**, 549-556.

Lau, K.-M. and P.J. Sheu, 1988: Annual cycle, Quasi-Biennial Oscillation, and Southern Oscillation in Global Precipitation. *J. Geophys. Res.*, **93**, 10975-10988.

Masumoto, Y. and T. Yamagata, 1991: The response of the western tropical Pacific to the Asian winter monsoon : The generation of the Mindanao Dome. *J. Phys. Oceanogr.*, **21**, 1386-1398.

Meehl, G.A., 1987: The annual cycle and its relationship to interannual variability in the tropical Pacific and Indian ocean regions. *Mon. Wea. Rev.*, **115**, 27-50.

Meehl, G.A., 1993: A coupled air-sea biennial mechanism in the tropical Indian and Pacific regions: Role of the ocean. *J Climate*, **6**, 31-41.

Morinaga, Y., 1992: Interactions between Eurasian snow cover and the atmospheric circulations in the northern hemisphere. Ph.D. dissertation, Institute of geoscience, Univ. of Tsukuba, 78 pp.

Parthasarathy, B., K. Rupa Kumar and A.A. Munot, 1991: Evidence of secular variations in Indian monsoon rainfall-circulation relationships. *J. Climate*, **4**, 927-938.

Philander, S.G.H., T. Yamagata and R.C. Pacanowski, 1984: Unstable air-sea interactions in the tropics. *J. Atmos. Sci.*, **41**, 604-613.

Rasumusson, E.M. and T.H. Carpenter, 1982: Variations in tropical sea surface temperature and surface wind fields associated with the Southern Oscillation/El Nino. *Mon. Wea. Rev.*, **110**, 354-384.

Rasumusson, E.M., X. Wang and C.F. Ropelewski, 1990: The biennial component of ENSO variability. *J. Mar. Sci.*, **1**, 71-96.

Ropelewski, C.F., M.S. Halpert and X. Wang : Observed tropospheric biennial variability and its relationship to the Southern Oscillation. *J. Climate*, **5**, 594-614.

Tomita, T. and T. Yasunari, 1993: On the two types of ENSO *J. Meteor. Soc. Japan*, **71**, (now printing).

Trenberth, K.E. and W.K. Shin, 1984: Quasi-biennial fluctuations in sea level pressures over the Northern Hemisphere. Mon. Wea. Rev., 112, 761-777.

Yasunari, T., 1990: Impact of Indian Monsoon on the Coupled Atmosphere/Ocean System in the Tropical Pacific. *Meteor. Atmos. Phys.*, **44**, 29-41.

Yasunari, T., 1991: Monsoon and ENSO - A coupled ocean / land / atmosphere system. *Proc. Int. Sci. Conf. TOGA*, July, 1990.

Yasunari, T., 1992: Role of the Asian Monsoon on the Interannual Variability of the Global Climate System. *J. Meteor. Soc. Japan*, **70**, 177-189.