11C.5 ROLE OF LARGE-SCALE CIRCULATION ON TROPICAL CYCLONE LANDFALL IN JAPAN

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1. INTRODUCTION

Harr and Elsberry(1995) examined tropical cyclone (TC) tracks associated with anomalous patterns of the low-level monsoon trough and subtropical ridge over the western North Pacific and found that TC moves westward toward the Philippines and southern China when the monsoon trough is located near the Philippines and subtropical ridge is located south of Japan. They also showed that when the monsoon trough covers over the whole western North Pacific (without any subtropical ridge), then TC tracks tend to move to Korea and Japan.

We would like to reconfirm their result using the global reanalysis datasets, ERA-40 (ECMWF) and JRA-25 (Japan), mainly focusing on the temporal/spatial evolution in the large-scale circulation over the western North Pacific.

2. DATASET

The datasets used in this study are as follows.
- ECMWF Reanalysis dataset, ERA-40 (1958-2001)
- Japan Reanalysis dataset, JRA-25 (1979-2004)
- Outgoing Longwave Radiation(OLR) (1979-2004)

3. METHODOLOGY

To examine the relationship between large-scale circulation and tropical cyclone landfall in Japan, combined EOF (CEOF) analysis has been performed. Before starting the analysis, we computed the steering flow (ui, vi), defined by the density-weighted mean flow between 1000 hPa and 300 hPa. Then, the CEOF was applied to the combination of the following variables of 5-month mean from June to October.

i) ui, vi, Z850 (1958-2001 for ERA-40, 1979-2004 for JRA-25), where Z850 is the geopotential height at 850 hPa.
ii) ui, vi, OLR (1979-2001 for ERA-40, 1979-2004 for JRA-25)

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4. RESULT

4.1 "Sub-High" and "ENSO" Patterns

For the CEOF analysis on ui, vi, Z850, using ERA-40, the first eigenmode is related with ENSO, and the second mode is characterized with the dominant subtropical ridge over the western North Pacific. Fig. 1 shows the first (a) and second (b) patterns and temporal coefficients. These modes explain 20.3 % and 15.1 % of the total variance, respectively. In Fig. 1a, El-Niño year and La-Niña year are marked by red and black triangle, respectively, in the right-bottom figure. All El-Niño years and La-Niña years fall perfectly in red or black triangles. Thus we call this mode as "ENSO" mode.

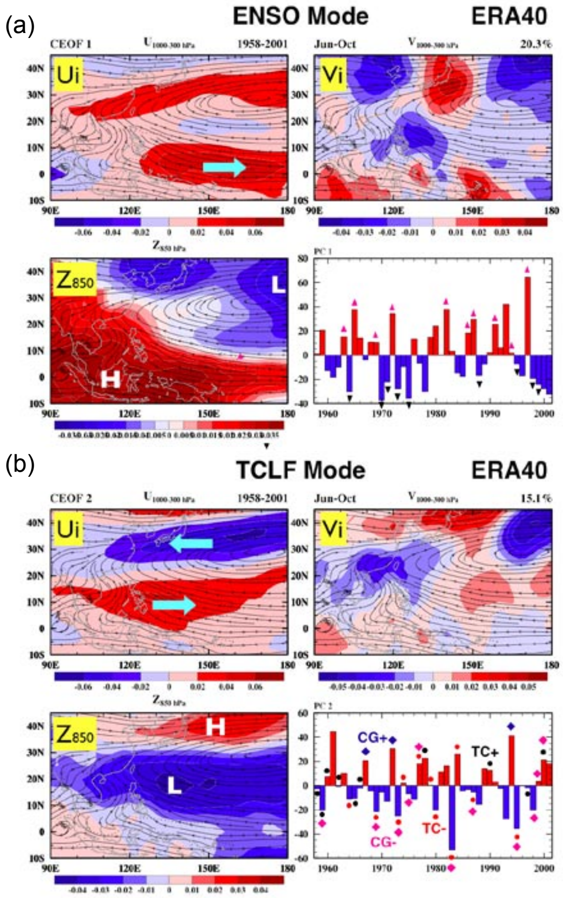


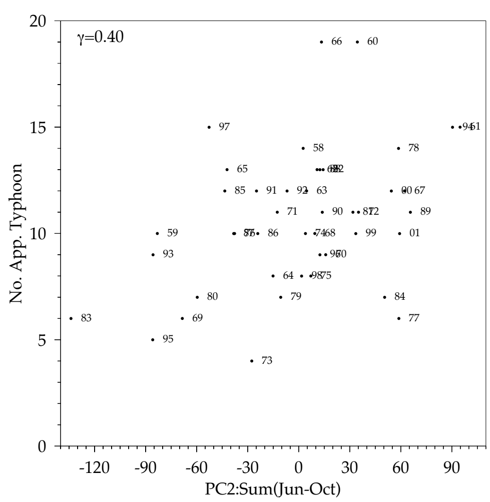
Fig. 1 The first(a) and second(b) CEOF mode of ui, vi and Z850 using ERA-40 dataset.

The second mode shows that there is a negative/positive anomaly of the geopotential height at 850 hPa over the western subtropical North Pacific with cyclonic/anti-cyclonic circulation of the steering flow (ui, vi). In Fig. 1b, we plotted the year with more (less) approaching/landfall TCs in Japan by black (TC+) and red (TC-) circle, respectively, in the right-bottom figure. We also plotted the year with more (less) generation TCs over the western North Pacific by blue (CG+) and red (CG-) square, respectively. In Fig. 1b, we find that the years with negative coefficients reasonably correlated with the year of TC- (1964, 69, 73, 80, 83, 87, and 95) and CG- (1959, 69, 73, 75, 83, 87, 95 and 98). Thus, we call the second mode as TC landfall (TCLF) mode. But the years of TC+ or CG+ do not correspond well to the years with positive coefficients.

Why do we have a strong correlation between TCLF mode with ui, vi and Z850 and TC-/CG-? If we change the sign in the ui, vi and Z850 horizontal pattern in Fig. 1b, we notice that this pattern is the same pattern as Harr and Elsberry (1995) described. That is, most of TCs moves westward with enhanced monsoon trough near the Philippines and westward elongated subtropical high south of Japan.

4.2 Correlation

We found that there is a strong tendency between TCLF mode with ui, vi and Z850 and TC-/CG-. So we scattered CEOF coefficient of TCLF mode with the approaching/landfall and generation numbers of TC in Japan. Fig. 2 shows the scatter diagram for approaching/landfall numbers of TC (a) and generation numbers of TC (b). The correlation coefficients are 0.41 and 0.47, respectively. We also plotted CEOF coefficient of ENSO mode with the approaching/landfall and generation numbers of TC in Japan and found the correlation coefficients are 0.20 and -0.13, respectively.



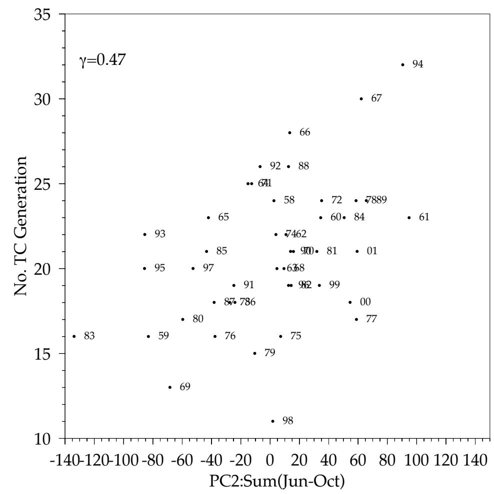


Fig. 2 Scatter diagram between TC approaching/landfall numbers in Japan (a) or TC generation numbers (b) and the coefficients of the TCLF mode in Fig. 1b.

4.3 ENSO mode and TCLF mode in JRA-25

How about the ENSO and TCLF mode in the JRA-25 dataset? Fig. 3 shows the first and second CEOF mode

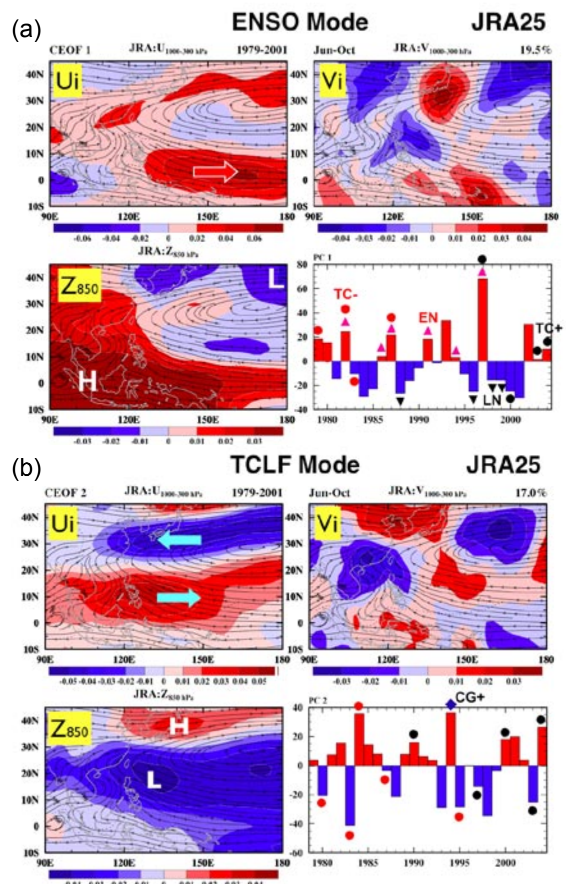


Fig. 3 Same as Fig. 1, but for using JRA-25.

using ui, vi and Z850 of the JRA-25 dataset (1979-2004). When we compare this with Fig. 1a and 1b, we notice that both are identical. The main reason why we use the JRA-25 dataset is that the dataset includes the year 2004, when there was the annual record (10) of the TC landfall in Japan. In the right-bottom figure in Fig. 3 we put black (TC+) and red (TC-) circle and black (CG+) square. The last year is 2004 with positive coefficient of the second CEOF. Although the time coefficients of the second CEOF in Fig. 3 do not show a strong correlation between the large-scale atmospheric pattern with the approaching/landfall number of TCs in Japan, we speculate that the identical patterns of both Fig. 3 and Fig. 1b confirm the favorable condition for more approaching/landfall TCs in Japan with large-scale cyclonic feature over the western North Pacific, embedding stronger monsoon trough, which resembles to the result of Harr and Elsberry(1995).

We also performed the CEOF analysis for ui, vi and OLR using both ERA-40 and JRA-25. Again both datasets show very similar horizontal patterns in the first and second CEOFs. Fig. 4 shows the TCLF mode of ui, vi and OLR using ERA-40 dataset. Enhanced subtropical high over the western North Pacific in the TCLF mode corresponds to more suppressed convective area.

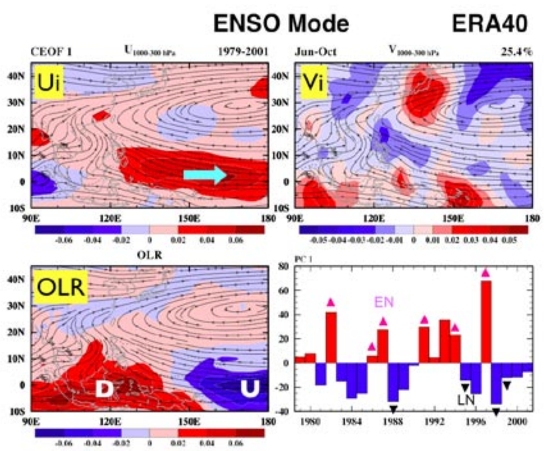


Fig. 4 Same as Fig. 1, but for ui, vi and OLR.

5. SUMMARY

We computed the characteristic atmospheric pattern, which is responsible to the approaching/landfall TC numbers in Japan, by the combined EOF analysis technique. We found that there are two major large-scale atmospheric patterns, one is sub-tropical high pattern and another is ENSO pattern. When we compared the temporal variation of these two modes with the numbers of tropical cyclone landfall in Japan, we recognize that sub-tropical high pattern corresponds well with the numbers of tropical cyclone landfall in Japan, especially less landfall years, such as 1964, 1969, 1973, 1980, 1983, 1987 and 1995. In these years positive height anomalies at 850 hPa over the western North Pacific are evident south of Japan, which prevent tropical cyclone approach to Japan. However, negative height anomalous year does not correspond well with more tropical cyclone landfall in Japan, but shows weak correlation. This result confirms the result by Harr and Elsberry(1995). It is also shown that ENSO pattern does not influence the number of tropical cyclone landfall in Japan. Fig. 5 is the schematic figure to summarize the result. The blue area shows the subtropical high and red area the monsoon trough.

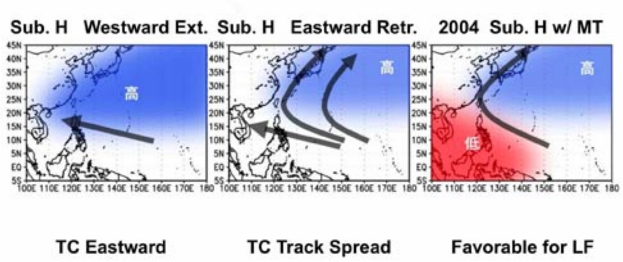


Fig. 5. Schematic figure, explaining the result.

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