論文内容の要旨

論文題目　Multi-scale Interaction in the Generation Process of Equatorial Westerly Wind Bursts (赤道域西風バーストの発生過程におけるマルチスケール相互作用に関する研究)

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Westerly wind bursts (WWBs) are synoptic-scale disturbances over the equatorial tropics represented by strong local westerly winds at the surface which last more than a few days. Since strong surface westerly winds can influence on the ocean through directly exciting oceanic Kelvin waves, WWBs have been indicated to play an important role for the development or maintenance of the El Nino events. However, the mechanism of the generation process of WWBs is still debatable because of its complicated interaction with larger-scale phenomena, such as El Niño-Southern Oscillation (ENSO), the Madden-Julian Oscillation (MJO), and mid-latitude forcing. The purpose of this study is to elucidate multi-scale interaction among WWBs, ENSO, the MJO, and mid-latitude forcing in the generation process of WWBs.

First, the statistical features of WWBs and their relations to ENSO, the MJO, and mid-latitude forcing are examined. Then, the energetics in the generation stage of WWBs especially with respect to the variation of MJO and ENSO phases is investigated using long-term reanalysis data (ERA-40) for the period of January 1979-August 2002.

Statistical analysis shows that WWBs are detected over the Indian Ocean and the Pacific Ocean, but not over the Atlantic Ocean. WWB occurrences both over the Pacific

and Indian Ocean are lag-correlated with the SST anomaly over the El Niño watch region defined by Japan Meteorological Agency (JMA). Lags of the significant correlations are found in sequence from the Pacific to the Indian Ocean. These results suggest that WWB occurrences are not random, but interrelated with ENSO, i.e. a specific phase of ENSO prepares the preferable environment for WWB occurrences, then WWBs can accelerate the El Niño development as mentioned in previous studies, in turn.

It is revealed by composite analysis that most of WWBs are associated with slowdowns of eastward-propagating convective regions, so-called MJO, with intensifications of the Rossby wave response. While an individual WWB is associated with MJO convection, seasonal and interannual variations of the MJO amplitude are not correlated with those of the WWB frequency. Moreover, it is shown that the MJO events with strong amplitude tend to bear WWBs, but not always. This result suggests that the strong MJO amplitude is a necessary condition but not a sufficient condition. Considering the significant lag-correlations between the WWB frequency and ENSO, it is suggested that ENSO controls the preferable environment for a structure transformation of MJO to bear WWBs. About the preferable environment, the warm pools are located around the WWB occurrence longitudes in the three Pacific regions. A preferable environment common in the Pacific and Indian Ocean regions is the existence of background westerlies with periods longer than the intraseasonal variation around the WWB center near the equator. It is also shown that the surges from mid-latitudes are not the necessary condition for the WWB occurrences.

Whereas the MJO has been recognized as a planetary scale disturbance, the MJO convection has a internal structure that consists of synoptic-scale disturbances (Nakazawa 1988). On the other hand, WWBs have synoptic scales. Therefore, we next focus on the development of synoptic-scale disturbances in the generation of WWBs in association with the MJO.

In the WWB occurrences, barotropic structures of equatorial eddy westerlies and eddy cyclonic disturbances with time scales shorter than the intraseasonal variation are found from the surface to the upper troposphere. In order to investigate the energy source of such deep disturbances in the WWB occurrences, the eddy kinetic energy budget is examined.

Composite analysis is performed for the westerly phase of the strongest 50 MJO events classified into 2 groups based on the lag-correlation with the ENSO index. Over the western/central Pacific, high EKE distribution is limited over the northwestern Pacific in the "uncorrelated periods" while it shifts equatorward and eastward in the "correlated periods". The areas of large EKE both over the Pacific and Indian Ocean regions in the correlated periods lie near the equator and correspond well with the locations of frequent WWB occurrences.

The barotropic energy conversion from low-frequency kinetic energy to EKE contributes to the EKE increase in the lower and mid troposphere. The existence of environmental (low-frequency) westerlies near the equator in the correlated periods results in strong zonal convergence and meridional shear of environmental zonal winds and links to the strong barotropic energy conversion. The active eddy convection also contribute to the EKE increase in the upper troposphere through the conversion from eddy available potential energy to EKE. It is concluded that environmental winds and SST variations due to ENSO contribute to the EKE increase near the equator and are important factors in WWB occurrences in addition to the westerly phases of the MJO.

The coincident distributions between the eddy enstrophy and EKE suggest that eddy activity of rotational disturbances contribute dominantly to the EKE increase in the correlated periods. Noteworthy common feature in the correlated periods is that the region of enhancement of the eddy cyclonic disturbances through the stretching effect coincides with that of large-scale MJO convection in the vicinity. It is suggested that the enhanced equatorial synoptic disturbances are internal disturbances embedded in the MJO convection.

To summarize, it is suggested by statistical analysis that ENSO controls the preferable environment for the development of MJO convection and cyclonic circulations to bear WWBs. After the results of the energetics, it is considered that this enhancement of the MJO Rossby wave response is a manifestation of the intensification of internal synoptic-scale disturbances within the MJO through the nonlinear interaction between synoptic and large-scale convection. This coincident enhancement of different scale disturbances occurs only if the environmental condition is preferable in association with ENSO.