学 位 論 文 内 容 の 要 旨

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学 位 論 文 題 名

Effects of ENSO-induced synoptic-scale environment on tropical cyclone activity and predictability over the western North Pacific

（ENSOに伴う総観規模場が北西太平洋における熱帯低気圧の活動と予測可能性に与える影響）

Tropical cyclone (TC) is one of the destructive natural phenomena which cause huge damage to society and economy. There are a variety of factors modulating TC activity over the western North Pacific (WNP). Large-scale environment, such as sea surface temperature (SST) and vertical wind shear, directly affects formation, development, and track of TCs. The El Niño–Southern Oscillation (ENSO) indirectly controls TC activity by modifying the large-scale environment. Effect of large-scale environment on ENSO-related TC activity was investigated by many previous studies. However, the physical mechanisms linking environmental factors and TC features were mainly explained in terms of anomalous large-scale environmental conditions. In recent decades, many studies have employed full dynamical models to understand the TC activity associated with ENSO. However, the role of individual large-scale environmental variables to ENSO-related TC features is limitedly understood although the importance of large-scale environmental fields was pointed out by many studies. Therefore, this study aims to reveal key environmental fields regulating ENSO-related TC activity by using an axisymmetric model. The design of the model allows to investigate the contribution of each environmental variable to TC features. For instance, to examine the role of humidity in TC genesis, we can discard the contributions of other input environmental variables.

To investigate how TC genesis anomaly is modulated by anomalous large-scale environment induced by ENSO, numerical experiments were conducted. Four monthly-mean variables, namely 600-hPa level relative humidity (RH600), SST, 850-hPa level relative vorticity (RV850), and vertical wind shear (VWS) derived from the reanalysis data were used to drive the model. The model run was performed for the storm season (June to October) of 16 conventional ENSO (i.e., El Niño or La Niña) years defined by Niño-3.4 SST anomaly during 1970–2015. The control experiment, in which realistic interannual variations of all four environmental variables were used, demonstrated that the model was able to replicate the spatial distributions and TC genesis anomalies corresponding to the conventional ENSO, particularly in the northwest (NW; 17°N–30°N, 120°E–140°E) and southeast (SE; 0°N–17°N, 140°E–180°E) sectors of the WNP. In addition, the model was able to reproduce anomalous TC genesis patterns for other types of ENSO which are the eastern Pacific warming (EPW) and central Pacific warming (CPW).

To elucidate individual contributions of four input variables, RH600, SST, RV850, and VWS, to EN

SO-related TC genesis frequency, sensitivity experiments were conducted. The experiment with the real interannual variation of RH600 can produce less TC geneses in the NW sector corresponding to lower RH600 in El Niño (EN) years, compared to La Niña (LN) years. The result indicated that relative humidity at mid-tropospheric layer plays a key role in regulating ENSO-related TC genesis. In the SE sector, the sensitivity experiment with real interannual variation of RV850 can reproduce more TC geneses corresponding to stronger RV850 in EN years, compared to LN years, which suggested that relative vorticity at lower tropospheric layer is the dominant factor in modulating ENSO-related TC genesis. In reality, the low-level convergence associated with stronger RV850 in EN years than LN years increases the water vapor transport toward the SE. This presumably sustains cumulus convection in the TC warm core. Although this effect was not explicitly included in the model, RV850 indirectly increased TC genesis through TC seeding process. Thus, more TC seeds were placed in the SE sector in EN years than LN years. In addition, it was revealed that the effects of ENSO-induced VWS and SST anomalies on TC genesis are negligible. The results of sensitivity experiments, thus, pointed out the importance of mid-tropospheric relative humidity and low-level relative vorticity to ENSO-related TC genesis anomaly over the WNP.

To examine the TC genesis, track and landfall anomalies in relation to ENSO-induced large-scale environmental anomalies, the simulated results were analyzed in monthly timescale. It was revealed that the model was capable of replicating monthly evolution of ENSO-related TC genesis anomaly during storm season. In addition, it can reproduce the contrast in TC landfalls between EN and LN years, especially in September to November (SON). In particular, TC landfall counts around China and Philippines dramatically decreased in EN years during SON, compared to LN years. The significant decrease in TC landfall counts during SON in EN years was attributed to the effect of both shift in TC genesis position and steering flow. In EN (LN) years, the mean TC genesis position moved eastward (westward), which might lead to less (more) chances of TC landfall during June to November. However, the simulated TC landfalls significantly decreased in only SON of EN years. Also, in the late storm season (SON), the occurrence of anomalous westerly in mid-latitudes can be an important factor to prevent TC landfalls around China and Philippines. Therefore, the model was sensitive to both the shifts in simulated TC genesis position and large-scale steering flow. However, the model also showed the limitation in predicting tracks of TCs generated over east WNP (140°E–180°E).

This study confirmed the dominant effects of environmental factors on ENSO-related TC genesis and landfall. In particular, it demonstrated that mid-tropospheric relative humidity and low-level relative vorticity play a key role in modulating ENSO-related TC genesis. In addition, both TC genesis position and large-scale steering flow are found to be important in controlling ENSO-related TC landfall. Furthermore, mid-tropospheric relative humidity, low-level relative vorticity, and large-scale steering flow can serve as the potential predictors of TC activity in seasonal timescale. Finally, the results suggested that ENSO-related TC features over the WNP are predictable by using a monthly-averaged status of large-scale environment. Therefore, having appropriate large-scale mean state is essential in predicting TC activity anomalies in the WNP corresponding to ENSO.