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Sub-weekly Scale Interactions between the Sea of Japan and Extratropical Cyclones in Winter

趙, 寧

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氏　名 ： 趙　寧 ZHAO NING チョウ ネイ
Name

論 文 名 ： Sub-weekly Scale Interactions between the Sea of Japan and Extratropical Cyclones in Winter
Title （冬季の日本海と温帯低気圧間における sub-weekly scale の相互作用）

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論 文 内 容 の 要 旨
Thesis Summary

Numerous studies showed the East Asian marginal seas play an important role on the cyclogenesis, while on the other hand, extratropical cyclones can also greatly influence the seas. In this study, we conducted both objective analysis and the sensitivity experiments using a regional numerical model based on the observational and reanalysis datasets and revealed a two-way coupling process that occurs between the Sea of Japan and extratropical cyclones in winter.

The response of the Sea of Japan to winter extratropical cyclones is investigated based on the quantitative analyses of gridded and satellite datasets. Cyclone passages affecting the sea are detected using time series of spatially averaged surface turbulent heat fluxes. As the cyclones develop, there is a strong cold-air outbreak causing twice the normal heat loss over the sea. After removal of sea surface temperature (SST) seasonal trends, we found that cyclone passage (hence, cooling) mainly occurred over 3 days, with maximum SST reduction of -0.4 ℃. The greatest reduction was found along the subpolar front, where frontal sharpness (i.e., SST gradient) increased by 0.1 ℃ (100 km)$^{-1}$. Results of a mixed-layer model were consistent with both SST and frontal sharpness, and localized surface cooling along the subpolar front resulted from both horizontal advection and turbulent heat flux at the sea surface. Further analyses show that this localized cooling from horizontal advection is caused by the cross-frontal Ekman flow (vertically averaged over the mixed layer) and strong northwesterly winds associated with the cold-air outbreak during cyclone passage.

The effects of the cyclone-induced sea surface temperature (SST) anomaly in the Sea of Japan on the following cyclones were investigated based on a regional numerical model. The numerical modeling was conducted with and without the SST anomaly owing to the cooling by a single extratropical cyclone in winter. According to 26 pairs of these sensitivity experiments, we found that cyclones were not always sensitive to the SST anomaly. The low-level trough (hence, strong northwesterly winds)

plays an important role on the cyclone sensitivity by controlling the cold air intrusion over the Sea of Japan. A strong (weak) cold air intrusion forms a relatively unstable (stable) and higher (lower) convective layer, which encourages (restrains) the upward penetration of the influences of the SST anomaly. Two specific cyclones (A and B) were analyzed to demonstrate two distinct patterns in cyclone modulation caused by the previously-passing cyclone via SST anomaly: wave-like pattern and path-shifting pattern. The wave-like pattern was formed by the combination of the weakened cyclone and a half-wavelength (hence, short-time) anomalous wave, while the poleward path shifting was caused by the positive potential vorticity anomaly on the northern side of the cyclone center which induced by the enhanced diabatic heating. The wavelet spectra demonstrate that both wave-like and path-shifting patterns were revealed among 20 affected cyclones as well as the two cyclones, although these patterns were likely to appear simultaneously in each cyclone. Our analyses demonstrated that a cyclone can modulated the following cyclone via the SST reduction over the Sea of Japan, and that the role of the colder Sea of Japan is not only for the weakening source to reduce the cyclone activity, but also for strengthening and/or generating baroclinic waves in surrounding regions.