学 位 論 文 内 容 の 要 旨

博士（環境科学）　　氏 名 田 村 健 太

学 位 論 文 題 名

Regional characteristics of winter cyclone activity around Hokkaido and its multidecadal trend associated with surface pressure patterns over Northeast Asia
(北海道周辺における冬季低気圧活動の地域特性と北東アジアの気圧配置に関連した数十年規模の傾向)

In East Asia, strong winter monsoon and high baroclinicity enhance cyclone activity. Winter cyclone activity modulates the daily weather over Japan by inducing low temperatures and snowfall. Strong wind and heavy precipitation induced by the winter cyclone can cause disasters. It is well known that mesoscale cyclones frequently occur in the Sea of Japan, causing locally but strong winds and heavy snowfall. Despite the high frequency of genesis of mesoscale cyclones around the Sea of Japan, most previous studies on the cyclone activity in the decadal timescale have focused only on synoptic-scale cyclones. Since mesoscale cyclones cause local snowfall, the understanding of the decadal trends in winter cyclone activity, including mesoscale cyclones, can provide new insights into regional responses to climate change, especially in Hokkaido where the frequency of mesoscale cyclones is high. The purpose of this study is to clarify the decadal trends of winter cyclone activity that include mesocyclones over and around northern Japan. In addition, the regional features of mesoscale cyclogenesis in the northern part of the Sea of Japan were investigated by using numerical experiments.

The decadal trend of the passage of cyclones over and around Japan, including mesoscale cyclones, was investigated during 62 winter seasons (December–March) from 1958/1959 to 2019/2020 using the long-term reanalysis dataset JRA-55. During the study period, the passage of cyclones around northern Japan showed a decreasing trend. Most of the cyclones that pass around northern Japan are generated over the northern part of the Sea of Japan where mesoscale cyclogenesis frequently occurs. It was also found that the duration of the cyclones generated in the northern part of the Sea of Japan is relatively short compared to the cyclones that originated in the other regions.

Analyses based on the weather pattern classification revealed that the passage of upper-level troughs and lower-level cold air outbreaks over the northern part of the Sea of Japan are preferential conditions for the cyclogenesis in the northern part of the Sea of Japan. These conditions are consistent with the conditions for the development of mesoscale cyclones in this region. Statistical analysis indicated that the magnitude of the cold air outbreak in this region was weakened. Hence, the changes in atmospheric conditions due to climate change may have reduced mesocyclone genesis over the northern Sea of Japan, resulting in a significant reduction in the number of cyclones passing over and around Hokkaido over the past 60 years.

In this study, the role of the surrounding topography in the cyclogenesis over the northern part of the Sea of Japan was also investigated. Long-term numerical experiments using the regional climate model WRF (The Weather Research and Forecasting model) were conducted to investigate the effects of mountains located on the eastern coast of the Eurasian continent (i.e., the Sikhote-Alin mountain region) on the mesoscale cyclones generated over the northern part of the Sea of Japan. Weather pattern classification clarified that the effects of the mountains on the mesoscale cyclone vary depending on synoptic-scale atmospheric conditions. The difference in sensitivity is due to the difference in the development mechanisms of the mesoscale cyclones. Mesoscale cyclogenesis over the northern part of the Sea of Japan associated with the Siberian high and Aleutian low is caused by the lower-level horizontal wind shear formed over the offshore region west of Hokkaido. This horizontal wind shear is caused by the northwesterly winds that blow across the Sikhote-Alin mountain region. Sensitivity experiment revealed that the removal of the Sikhote-Alin mountain region weakens the horizontal shear of the lower-level winds over the northern part of the Sea of Japan and decreases this type of mesoscale cyclogenesis. Therefore, the mesoscale cyclogenesis caused by lower-level horizontal wind shear is very sensitive to the local topography. In contrast, the number of occurrences of mesoscale cyclogenesis induced by baroclinic instability did not vary even after the removal of mountains. It is suggested that formation of the mesoscale cyclones is not affected by the surrounding topography if their development is driven by upper-level atmospheric conditions.

The analysis using reanalysis dataset and high-resolution datasets derived from the regional climate model clarified the regional characteristics of winter cyclone activities around northern Japan. The results are summarized as follows; 1) the passage frequency of winter cyclones around Hokkaido originated from the northern part of the Sea of Japan has decreased since the 1960s, 2) the weakening of the cold air outbreak over the northern part of the Sea of Japan suppressed the mesoscale cyclogenesis in this region, and 3) the mesoscale cyclogenesis over the northern part of the Sea of Japan associated with the Siberian high and Aleutian low is caused by the lower-level wind shear formed by the mountains along the eastern coast of the Eurasian continent. Decadal trend of cyclone activity over recent years and the factors behind that revealed in this study can provide new insights into the response of regional climate in Hokkaido under ongoing climate change.