Future Changes in a Typhoon in the Midlatitude Regions: Downscaling simulations form d4PDF data by using a 4-km-mesh nonhydrostatic model

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Future projection studies have recently shown that the tropical cyclone (TC) intensity in the higher latitude will increase in the future warmer climate. To understand the impact of global warming on TCs in the higher latitude, changes in a typhoon that travels over the sea to the east of Japan were investigated using an unprecedentedly large ensemble of climate simulations for current and 4K warming climates with a 60-km-mesh atmosphere global circulation model (d4PDF: Mizuta et al, 2017).

All the typhoons that hit eastern Hokkaido in northern Japan (142˚E–146˚E and 42˚N–46˚N) from the western North Pacific Ocean were selected as the targeted typhoons. In total, 98 and 125 typhoons were selected from the 3,000 years current and 5,400 years 4K warming climate runs. Then, the downscaling experiments on all the targeted typhoons were conducted using a high-resolution non-hydrostatic regional model, the Cloud Resolving Storm Simulator version 3.4 (CReSS; Tsuboki and Sakakibara 2002). CReSS considers the SST-cooling associated with the storm passage by a simple thermal diffusion model. The horizontal domain of the CReSS simulation covers 132˚E–155˚E and 25˚N–50˚N, and is discretized with a grid spacing of 0.04˚ by 0.04˚. The results in 136˚E–150˚E and 30˚N–46˚N were used for the analyses.

Mean minimum central pressure (MCP) in the analysis region decreased from 955 hPa to 945 hPa from current to the warming climates at the 95% confidence level based on Welch's t-test. The frequency of intense typhoon in the warming climate with a MCP not larger than 940 hPa increases nearly three times as much as that in the current climate. Furthermore, the future typhoons traveled northward at a slower translation speed than in the current climate. The results implied that the coastal regions of Japan will be exposed to a stronger typhoon to a longer period of precipitation in the future warmer climate. Downscaling experiments by CReSS indicate significant increases in mean precipitation and wind speed averaged within 200 km of the typhoon center by 30-40% and 10% from the current to warming climates, respectively. The large changes were seen around the storm center. Furthermore, much taller and stronger eyewall updrafts developed in the core-region of future typhoons, although little changes appeared in a radius of the maximum wind speed (RMW). In the current climate, the typhoon in the vicinity of Japan tended to decrease the storm height and increase RMW losing the axisymmetric structures as its traveled northward. In the warming climate, SST is projected to increase by 4˚C and the baroclinicity will decrease in the vicinity of Japan. The high SST and the reduction of baroclinicity allow the typhoon to remain the axisymmetric TC structure with tall and intense eyewall updrafts and led the significant increases in precipitation amount and wind speed around the center of the storm in the higher latitude regions.

Keywords: Future Changes in a Typhoon, Downscaling simulations, a 4-km-mesh nonhydrostatic model

