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Abstract of Doctoral Dissertation

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Title of Doctoral Dissertation

Bomb Cyclones in the HighResMIP Historical Simulations and Future Projections
(HighResMIP の過去再現と将来投影実験における爆弾低気圧)

Bomb cyclones, also known as explosive cyclones, are extratropical cyclones that intensify explosively in about one day. The projection of future bomb cyclones under global warming is crucial for climate change risk assessment as bomb cyclones are often associated with extreme wind and precipitation. However, the bomb cyclone frequency is significantly underestimated in coarse-resolution climate models and it is unclear how this systematic bias will affect the future projections. It is thus important to examine how high-resolution climate models can simulate bomb cyclones. This thesis analyzes the bomb cyclones simulated by the high-resolution global climate models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6) High Resolution Model Intercomparison Project (HighResMIP).

The dependence of bomb cyclone characteristics on horizontal resolution from 142 to 18 km is investigated by analyzing the outputs of HighResMIP atmosphere-only simulations from 1950 to 2014 and four reanalysis datasets. Robust resolution dependence of bomb cyclone characteristics is identified for both the models and the reanalyses. Finer horizontal resolution significantly increases the annual frequency of bomb cyclones and reduces their average horizontal size. A regression analysis indicates that bomb cyclone frequency is roughly doubled from 140 km to 25 km resolution. The overall increase in bomb cyclone number is associated with a large increase in small bomb cyclones and a moderate decrease in large ones. Bomb cyclones in higher-resolution models are also accompanied by a higher maximum wind speed and more extreme wind events, which is probably related to the increased pressure gradients due to the smaller size of the bomb cyclones. These results highlight the added value of using high-resolution climate models for bomb cyclone simulation.

The projected future changes in bomb cyclones by the HighResMIP multimodel ensemble are investigated using both the atmosphere-only and coupled simulations for the period of 1950 to 2050. The annual bomb cyclone frequency is projected to decrease significantly by about 5% in the southern North Pacific as indicated by the multimodel mean. In the Southern Hemisphere, both the atmosphere-only and coupled runs project a statistically significant poleward shift of bomb cyclone activity. This shift is accompanied by a 9% (6%) increase in bomb cyclone frequency in the atmosphere-only (coupled) runs. In the atmosphere-only runs, the projected increase becomes smaller with higher model resolution, suggesting the projection can be sensitive to horizontal resolution. The significant bomb cyclone changes are further compared with projected environmental changes. The frequency decrease in the North Pacific is associated with changes in the mid-latitude jet and weakened local meridional temperature gradient. The frequency decrease in the Southern Hemisphere is related to the enhanced mid-latitude westerly wind. These results complement our current knowledge about how bomb cyclones will change under global warming and suggest high-resolution climate models should be used to better understand the projection and impacts of future bomb cyclones.