EGU21-13685
https://doi.org/10.5194/egusphere-egu21-13685
EGU General Assembly 2021

Horizontal scale of large-scale convective self-aggregation and their sensitivity to SST

Shuhei Matsugishi[1] and Masaki Satoh[2]
[1]Atmosphere and Ocean Research Institute, The University of Tokyo, Kashiwa-shi, Japan (matsugishi@aori.u-tokyo.ac.jp)
[2]Atmosphere and Ocean Research Institute, The University of Tokyo, Kashiwa-shi, Japan (satoh@aori.u-tokyo.ac.jp)

We conducted radiative convective equilibrium (RCE) experiments with varying domain size and sea surface temperature (SST) using the global cloud-system-resolving model NICAM (Satoh et al. 2014) to investigate the dependence of the maximum horizontal scale of the convective cluster on SST.

Convective self-aggregation in RCE simulations are widely studied, where convections spontaneously organize into a humid convective cluster even in the absence of inhomogeneities in boundary conditions and forcing. Previous studies show that convective self-organization does not occur when the domain size is too small, and that convective region become single-connected regions within a certain domain size, whereas when the domain size is large enough, multiple convective clusters are generated. In a previous study, although the maximum horizontal scale of the convective cluster was estimated to be about 4000 km, but the domain size of the simulation was smaller than the Earth surface, so it is not certain whether the preferable size of the convective aggregation exists over the realistic domain of the Earth. Moreover, it is now well understood how the horizontal size of the aggregation depends on SST; this aspect is relevant to understanding of the climate sensitivity.

The experiments were conducted with the NICAM simulations with switching off convective parameterization over a non-rotating spherical domain over the area of the region by varying the radius (the Earth radius R, R/2, R/4, R/8, and R/16). The horizontal uniform constant SST was changed as 295, 300, and 305K. The results show that there was a single convective cluster at a radius of R/4 or less, while there were multiple convective clusters at a radius of R/2 or more. The threshold for the transition between multiple convective clusters and a single convective cluster is found to be between R/4 and R/2. Physical variables such as vertical profiles of temperature and humidity gradually changes as the radius becomes larger, and converged at the radius R/2. For the SST dependency, the result robustly indicates that the maximum horizontal scale of the convection cluster is not monotonic with SST and it was largest for SST 300K.

As the domain size increases, the domain average moistens, and the boundary layer wind speed increases. Because the diabatic radiative cooling is constrained by the temperature and humidity structure, the surface evaporation and thus the surface wind speed must also be constrained with an upper limit; this is why the maximum horizontal scale exists and there are multiple convective clusters for the domain size larger than R/2. We also found that the moist static energy transport from the convective region decreases as the domain becomes larger, as pointed out by Patrizio and Randall (2019). The horizontal scale dependence of the convective cluster is related to two factors: the effect of the horizontal pressure difference in the boundary layer and the circulation structure of free troposphere. The energy budget analysis also explains the SST dependence of the maximum horizontal scale of the convective clusters.