Dependence of equatorial precipitation activity on the vertical profile of radiative cooling in an aqua-planet experiment

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An aqua-planet GCM (general circulation model) experiment is performed to examine the effect of vertical profile of radiative cooling on the varieties of the appearance of equatorial precipitation structures.

One of the possible causes for the difference of the appearance of precipitation pattern in a GCM is the difference of vertical profile of condensation heating. Numaguti and Hayashi (1991) argued that, by performing an aqua-planet experiment, the eastward moving grid-scale precipitation structures are maintained by the wave-CISK (conditional instability of the second kind) dynamics. In order for the wave-CISK dynamics to operate, the vertical profile of condensation heating has a great influence. If the eastward moving grid-scale precipitation structures are maintained by the wave-CISK dynamics, it is expected that they will become less evident when the vertical profile of condensation heating is inconsistent with the wave-CISK dynamics. According to this expectation, we performed here an experiment where the vertical profile of condensation heating was varied by changing the profile of radiative cooling through tuning the absorption coefficients of longwave radiation scheme.

In the cases with Kuo scheme as cumulus parameterization, eastward propagating grid-scale precipitation structures are clearly observed at the equator when condensation heating rate has its maximum in the upper troposphere. Westward propagating precipitation structures appear when condensation heating rate has its maximum in the lower troposphere. The composite circulation structure with reference to eastward propagating precipitation peaks shows the westward phase tilt of temperature and wind fields in longitude-height section, which is consistent with CISK dynamics. The composite structure with reference to westward propagating precipitation peaks shows the upright convection, or CIFK (conditional instability of the first kind) structure. In the cases with convective adjustment scheme, significant differences of grid-scale precipitation structures can not be observed with the change of absorption coefficients of longwave radiation scheme. This is considered to be caused by the fact that the vertical profile of condensation heating does not change drastically with the changes of absorption coefficients.