NUMERICAL MODELING OF MULTISCALE ATMOSPHERIC FLOWS: FROM CLOUD MICROSCALE TO CLIMATE

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ABSTRACT

An outstanding feature of atmospheric flows is the range of spatial and temporal scales involved. Development of rain through gravitational collisions of small cloud droplets concerns processes at sub-centimeter scales. Size distribution of cloud droplets within turbulent cumulus and stratocumulus clouds in the tropics and subtropics, where the solar insolation is at its peak, significantly affects the amount of solar radiation reflected back to space, and thus the planetary albedo. Tropical deep convective clouds, often organized into mesoscale convective systems with horizontal scales of tens to hundreds of kilometers, drive planetary-scale Hadley circulation, which plays an important role in Earth energy and water budgets. For all these scales, numerical modeling---either for scientific research or for practical purposes, like the numerical weather prediction---plays an important role. The multiscale nature of these flows, often involving variable physics (e.g., hydrostatic large-scale flow and nonhydrostatic convective dynamics for the climate problem) needs to be carefully addressed.

This paper will present two examples of the multiscale approaches at the two ends of the range of scales introduced above. The first example concerns the effects of cloud turbulence on collisions of cloud droplets, the key mechanism of rain formation. Hydrodynamic interactions between colliding droplets involve processes at separation distances much smaller than the mean distance between cloud droplets and cannot be resolved by traditional DNS techniques. A novel computational approach was developed, referred to as the Hybrid DNS (HDNS; [1]), which allows not only interactions of individual droplets with the turbulent carrier flow, but also hydrodynamic interactions between the droplets. HDNS enables to estimate the impact of cloud turbulence on the collision efficiency of cloud droplets. The second example will introduce the concept of the "super-parameterization" (SP) that is gaining popularity in climate modeling. SP involves embedding a nonhydrostatic 2D (x-z) cloud model in every column of a hydrostatic atmospheric general circulation model [2, 3}. In a nutshell, the SP model replaces moist convection and cloud parameterizations, and leads to a more realistic representation of cloud processes and radiative transfer in climate models.

References

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