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Toward the end of cumulus parameterization

The current generation of General Circulation Models can simulate the global atmosphere with a resolution of the order of 50 km. Such a resolution is insufficient to explicitly simulate the deep convective motions that are responsible for the bulk of the vertical energy transport in the atmosphere. To compensate for this limitation, climate models have used various cumulus parameterizations to account for the effects of convective motions on the atmospheric temperature, humidity and cloud distribution. However, due to the continuous increase in computational power, the next generation of global models might be run at a sufficiently fine resolution as to make the use of cumulus parameterization unnecessary.

This paper investigates the impacts of horizontal resolution on the statistical behavior of convection. An idealized radiative-convective equilibrium is simulated for model resolutions ranging between 2 and 50 km. The simulations are compared based upon the analysis of the mean state, of the energy and water vapor transport, and of the probability distributions functions for various quantities. It is found that, despite some bias in temperature and humidity, coarse resolution simulations are able to reproduce reasonably well the statistical properties of deep convective towers. This is particularly apparent in the cloud ice and vertical velocity distributions that exhibit a very robust behavior at resolution up to 16 km.

A theoretical scaling for the vertical velocity as function of the grid resolution is derived, based upon the behavior of an idealized air bubbles. The vertical velocity of an ascending bubble is determined by its aspect ratio, with a wide, flat parcel rising at a much slower pace than a narrow one. This theoretical scaling law can explain the behavior of the numerical simulations, and be used to re-normalize the probability distribution functions for vertical velocity.