Radiation Effects in the Cloud-topped Marine Boundary Layer

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ABSTRACT

This paper investigates the interaction between dynamics and infrared radiation in the cloud-topped marine boundary layer. A two-dimensional Boussinesq moist model with a numerical technique (Fourier-Chebyshev spectral tau method) and resolution (10 m) sufficient to simulate cloud top processes has been used. With the spectral tau method and the fourth-order Runge-Kutta time integration scheme, great computational efficiency are realized even with high model accuracy.

Measurements suggest that the cloud-top radiative cooling is likely to exhibitsignificant horizontal as well as vertical variability which is principally governed by the variability of cloud liquid water. To investigate the impact of infrared cooling on boundary layer dynamics, numerical experiments on marine boundary layer convection under various idealized radiative forcings are performed. The results indicate that the dynamics of the cloud-topped marine boundary layer do not depend on the horizontal and the vertical distribution of the cooling so long as the cooling is confined to the turbulent boundary layer. The sensitivity of stratocumulus-topped boundary layer dynamics to the infrared cooling appears to be primarily in the vertical placement of the cooling relative to the turbulent cloud top region. This is due to the fact that the turbulent dynamical mixing time scale is smaller than the radiation build up time scale. Before radiation can cool a local region appreciably to influence the dynamics, the circulation inside the boundary layer has already transported the cloudy parcel out of the radiative cooling zone. Since the theory of radiation does not support the existence of infrared cooling in the capping inversion (zero cloud fraction or non-turbulent region), the spatial variability of cloud-top cooling needs to be considered only when the radiation build up time scale is comparable to the turbulent mixing time scale.

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