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A cumulus parameterization with state-dependent entrainment rate

Minoru Chikira
Research Institute for Global Change, JAMSTEC, Yokohama, Japan (chikira@jamstec.go.jp)

A new cumulus parameterization is developed for the use in climate models. An entraining-plume model is adopted. Lateral entrainment rate varies vertically depending on surrounding environment following Gregory (2001). Cumulus ensemble is spectrally represented according to updraft velocity at cloud base. Cloud base mass flux is determined by a method identical to the prognostic Arakawa-Schubert scheme. Entrainment rate tends to be large near cloud base because of small updraft velocity around the level. Deep convection tends to be suppressed when convective available potential energy is small owing to upward reduction of in-cloud moist static energy. Dry environmental air significantly reduces in-cloud humidity mainly because of large entrainment rate in the lower troposphere, which leads to suppression of deep convection, consistent with observations and previous results of cloud resolving models. Change in entrainment rate has a potential to influence on cumulus convection through many feedbacks. The results of an atmospheric general circulation model are improved in both climatology and variability. A representation of the Southern Pacific Convergence Zone and double intertropical convergence zone is improved. The moist Kelvin waves are represented without empirical triggering schemes with a reasonable equivalent depth. A spectral analysis shows a strong signal of the Madden-Julian oscillation. The scheme provides new insights and better understanding on an interaction between cumuli and the surrounding environment.