Geophysical Research Abstracts
Vol. 18, EGU2016-18313, 2016
EGU General Assembly 2016

On the Representation of Cloud Phase in Global Climate Models, and its Importance for Simulations of Climate Forcings and Feedbacks

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Despite the growing effort in improving the cloud microphysical schemes in GCMs, most of this effort has not focused on improving the ability of GCMs to accurately simulate phase partitioning in mixed-phase clouds. Getting the relative proportion of liquid droplets and ice crystals in clouds right in GCMs is critical for the representation of cloud radiative forcings and cloud-climate feedbacks. Here, we first present satellite observations of cloud phase obtained by NASA's CALIOP instrument, and report on robust statistical relationships between cloud phase and several aerosols species that have been demonstrated to act as ice nuclei (IN) in laboratory studies. We then report on results from model intercomparison projects that reveal that GCMs generally underestimate the amount of supercooled liquid in clouds. For a selected GCM (NCAR 's CAM5), we thereafter show that the underestimate can be attributed to two main factors: i) the presence of IN in the mixed-phase temperature range, and ii) the Wegener-Bergeron-Findeisen process, which converts liquid to ice once ice crystals have formed. Finally, we show that adjusting these two processes such that the GCM's cloud phase is in agreement with the observed has a substantial impact on the simulated radiative forcing due to IN perturbations, as well as on the cloud-climate feedbacks and ultimately climate sensitivity simulated by the GCM.