Geophysical Research Abstracts
Vol. 18, EGU2016-2194, 2016
EGU General Assembly 2016

Cloud Dynamical Controls on Climate Forcing by Aerosol-Cloud Interactions: New Insights from Observations, High-Resolution Models, and Parameterizations

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At frequently observed, low updraft speeds, cloud droplet and ice crystal number concentrations are controlled mostly by cloud-scale vertical velocities and not aerosol number concentrations. Reducing uncertainty in estimates of climate forcing by aerosol-cloud interactions will require taking account of these thermodynamically limited cloud regimes in global climate models. The scales of the relevant cloud dynamics are often well-below resolved scales in climate and numerical weather prediction models, ranging to tens of meters at large-eddy scale for stratocumulus clouds.

Observations of vertical velocities from cloud radars in field programs and at fixed observational sites are providing a basis for evaluating new classes of parameterizations for convective and non-convective clouds that include probability distribution functions (PDFs) for vertical velocity, which can be used to drive physically based representations of droplet and crystal activation. High-resolution cloud models with detailed treatments of aerosol and microphysical processes can also be evaluated using these observations. Vertical velocities in both high-resolution models and parameterizations currently show discrepancies from observations while capturing qualitative features. Improved treatments of microphysical and turbulence processes in high-resolution cloud models hold promise for improving agreement with observations, while a wide range of advances in parameterization are possible paths to improvement for simulating sub-grid vertical velocities and aerosol-cloud interactions.