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A microphysical pathway analysis to investigate aerosol effects on convective clouds

Max Heikenfeld, Bethan White, Laurent Labbouz, and Philip Stier

University of Oxford, Atmospheric, Oceanic and Planetary Physics, Department of Physics, Oxford, United Kingdom (max.heikenfeld@physics.ox.ac.uk)

The impact of aerosols on ice- and mixed-phase processes in convective clouds remains highly uncertain, which has strong implications for estimates of the role of aerosol-cloud interactions in the climate system. The wide range of interacting microphysical processes are still poorly understood and generally not resolved in global climate models.

To understand and visualise these processes and to conduct a detailed pathway analysis, we have added diagnostic output of all individual process rates for number and mass mixing ratios to two commonly-used cloud microphysics schemes (Thompson and Morrison) in WRF. This allows us to investigate the response of individual processes to changes in aerosol conditions and the propagation of perturbations throughout the development of convective clouds.

Aerosol effects on cloud microphysics could strongly depend on the representation of these interactions in the model. We use different model complexities with regard to aerosol-cloud interactions ranging from simulations with different levels of fixed cloud droplet number concentration (CDNC) as a proxy for aerosol, to prognostic CDNC with fixed modal aerosol distributions. Furthermore, we have implemented the HAM aerosol model in WRF-chem to also perform simulations with a fully interactive aerosol scheme.

We employ a hierarchy of simulation types to understand the evolution of cloud microphysical perturbations in atmospheric convection. Idealised supercell simulations are chosen to present and test the analysis methods for a strongly confined and well-studied case. We then extend the analysis to large case study simulations of tropical convection over the Amazon rainforest. For both cases we apply our analyses to individually tracked convective cells.

Our results show the impact of model uncertainties on the understanding of aerosol-convection interactions and have implications for improving process representation in models.