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Simulating the effects of semivolatile compounds on clouds

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In cloud formation, semivolatile compounds can condense on aerosol droplets simultaneously with water affecting the activation of aerosol to cloud droplets. Thus, they affect the evolution of the physical properties of clouds altering their optical properties and their effects on the Earth's radiative balance. In addition, as they affect the cloud life cycle, they can affect the life cycle of other chemical species in aerosol. The role of semivolatile compounds such as ammonia and nitric acid in the atmosphere will become more important in the future since while e.g. sulfate emissions are expected to decrease the nitrate emissions are expected to increase.

In this study, we have investigated how ammonia and nitric acid affect the life cycle of a cloud and thus the life cycle non-volatile aerosol compounds. To achieve this, we use the Large Eddy Simulations (LES) model UCLALES-SALSA which consists of the LES model UCLALES that simulates the dynamics of the boundary layer and the aerosol-cloud model SALSA which simulates the aerosol and cloud microphysics. In the UCLALES-SALSA model the aerosol properties are tracked through cloud processing from cloud droplet activation to precipitation formation and ice nucleation to melting and evaporation. It is a sectional model that includes separate size sections for interstitial aerosol, cloud droplets, precipitation droplets, and ice crystals. In SALSA, the partitioning of semivolatile compounds are calculated solving the kinetics of condensation and evaporation of ammonia, nitric acid, and water. Thus, the model takes explicitly into account the effect on semivolatile compounds the cloud droplet formation, but also their effect on the evolution of the cloud. As opposed to non-volatile compounds such as sulfate, the distribution among interstitial aerosol and cloud hydrometeors changes during a cloud cycle as nitric acid and ammonia are evaporated from the non-activated particles then condensing on the activated droplets. This yields to a significantly different wet deposition between non-volatile and volatile compounds. In addition, especially in polluted conditions, these compounds significantly affect the properties of cloud droplets thus significantly affecting the lifecycle of different aerosol compounds. The co-condensation of ammonia and nitrate significantly increases the number of activated cloud droplets thus suppressing the formation of precipitation. Our results show that in order to simulate the transport of aerosol from source regions to remote regions accurately, the effects of semivolatile compounds should be taken into account in the atmospheric models.