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Modelling the effects of primary marine organic aerosol on mixed-phase clouds

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Recent studies have shown that primary marine organics which are emitted as sea spray aerosol can be the main driver of ice nucleation in remote boundary layer clouds. Here we examine this by using a state-of-the-art large eddy simulator UCLALES-SALSA. The model describes aerosol, cloud and ice size distributions and chemical compositions using several dry size bins. This allowed the implementation of prognostic ice nucleation approach where cloud droplet freezing rate is calculated based on ambient conditions and chemical composition of the droplets. Specifically, ice nucleating particles (INPs) for the immersion freezing mode can be identified and tracked by the insoluble compounds they contain.

Development of mixed-phase clouds is sensitive to INP concentration, which depends on the balance between sources (free troposphere and marine emissions), sinks (removal with precipitation) and vertical transport. Simulations show that turbulent vertical transport of marine INPs is efficient when the boundary layer is coupled. On the other hand, almost constant boundary layer height means limited import of background INPs from the free troposphere. For the simulated cases, most INPs originate from the sea surface rather than free troposphere. Typically cloud droplet freezing starts at the very top of updrafts. First these newly formed ice crystals grow with the expense of cloud droplets, but soon precipitation and downdrafts redistribute ice more evenly. The largest ice particles can fall though the sublimation region, which means that these INPs are permanently removed with precipitation. Smaller particles are released back to aerosol when the ice has sublimated, and those particles can act as INP in the following updrafts. In general, our simulations show that marine aerosol emissions can be efficiently mixed and re-circulated within the boundary layer while free troposphere can be isolated from the clouds.