



Tracing cirrus cloud formation history using satellite observations and Lagrangian trajectories

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Cirrus clouds, composed of pure ice crystals and forming in the upper troposphere, are particularly challenging to characterize because of their complex microphysics and diverse growth processes. Satellite observations capture only snapshots of cirrus cloud properties, offering limited insight into cloud history. Here, we present DC-Ice, which combines satellite observations and Lagrangian microphysical modelling to trace the history of air parcels contributing to cirrus cloud formation. The Chemical Lagrangian Model of the Stratosphere (CLaMS) is employed to trace air-parcel trajectories along the DARDAR-Nice track, along which cirrus cloud formation and evolution are simulated using the CLaMS-Ice microphysical model. Satellite observations are complemented with origin-based metrics describing ice formation pathways (homogeneous vs heterogeneous), ice crystal origin (liquid-phase or in-situ), and the time since ice formation.

DC-Ice is applied to three representative midlatitude cirrus cases spanning fast updrafts, slow updrafts, and orographically driven conditions. Air parcel histories and reconstructed vertical profiles along the satellite track are used to identify distinct phases of the cirrus life cycle and the distribution of origin-based metrics across cloud layers. Modelled microphysical properties are statistically evaluated against satellite retrievals. In addition, a series of sensitivity experiments assesses the influence of key CLaMS-Ice input parameters, including small-scale temperature fluctuations, environmental ice-nucleating particle (INP) concentrations, and sedimentation parameterizations. Taken together, this framework adds a process-based context to satellite observations and supports a more comprehensive understanding of cirrus cloud origins and their role in the climate system.