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Exploring ice cloud formation mechanisms through satellite observations and integrated Lagrangian transport with microphysical models

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Understanding the formation mechanisms of ice clouds has been hindered by the complexity of their composition and the diversity of their growth processes. Previously, observational constraints have been limited, leading to substantial gaps in our comprehension and representation of ice clouds. Satellite measurements face a significant challenge due to the lack of essential environmental context information, that is necessary to identify and understand the cloud's formation mechanism and evolution. Indeed, these representations only capture a snapshot of the state of a cloud and its microphysical properties at a given time. This study addresses this limitation by providing additional metrics on ice cloud history and origin along with operational satellite products.

Here, we present a novel framework that combines satellite observations with Lagrangian transport and ice microphysical models, to obtain information on the history and origin of air parcels that contributed to their formation. The air mass transport model CLaMS (Chemical LAgrangian Model of the Stratosphere) was employed to track the trajectory of air parcels along the DARDAR-Nice track. CLaMS-Ice model is jointly used to simulate cirrus clouds along trajectories derived by CLaMS. This approach provides information on the cloud regime as well as the ice formation (in-situ vs liquid origin) pathway. Our findings, derived from case studies involving multiple cloud types, present a realistic representation of these complex processes. We explore the sensitivity of our methodology to initial conditions and thresholds. Additionally, a statistical analysis examines how satellite cloud microphysics are sensitive to CLaMS-Ice metrics. This comprehensive approach advances our understanding of ice cloud processes and helps to refine satellite-based representations of these atmospheric phenomena.