# Importance of Secondary Ice Production to Ice Formation and Phase of High-Latitude Mixed-Phase Clouds during SOCRATES and MARCUS

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Measured ice number concentrations are often much higher than the number concentrations of ice nucleating particles (INPs) in moderately cold mixed-phase clouds, suggesting the potential importance of secondary ice nucleation (SIP). However, the occurrence frequency and importance of SIP relative to primary ice nucleation for ice formation and mixed-phase cloud properties are largely unknown. Representing the SIP processes in weather and climate models is equally challenging.

In this study, we present a process-level understanding of SIP in high-latitude mixed-phase clouds based on integrated model-observational analyses of the NSF SOCRATES aircraft and DOE ARM MARCUS ship-borne data. We run the Community Earth System Model version 2 (CESM2) nudged towards the MERRA2 Reanalysis and output the modeled clouds and aerosols along the aircraft flight and ship tracks for direct model-observation comparisons. We found that CESM2 with a physical representation of SIP processes (e.g., ice-ice collisional break-up, droplet shattering during rain freezing) better capture the observed ice crystal number concentrations (ICNCs) and cloud properties. SIP often dominants the ice formation in the moderately cold mixed-phase clouds, and transforms ~30% of pure liquid-phase clouds simulated in the model into mixed-phase clouds. We also compare modeled ice enhancement ratio due to SIP to ICNC and INP number concentrations observed during SOCRATES and MARCUS.