A Model Intercomparison Study of Mixed-Phase Clouds in a Laboratory Chamber

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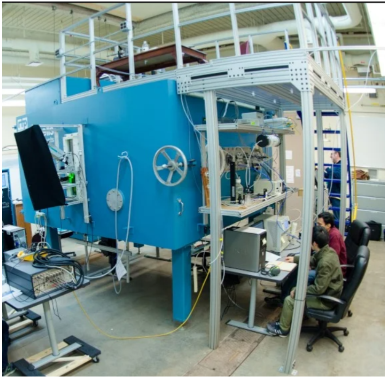
The Pi Chamber

- Size 2 m x 2 m x 1 m.
- Rayleigh-Bénard convection and mixing, resulting in supersaturation.
- CCN and INPs injected to form a steady-state mixed-phase cloud (Desai et al., 2019).



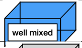
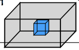
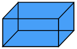
Pi Chamber, Michigan Technological University, https://blogs.mtu.edu/

Numerical models

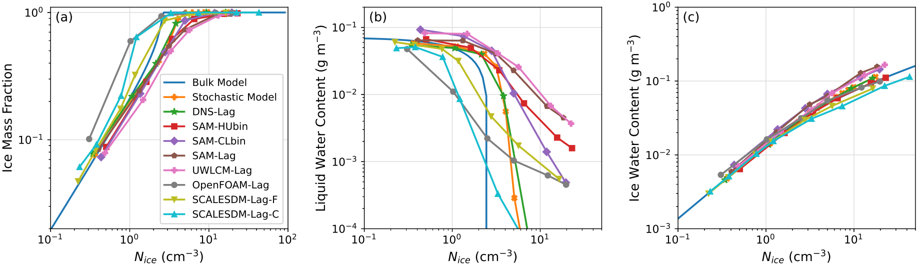
- 8 different models (10 configurations)
- Liquid spinup - injecting sea salt (CCN) with a diameter 125 nm.
- Mixed-phase period - injecting ice particles with initial radius 2 μm together with the CCN.
- Models' responses to different ice injection rates were tested.
- Focus on the cloud glaciation (the WBF process).

Numerical models

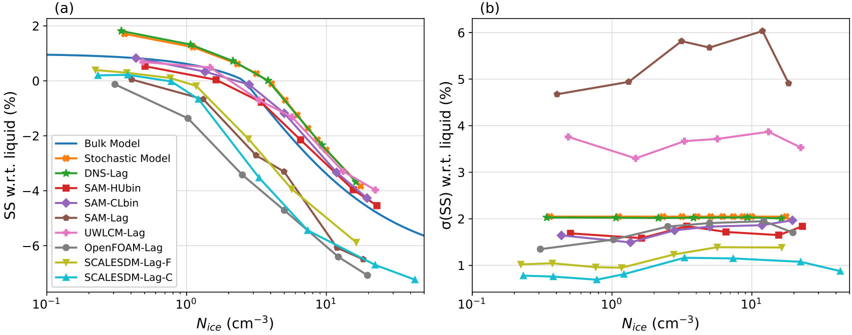
Names and configurations of the models (Wang et al., 2025).

Member Name	Type	Microphysics Scheme	Grid Spacing	Side Wetness	CCN Inj. Rate	Simulated Domain
Bulk Model	Bulk Scalar-Flux Model					
Stochastic Model	Stochastic Model			–	10.0 cm^{-3} min^{-1}	
DNS Lag	DNS	Lagrangian	0.78125 mm	–	10.0 cm^{-3} min^{-1}	
SAM-HUJIbin	LES	HUJI bin	3.125 cm	30%	10.0 cm^{-3} min^{-1}	
SAM-CLbin		Chen-and-Lamb bin		30%	10.0 cm^{-3} min^{-1}	
SAM-Lag		Lagrangian		30%	10.8 cm^{-3} min^{-1}	
UWLCM-Lag				52%	11 cm^{-3} min^{-1}	
OpenFOAM-Lag				??	?? cm^{-3} min^{-1}	
SCALE-SDM-Lag-F				66%	10 cm^{-3} min^{-1}	
SCALE-SDM-Lag-C			6.25 cm	66%	8 cm^{-3} min^{-1}	

Ice mass fraction

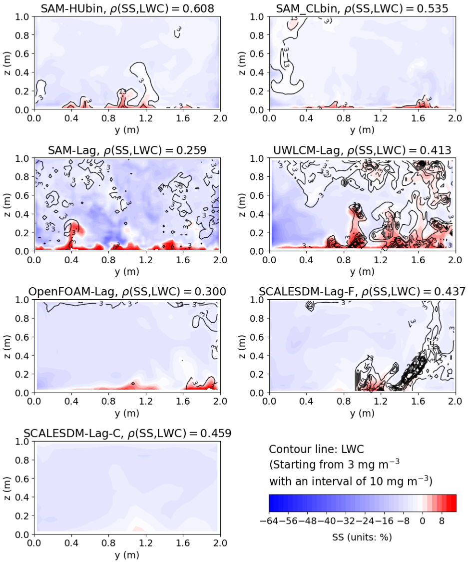


Supersaturation



The (a) mean supersaturation and (b) standard deviation of supersaturation versus ice number concentration.

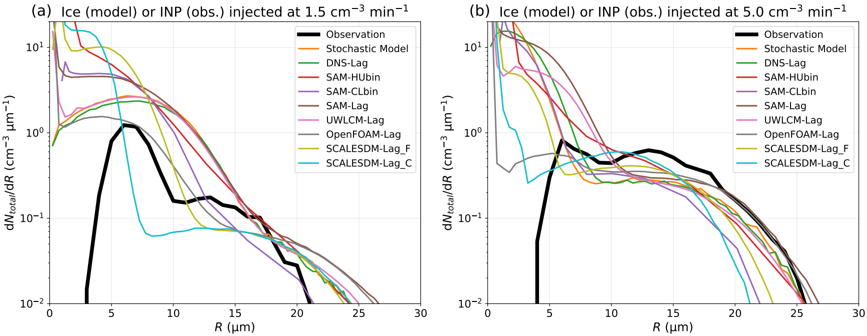
Supersaturation



Slices of supersaturation (color), with respect to LWC (contour), for the ice injection rate 10 cm^{-3} min^{-1}.

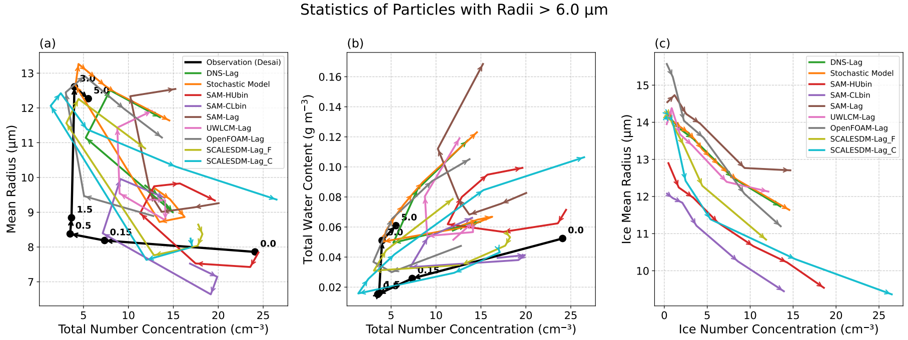
Correlation coefficient ρ between supersaturation and LWC shown in each subpanel.

Particle size distribution



PSD including liquid and ice, at two injection rates.

Microphysical statistics vs. number concentration



Key points

- Differences in grid resolution, microphysical schemes and wall-forcing treatments influenced glaciation rates.
- Rapid, sometimes complete, glaciation occurred in models with coarse resolution or simplified microphysics.
- Sustained mixed-phase states occurred in higher-resolution Lagrangian and bin microphysics schemes.
- Results emphasize the importance of laboratory experiments as benchmarks for numerical models.

Bibliography

Desai, N., Chandrakar, K. K., Kinney, G., Cantrell, W., & Shaw, R. A. (2019).Aerosol-mediated glaciation of mixed-phase clouds: Steady-state laboratory measurements. *Geophysical Research Letters*, *46*(15), 9154–9162.

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