Spectrally resolved Polarimetric Observation and Computation of Clouds - SPOCC

PROM annual meeting, Kiel, 17-19 July 2023

PI‘s: Patric Seifert (obs), Oswald Knoth (model)

PhD‘s: Junghwa Lee (model), Majid Hajipour (obs)

Partners:
- Michael Frech (DWD)
- Herman Russchenberg (TU Delft)
- Alexander Myagkov (shape retrieval)
- Tempei Hashino (bin-spectral modelling)
- Colleagues at LIM (Maximilian Maahn, Heike Kalesse-Los et al.)

„Toward modeling and observing the hydrometeor ratio during the onset of precipitation.“

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ACCEPT

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Numerical evidence that the impact of CCN and INP concentrations on mixed-phase clouds is observable with cloud radars

18. July 2023

Junghwa Lee

Member of the Leibniz Association

PROM

UNIVERSITÄT LEIPZIG

高知工科大学 Kochi University of Technology

TROPOS Leibniz Institute for Tropospheric Research

Content

1. Motivation
2. Method
3. Result
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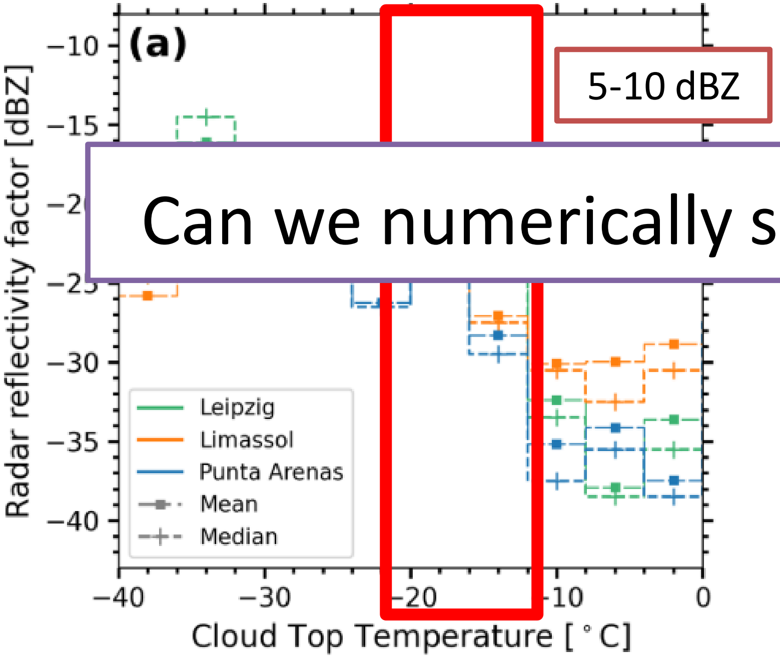
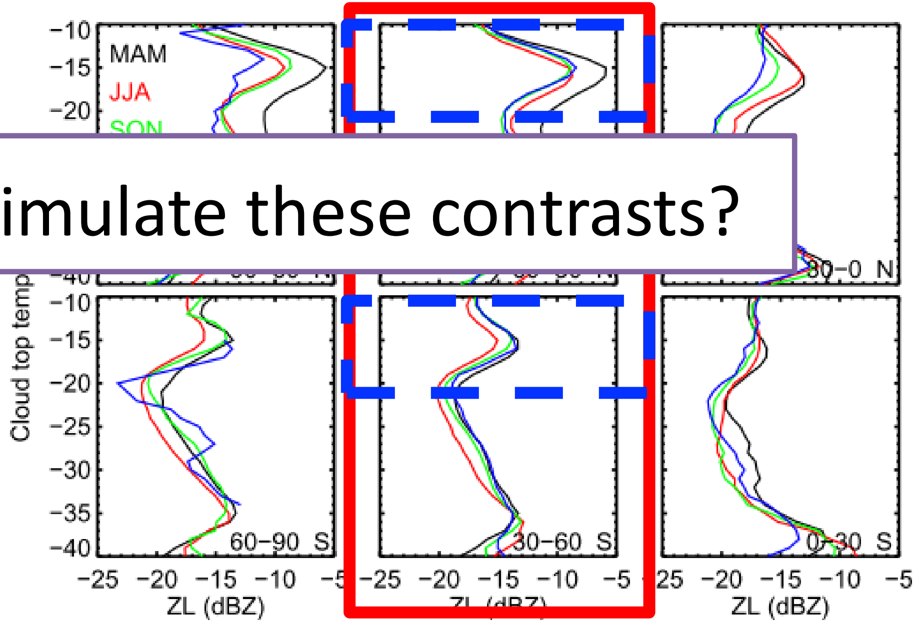
Analysis of Aerosol-Related Contrasts in Cloud-Radar Reflectivities Observed in Stratiform Supercooled Mixed-Phase Clouds

Radenz et al. (2021), ACP



Zhang et al. (2018), ACP



Can we numerically simulate these contrasts?

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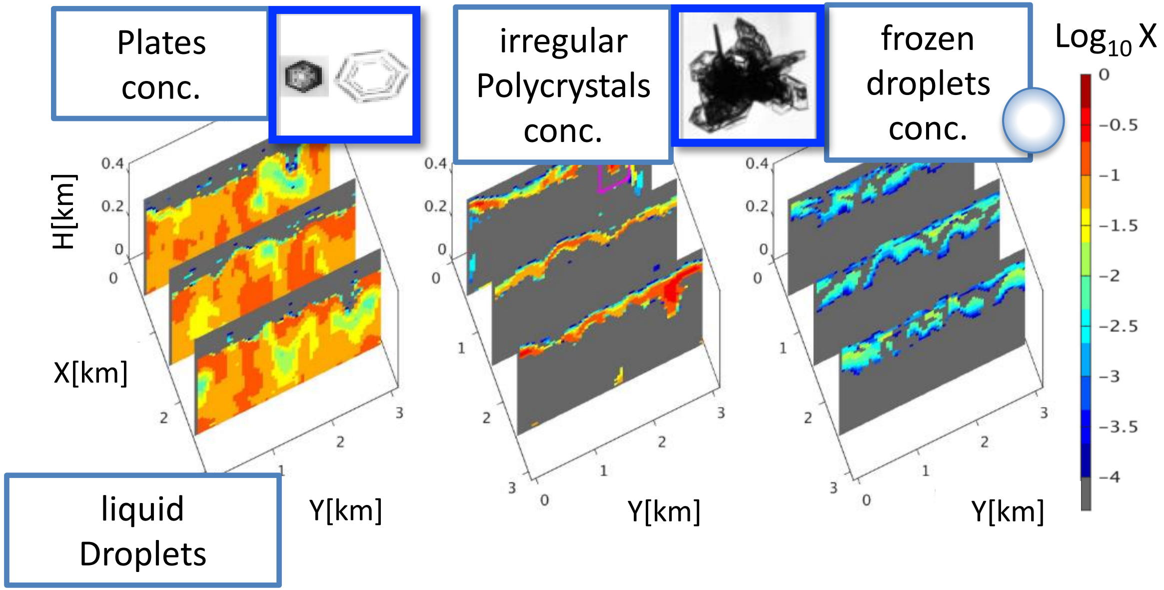
The motivation of advanced microphysics modeling: Spectral-bin model → Advanced Microphysical Prediction System (AMPS; Hashino et al. (2020), JAS)

- Hydrometeor shapes can be distinguishable
- Modeling can suggest the possible pathway of precipitating the evolution of hydrometeors



Number concentration for Surface HEat Budget of the Arctic Ocean (SHEBA)

Warm cloud	Cold cloud
- CCN activation - Coliision-coalescence - Collision-breakup	- Nucleation Process - Riming - Aggregation - Secondary process

Both

- Sedimentation
- Ventilation effect

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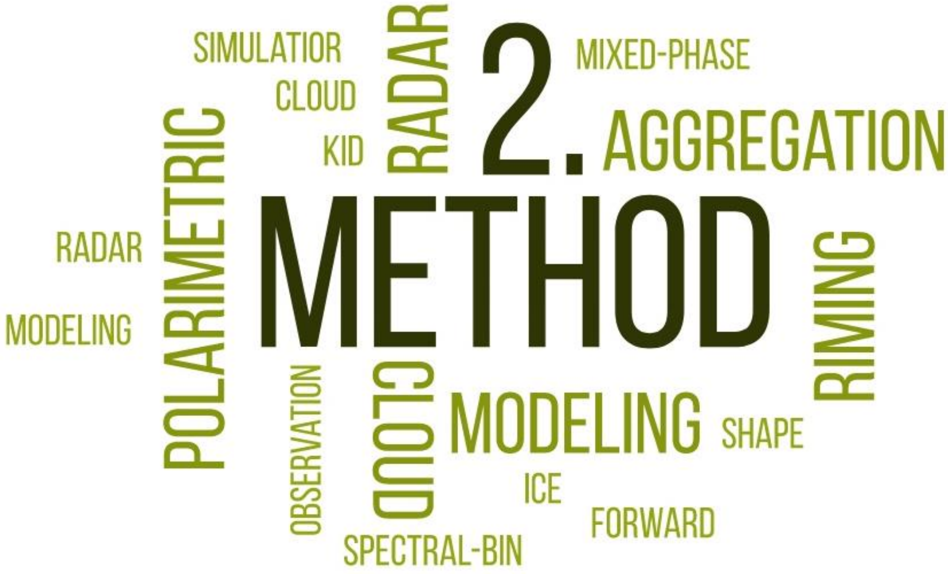

SIMULATIOR
CLOUD
KID
RADAR
2.
MIXED-PHASE
AGGREGATION
POLARIMETRIC
RADAR
MODELING
METHOD
RIMING
OBSERVATION
CLOUD
MODELING
SHAPE
ICE
FORWARD
SPECTRAL-BIN

The spectral-bin microphysics model

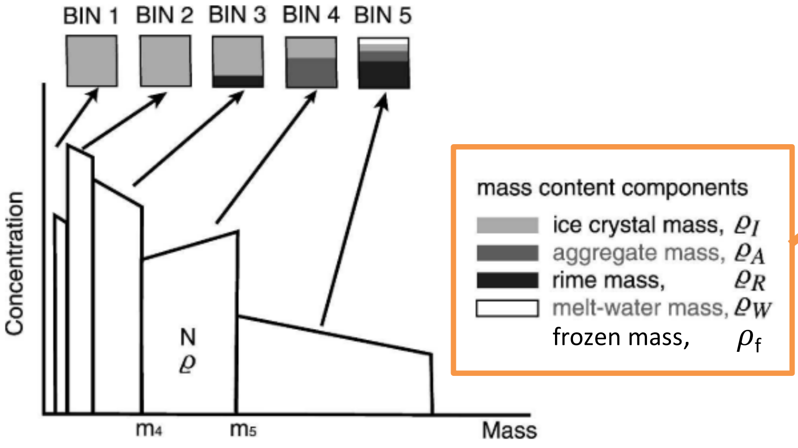
→ Advanced Microphysical Prediction System (AMPS; Hashino and Tripoli (2007), JAS)

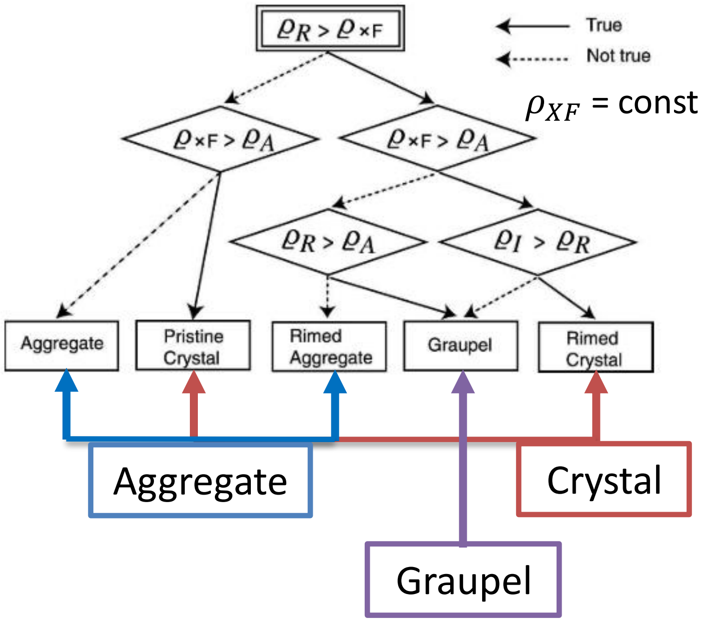
18 prognostic variables / bin

Mass ρ
Concentration N

+

Particle Property Variables (PPVs)





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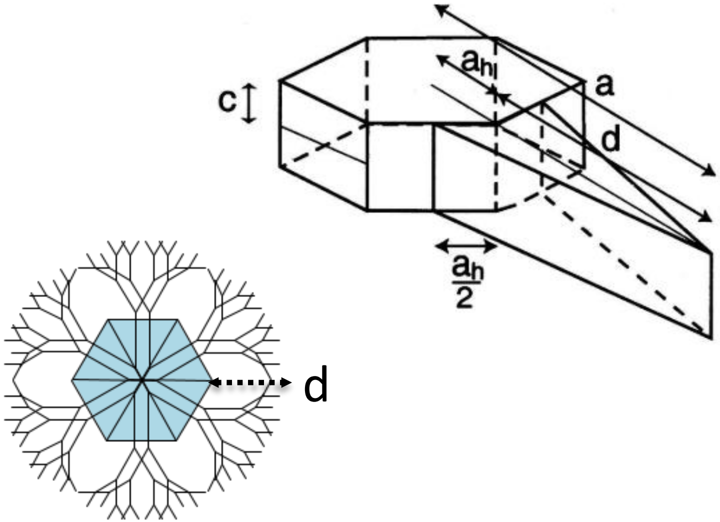
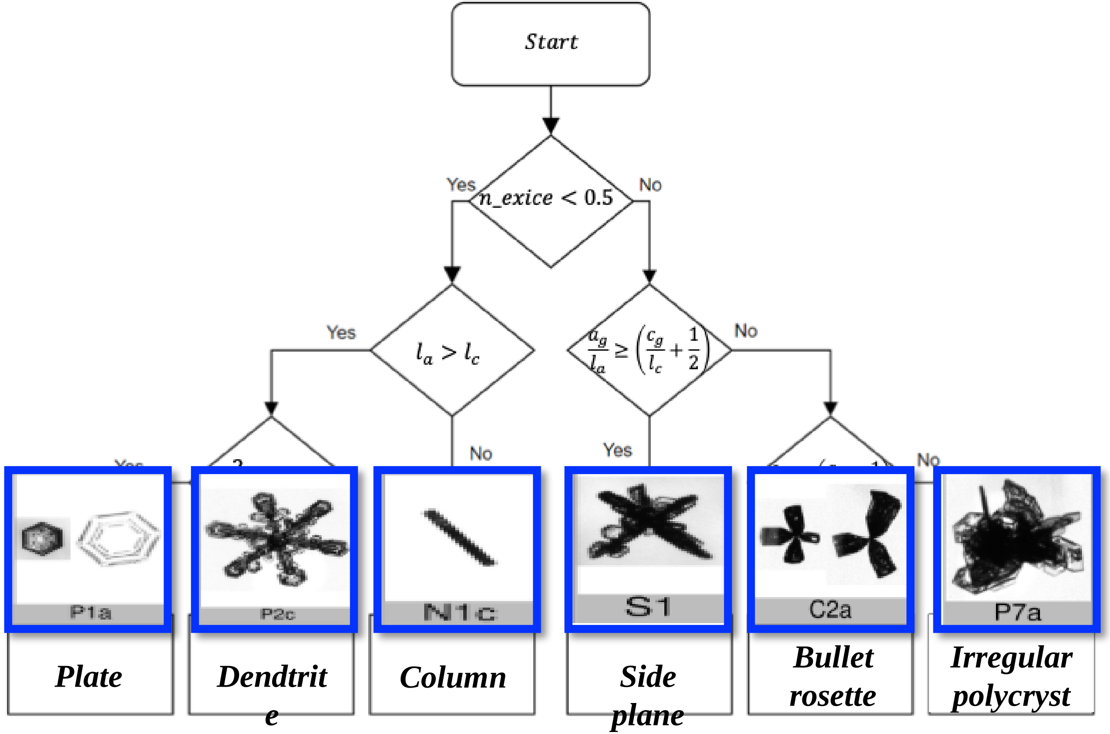
Particle Property Variables (PPVs) in AMPS: Diagnosis of Habit

(a) Dimension of the Hexagonal Crystal Model



Hashino and Tripoli (2006), JAS

(b) Diagnosis Flowchart



Vázquez-Martín (2020)

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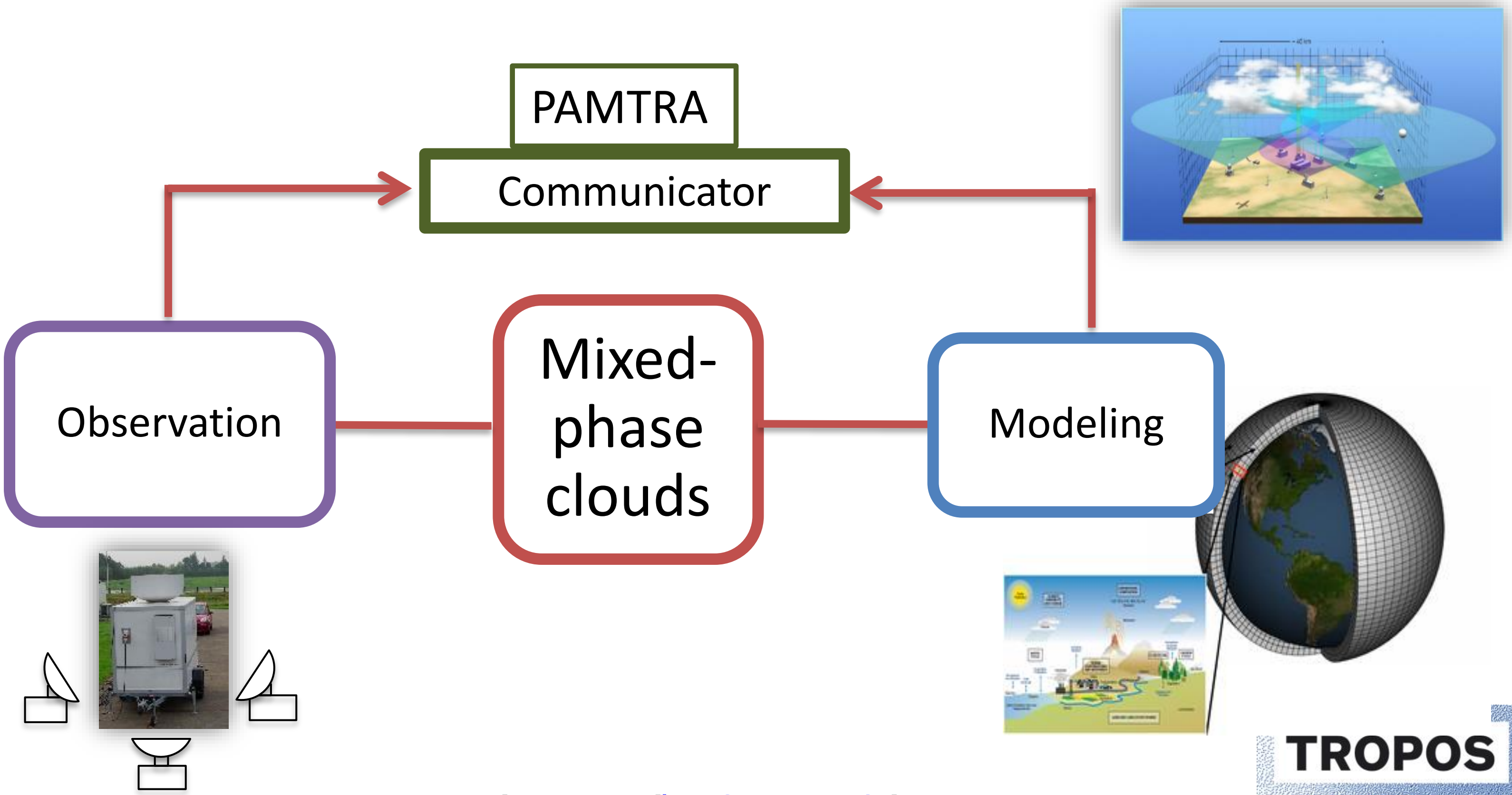
Radar forward simulator (PAMTRA: Mech et al., 2020, GMD)



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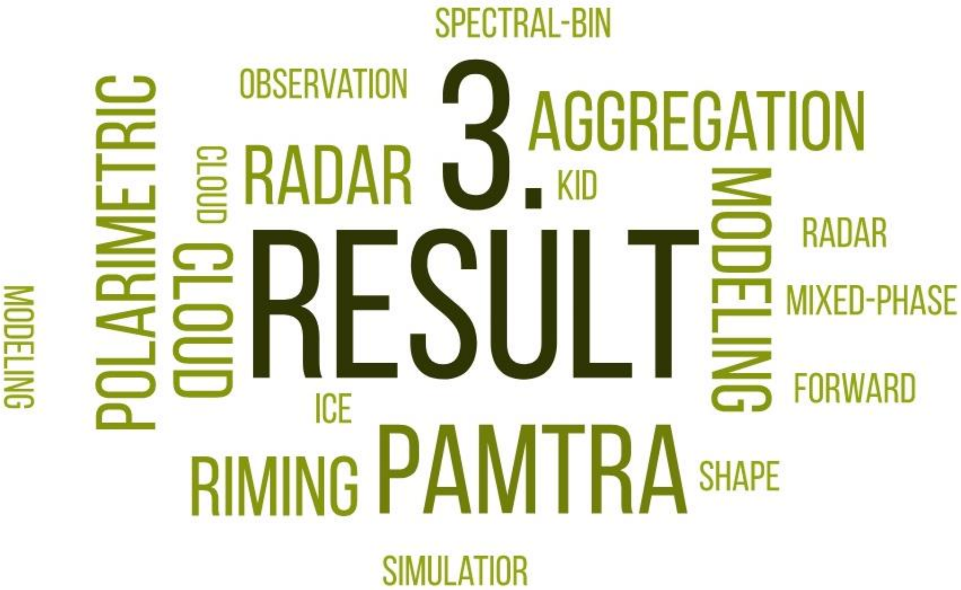

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The impact of CCN and INP perturbations on mixed-phase clouds with AMPS and Radar forward simulator (PAMTRA)

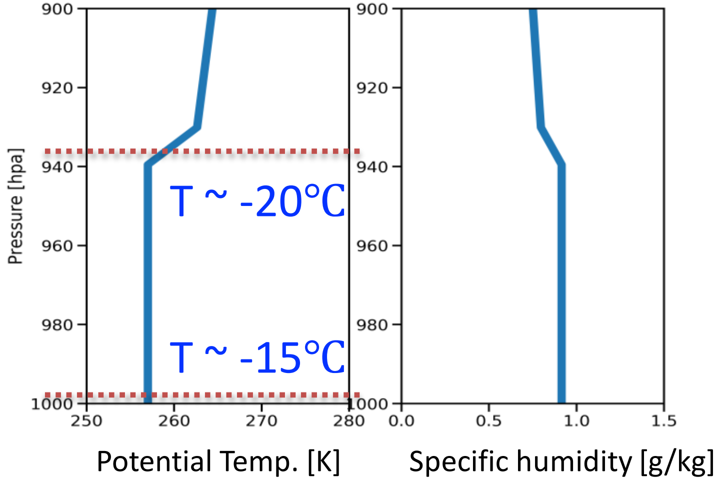
- Simulations with AMPS for the same thermodynamical condition of stratiform supercooled liquid cloud, but strongly different aerosol conditions

Pristine → CCN Mid; Polluted → CCN High

Typical Arctic mixed-phase clouds → INP Mid

		CCN		
		Low 10 cm^{-3}	Mid 50 cm^{-3}	High 500 cm^{-3}
INP	Low 0.001 L^{-1}		EXP3	
	Mid 0.1 L^{-1}	EXP4	EXP2 (Control)	EXP5
	High 10 L^{-1}		EXP1	

- Initial condition



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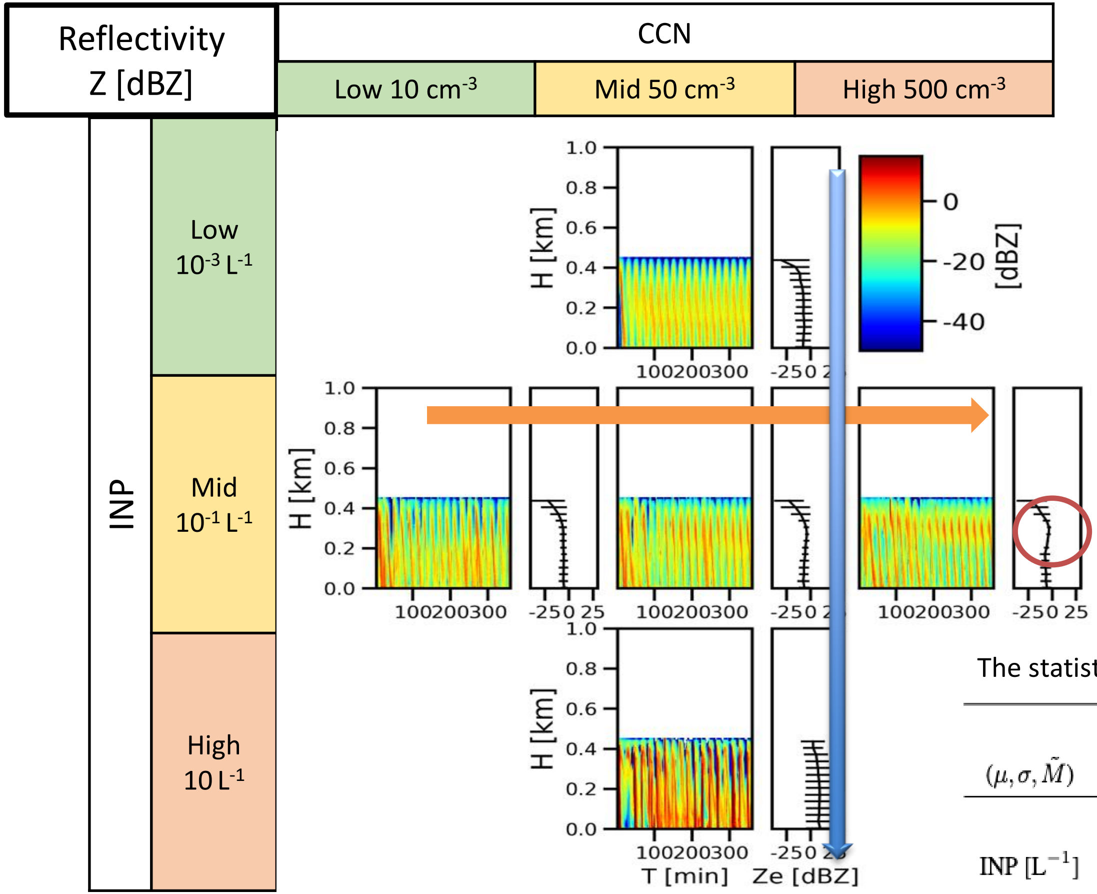
Radar Reflectivity factor from AMPS-PAMTRA (Ka-band)



- SSRG method (Maherndl et al., 2023, under review)
  (Self-Similar Rayleigh–Gans Approximation)
- CCN concentration ↑
  → Z similar
  → ↓ standard deviation
- INP concentration ↑
  → ↑ Z
  → Consistent with the observation findings
  (Zhang et al., 2018, Radenz et al., 2021)

The statistical analysis of radar reflectivity factor Z [dBZ]

$(\mu, \sigma, \tilde{M})$		CCN $[cm^{-3}]$ 10	50	500
INP $[L^{-1}]$	0.001		(-11.83, 9.12, 0.36)	
	0.1	(-10.23, 5.70, 1.63)	(-10.09, 5.60, 1.19)	(-9.87, 5.05, 1.71)
	10		(4.65, 12.47, 2.87)	

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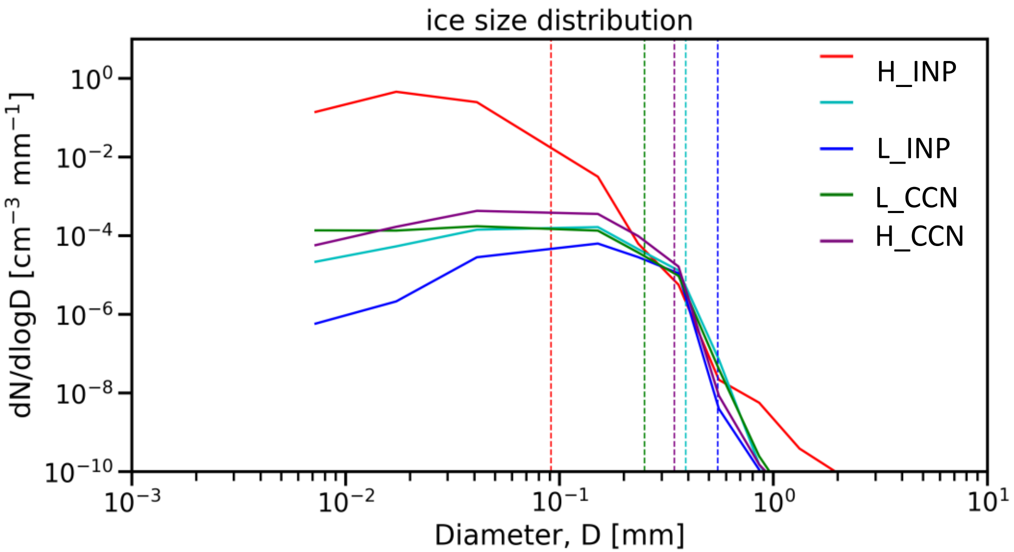
Simulation results of AMPS

$$Z \propto \int N(D) D^6 \, dD$$



- INP concentration ↑
  → ↓ D & ↑ N
  → **Z ↑**
- CCN concentration ↑
  → slightly ↑ D & ↓ N
  → **Similar Z**

Z is not solely influenced by the Number Concentration

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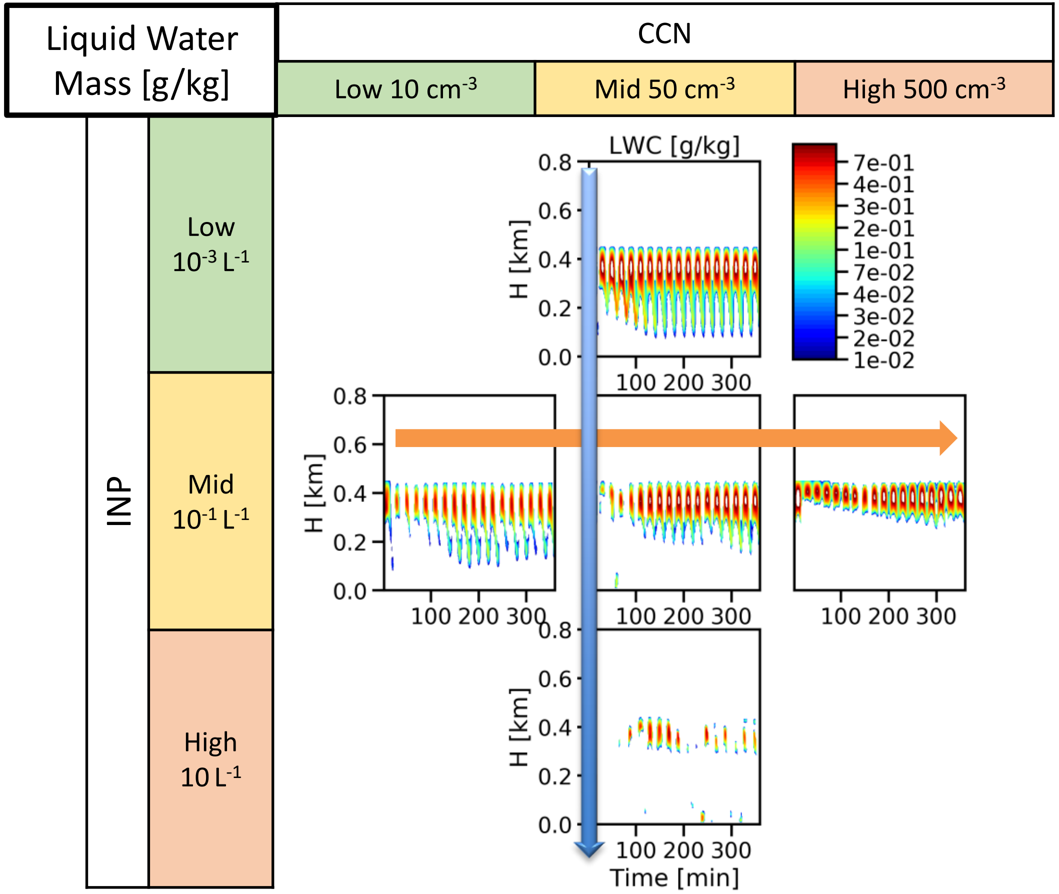
Simulation results of AMPS



- CCN concentration ↑
  → ↑ Liquid water mass
  → suppresses precipitation
- INP concentration ↑
  → ↓ Liquid water mass

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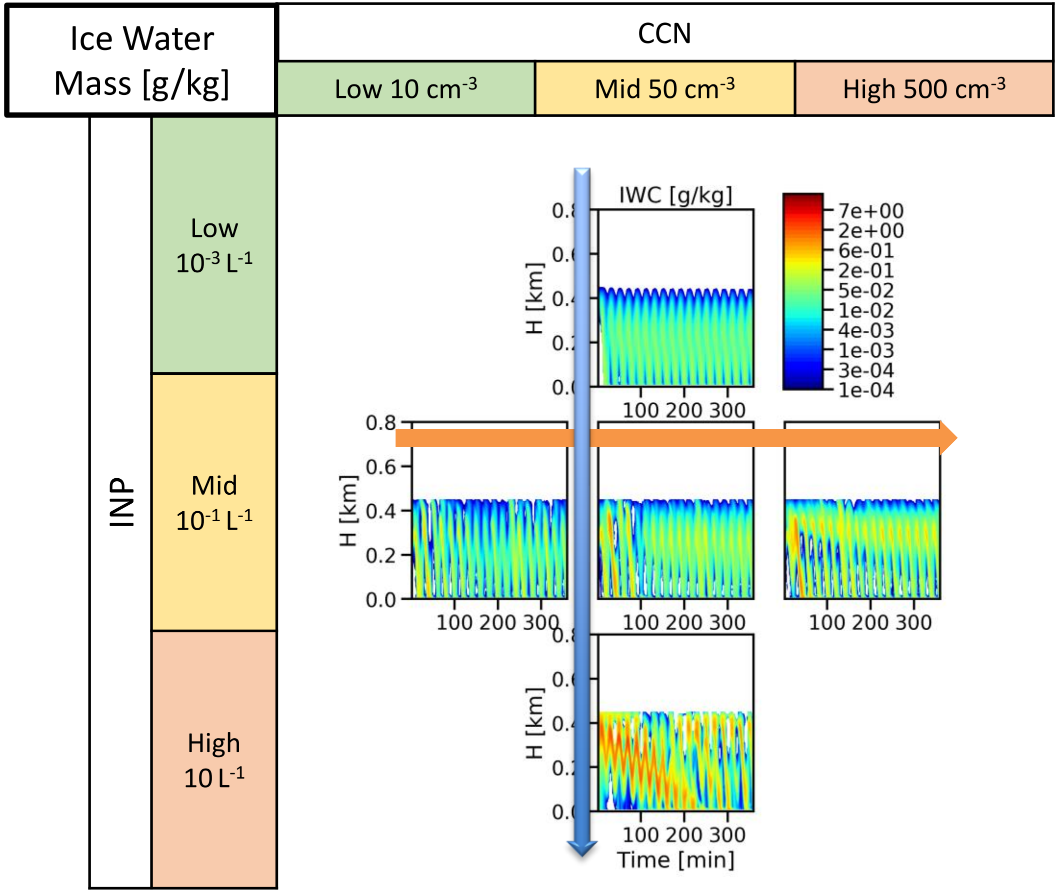
Simulation results of AMPS



- CCN concentration ↑
  → ↑ Ice water mass

- INP concentration ↑
  → ↑ Ice water mass

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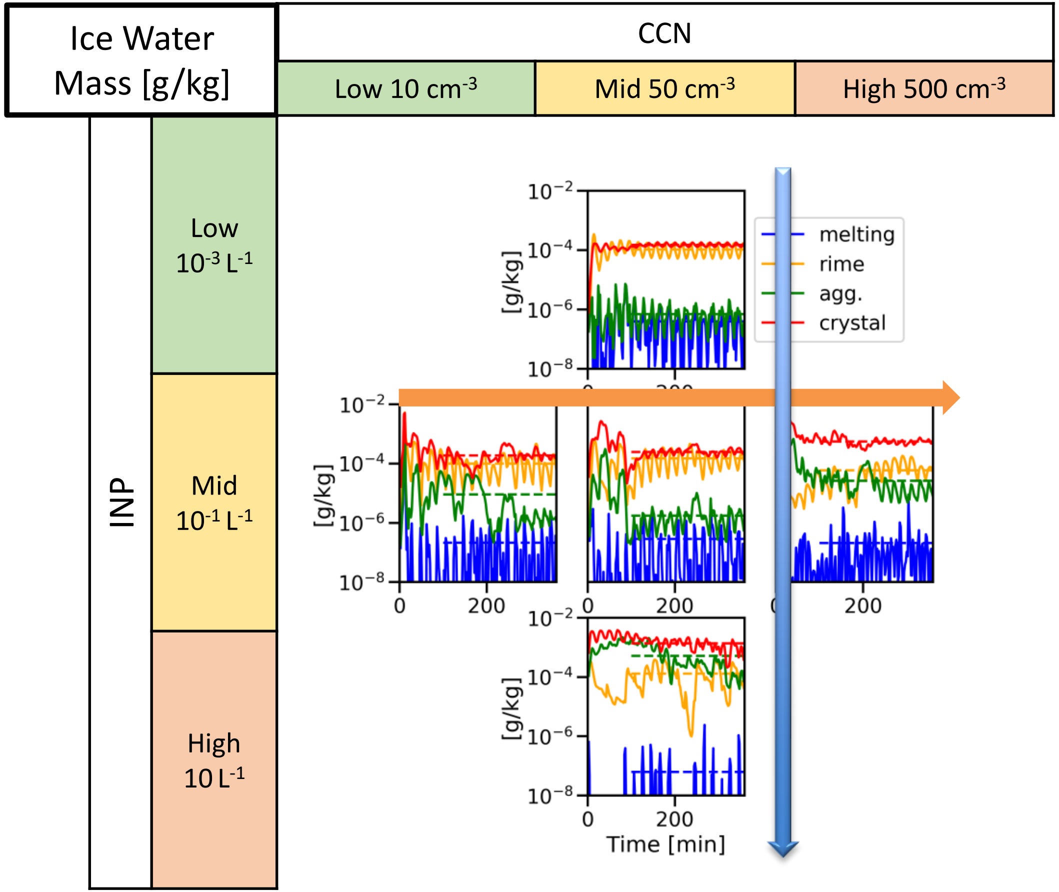
Simulation results of AMPS



- CCN concentration ↑
  → slightly ↑ aggregation
  → ↓ Riming

Reduction in the size of supercooled liquid particles available for riming

(Borys and Lowenthal, 2003, GRL)

- INP concentration ↑
  → ↑ Aggregation and ↑ Crystal
  → ↓ Riming

Reduction in the number of supercooled liquid particles available for riming

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Conclusion

- CCN and INP concentrations play a vital role in determining the shape of ice particles and influencing cloud microphysics.
- The efficiency of the riming process decreases, while the aggregation process increases, with higher concentrations of INP and CCN..
- Higher INP concentrations result in smaller effective diameters, while increased CCN concentrations lead to a slight increase in size.
- We successfully coupled the AMPS model with PAMTRA to obtain radar-related variables.
- An increase in the INP concentration leads to an increase in **Z.**
  (Zhang et al., 2018 and Radenz et al., 2021)
- Through modeling and the radar forward simulator, we confirmed that Z is influenced by factors beyond just Number Conc.

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Thank you!

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