GCM-Oriented Ground-Observation Forward-Simulator $(GO)^2$-SIM For Hydrometeor Phase Evaluation

Lamer K.[1], Fridlind A.M.[2], Ackerman A.S.[2],
Kollias P.[3-4-5], Clothiaux E.E.[1] and Kelley M.[2]

[1] *Pennsylvania State University*
[2] *NASA Goddard Institute for Space Studies*
[3] *Brookhaven National Laboratory*
[4] *Stony Brook University*
[5] *University of Cologne, Germany*

Figures from: http://pedagotech.inp-toulouse.fr & www.arm.gov

GCM hydrometeor phase evaluation

- How can model hydrometeor phase be evaluated?
- Sensors provide a lot of information but cannot observe all hydrometeors produced by models owing to instrument limitations
- Model and observations have different hydrometeor and phase definitions
- Propose to use a forward-simulator

GCM hydrometeor phase evaluation using ground-based remote sensing observations

- Extract a column from a global GCM run
  - E.g., Goddard Institute for Space Study's ModelE3

- Target regions where mixed-phase cloud observations are collected
  - E.g., North Slope of Alaska

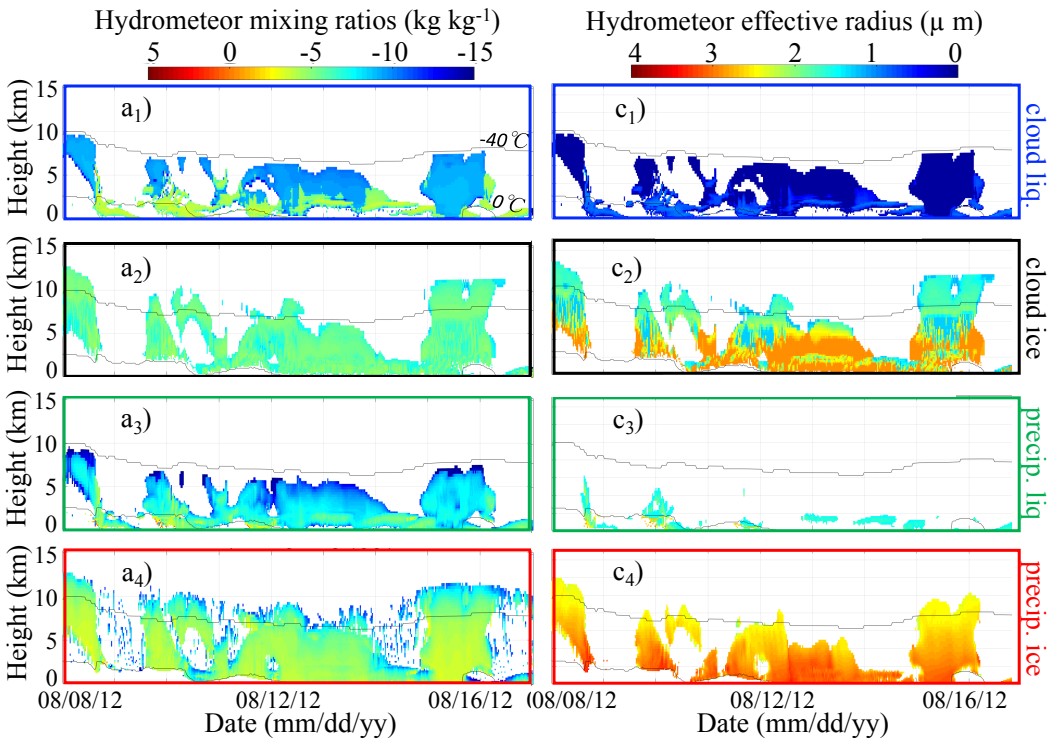
- Use a statistical approach

  Rely on long-continuous data record from remote sensors
  - Doppler radar (e.g., KAZR)
  - Polarized lidar (e.g., MPL)

Model Output for 4 species

Cloud liquid **Cloud ice**

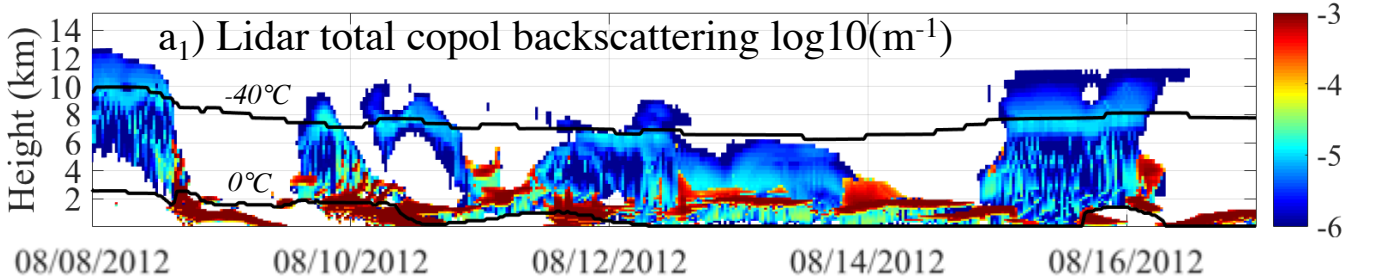
Precipitation liquid **Precipitation ice**

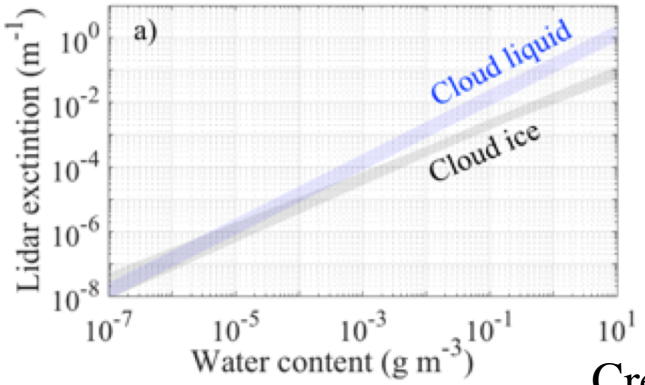


Lidar

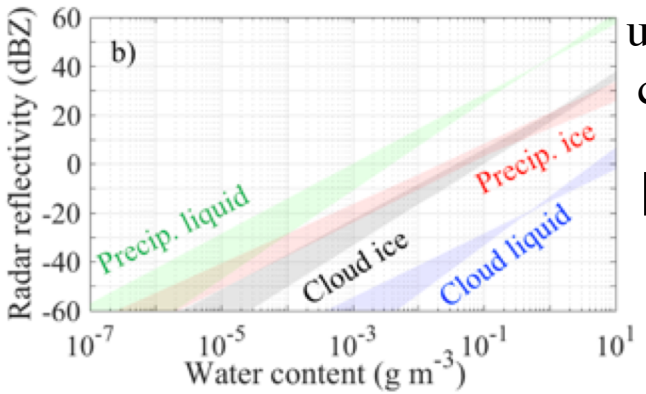
18 empirical relationships are used to relate hydrometeor properties to backscattering

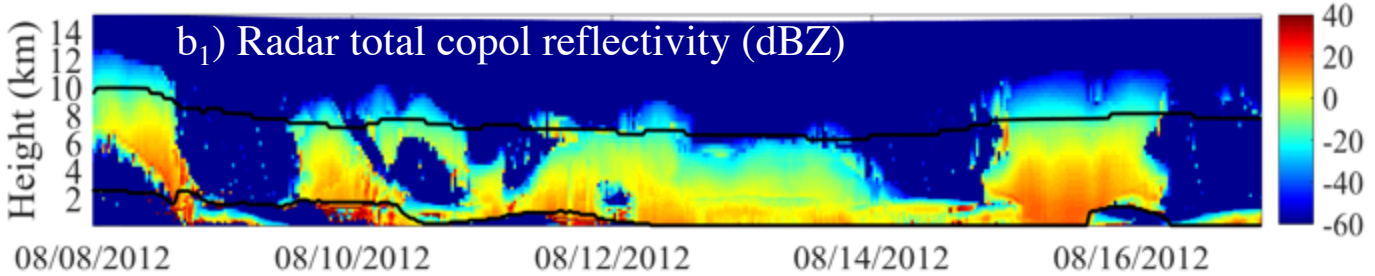
Radar



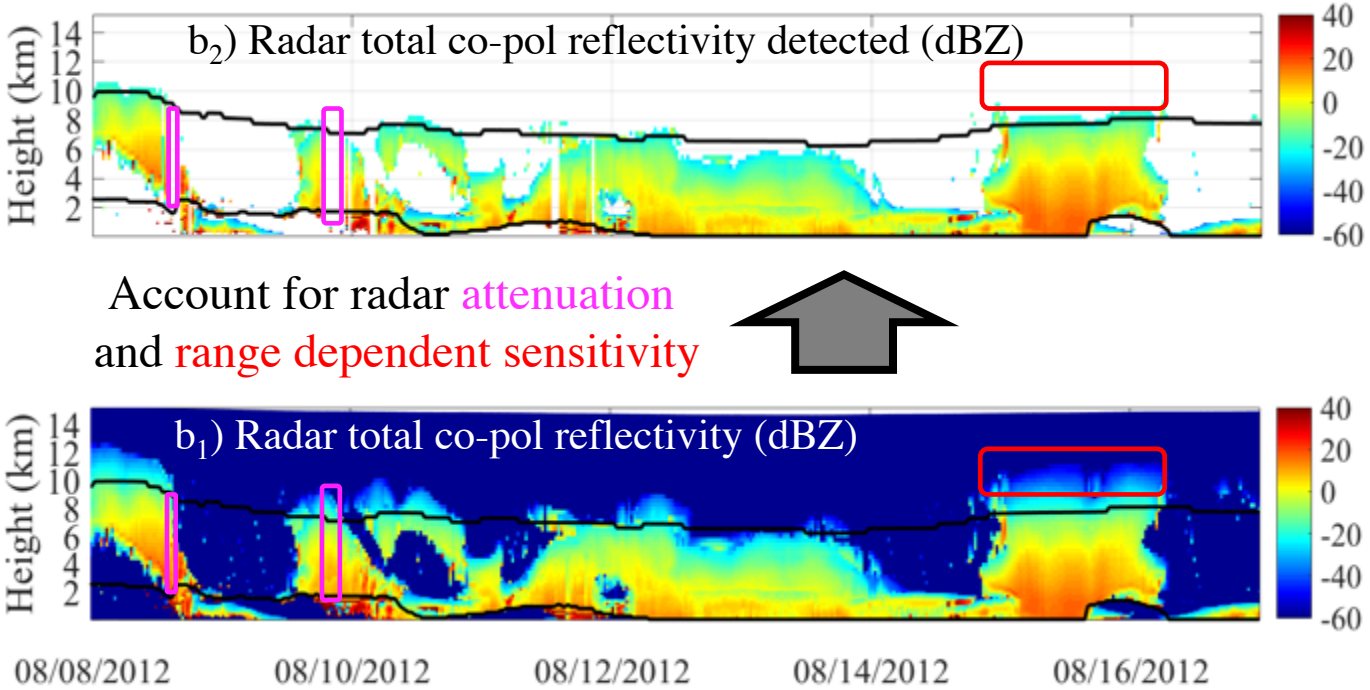


Create an ensemble forward-simulations using different combinations

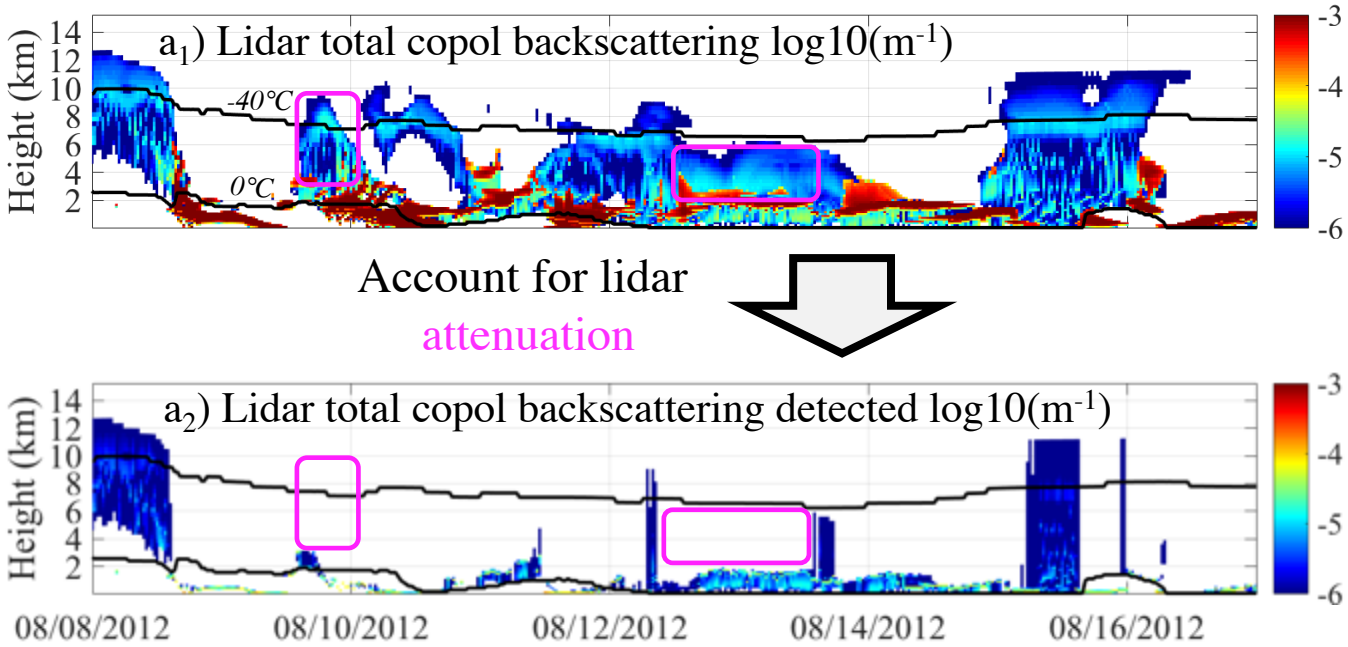




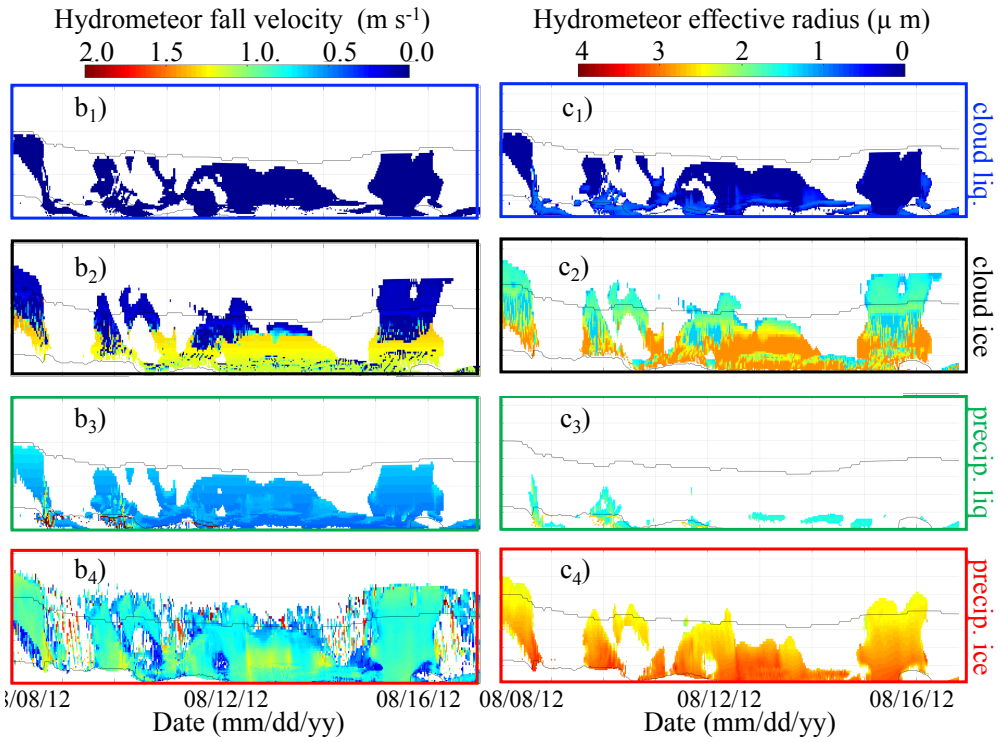
Account for Instrument Detection Limitation

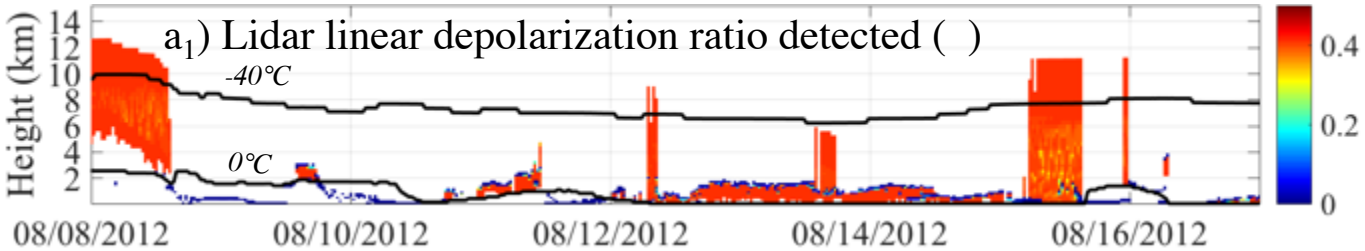


Account for Instrument Detection Limitation



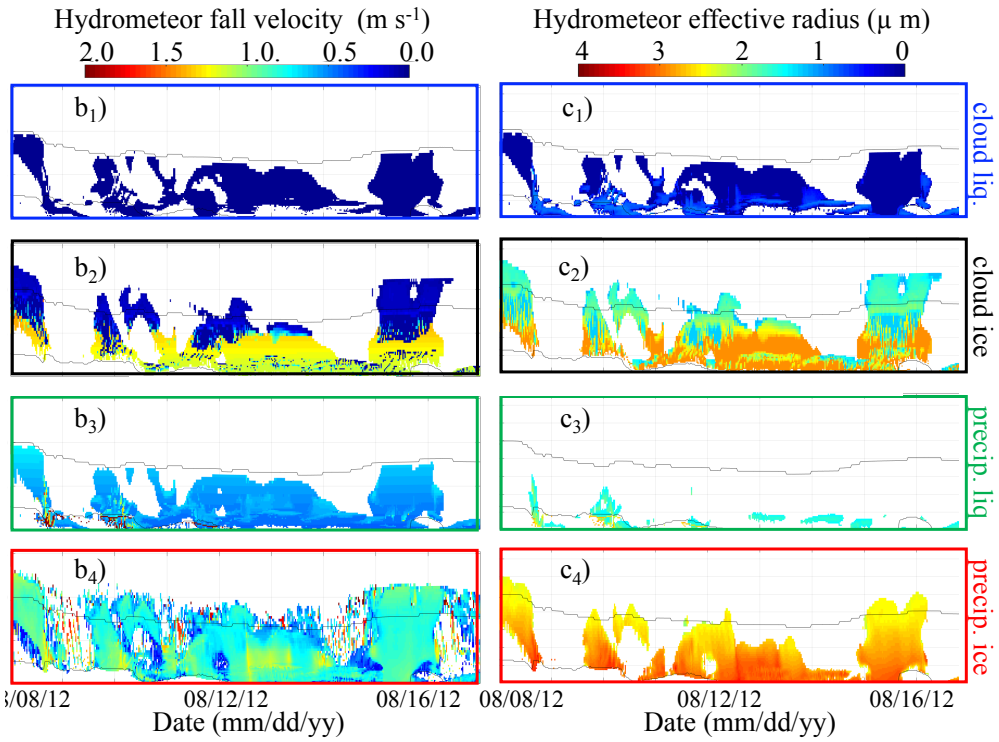
Use additional hydrometeor properties simulated and climatological





Doppler and depolarization observations are backscattering weighted averages of hydrometeor properties

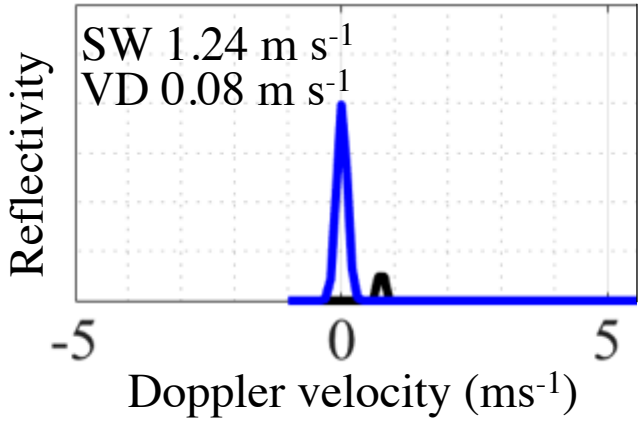
Use additional hydrometeor properties simulated and climatological

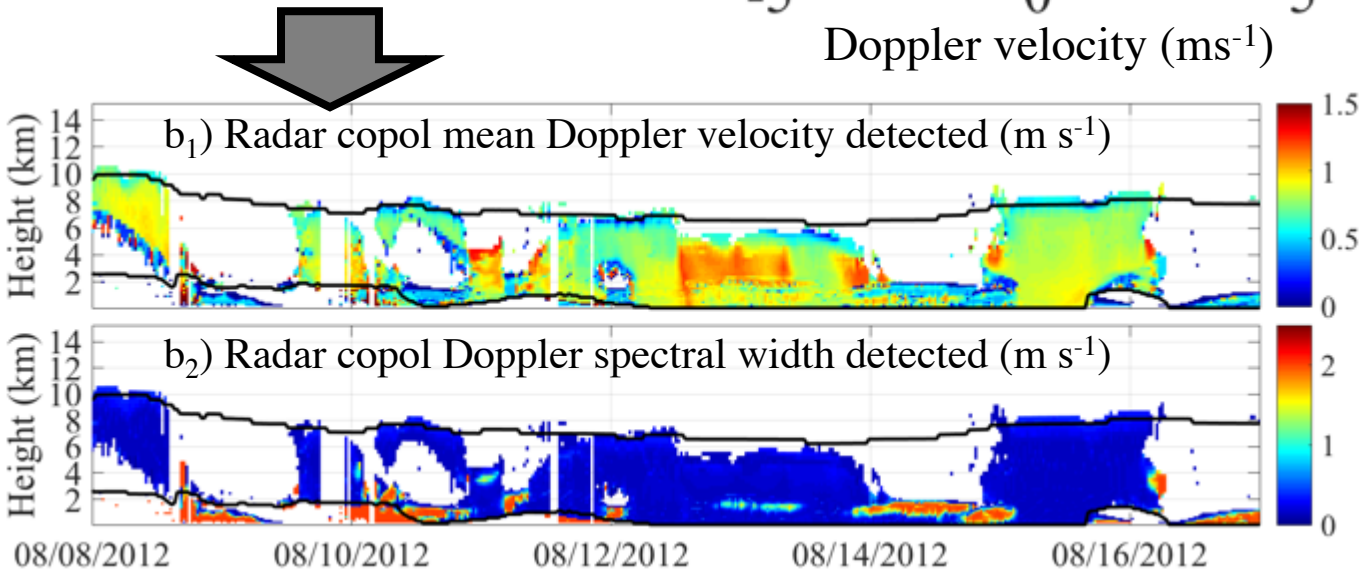


Doppler and depolarization observations are backscattering weighted averages of hydrometeor properties

10% ci $SW_{ci} = 0.05$ $V_{ci} = 0.75$

90% cl $SW_{cl} = 0.1$ $V_{cl} = 0.01$



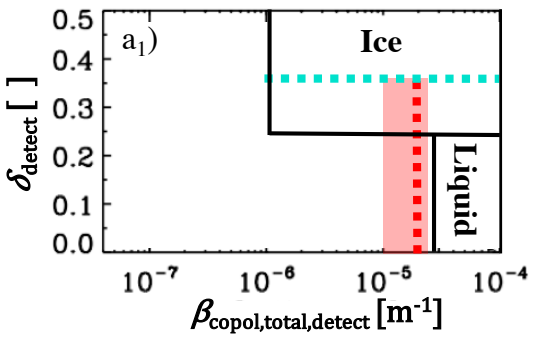


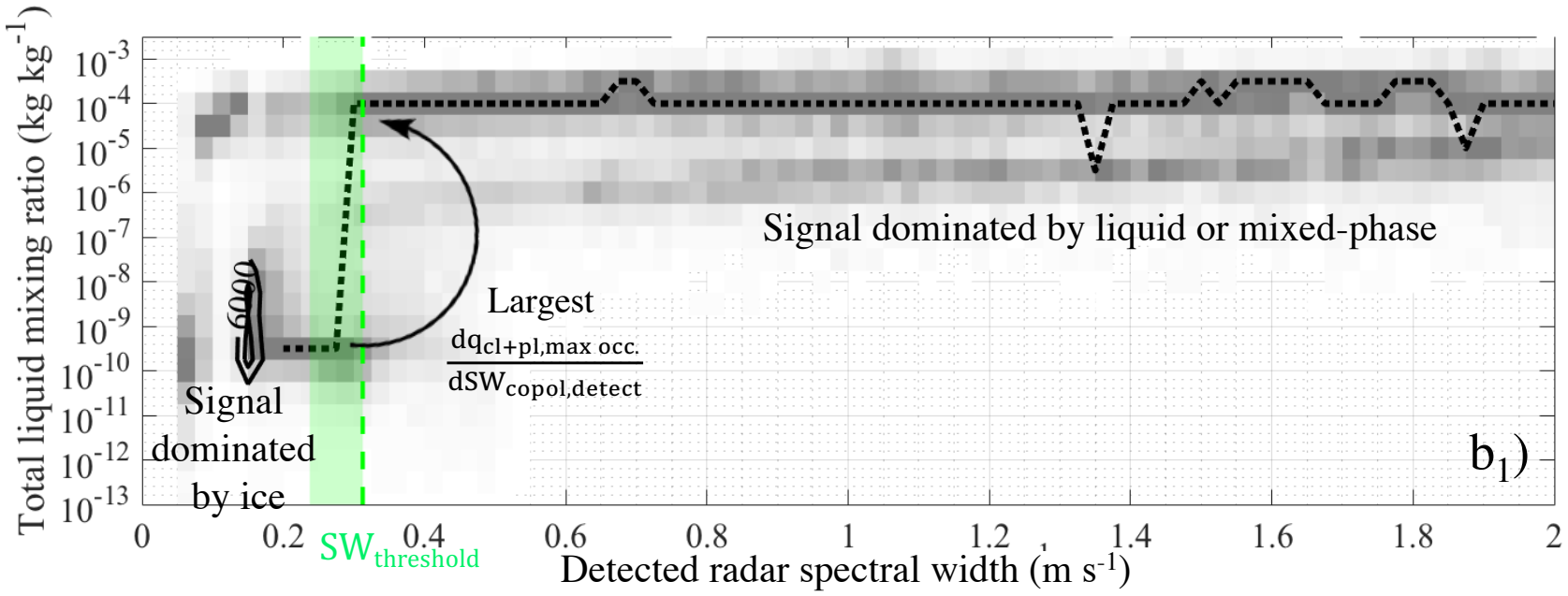
Beyond Model Evaluation using Observable Variables

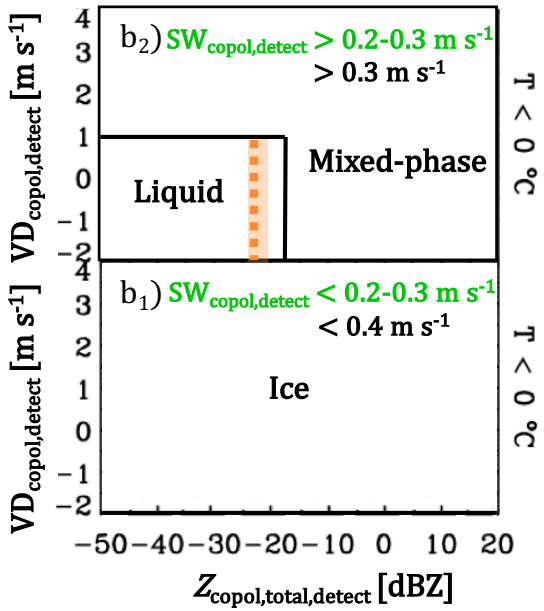
Hydrometeor Phase Classifier

Modified from *Shupe* [2007]

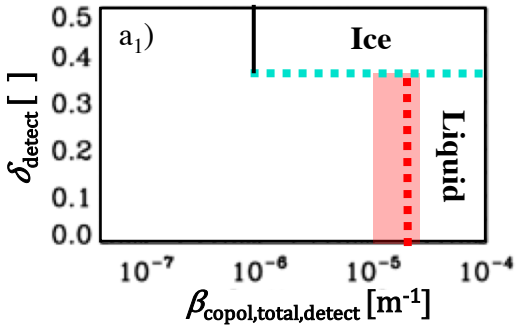
Can thresholds be used for hydrometeor phase classification?

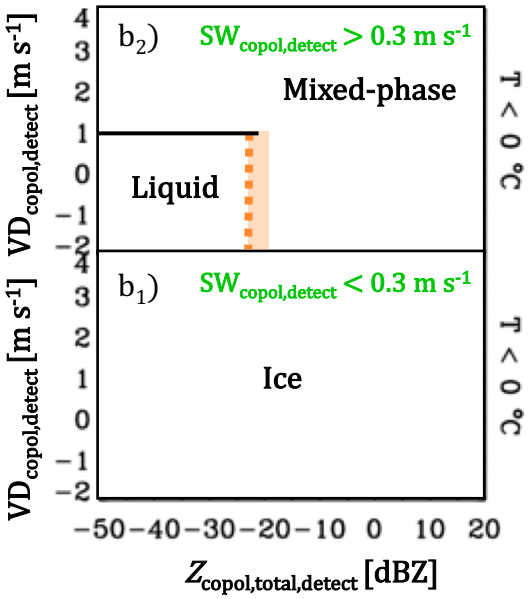




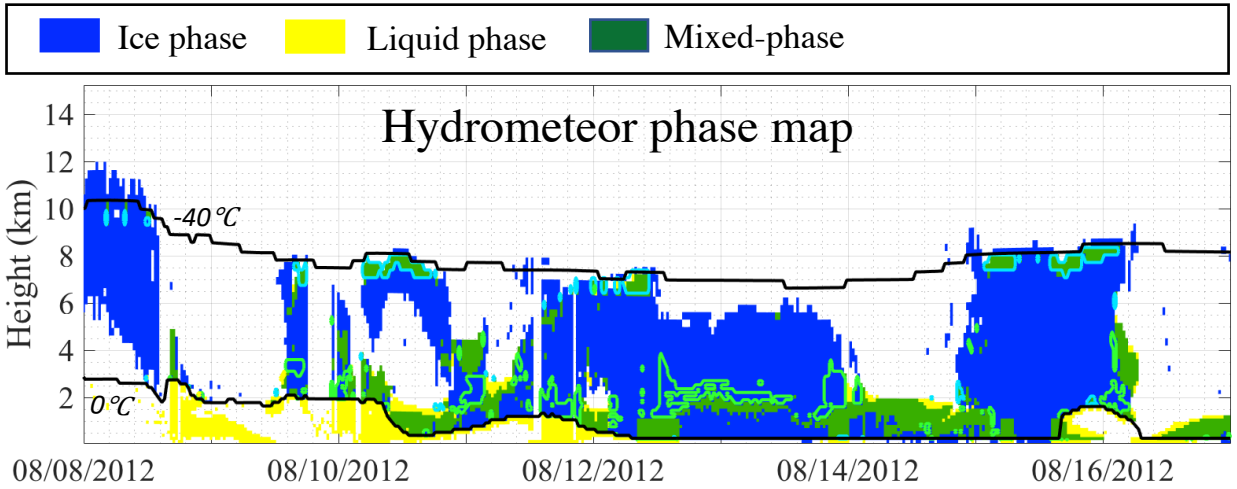


Hydrometeor Phase Classifier





Create a phase map from each forward-simulation in the ensemble (576)



Sensitivity and Uncertainty Quantification

1) Phase statistics vary less than 4% depending on the choice of backscattering empirical relationship

2) Flexible and fixed thresholds produce phase statistics within 6% of each other

3) Using thresholds leads to phase misclassification in less than 7% of hydrometeor-containing pixels

4) Model output and forward-simulated phase statistics differ by up to 45%

a) Determined using ModelE Output Mixing Ratio

	Liquid	Mixed-phase	Ice	Total hydrometeors Simulated
Frequency of occurrence (%)	1	60	39	42

b) Determined using Fixed Thresholds modified from *Shupe* [2007]

	Liquid			Mixed-phase			Ice			Total Hydrometeors Retrieved		
	Median		½ IQR	Median		½ IQR	Median		½ IQR	Median		½ IQR
Frequency of occurrence (%)	9	±	0	14	±	3	74	±	4	78	±	2
Wrong (%)	0	±	0	0	±	0	0	±	0	1	±	0
Missed (%)	0	±	0				1	±	0	1	±	0
Questionable (%)	0	±	0				6	±	1	6	±	1
Total error (%)										7	±	1

c) Determined Using Flexible Objective Thresholds from model output mixing-ratio

	Liquid			Mixed-phase			Ice			Total Hydrometeors Retrieved		
	Median		½ IQR	Median		½ IQR	Median		½ IQR	Median		½ IQR
Frequency of occurrence (%)	8	±	1	20	±	2	71	±	3	78	±	2
Wrong (%)	0	±	0	1	±	0	0	±	0	2	±	0
Missed (%)	0	±	0				1	±	0	2	±	0
Questionable (%)	0	±	0				4	±	1	4	±	1
Total error (%)										6	±	1

Conclusions

- ✓ GCM output is forward-simulated to Doppler radar and polarized lidar measurements
  - Including the effects of sensor limitation
- ✓ Radar Doppler spectral width can be used for hydrometeor phase identification
  - Low misclassification rate
- ✓ Hydrometeor phase statistics are robust
  - Little dependence on the choice of backscattering relationship
  - Little dependence on the choice thresholds
- ✓ $(GO)^2$-SIM forward-simulator framework offers an opportunity for a fairer model evaluation

Katia Lamer
kxl5431@psu.edu

Poster #46 Wednesday 5:00-6:30 pm