Using Field and Satellite Measurements to Improve Snow and Riming Processes in Cloud Resolving Models

[1]Brian A. Colle and [2]Andrew L. Molthan
[1]School of Marine and Atmospheric Sciences, Stony Brook University / SUNY, Stony Brook, New York
[2]NASA Marshall Space Flight Center / Earth Science Office, Huntsville, Alabama

Introduction

- The representation of clouds in climate and weather models is a driver in forecast uncertainty.
- Cloud microphysics parameterizations are challenged by having to represent a diverse range of ice species.
- Key characteristics of predicted ice species include habit and fall speed, and complex interactions that result from mixed-phased processes like riming.
- Our proposed activity leverages Global Precipitation Measurement (GPM) Mission ground validation studies to improve parameterizations.

Motivating Questions

- How does the inclusion of predicted riming intensity, ranging from dry snow to graupel, compare with other community schemes?
- How does riming intensity vary within different synoptic or mesoscale environments?
- Are there reliable relationships between riming intensity and remotely sensed quantities?
- Will proposed scheme improvements demonstrate persistent skill in multiple events on a seasonal basis?

Research Tasks and Use of PMM Data Sets

- Incorporate GPM-GV measurements, primarily from the C3VP and GCPEX campaigns, combined with forecast model simulations that can be used to infer parameterization errors.
- Propose corrections and infer improvements via multiple forecast simulations.
- Leverage "satellite simulators" via radiative transfer code and flight instruments, to understand potential relationships between remotely sensed quantities and microphysics.
- Verify microphysics scheme improvements through available satellite data and simulators.
- Ensure that proposed scheme improvements are observed throughout a variety of synoptic and mesoscale environments.

Related Work

- The investigators have been involved in several recent studies that have highlighted potential improvement in cloud microphysics parameterizations and remote sensing.
- Previous work has leveraged C3VP-collected data sets (Figure 1) to support model evaluation studies .

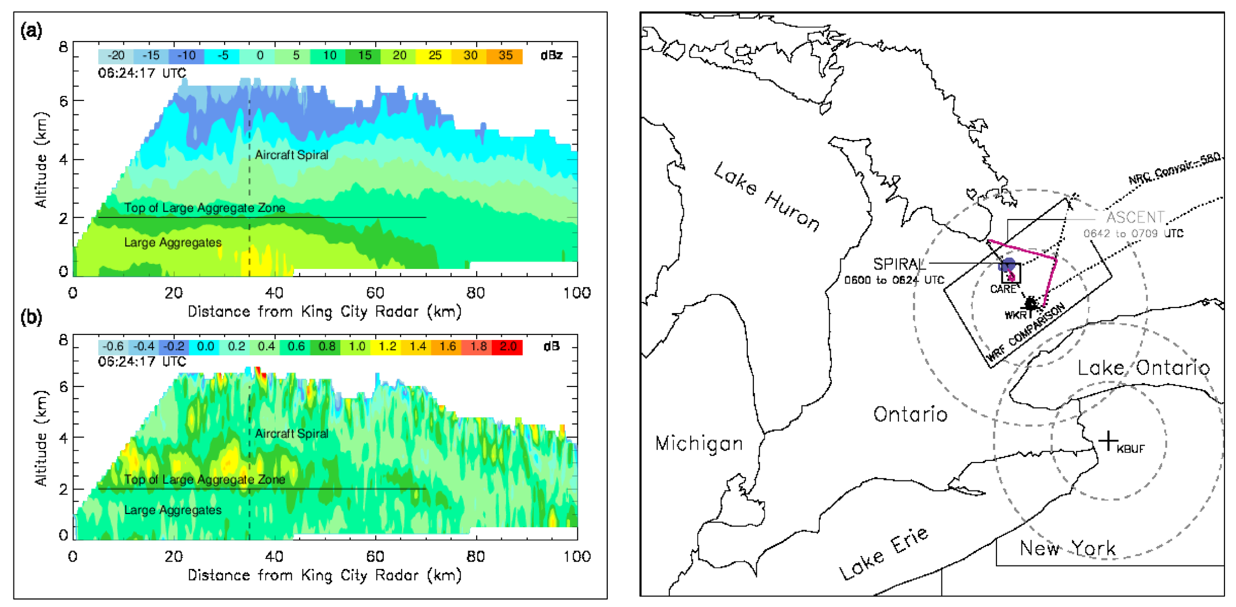

Figure 1. *Example of C3VP assets and value of field campaign data, with aircraft flight tracks (right) sampling a synoptic-scale snowfall event (left), with comparison to model output.*

- Aircraft measurements provide crucial data that allow for estimation of particle size distributions and values assumed within a parameterization scheme (Figure 2), or their resulting calculated moments (Figure 3).

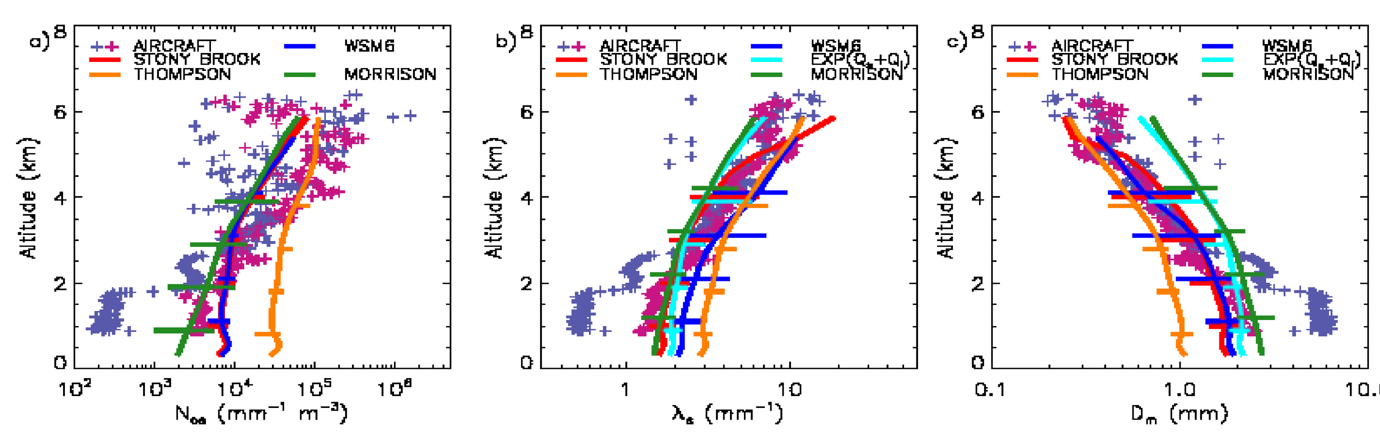

Figure 2. *Comparison of C3VP campaign aircraft-measured particle size distributions and model output or assumptions. (a) Size distribution intercept, (b) slope parameter, and (c) mass-weighted mean diameter as in Molthan and Colle (2012).*

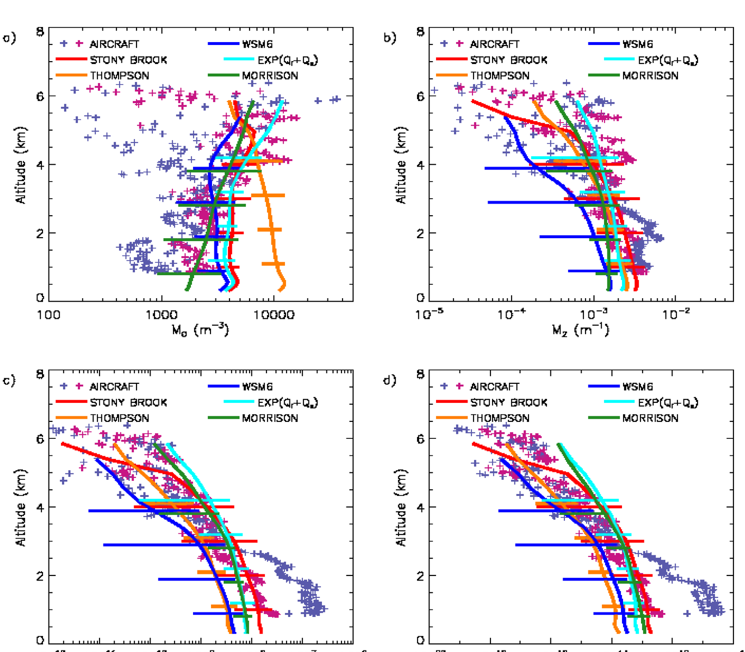

Figure 3. *Various moments calculated from available microphysics schemes and their comparison to available aircraft data. Schemes incorporating variability with temperature and riming demonstrated improved performance.*

Investigating Riming Processes

- This study will focus on the spectrum of dry snow to graupel and the representation of a single precipitating ice class proposed in the scheme by Lin and Colle (2011) and Lin et al. (2011).
- The Lin and Colle (2011) scheme incorporates a riming factor that allows for flexibility in the mass-diameter and diameter-fall speed relationship (Figure 4), and compared favorably to C3VP observations (Molthan and Colle 2012).

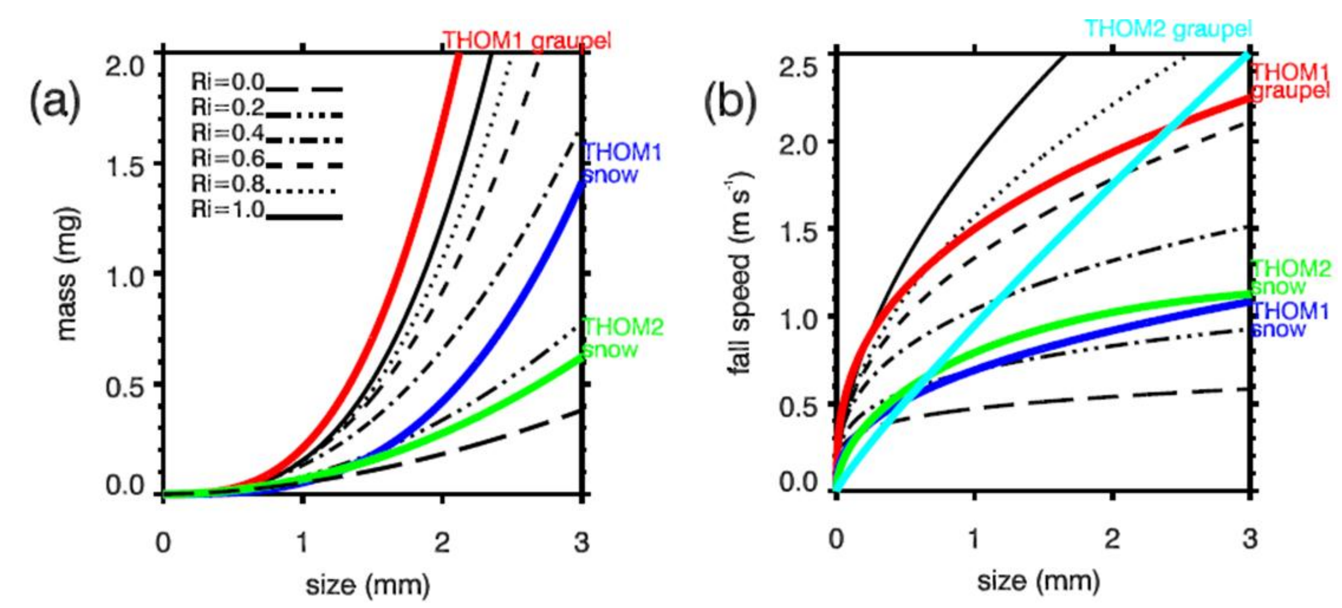

Figure 4. *Variability in mass-diameter relationship and fall speed-diameter relationships included within the current Thompson microphysics scheme and variability as a function of riming degree within the parameterization of Lin and Colle (2011) and Lin et al. (2011).*

- Research activities will emphasize the use of data collected during the GCPEX and C3VP campaigns (Table 1) and sampled within synoptic and mesoscale lake-effect environments.

GCPEx GV measurements			Applicable Measured and/or Diagnosed Parameters																
	Instruments	Measurable	Z	Z_{DFR}	R	PSD sfc	PSD col	PID	ρ_b	ρ_p	T	Q_v	Q_{soil}	CN, CCN	TW_c	CW	IW	ε/σ_{sfc}	T_B
Ground Radar and Profiler	C-band Dual-Pol	Z, Vr, W, ZDR, Φ_{DP}, ρ_{hv}	☒		☒	☒	☒	☒											
	D3R Ka/Ku Dual-Pol	Z, Vr, DFR, W, ZDR, Φ_{DP}, ρ_{hv}, LDR	☒	☒	☒	☒	☒	☒											
	X-band profiling	Z, Vr, W	☒		☒			☒											
	MRR2 profiling	Z, Vr, W	☒		☒	☒	☒	☒											
	W-band profiling	Spectra (Z, Vr)	☒		☒	☒	☒	☒								☒			☒
	Dual freq. LIDAR	σ					☒												
Ground Gauge and Radiometer	2DVD/Parsivel/POSS	DSD, shape, fall spd	☒		☒	☒		☒											
	Pluvio2 SWE Gauges	SWE Rate			☒														
	TPS 3100 Hot Plate	SWE Rate, Wind, T			☒						☒								
	Soundings	P, T, RH, wind									☒	☒							
	ADMIRARI Radiometer, MRR	T_B 19, 37 Z 24 GHz	☒		☒											☒			
	EC TP3000 Radiometer	TB 23-59 GHz									☒	☒				☒			
	EC Ground-Staring Radiometer	TB 10-89 GHz															☒		☒
	EC Surface Met. Inst.	P,T,RH, wind									☒	☒							
Aircraft	APR2 (Ka/Ku Radar)	Z, Vr, DFR, W, ZDR, Φ_{DP}, ρ_{hv}, LDR	☒	☒	☒		☒	☒										☒	
	CoSMIR (Radiometer)	T_B 37,89, 165.5,183 H/V															☒	☒	☒
	CPI/2D-C/CIP, HVPS	Precip. Image	☒		☒		☒	☒	☒	☒					☒		☒		
	CDP	Cloud Water/Spectra					☒									☒			
	Nevzorov	Total water							☒						☒	☒	☒		
	King Probe	Cloud water bulk														☒			
	Rosemount Icing Probe	Supercooled water														☒			
	Aircraft T/RH/Gust	Air T, RH, wind									☒	☒							

Table 1. *Instrumentation provided during the GCPEX campaign, as reported in Table 3 of the GCPEX Science Plan.*

Satellite and Radar Evaluations

- Instrumentation in the GCPEx campaign offers opportunities to compare model output against traditional radar observations as well as data similar to the future GPM mission.
- Proposed work includes the use of satellite simulators, such as the NASA Goddard Satellite Data Simulator Unit (SDSU) or other community assets to compare satellite observations to those generated from model output.

Seasonal Evaluations

- To avoid the limitations of comparisons to only GCPEx and C3VP, this project will leverage ongoing microphysics studies at Stony Brook.
- Habit, riming characteristics, NEXRAD, and microwave rain radar data are available from field work at Stony Brook (Fig. 5).

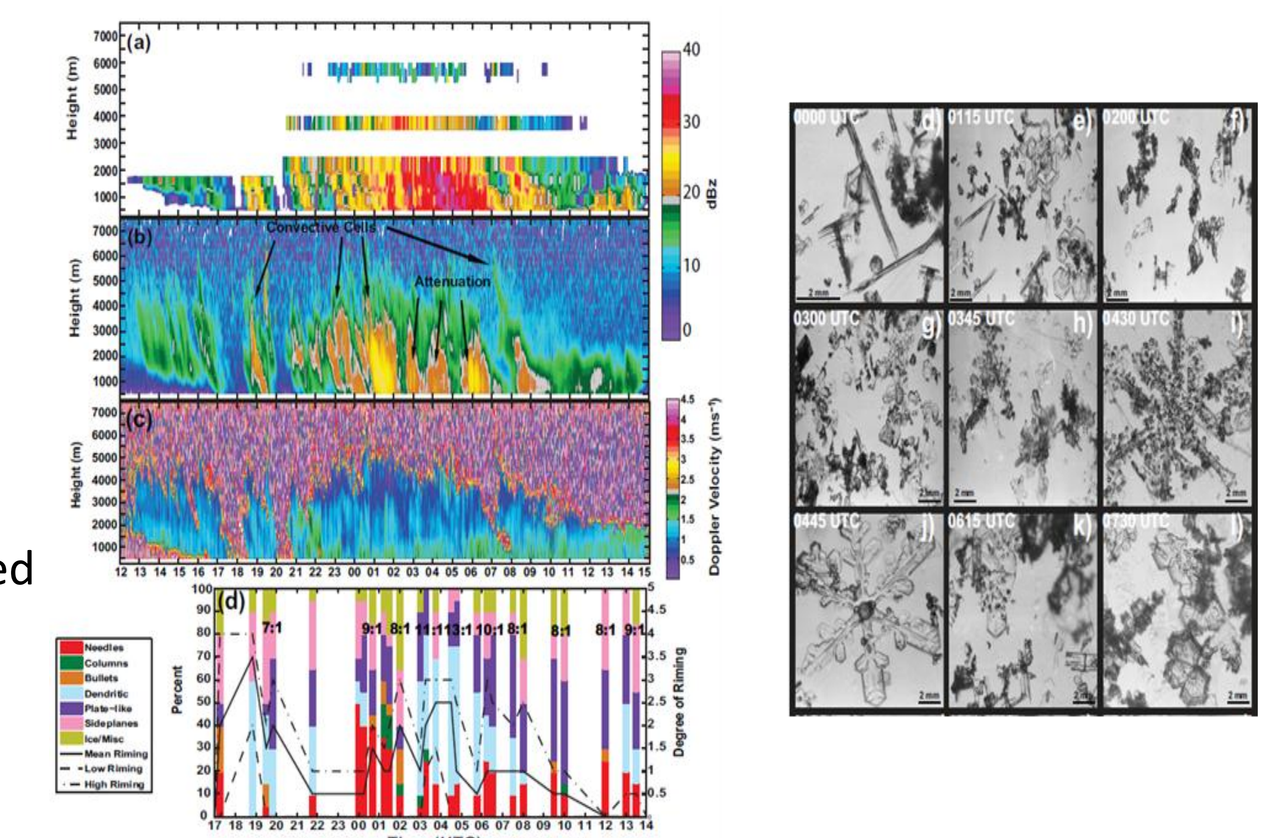

Figure 5. *(a) KOKX radar reflectivity time height, (b) MRR reflectivity time-height, (c) MRR velocity time-height, and (d) field observations of the microphysical evolution of ice habits during a 19-20 December 2009 heavy snow band event. (e-l) Selected snow habit imagery taken under stereomicroscope for the same event.*

Acknowledgements

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References

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