Properties for cold-cloud precipitation derived from ARM North Slope of Alaska observations

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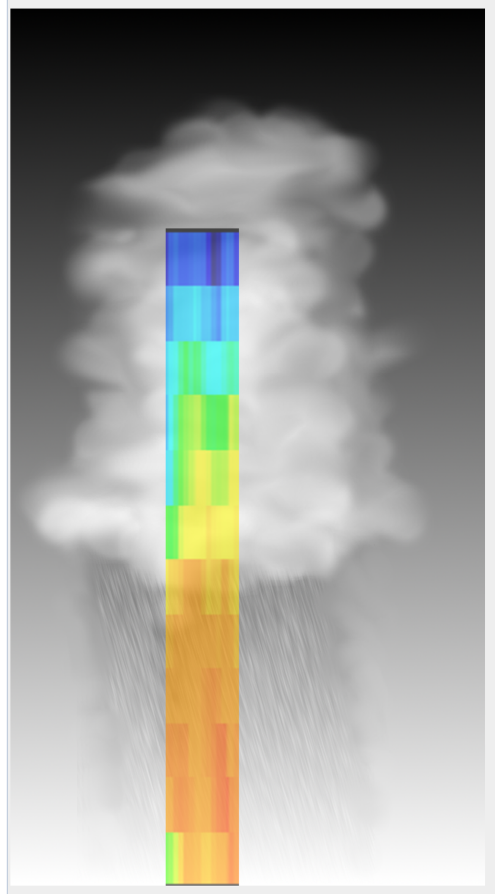
Introduction

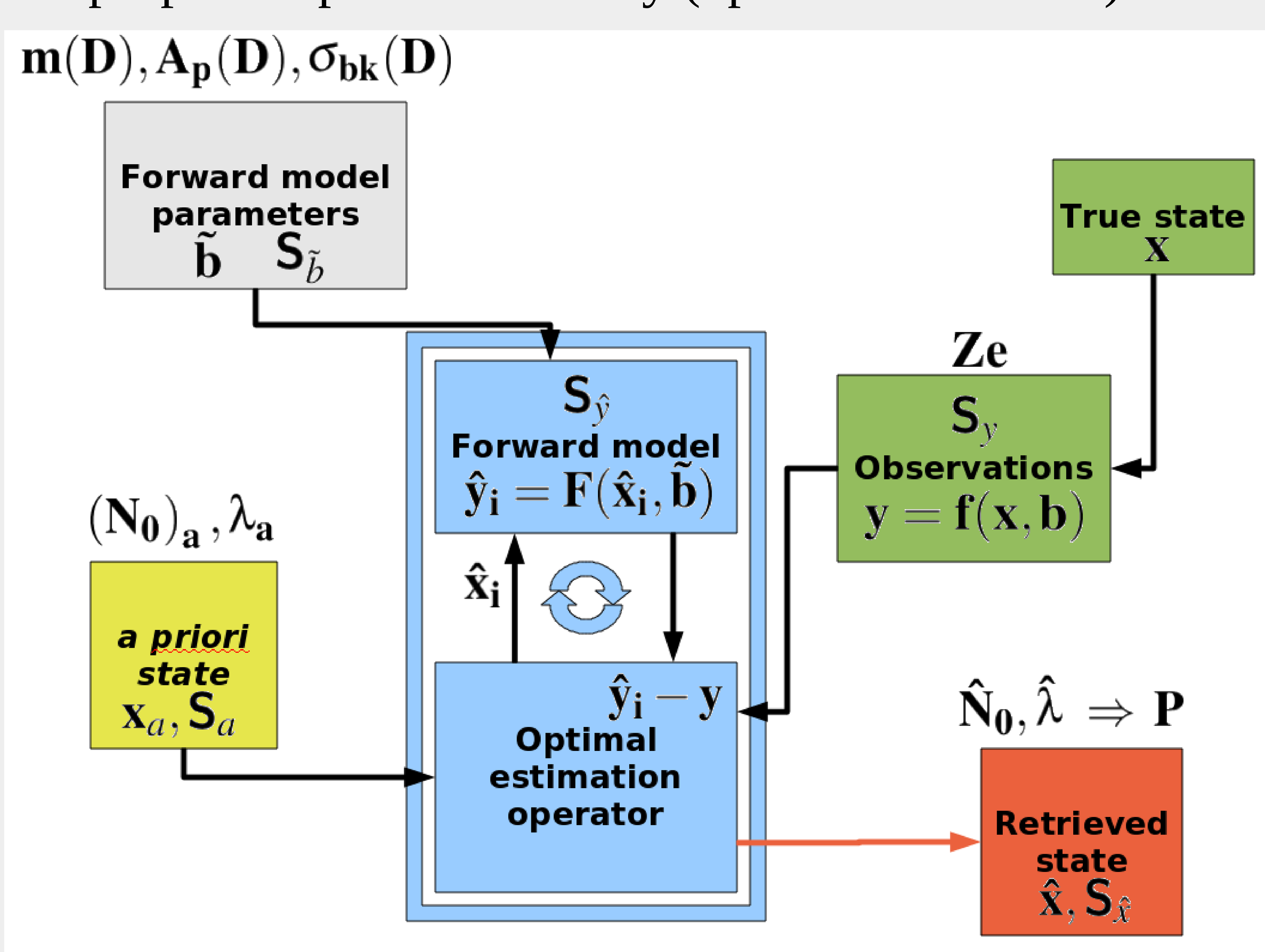
We aim to ultimately develop a data product for use in process analysis for cold-cloud precipitation, focusing first on Arctic cloud systems observed at Barrow (BRW) and Oliktok Point (OLI).



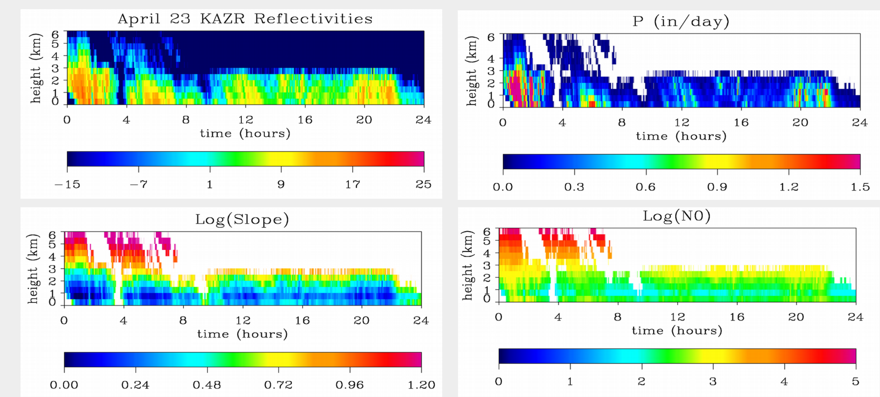
- Vertically- and temporally-resolved variations in the microphysical properties of precipitation supply potentially significant information about the processes controlling precipitation formation.
- Measurements by vertically-profiling radars provide information about these properties, but the inversion processes are often markedly underconstrained. Ancillary measurements constrain these inversions by reducing uncertainties in retrieval algorithm a priori assumptions.
- For the work presented here, we augment KaZR reflectivity observations with fallspeed, size distribution (Multi-Angle Snowflake Camera – MASC), and thermal structure (sonde) information as available to enhance constraints on retrieved properties.

How the retrieval works

We use radar reflectivity (Ze) profiles to estimate profiles of size distributions for snow and associated cloud. The retrieval incorporates a priori expectations about single-particle properties and background size distribution properties probabilistically (optimal estimation).



Results

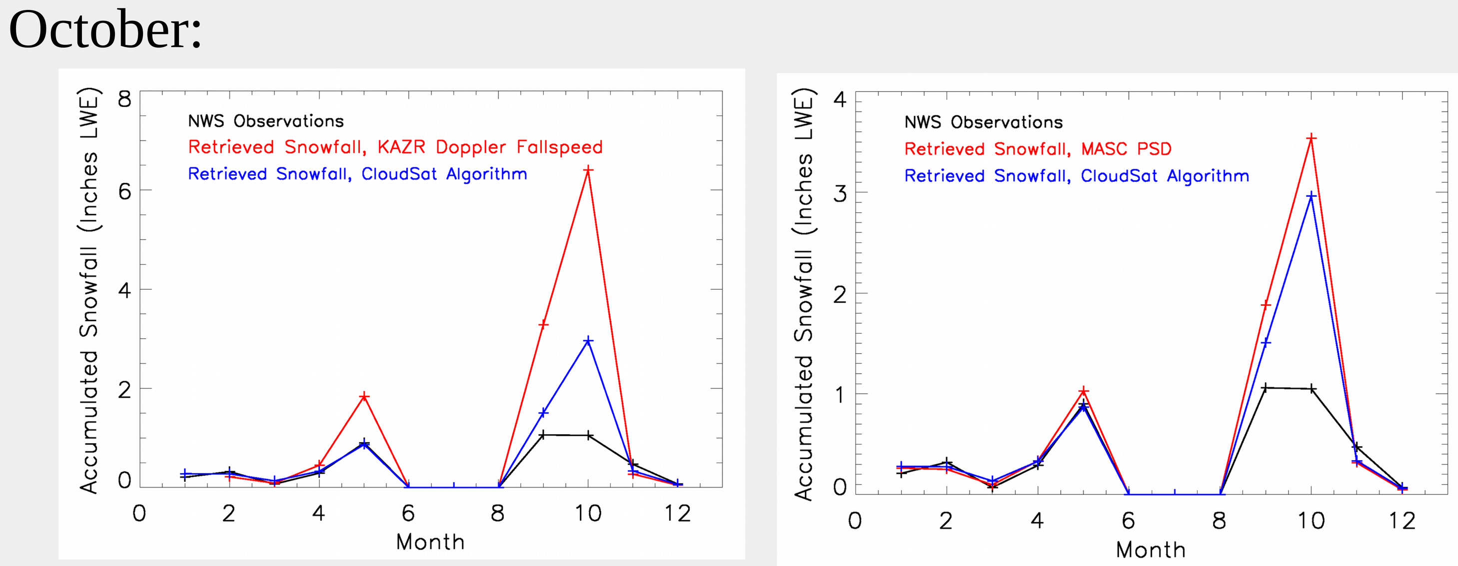


1. Over five BRW snow events (total accumulation 0.62" per NWS), permutations of habit, particle size distribution and fallspeed gave retrieved accumulations of -64% to +94% of observed, with agreements as good as -3% to -18% :

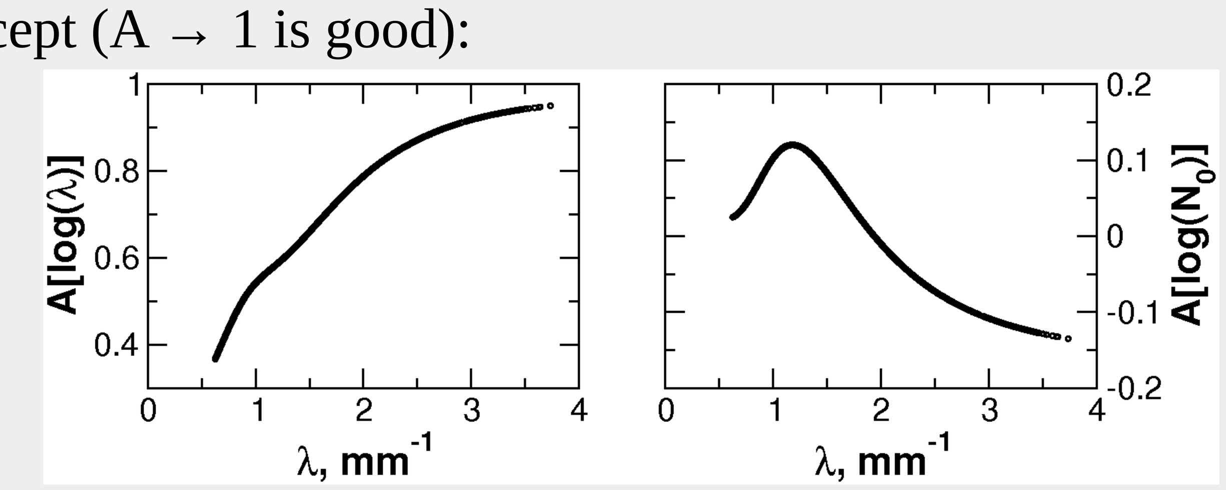
Particle Model	λ (mm^-1)	Fallspeed	Snowfall (in)	% Error
CloudSat	MASC	MASC obs	0.516	-18
CloudSat	MASC	Doppler	1.195	+90
CloudSat	MASC	LH74, Aggs Den*	0.811	+29
CloudSat	MASC	LH74, Graupel*	1.22	+94
CloudSat	MASC	1 m/s	1.009	+60
CloudSat	Field- C3VP**	MASC obs	0.609	-3
Sector Plates	MASC	MASC obs	0.338	-46
Sector Plates	MASC	Doppler	0.777	+23
Hex Columns	MASC	MASC obs	0.228	-64
Hex Columns	MASC	Doppler	0.527	-16

Note: 'CloudSat' particle model is aggregate-like

2. Retrieved snowfall matches annual pattern in monthly accumulations, but has unexplained biases in September and October:

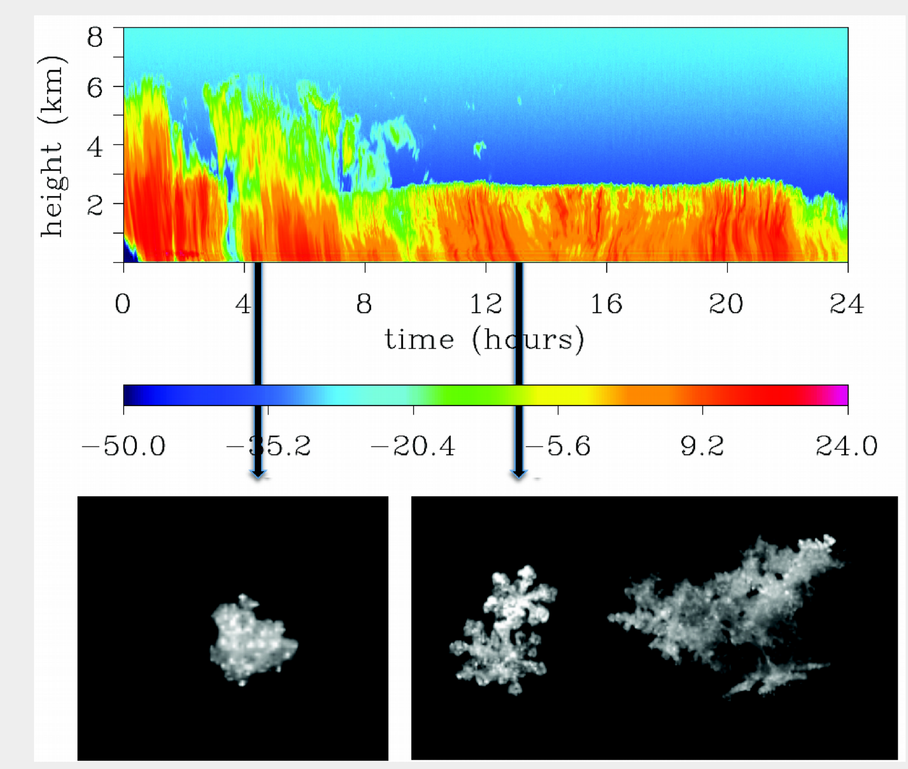


3. Diagnostics indicate these single-frequency retrievals constrain the particle size distribution slope better than the intercept (A → 1 is good):



Conclusions

- Unexplained Fall season biases may result from too-weakly backscattering particle models. Alternatives (graupel-like or rimed particles) could be more appropriate but need to be justified by examining particle imagery, evidence for supercooled water.
- Weak constraints on N_0 are undesirable. Dual wavelength radar observations (known to constrain lambda very well) could help with this.
- The sensitivity of retrieved surface snowfall rates to particle habit and fallspeed reinforce the value to retrieval development of particle imaging such as the MASC provides, e.g.:



Next steps

- Examine September and October anomalies, and adapt current particle models to account for rime growth if needed.
- Extend these analyses to Oliktok Point data
- Evaluate ancillary observations as additional constraints:
  - XSAPR collocations (via PyART)
  - Radiometer estimates of liquid water presence/amount
- Begin collaboration with ARM translators on data product development

For more information

Cooper, S. J., N. B. Wood and T. S. L'Ecuyer, 2017: A variational technique to estimate snowfall rate from coincident radar, snowflake and fallspeed observations. Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2017-26.

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