Deriving Arctic Mixed-Phase Cloud Microphysical Properties from Aircraft and ARM NSA Surface Observations during MPACE

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Motivation

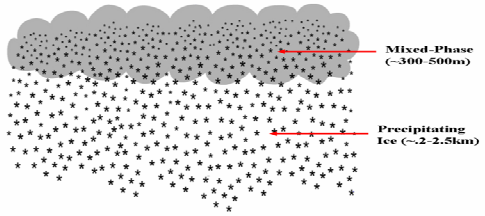


FIG.1 Typical Arctic Mixed-Phase stratus cloud structure. Mixed-Phase clouds dominate the total cloud fraction in Arctic during the transition seasons, and hence critically influence the radiative transfer. However, from the perspective of MMCR, the precipitating ice dominates the radar signal.

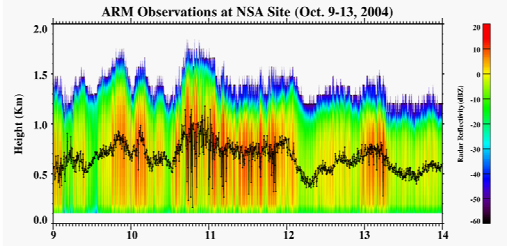


FIG.2 Sing-layer Mixed-Phase Arctic stratus was observed from Oct 9th to Oct 13th 2004 in Barrow, AK, during MPACE. The black solid line was cloud base from Laser Ceilometer. The high reflectivity indicated precipitating ice.

Strategy and Methodology

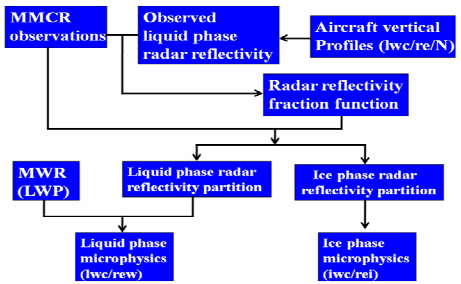


FIG.3 Schematic view of the retrieval approach. A liquid radar reflectivity fraction function was defined in terms of temperature and altitude. In-situ data was used as 'ground truth' to estimate the liquid phase radar reflectivity fraction function. Liquid radar fraction increases with increasing altitude and decreasing temperature.

$$f = f(T, H)$$

$$Z_{liquid,est} = Z_{total,obs} * f$$

$$Z_{ice,est} = Z_{total,obs} * (1 - f)$$

Results

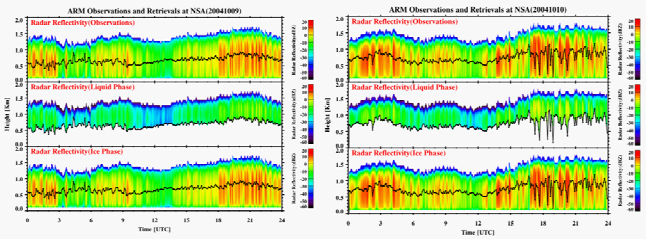


FIG.4 Two cases of liquid and ice phases identification on Oct 9th and Oct 10th 2004. The black solid line is cloud base. Liquid phase was identified within the cloud; while precipitating ice which dominates the radar signal was through the stratus towards the surface.

A) Liquid Phase retrievals

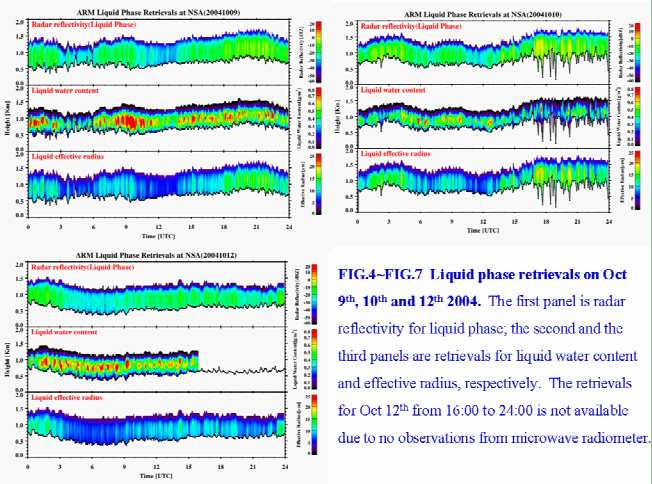


FIG.4~FIG.7 Liquid phase retrievals on Oct 9th, 10th and 12th 2004. The first panel is radar reflectivity for liquid phase; the second and the third panels are retrievals for liquid water content and effective radius, respectively. The retrievals for Oct 12th from 16:00 to 24:00 is not available due to no observations from microwave radiometer.

B) Ice Phase retrievals

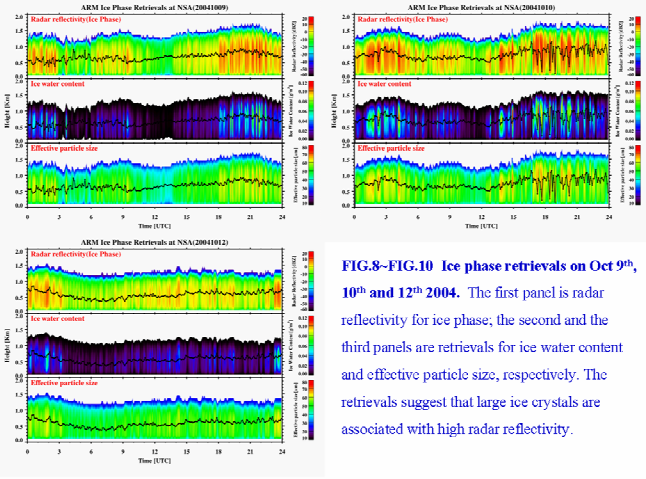


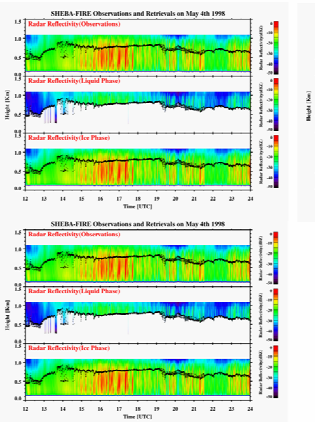
FIG.8~FIG.10 Ice phase retrievals on Oct 9th, 10th and 12th 2004. The first panel is radar reflectivity for ice phase; the second and the third panels are retrievals for ice water content and effective particle size, respectively. The retrievals suggest that large ice crystals are associated with high radar reflectivity.

C) Comparison with in-situ

DATE	LWC [g/m³]	IWC[g/m³]	Rew[μm]	Rei[μm]
10/09/2004	0.311±0.254	0.013±0.016	8.05±3.51	20.96±5.60
	(0.335±0.278)	(0.040±0.031)	(12.7±4.71)	(25.99±6.38)
	0.193±0.131	0.025±0.060	9.37 ±2.23	25.48±1.30
10/10/2004	0.209±0.196	0.019±0.022	9.16±4.37	22.35±6.10
	(0.222±0.198)	(0.034±0.026)	(10.4±4.65)	(24.68±7.09)
	0.174±0.120	0.015±0.032	9.04±2.41	24.61±2.35
10/12/2004	0.305±0.247	0.010±0.011	7.06±2.81	20.70±5.37
	0.193±0.116	0.006±0.018	9.07±2.29	25.15±7.28

Both liquid and ice retrievals are averaged over 24 hrs and also the same time period as in-situ aircraft which is in the parenthesis through the mixed-phase stratus on Oct 9th,10th, and 12th in the first row, respectively. In-situ data, the second row, is from Prof. McFarquhar's group at Univ. of Illinois, IL.

D) Approach assessment during SHEBA/FIRE



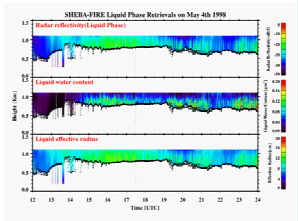


FIG.11~FIG.13 Mixed-Phase identification and microphysical retrievals for both liquid and ice phases on May 4th 1998. The black line is cloud base from Ceilometer; Cloud top is fixed at 1.1 Km;

DATE	LWC [g/m3]	IWC[g/m3]	Rew[μm]	Rei[μm]
05/04/1998	0.062±0.042	0.009±0.010	8.40±1.95	69.02±25.4
	(0.085±0.054)	(0.010±0.010)	(8.74±1.81)	(72.7±26.3)

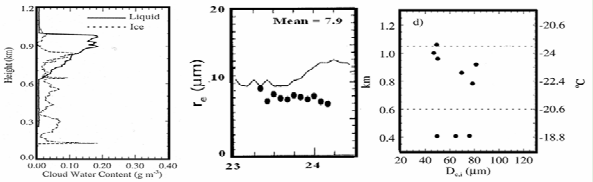


FIG.14~FIG.16 In-Situ vertical profile of the boundary stratus on 4 May 1998. Figures courtesy from left to right are Curry et al 2000, Dong et al 2001, and Zuidema et al 2005.

Summary

- New algorithms are developed and validated to retrieve single-layer Arctic mixed-phase stratus microphysical properties.
- The results suggested that the retrievals are comparable with in-situ measurements.

Acknowledgements

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