Observations of Melting Layer Microphysical Processes

Andrew Heymsfield and Aaron Bansemer, NCAR

Overview

- The melting layer has an important effect on the structure of the troposphere, producing thermal decoupling from above to below the 0C level
- What we've learned about the melting layer comes mainly from radar observations
- Modeling of the melting layer microphysics and thermal structure could benefit from detailed in-situ observations.

Table 1

Physics Assumed in Three Major Modeling Studies

Researcher(s)	Particle Shape	Initial Ice Bulk Density	Terminal Velocity	Enhanced Cooling by Ventilation	Lapse Rate Derived w/melting	PSD	Continued Aggregation in ML	RH_w
Matsuo/Sasyo (1981)	Spherical	0.014 g/cm^{-3}	Aggregates C_d=1.2, w/melting, f(D, D_m)	Yes	Fixed rate of $6^0C/km$	Single Particles Of Different Sizes	No	50-100%
Klaassen (1988)	Spherical	Magono/Nakamura, 1965) w/scatter added	C_d=1-0.5e, e is fraction melted	Yes	Yes	Gamma	Yes	100%
Szyrmer/Zawadzki	Spherical	Plates, dendrites	Langleben	Yes	Yes	Marshall	No	100%

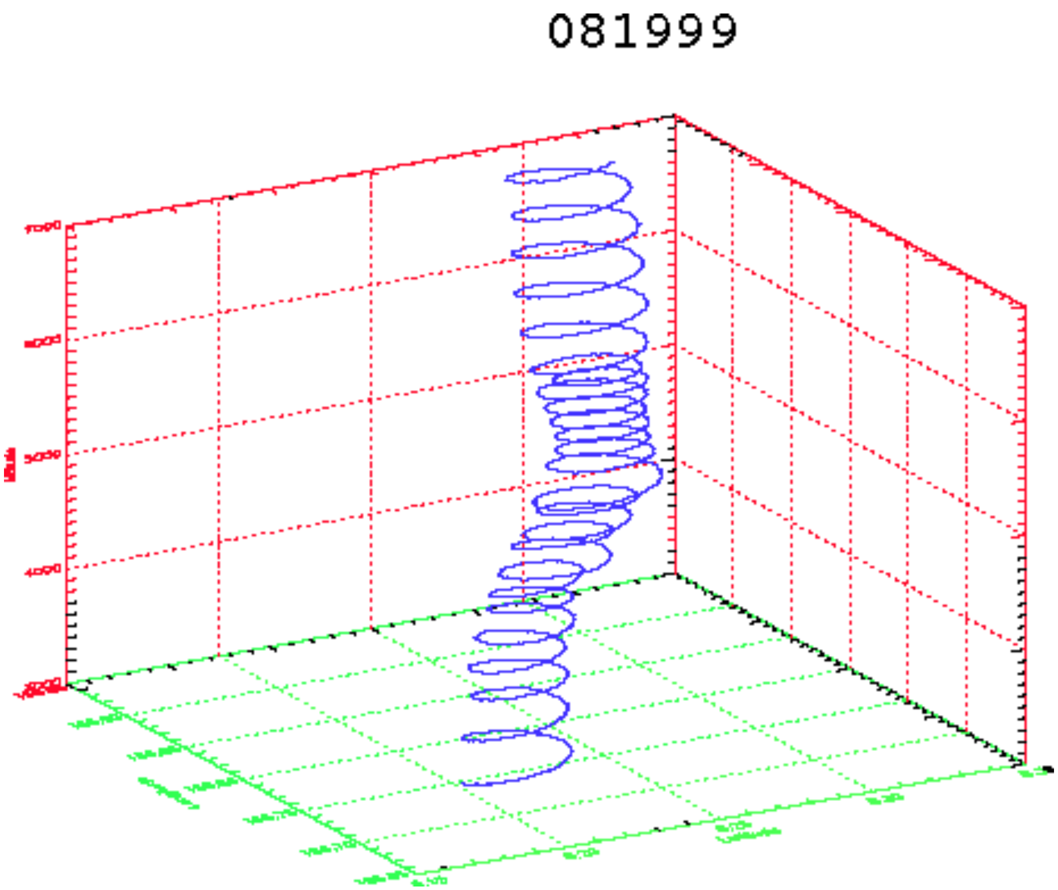
Data

- Three aircraft Lagrangian Spiral Descents from above to below the melting layer during the NASA TRMM KWAJEX field program in 1999 [Summer, Kwajalein M.I.
- Four melting layer ascents/descents during the NASA GPM Mid-latitude Continental Convective Cloud Experiment (MC3E) [ARM SGP site, Spring 2011]
- Two melting layer ascents/descents during the PMM GPM Canadian Precipitation Experiment (GCPEX) [Barrie, Ontario, Canada, winter 2012]

Particle Probes and Data

- KWAJEX: 2D-C and HVPS (100 μm to >2 cm)
- MC3E and GCPEX: CIP and HVPS-3 (50 μm to >2 cm)

  --Nevzorov Condensed Water Content Probe
- Exponential PSDs were fitted for each 5-sec of data [$N=N_0e^{-\lambda D}$]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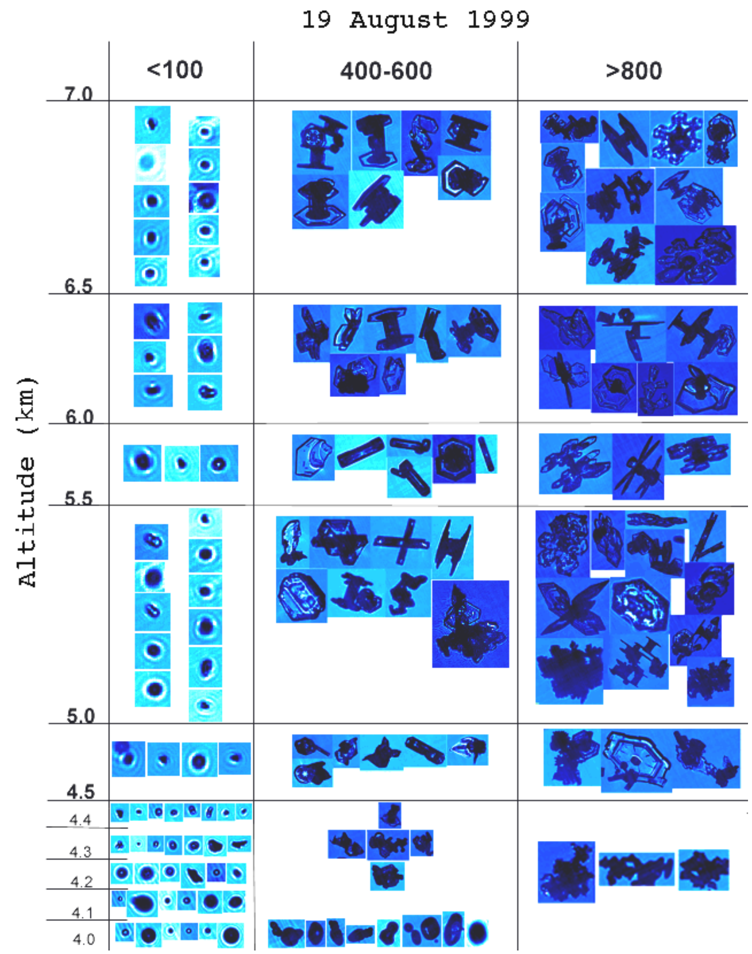
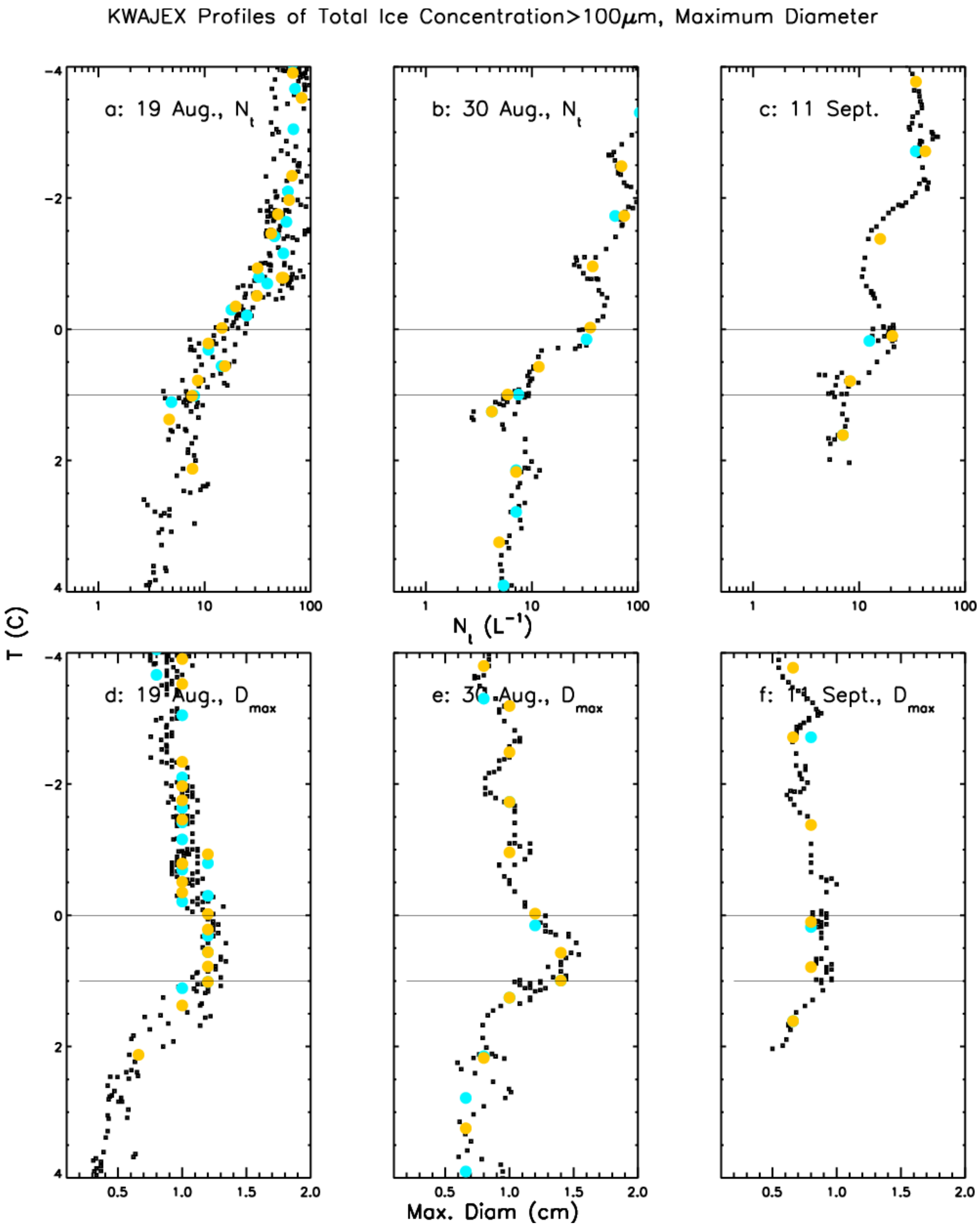
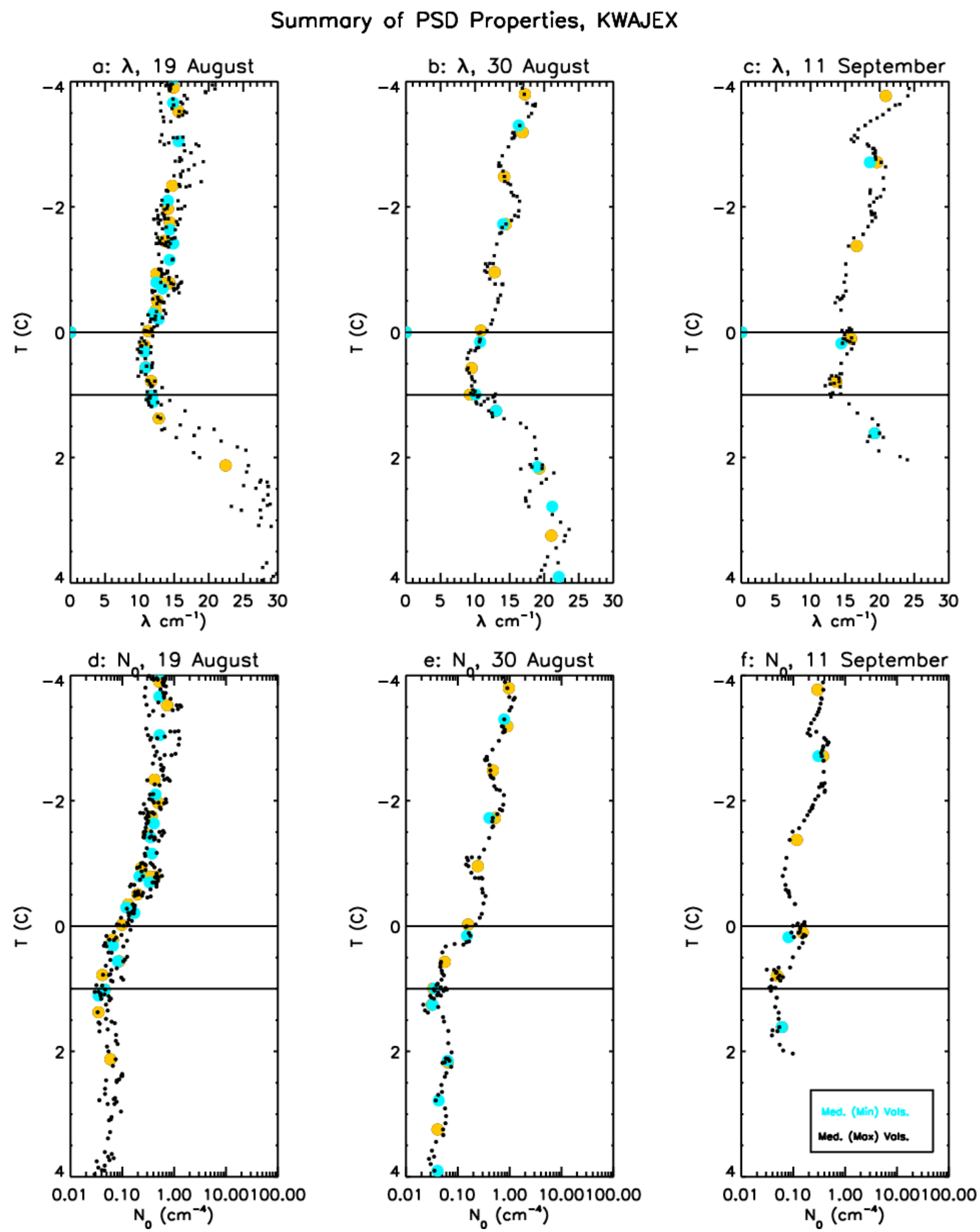
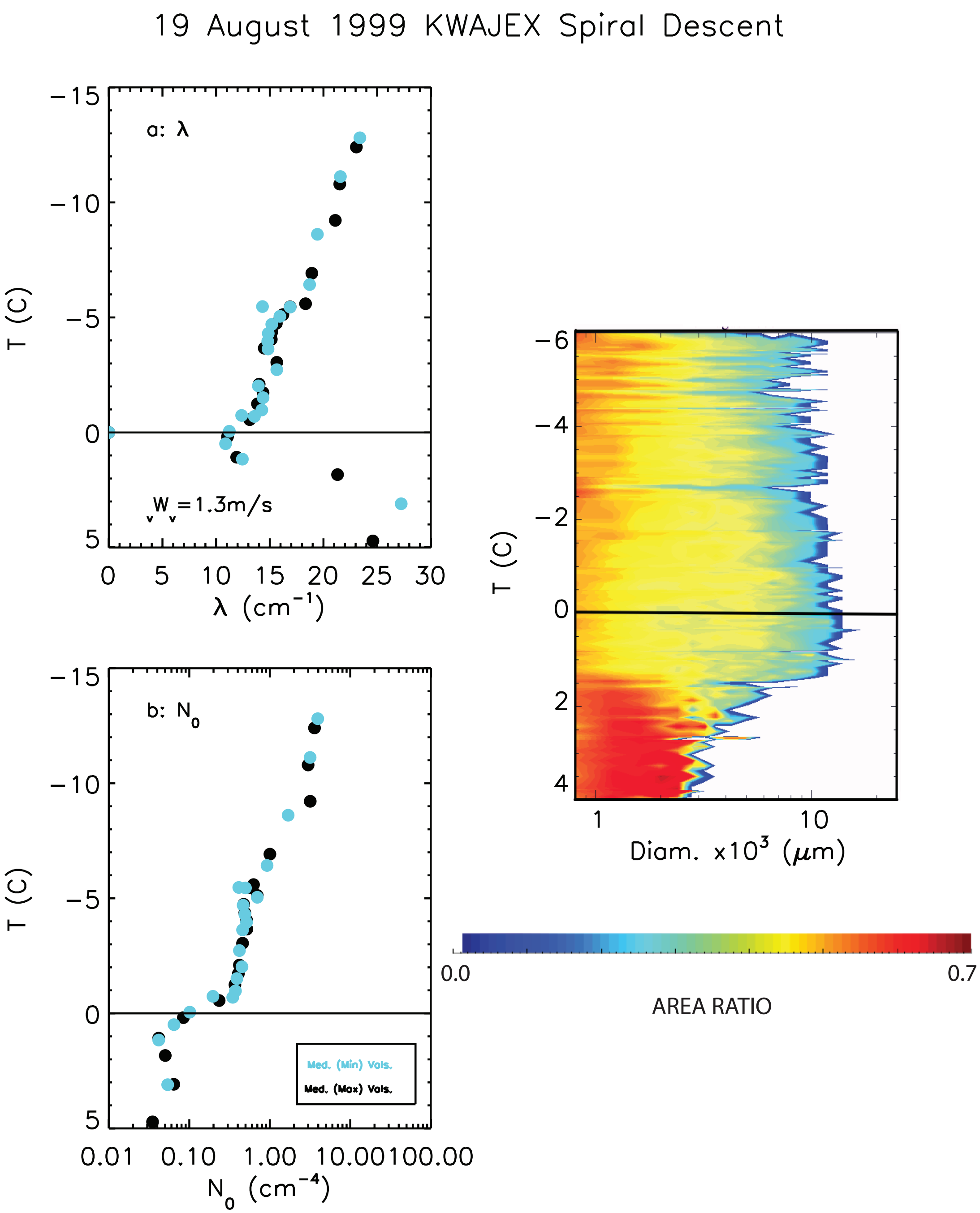

19 August 1999
<100
400-600
>800
Altitude (km)
7.0
6.5
6.0
5.5
5.5
5.0
4.5
4.4
4.3
4.2
4.1
4.0



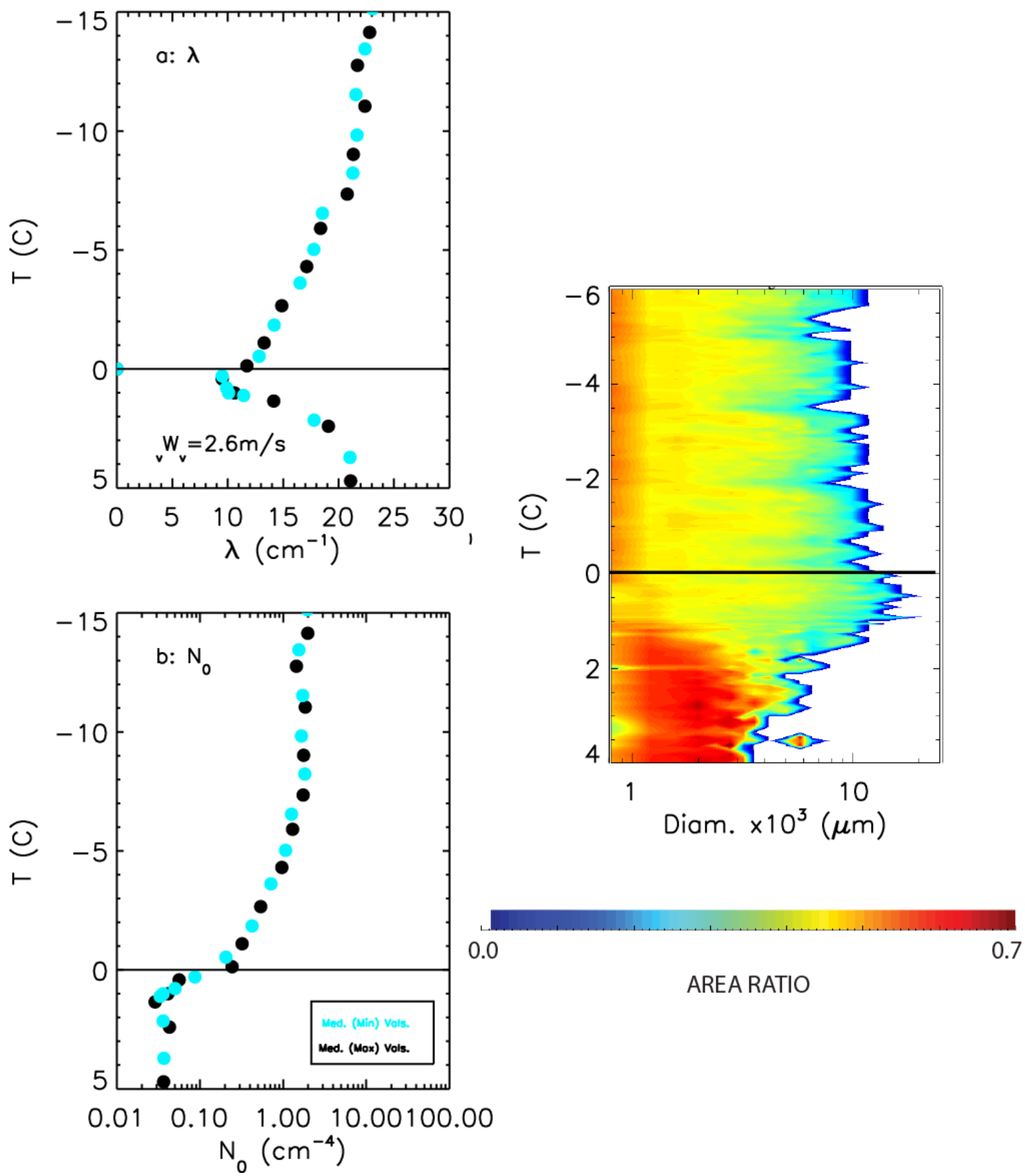
KWAJEX Profiles of Total Ice Concentration>100μm, Maximum Diameter
a: 19 Aug., N_t
b: 30 Aug., N_t
c: 11 Sept.
d: 19 Aug., D_max
e: 30 Aug., D_max
f: 11 Sept., D_max
T (C)
N_t (L^-1)
Max. Diam (cm)

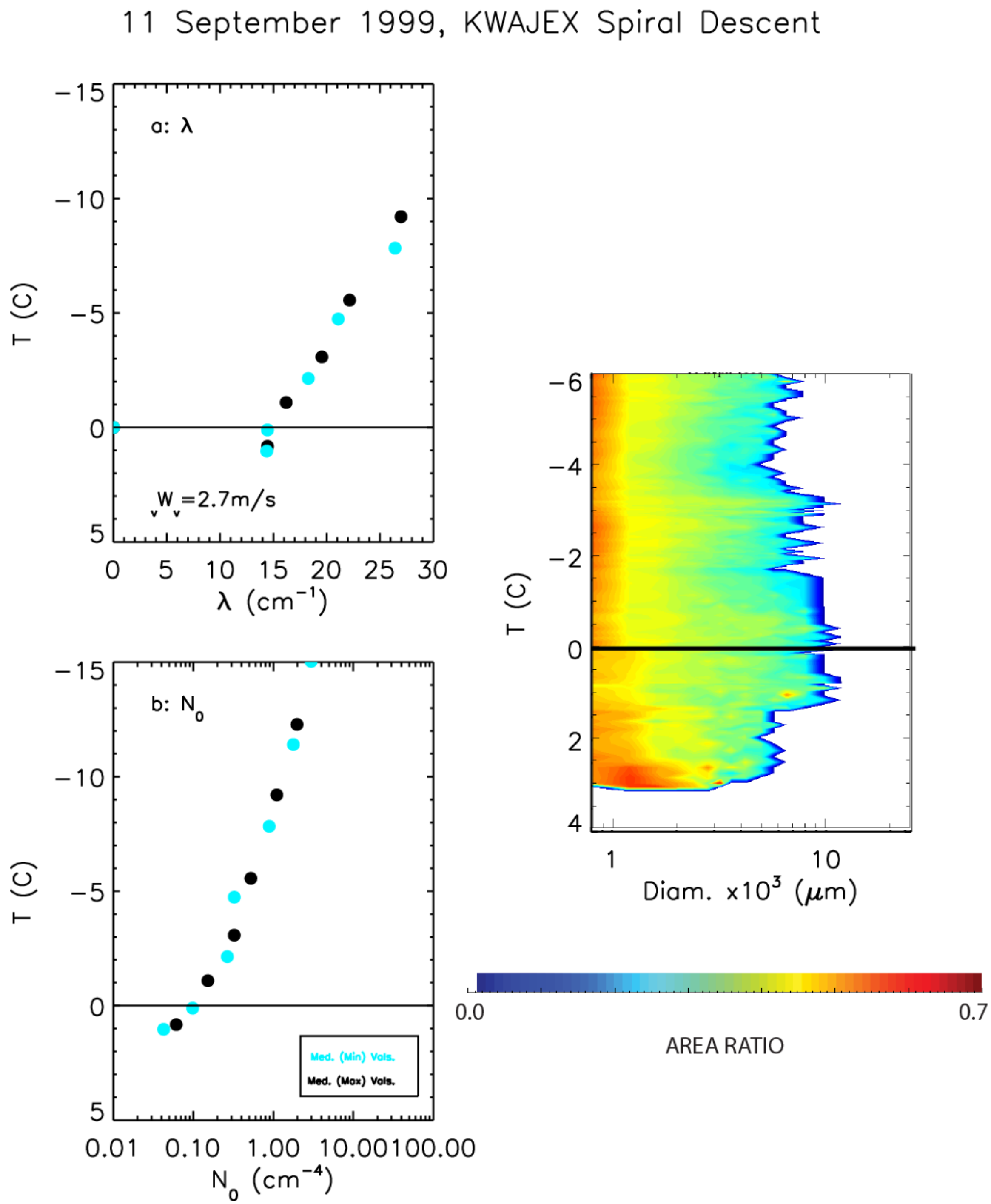


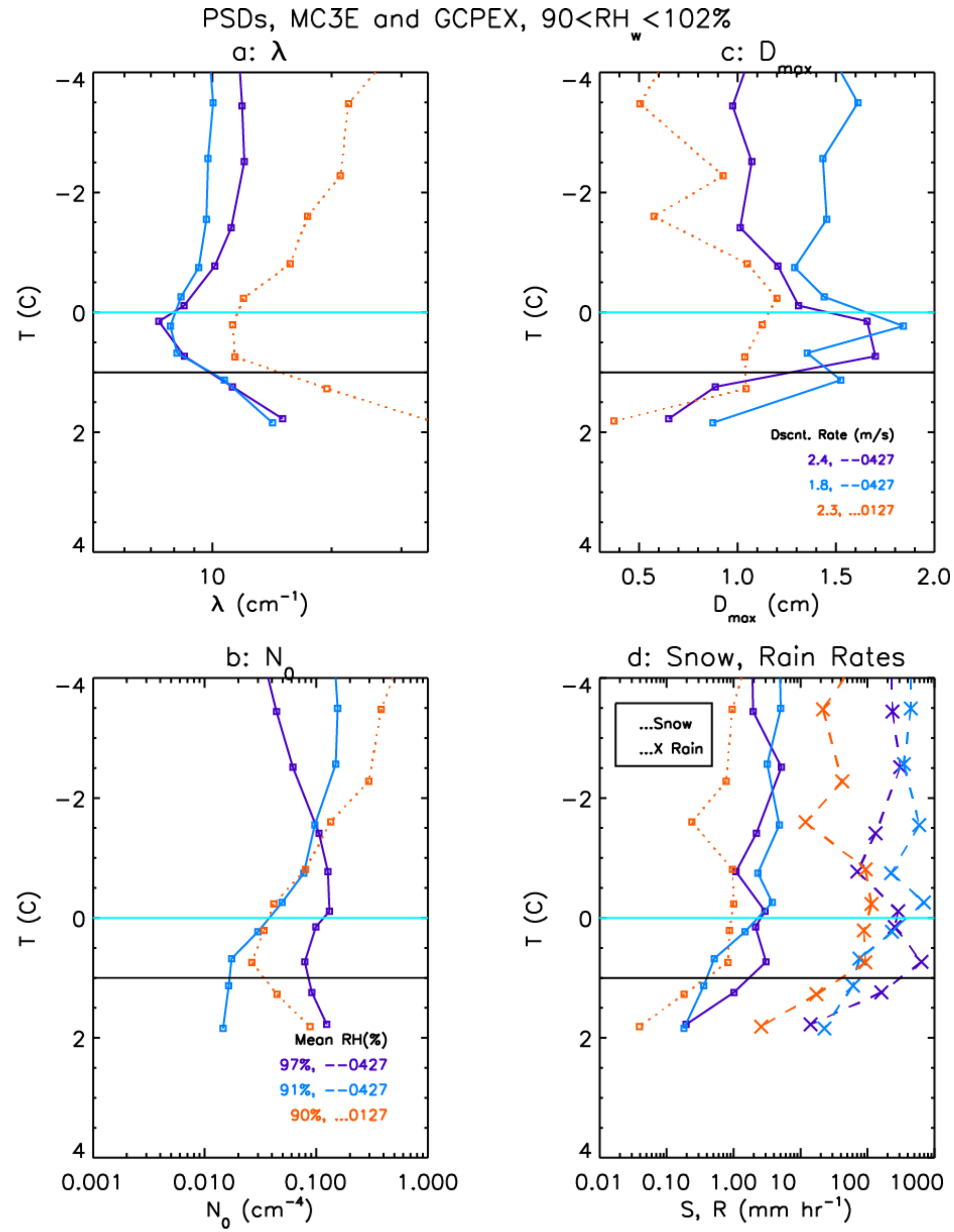
$$N=N_0e^{-\lambda D}$$

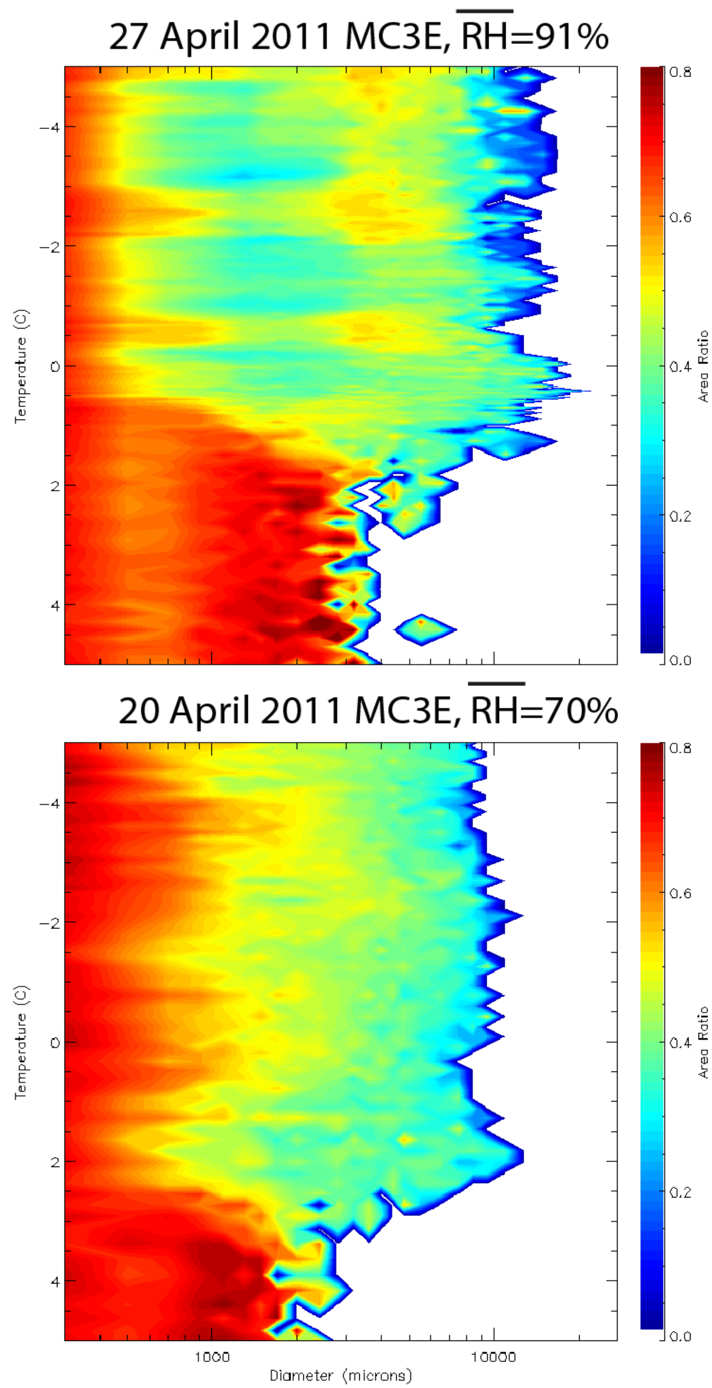

19 August 1999 KWAJEX Spiral Descent
a: λ
W = 1.3m/s
T (C)
λ (cm⁻¹)
b: N0
Med. (Min) Vols.
Med. (Max) Vols.
N0 (cm⁻⁴)
Diam. x10³ (μm)
0.0
0.7
AREA RATIO

30 August 1999, KWAJEX Spiral Descent




11 September 1999, KWAJEX Spiral Descent
a: λ
W = 2.7m/s
T (C)
λ (cm⁻¹)
b: N0
Med. (Min) Vols.
Med. (Max) Vols.
N0 (cm⁻⁴)
Diam. x10³ (μm)
0.0
0.7
AREA RATIO


PSDs, MC3E and GCPEX, 90<RHw<102%
a: λ
T (C)
λ (cm⁻¹)
c: Dmax
Dmax (cm)
Dscnt. Rate (m/s)
2.4, --0427
1.8, --0427
2.3, ...0127
b: N0
N0 (cm⁻⁴)
Mean RH(%)
97%, --0427
91%, --0427
90%, ...0127
d: Snow, Rain Rates
...Snow
...X Rain
S, R (mm hr⁻¹)


27 April 2011 MC3E, RH=91%
Temperature (C)
Area Ratio
20 April 2011 MC3E, RH=70%
Temperature (C)
Area Ratio
Diameter (microns)
1000
10000

Summary

- With decreasing temperatures from -4 to +1^{0}C and with relative humidities with respect to water of 90% or above, the PSD slope and intercept parameters uniformly decreased downward, while the maximum particle size of the largest particle continued to increase
- For highly subsaturated conditions and for temperatures from about –4 to +2^{0}C, the PSD slope and intercept parameters continued to decrease downwards, whereas the size of the largest particles either remained about the same or increased. There was relatively little melting until a temperature of +2 C or above was reached.
- It is often assumed that the relative humidity in the melting layer is at water saturation. What is really important to the melting process is the ice bulb temperature, which controls whether the ice particles are sublimating or growing or melting.