Ice Cloud Particle Parameterizations for Temperatures of 0 to -85C

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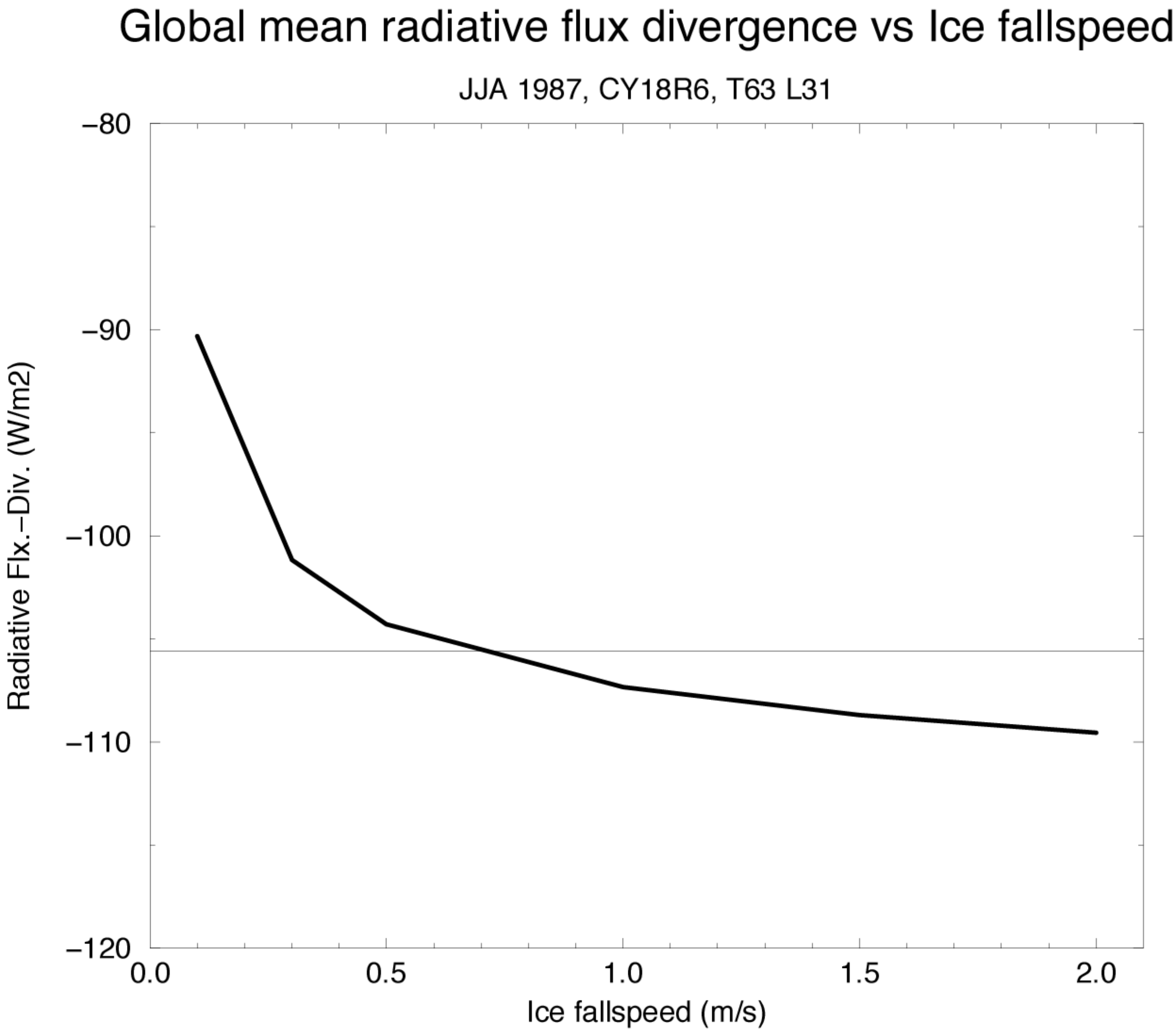
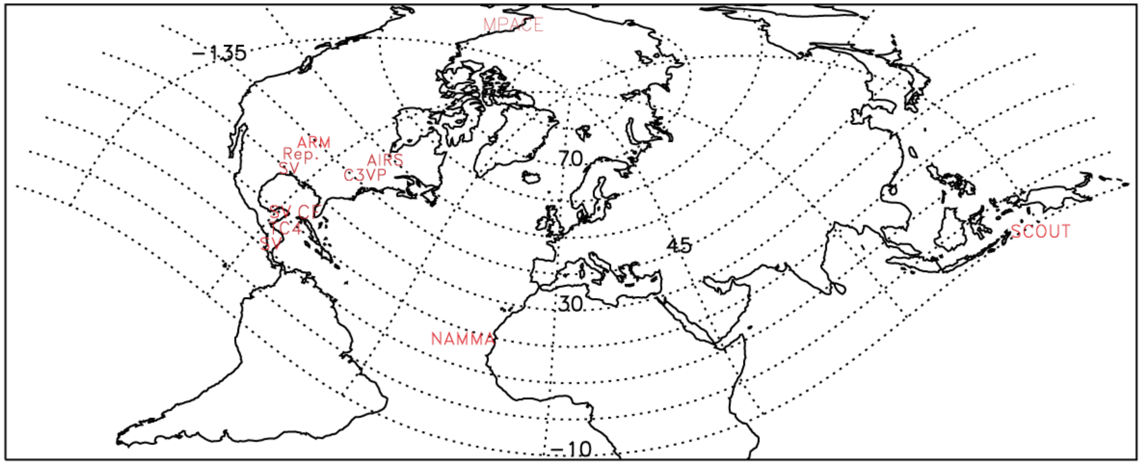


From Jakob, 1999, private communication based on refinements to the Tiedtke scheme

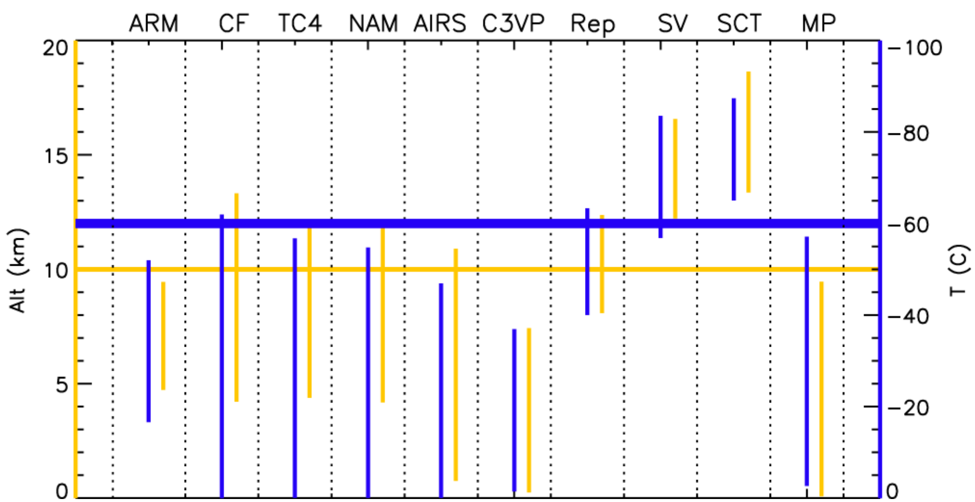
Overview

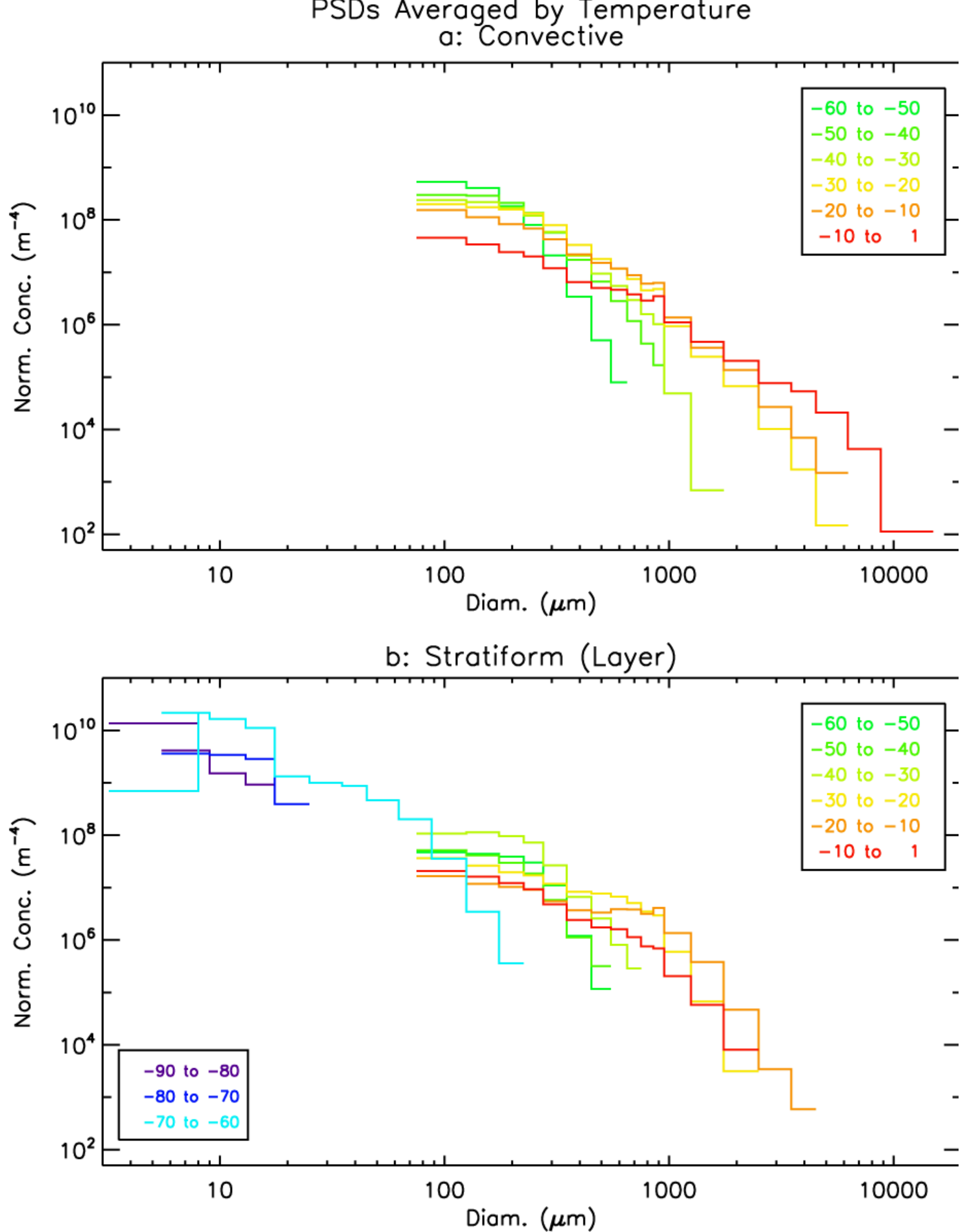
- Field programs, data
- PSD functional form
- Ice particle shape characteristics
- Terminal velocities
- Upscaling
- Considerations

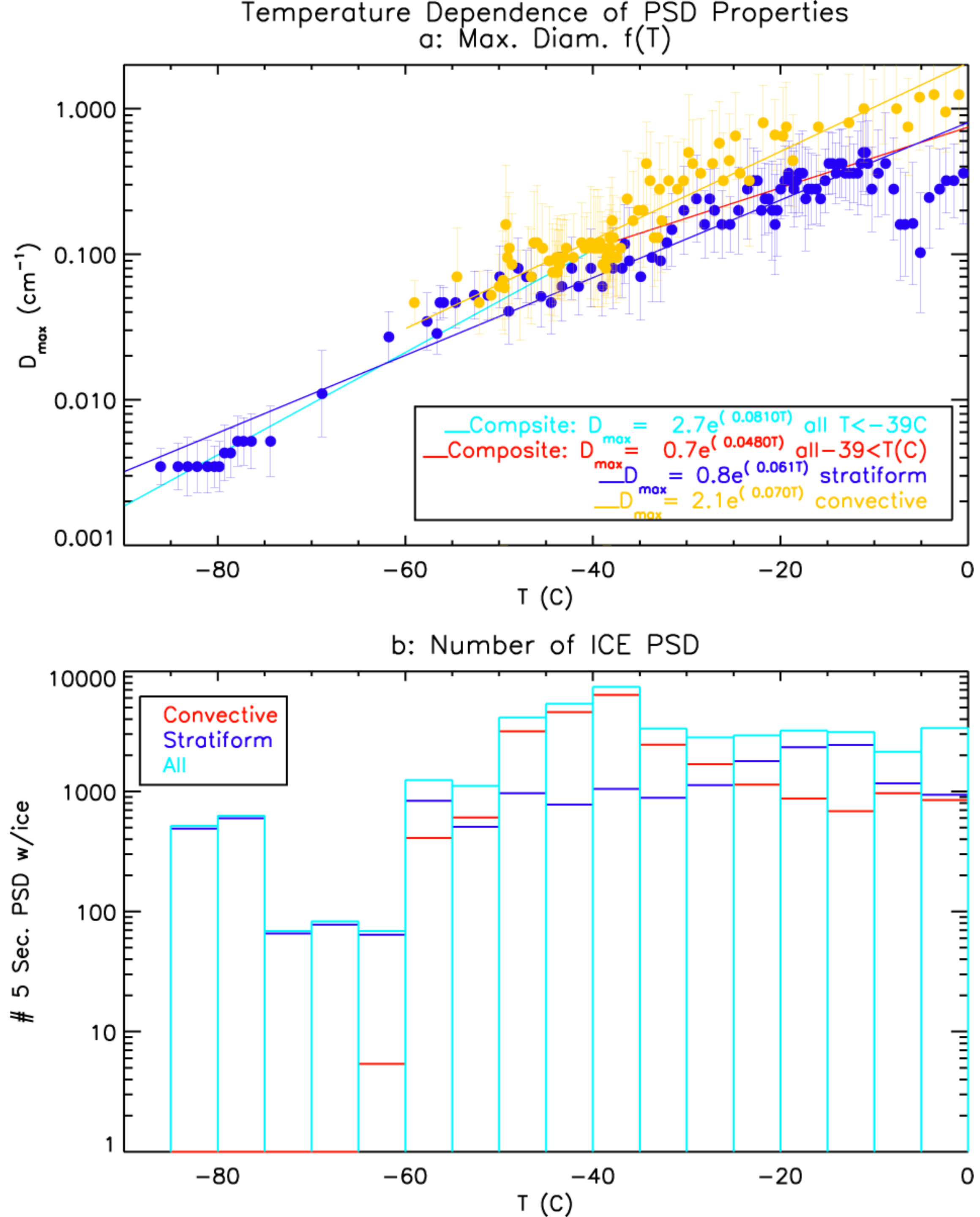
FIELD CAMPAIGNS



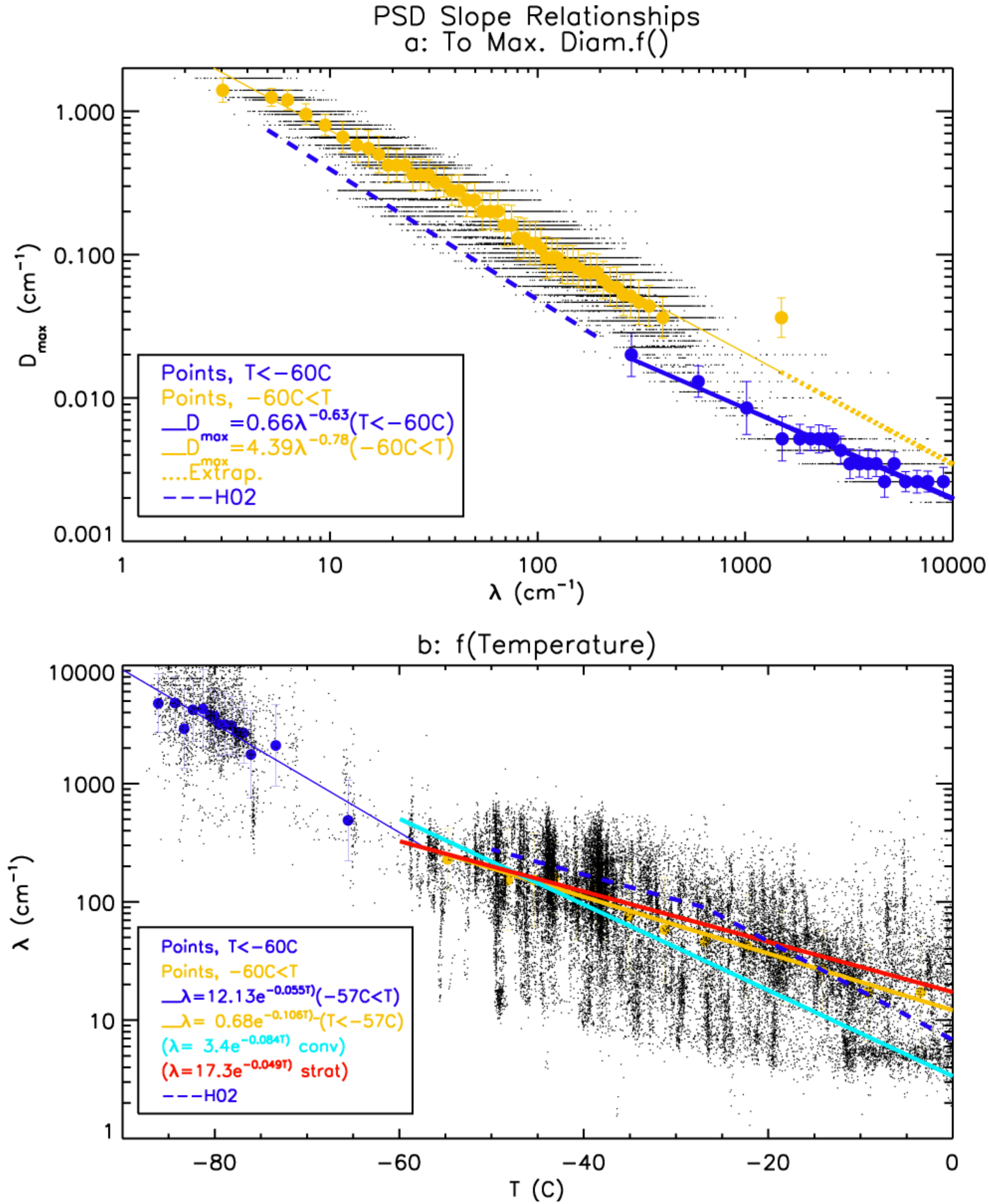
ARM: ARM 2000, Atmospheric Radiation Measurement (ARM) Field Campaign, 2000
CF: CRYSTAL–FACE, The Cirrus Regional Study of Tropical Anvils and Cirrus Layers – Florida Area Cirrus Experiment, 2002
TC4: The Tropical Composition, Cloud and Climate Coupling (TC4) Field Campaign, 2007
NAM: NAMMA – The NASA African Monsoon Multidisciplinary Analyses Campaign, 2006
AIRS: AIRS_2, Alliance Icing Research Study II, 2003–2004
C3VP: Canadian CloudSat/CALIPSO Validation Program, 2006–2007
Rep: Replicator Observations, First ISCCP Research Experiment (FIRE)–2, 1991
SV: Experiments with CF and pre–AURA Validation Experiment, 2002 and 2004
SCOUT: StratosphericĐClimate Links w/Emphasis on the Upper Troposphere/Lower Stratosphere, 2003
MPACE: Mixed–Phase Arctic Cloud Experiment, 2004



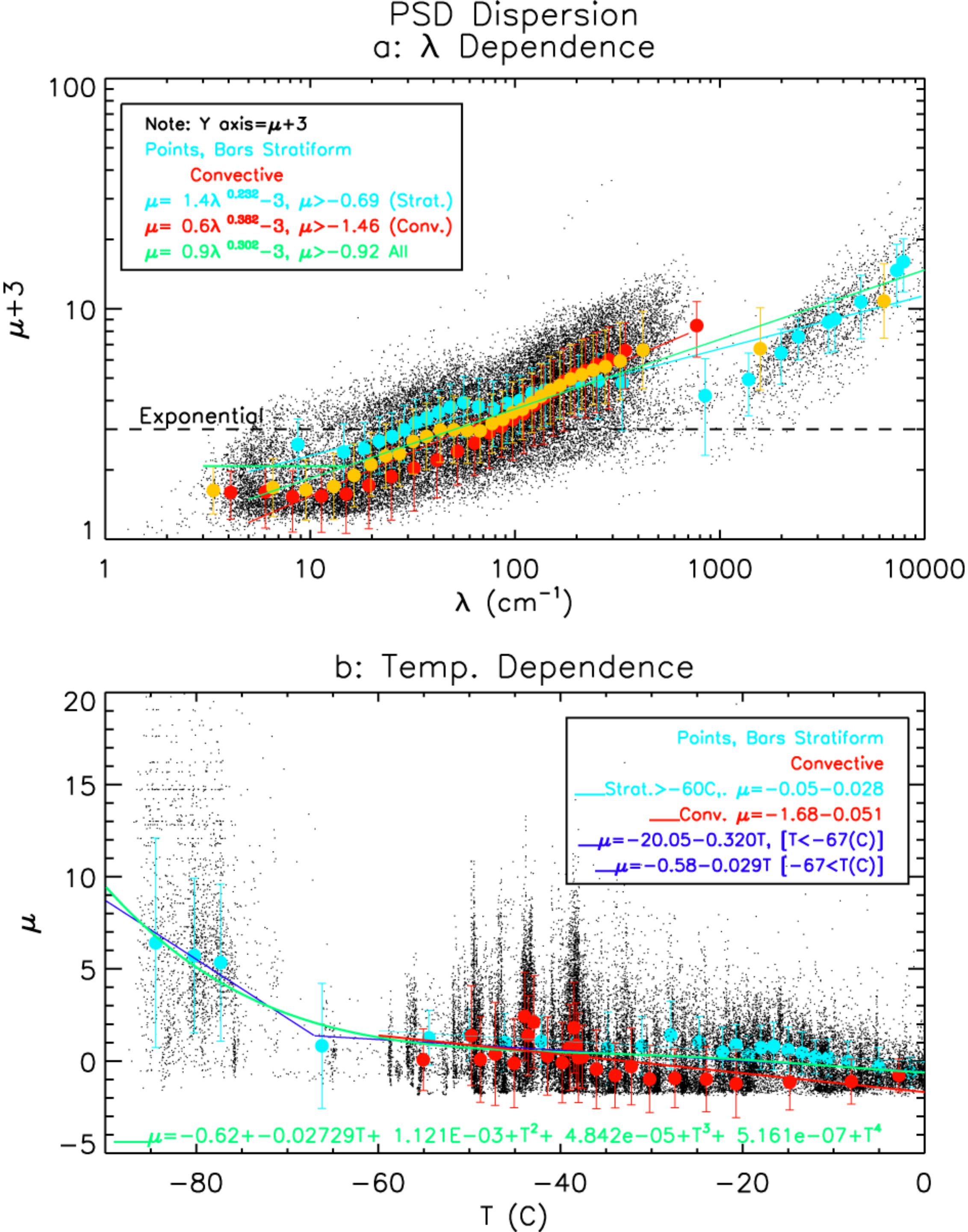

PSDs Averaged by Temperature
a: Convective
Norm. Conc. (m^{-4})
Diam. (μm)
−60 to −50
−50 to −40
−40 to −30
−30 to −20
−20 to −10
−10 to 1
b: Stratiform (Layer)
−90 to −80
−80 to −70
−70 to −60

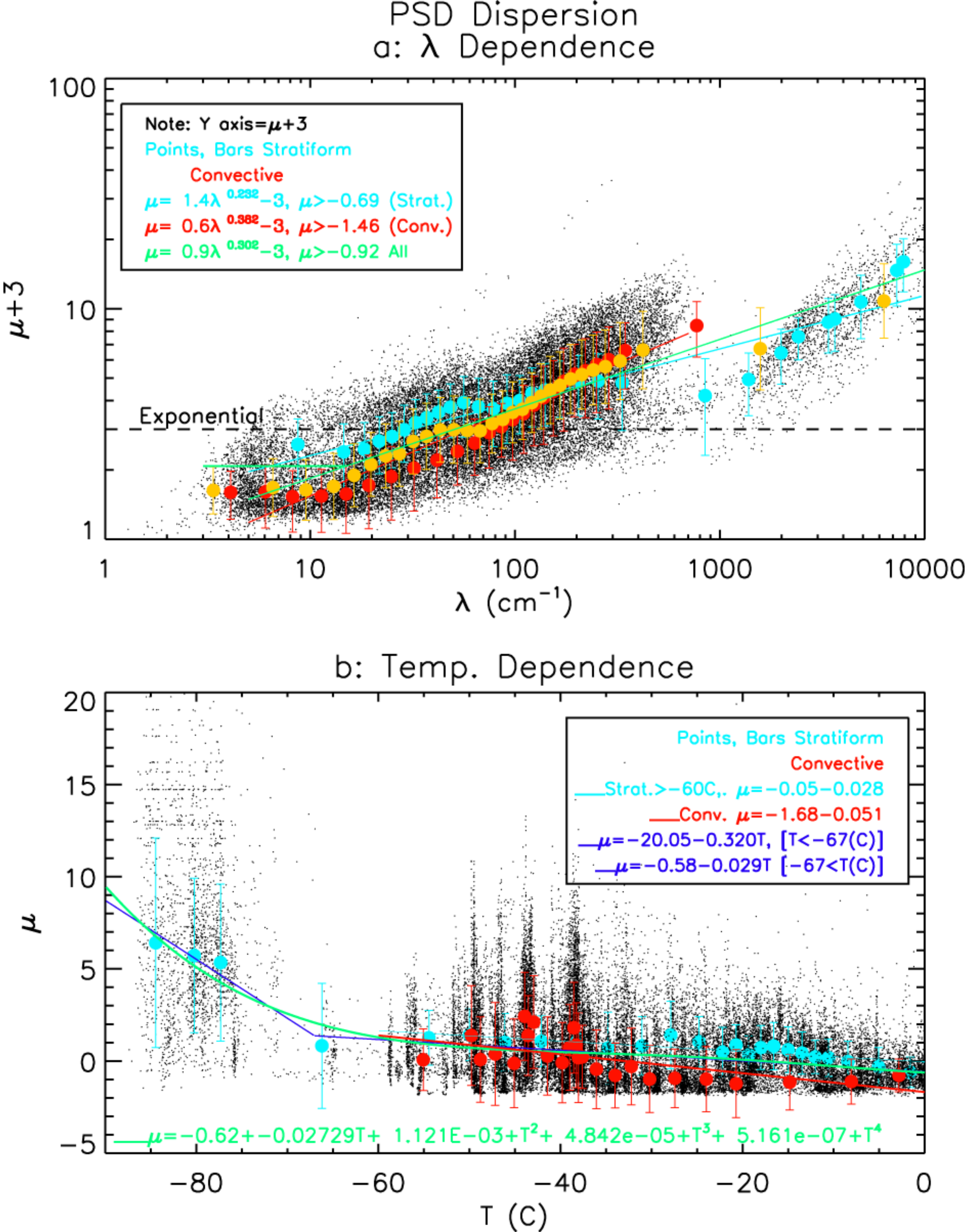


Temperature Dependence of PSD Properties
a: Max. Diam. f(T)
1.000
0.100
0.010
0.001
D_{max} (cm^{-1})
Compsite: D_{max} = 2.7e$^{(0.0810T)}$ all T<−39C
Composite: D_{max} = 0.7e$^{(0.0480T)}$ all−39<T(C)
D_{max} = 0.8e$^{(0.061T)}$ stratiform
D_{max} = 2.1e$^{(0.070T)}$ convective
−80
−60
−40
−20
0
T (C)
b: Number of ICE PSD
10000
1000
100
10
1
5 Sec. PSD w/ice
Convective
Stratiform
All
−80
−60
−40
−20
0
T (C)



$$N_0 D^{\mu} e^{-\lambda D}$$


PSD Dispersion
a: λ Dependence
Note: Y axis=μ+3
Points, Bars Stratiform
Convective
μ= 1.4λ 0.232−3, μ>−0.69 (Strat.)
μ= 0.6λ 0.382−3, μ>−1.46 (Conv.)
μ= 0.9λ 0.302−3, μ>−0.92 All
Exponential
μ+3
100
10
1
1
10
100
1000
10000
λ (cm−1)
b: Temp. Dependence
Points, Bars Stratiform
Convective
Strat.>−60C,. μ=−0.05−0.028
Conv. μ=−1.68−0.051
μ=−20.05−0.320T, [T<−67(C)]
μ=−0.58−0.029T [−67<T(C)]
μ=−0.62+−0.02729T+ 1.121E−03+T2+ 4.842e−05+T3+ 5.161e−07+T4
μ
20
15
10
5
0
−5
−80
−60
−40
−20
0
T (C)



PSD Dispersion
a: λ Dependence
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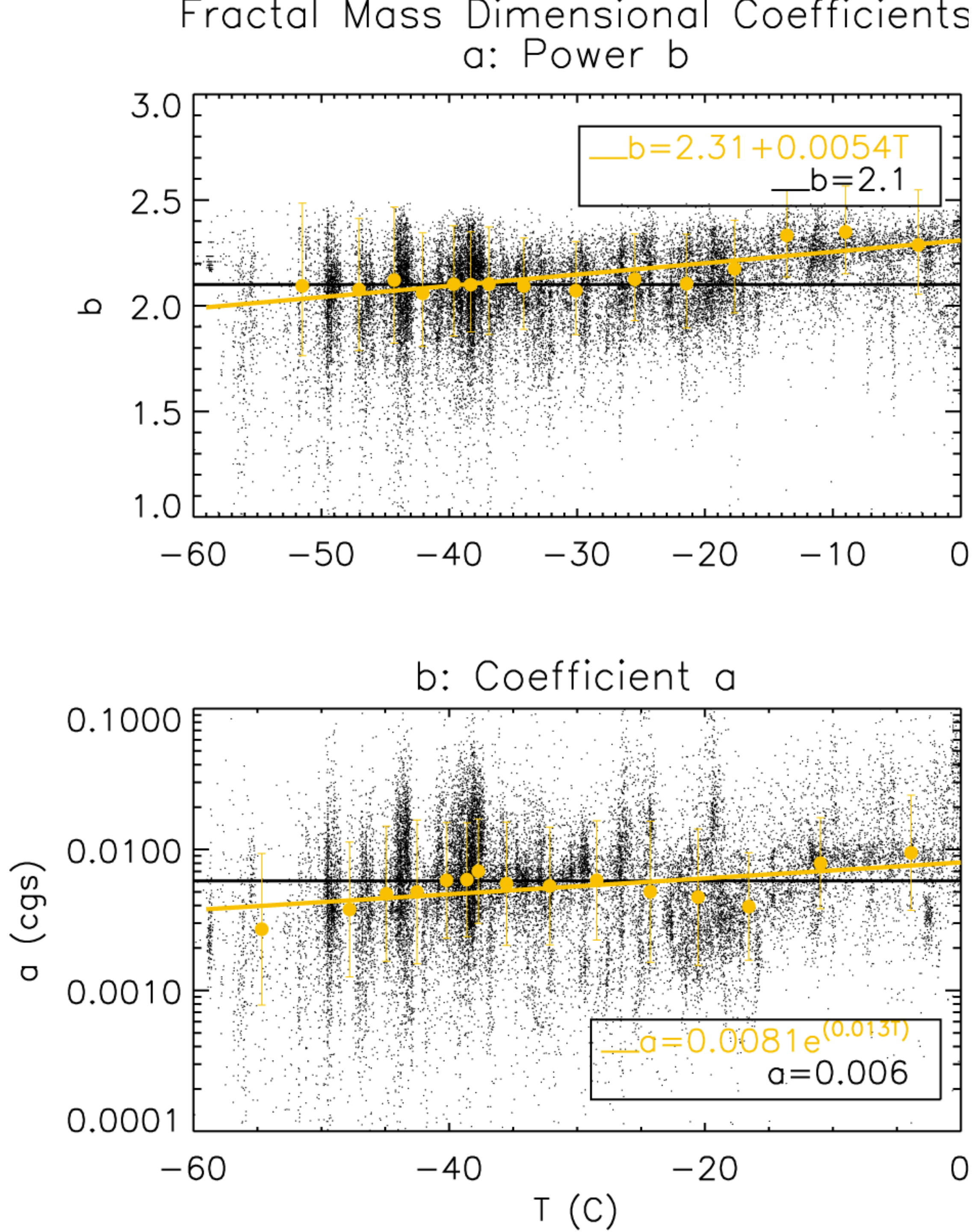
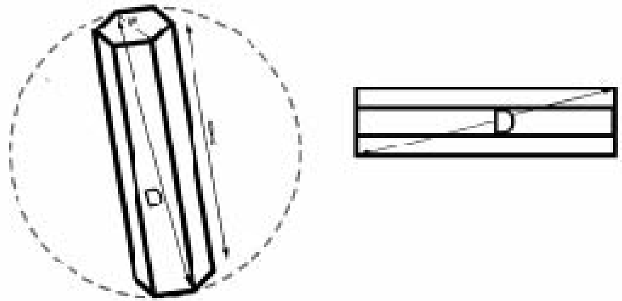
μ= 0.9λ 0.302−3, μ>−0.92 All
Exponential
μ+3
λ (cm−1)
1
10
100
1000
10000
b: Temp. Dependence
Points, Bars Stratiform
Convective
Strat.>−60C,. μ=−0.05−0.028
Conv. μ=−1.68−0.051
μ=−20.05−0.320T, [T<−67(C)]
μ=−0.58−0.029T [−67<T(C)]
μ=−0.62+−0.02729T+ 1.121E−03+T2+ 4.842e−05+T3+ 5.161e−07+T4
μ
T (C)
20
15
10
5
0
−5
−80
−60
−40
−20
0

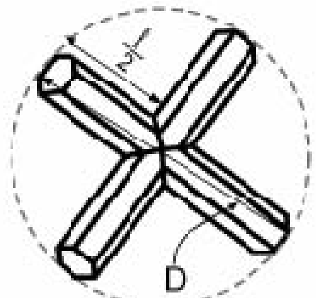


Fractal Mass Dimensional Coefficients
a: Power b
b=2.31+0.0054T
b=2.1
b
3.0
2.5
2.0
1.5
1.0
−60
−50
−40
−30
−20
−10
0
b: Coefficient a
a (cgs)
0.1000
0.0100
0.0010
0.0001
a=0.0081e$^{(0.013T)}$
a=0.006
−60
−40
−20
0
T (C)

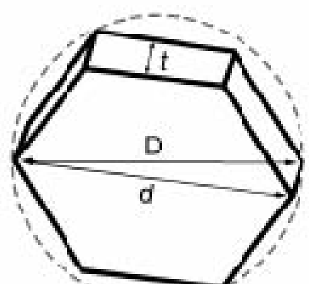
Idealized Crystal Geometries



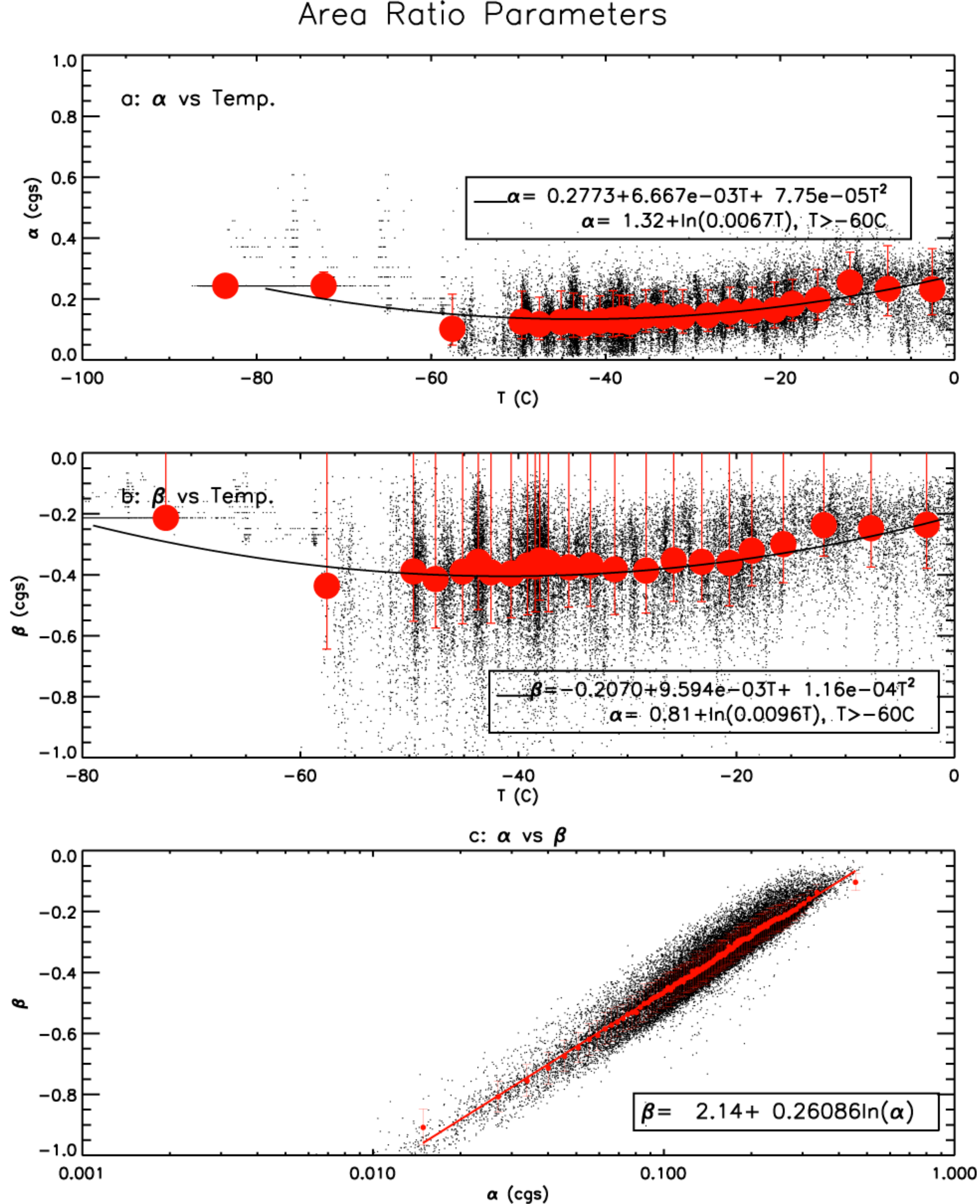
Hexagonal column



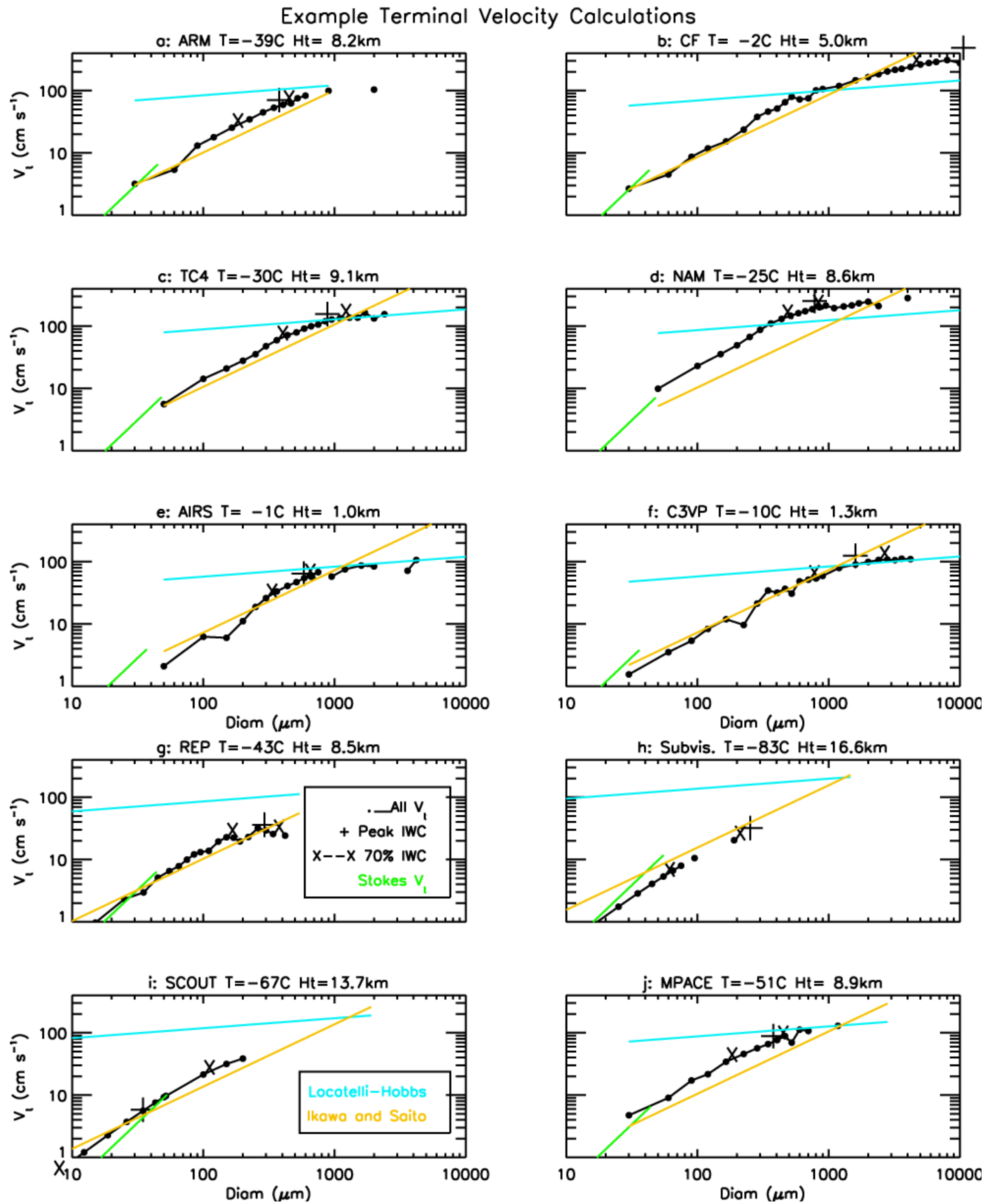
Bullet rosette



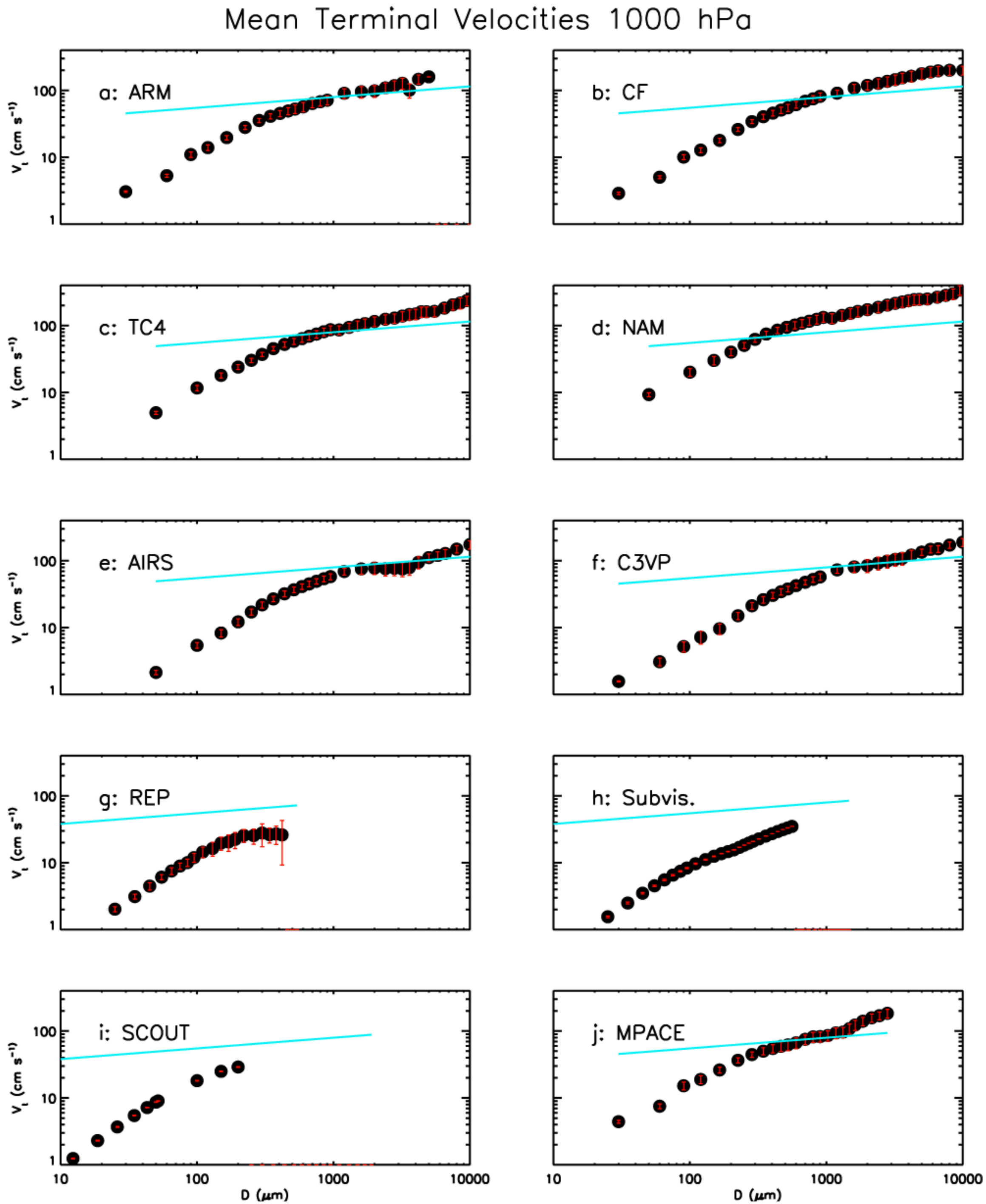
Plate



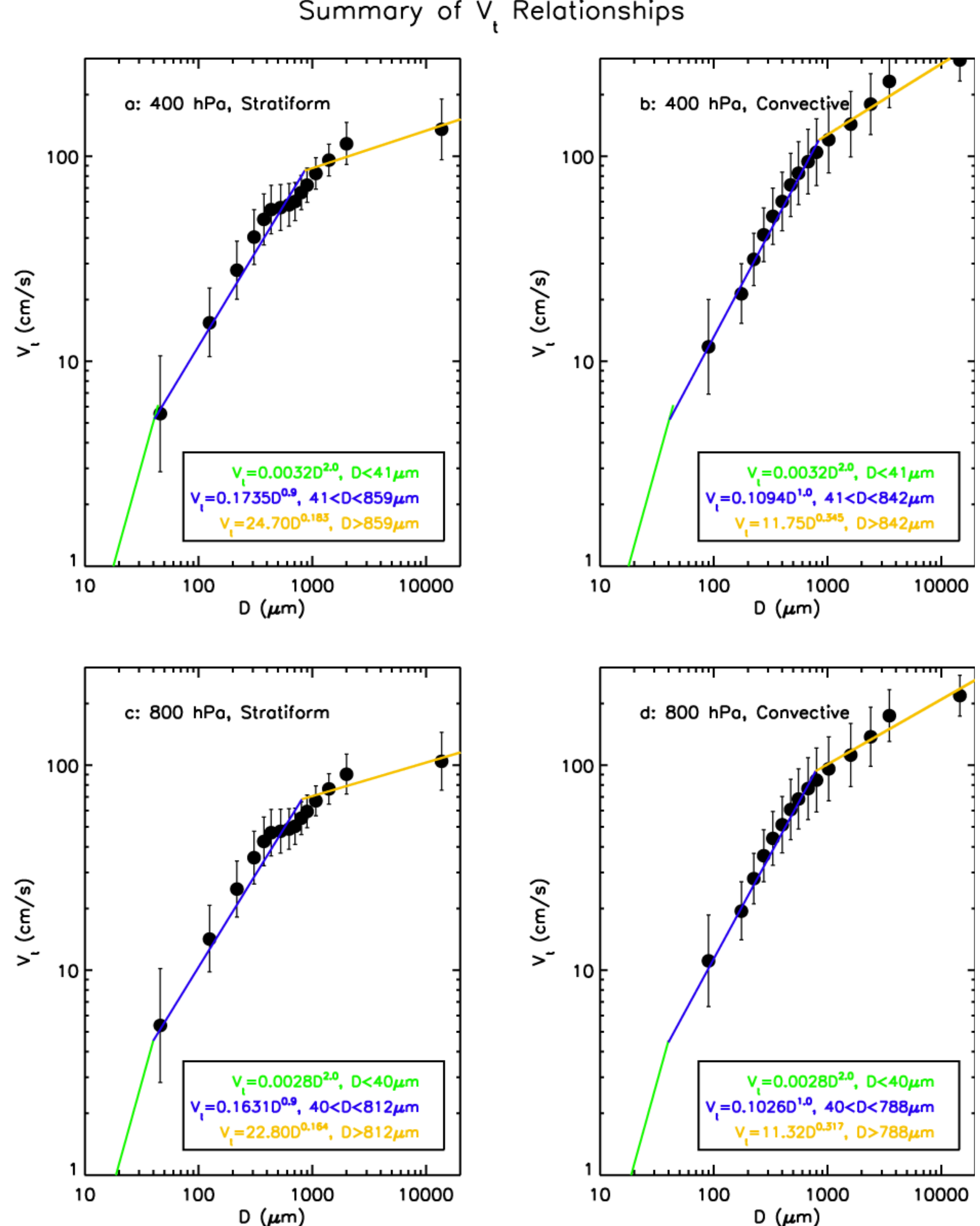
Area Ratio Parameters
a: α vs Temp.
α= 0.2773+6.667e−03T+ 7.75e−05T²
α= 1.32+ln(0.0067T), T>−60C
α (cgs)
T (C)
b: β vs Temp.
β=−0.2070+9.594e−03T+ 1.16e−04T²
α= 0.81+ln(0.0096T), T>−60C
β (cgs)
T (C)
c: α vs β
β= 2.14+ 0.26086ln(α)
β
α (cgs)



Example Terminal Velocity Calculations
a: ARM T=-39C Ht= 8.2km
b: CF T= -2C Ht= 5.0km
c: TC4 T=-30C Ht= 9.1km
d: NAM T=-25C Ht= 8.6km
e: AIRS T= -1C Ht= 1.0km
f: C3VP T=-10C Ht= 1.3km
g: REP T=-43C Ht= 8.5km
h: Subvis. T=-83C Ht=16.6km
i: SCOUT T=-67C Ht=13.7km
j: MPACE T=-51C Ht= 8.9km
V_t (cm s^{-1})
Diam (μm)
All V_t
+ Peak IWC
X--X 70% IWC
Stokes V_t
Locatelli-Hobbs
Ikawa and Saito



Mean Terminal Velocities 1000 hPa
a: ARM
b: CF
c: TC4
d: NAM
e: AIRS
f: C3VP
g: REP
h: Subvis.
i: SCOUT
j: MPACE
V_t (cm s^{-1})
D (μm)
1
10
100
1000
10000


Summary of V_t Relationships
a: 400 hPa, Stratiform
V_t=0.0032D^2.0, D<41μm
V_t=0.1735D^0.9, 41<D<859μm
V_t=24.70D^0.183, D>859μm
b: 400 hPa, Convective
V_t=0.0032D^2.0, D<41μm
V_t=0.1094D^1.0, 41<D<842μm
V_t=11.75D^0.345, D>842μm
c: 800 hPa, Stratiform
V_t=0.0028D^2.0, D<40μm
V_t=0.1631D^0.9, 40<D<812μm
V_t=22.80D^0.164, D>812μm
d: 800 hPa, Convective
V_t=0.0028D^2.0, D<40μm
V_t=0.1026D^1.0, 40<D<788μm
V_t=11.32D^0.317, D>788μm
V_t (cm/s)
D (μm)
1
10
100
1000
10000

Additional Considerations

- Ice shattering
- Sub-150 micron ice particles
  - Undersized >> Concentrations
  - Sampling Statistics
  - Shape discrimination
  - 2D-S probe major improvement
  - SID-2, SID-3, VIPS, Replication
- HVPS-3 big improvement
  - Sample volume, shape discrimination
- Upscaling from In-situ observations ~1km to ECMWF~16km or above

Upscaling

- Primary question: Is the mean concentration at a given size in a PSD through a horizontal slice through a cloud layer missing any preferred horizontal scale.
- Used Bayesian analysis to look for preferred PSD horizontal scales, using one very long horizontal penetration (80 km) at constant altitude through an ice layer cloud
- An an example, took horizontal spacing of all 200-250 micron particles with 25 micron horizontal resolution based on interarrival time and found a “preferred” PDF scale of 4 km.
- Did a similar analysis for other size ranges and found that the mean concentration only fairly represents preferred scale
- Similar analysis needed for many case studies to investigate whether there are preferred horizontal scales.