Use of SPARTICUS ice crystal image analysis to develop internally consistent representations of ice physical and optical properties for a size-resolved microphysics model

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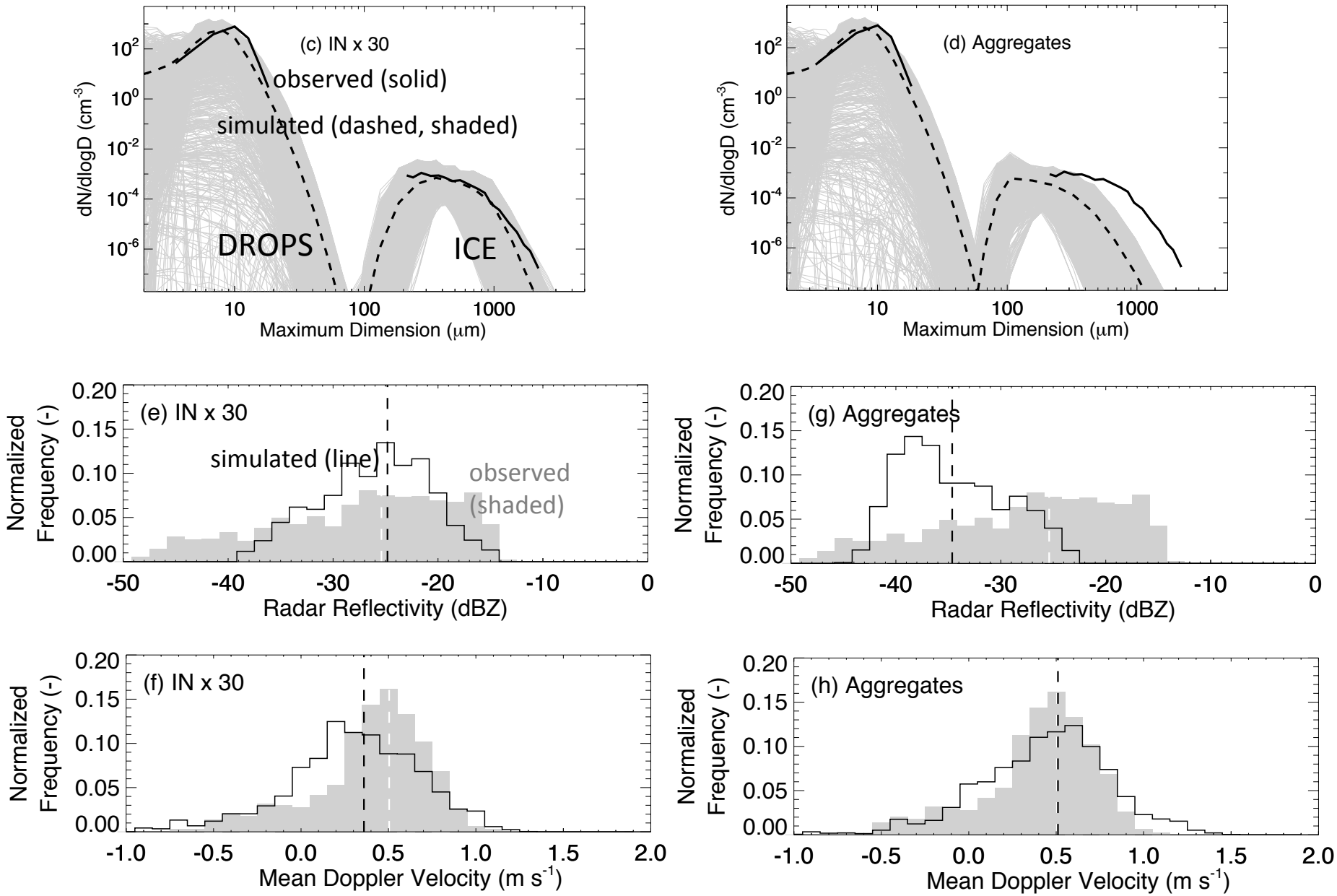
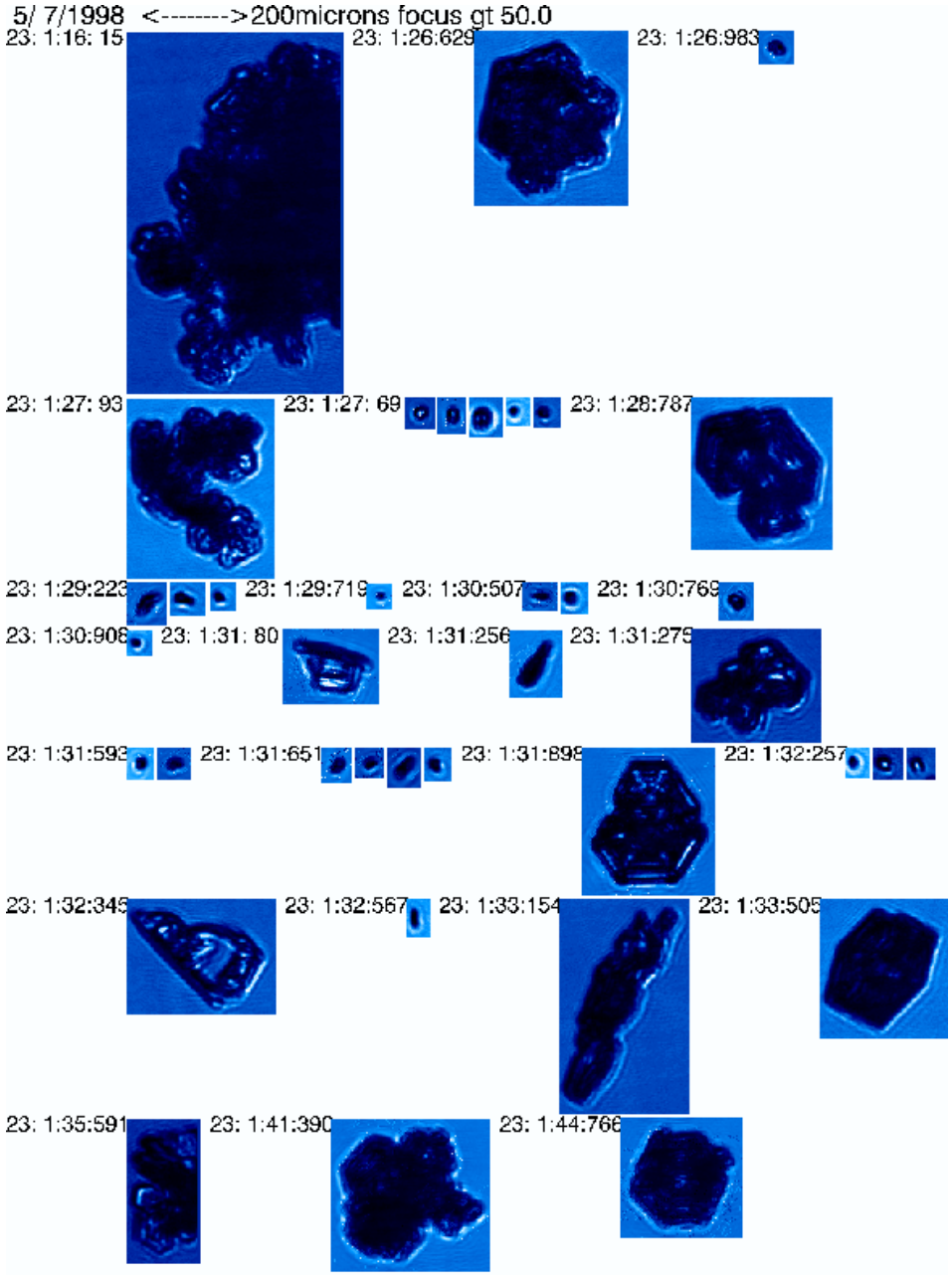
RADIATING PLATES

AGGREGATES




5/ 7/1998 <-------->200microns focus gt 50.0
23: 1:16: 15
23: 1:26:629
23: 1:26:983
23: 1:27: 93
23: 1:27: 69
23: 1:28:787
23: 1:29:223
23: 1:29:719
23: 1:30:507
23: 1:30:769
23: 1:30:908
23: 1:31: 80
23: 1:31:256
23: 1:31:279
23: 1:31:593
23: 1:31:651
23: 1:31:898
23: 1:32:257
23: 1:32:349
23: 1:32:567
23: 1:33:154
23: 1:33:505
23: 1:35:591
23: 1:41:390
23: 1:44:766

SHEBA Arctic stratus

$m = aD^b$

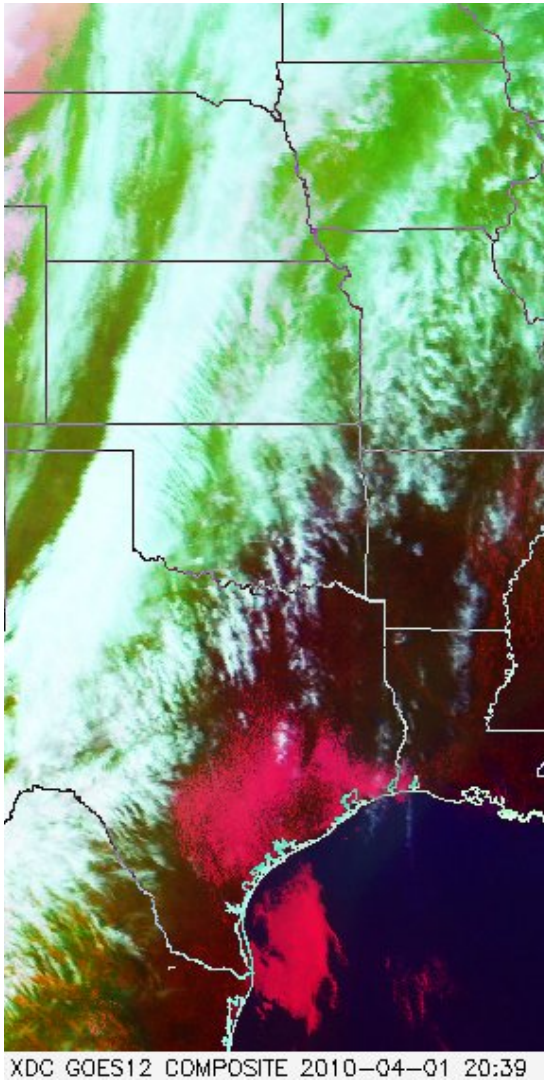
$A = cD^d$

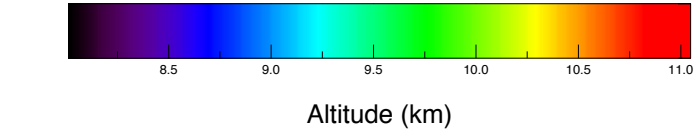
TABLE 1. Mass- and area-dimensional power laws used in simulations and radar reflectivity calculations.

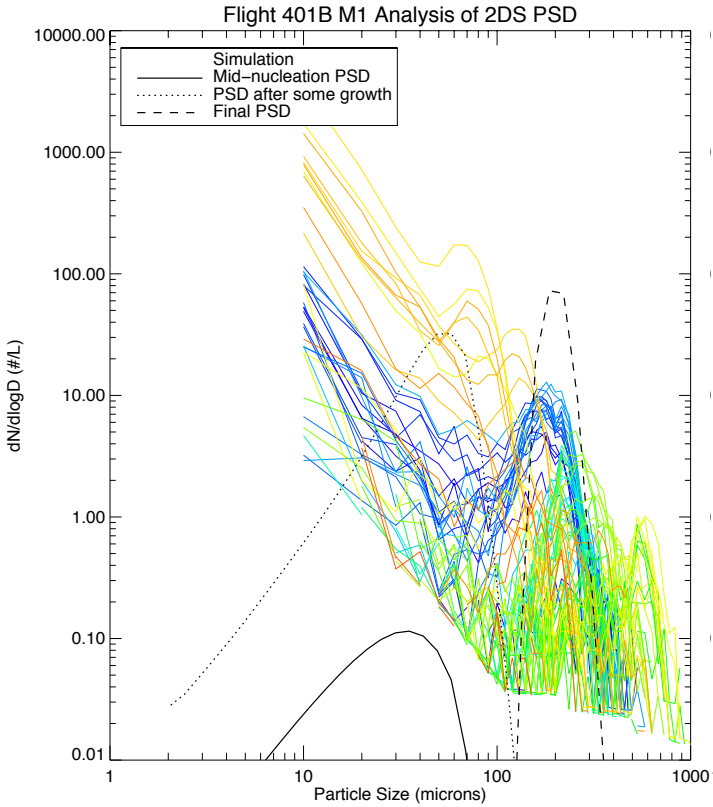
Habit	D (cm)[a]	a[b]	b[b]	c[b]	d[b]	Source[c]
Spheres	0.0002–0.0005	0.480 14	3.00	0.785 40	2.00	—
Transitional	0.0005–0.012	0.023 06	2.61	0.175 96	1.82	—
Radiating assemblages of plates	>0.012	0.002 40	2.1	0.228 50	1.88	LH74, MZP90, M96, BL06
Aggregates of unrimed radiating assemblages of plates, side planes, bullets, and columns	>0.012	0.002 94	1.9	0.228 50	1.88	LH74, M96
Plates with sectorlike branches	0.001–0.016	0.006 14	2.42	0.24	1.85	M96
	>0.016	0.001 42	2.02	0.55	1.97	M96
Hexagonal plates	>0.012	0.007 39	2.45	0.65	2.00	M96

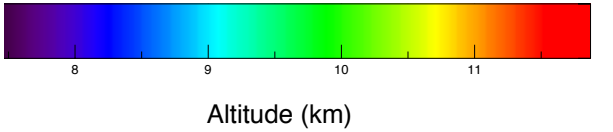
Fridlind et al. [*JAS 2012*]

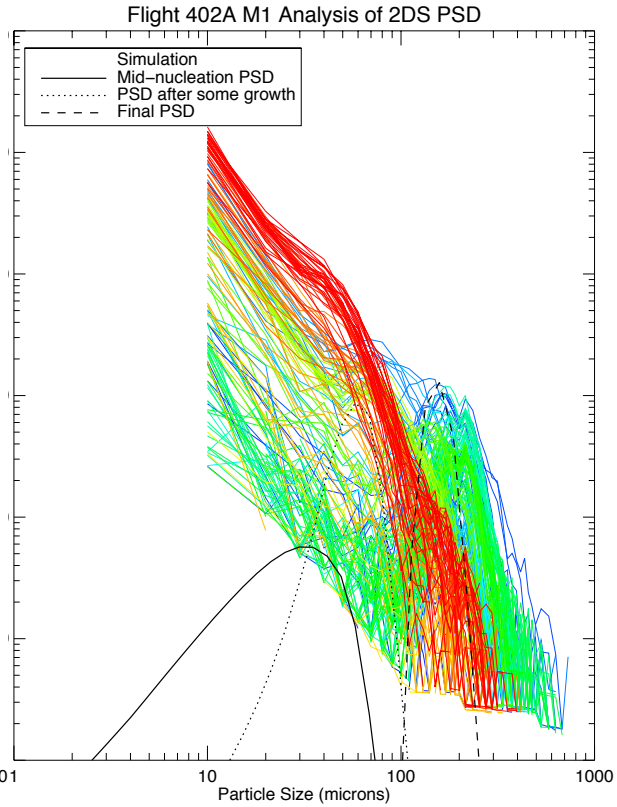
SPARTICUS

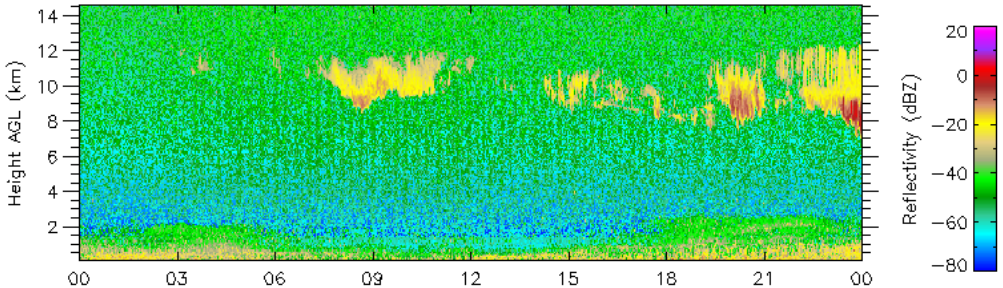

XDC GOES12 COMPOSITE 2010-04-01 20:39


8.5
9.0
9.5
10.0
10.5
11.0
Altitude (km)

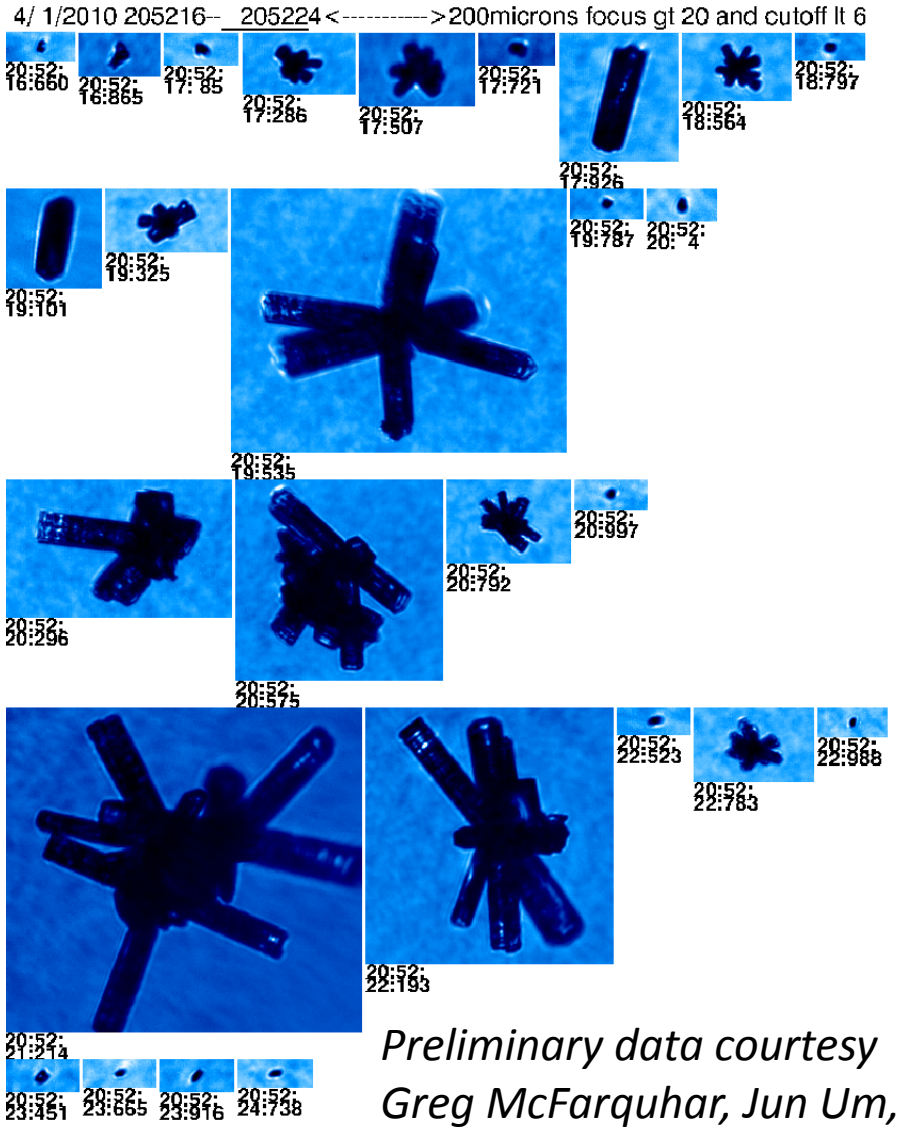

Flight 401B M1 Analysis of 2DS PSD
Simulation
Mid-nucleation PSD
PSD after some growth
Final PSD
dN/dlogD (#/L)
10000.00
1000.00
100.00
10.00
1.00
0.10
0.01
1
10
100
1000
Particle Size (microns)

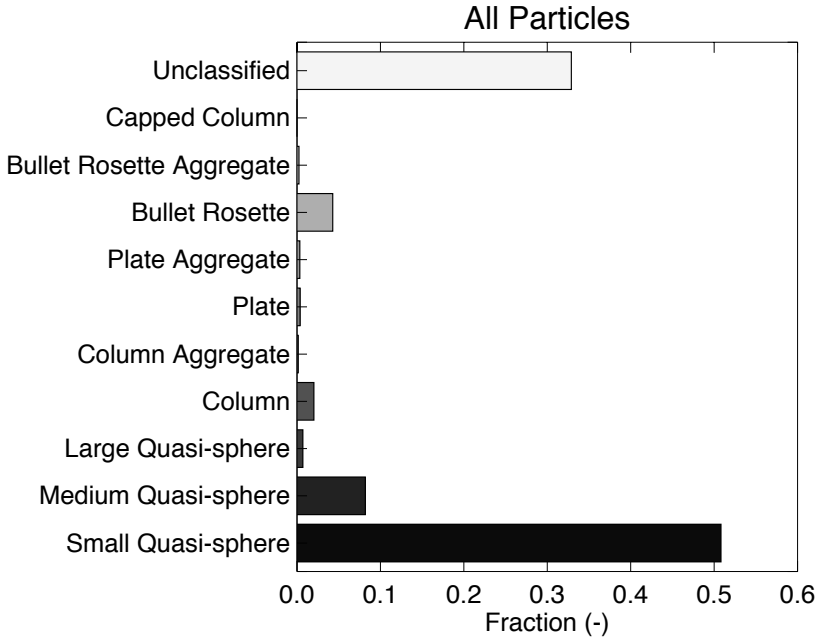

8
9
10
11
Altitude (km)

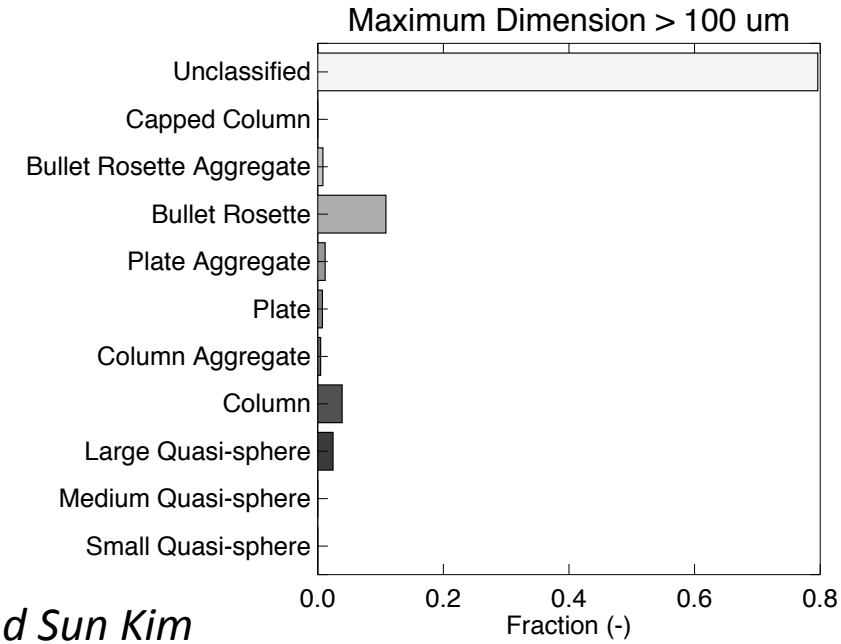

Flight 402A M1 Analysis of 2DS PSD
Simulation
Mid-nucleation PSD
PSD after some growth
Final PSD
1
10
100
1000
Particle Size (microns)


Height AGL (km)
14
12
10
8
6
4
2
00
03
06
09
12
15
18
21
00
Reflectivity (dBZ)
20
0
−20
−40
−60
−80

SPARTICUS

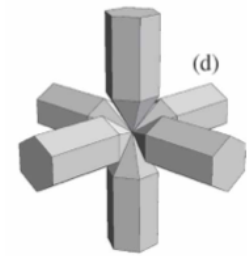






Preliminary data courtesy
Greg McFarquhar, Jun Um, and Sun Kim

SPARTICUS



- Bullet rosettes
  - branch length linear with D
  - branch width wider (thinner) with fewer (more) arms
  - assume that early branch width increases rapidly from *same number of branches*
  - A < 0.25*SA (as expected)
  - *calculate* mass
  - solid line mass, area for 6 arms
  - compare with bulk spheres (dashed), Mitchell et al. [1996] (dotted), Heymsfield et al. [2002] (dash-dotted)
  - *randomly oriented* D

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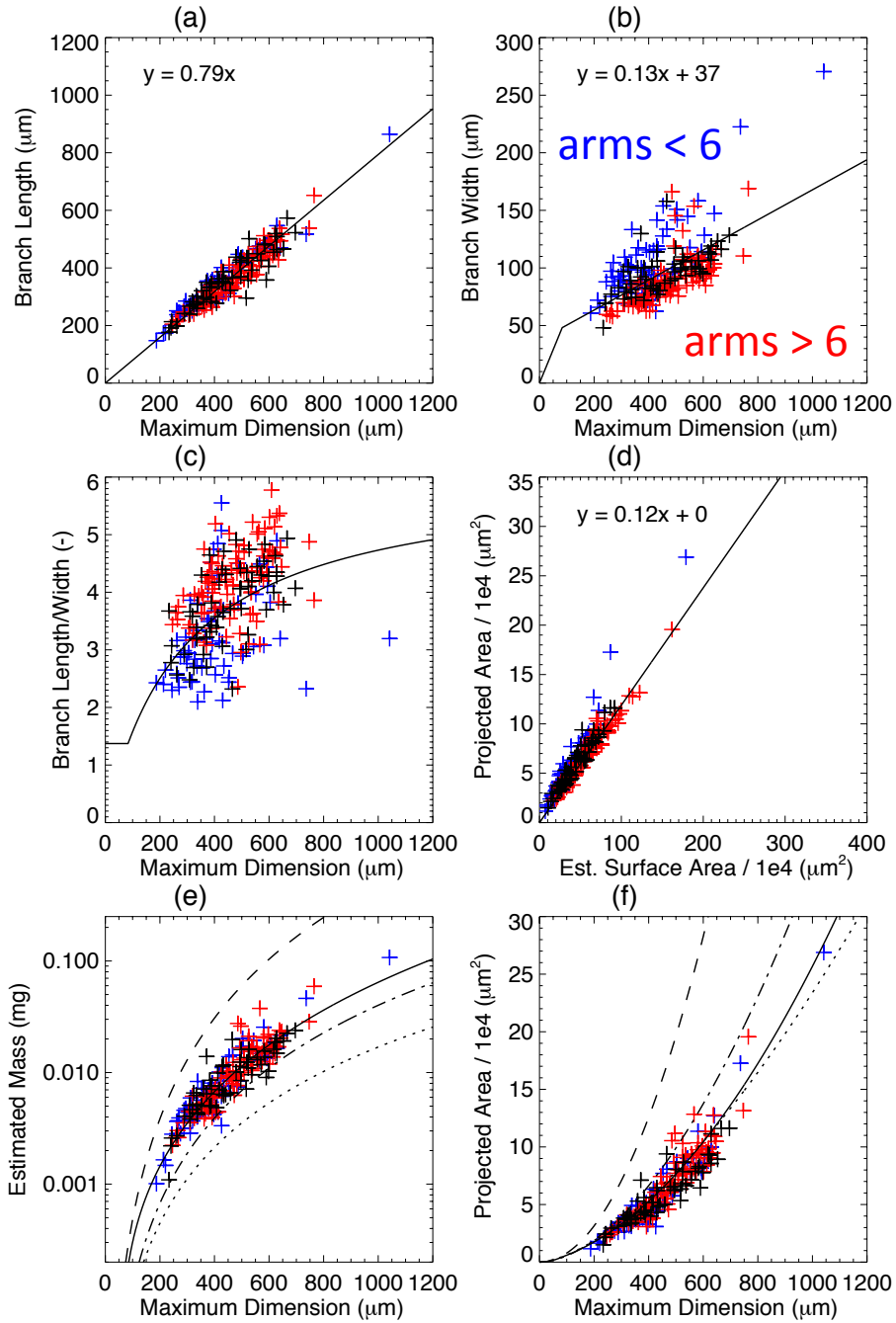

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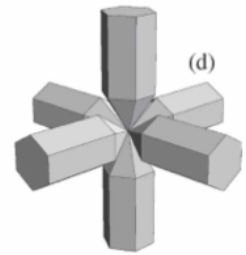
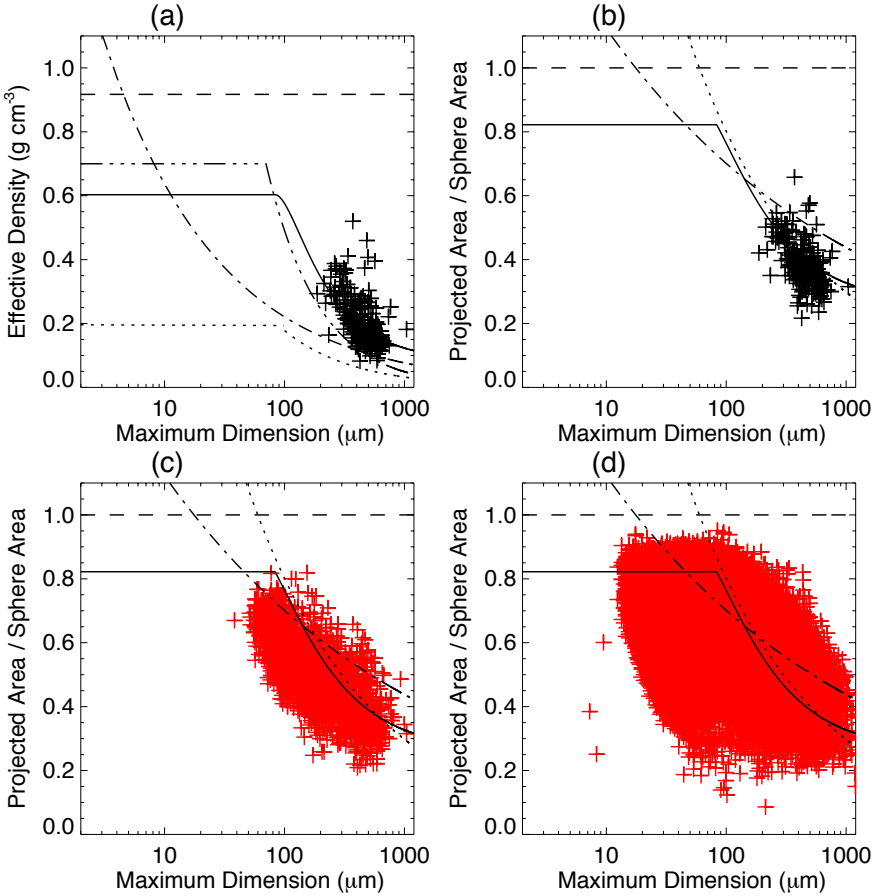


- Bullet rosettes
  - results for D < 200 µm
  - solid line = our 6-arm model
  - compare with bulk spheres (dashed), Mitchell et al. [1996] (dotted), Heymsfield et al. [2002] (dash-dotted), Cotton et al. (dash-triple-dotted)
  - *randomly oriented* D



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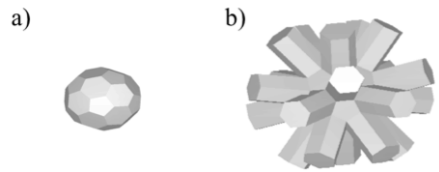
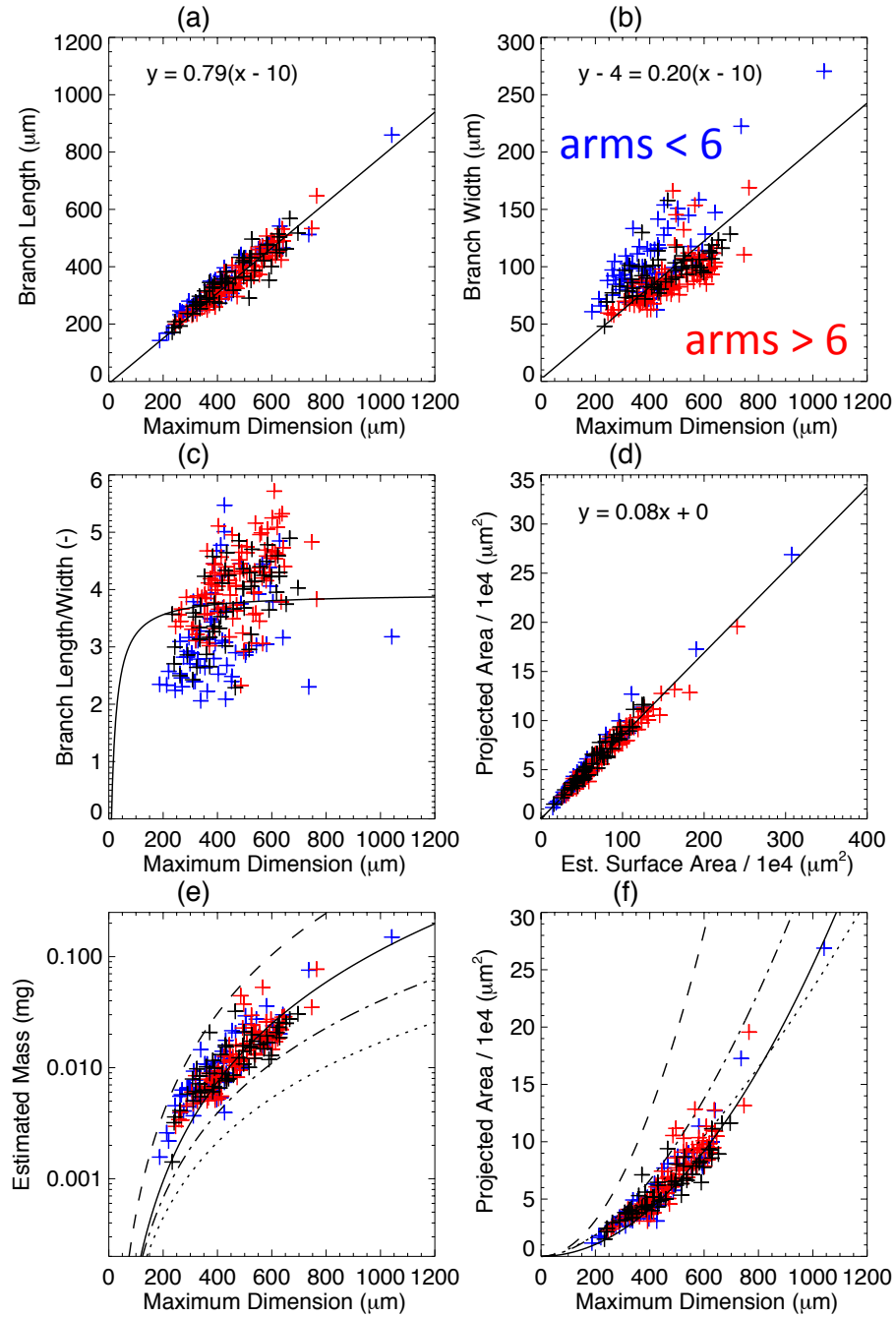


- Bullet rosettes
  - force branch width to zero at a fixed "core" size
  - assume that early branch width increases linearly from *same number of branches*
  - A < 0.25*SA (as expected)
  - *calculate* mass
  - solid line mass, area for 6 arms
  - compare with bulk spheres (dashed), Mitchell et al. [1996] (dotted), Heymsfield et al. [2002] (dash-dotted)
  - *randomly oriented* D



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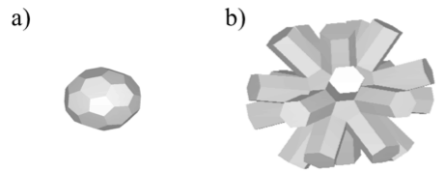

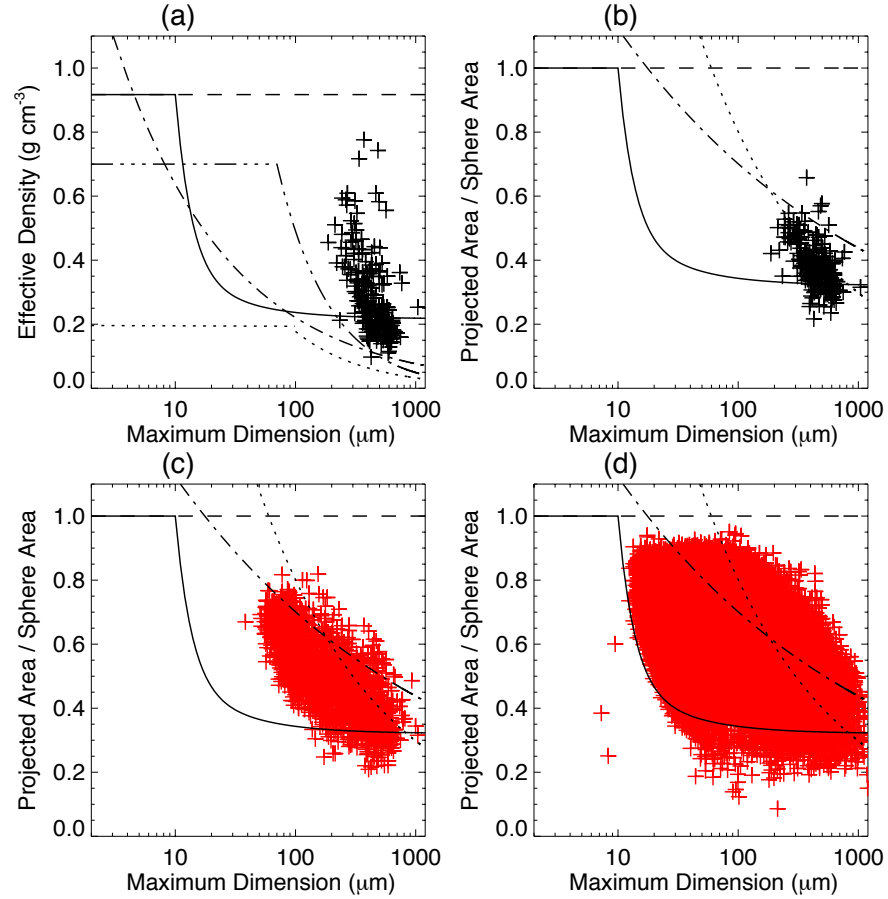

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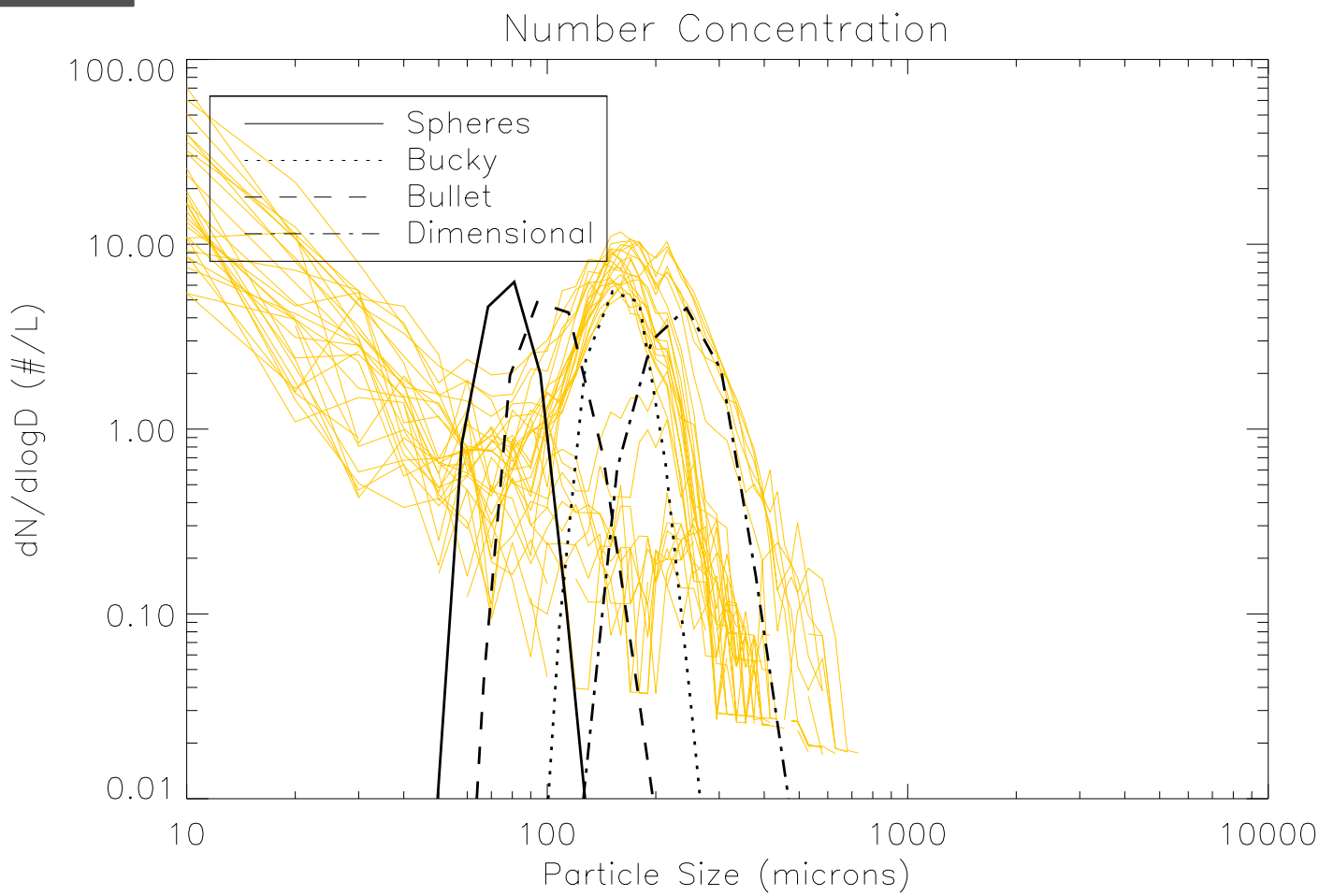
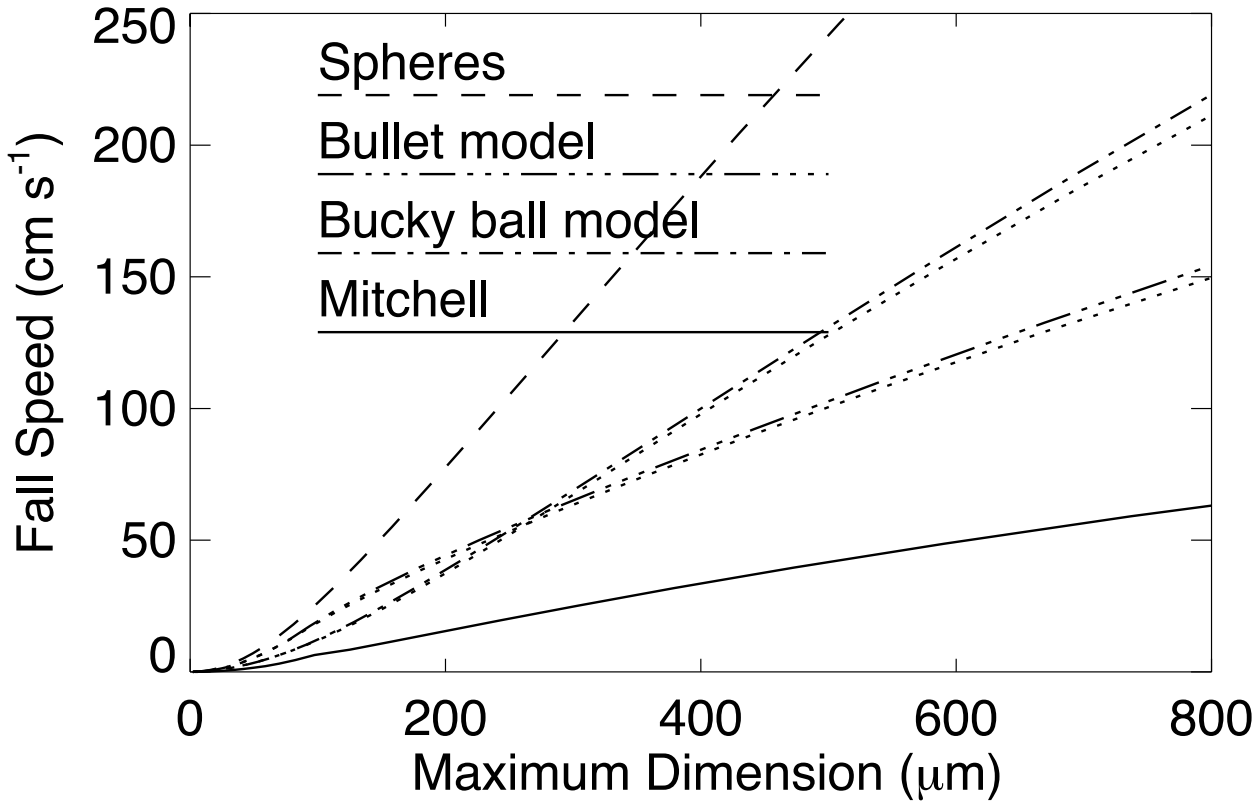


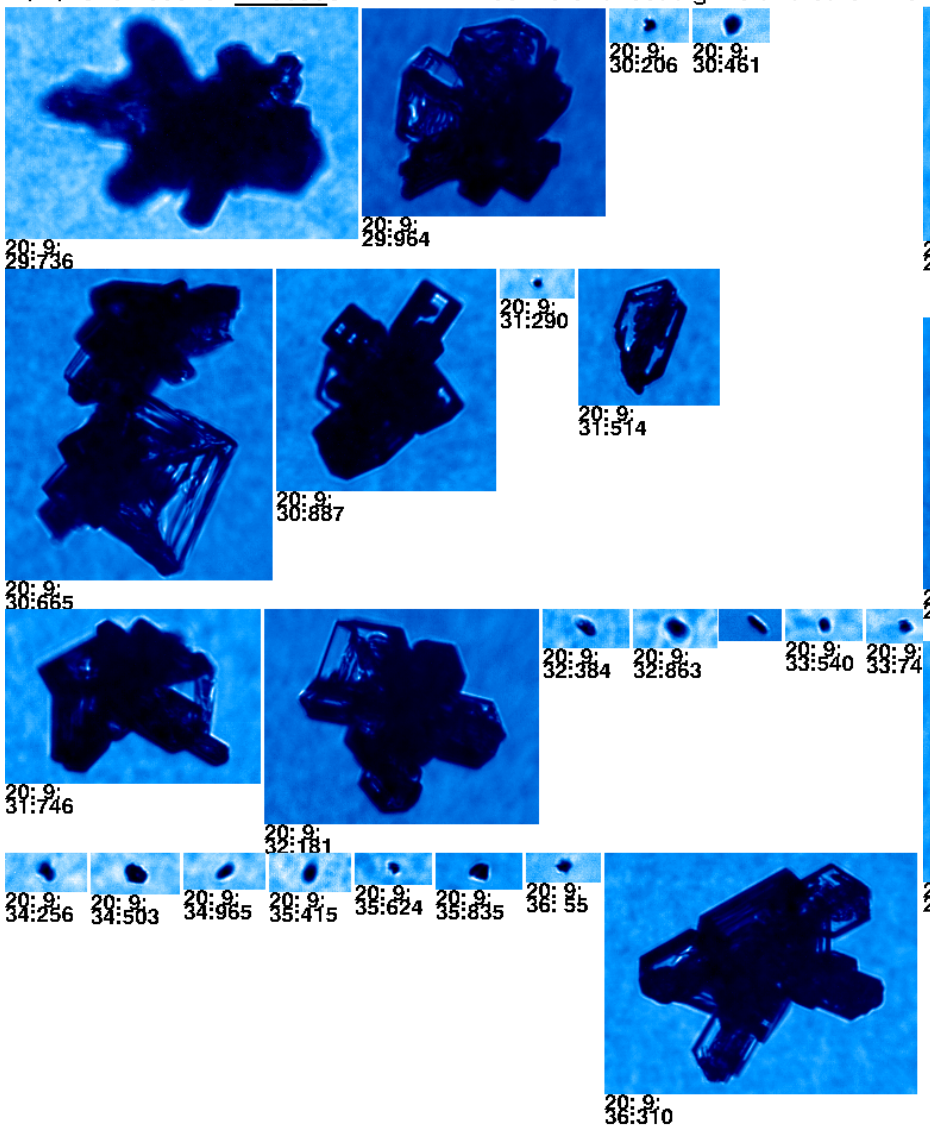
Preliminary parcel model results
Rachel Atlas, Ann Fridlind, Andy Ackerman

SPARTICUS



Preliminary parcel model results
Rachel Atlas, Ann Fridlind, Andy Ackerman

4/ 1/2010 200929-- 200936<---------->200microns focus gt 20 and cutoff lt 6



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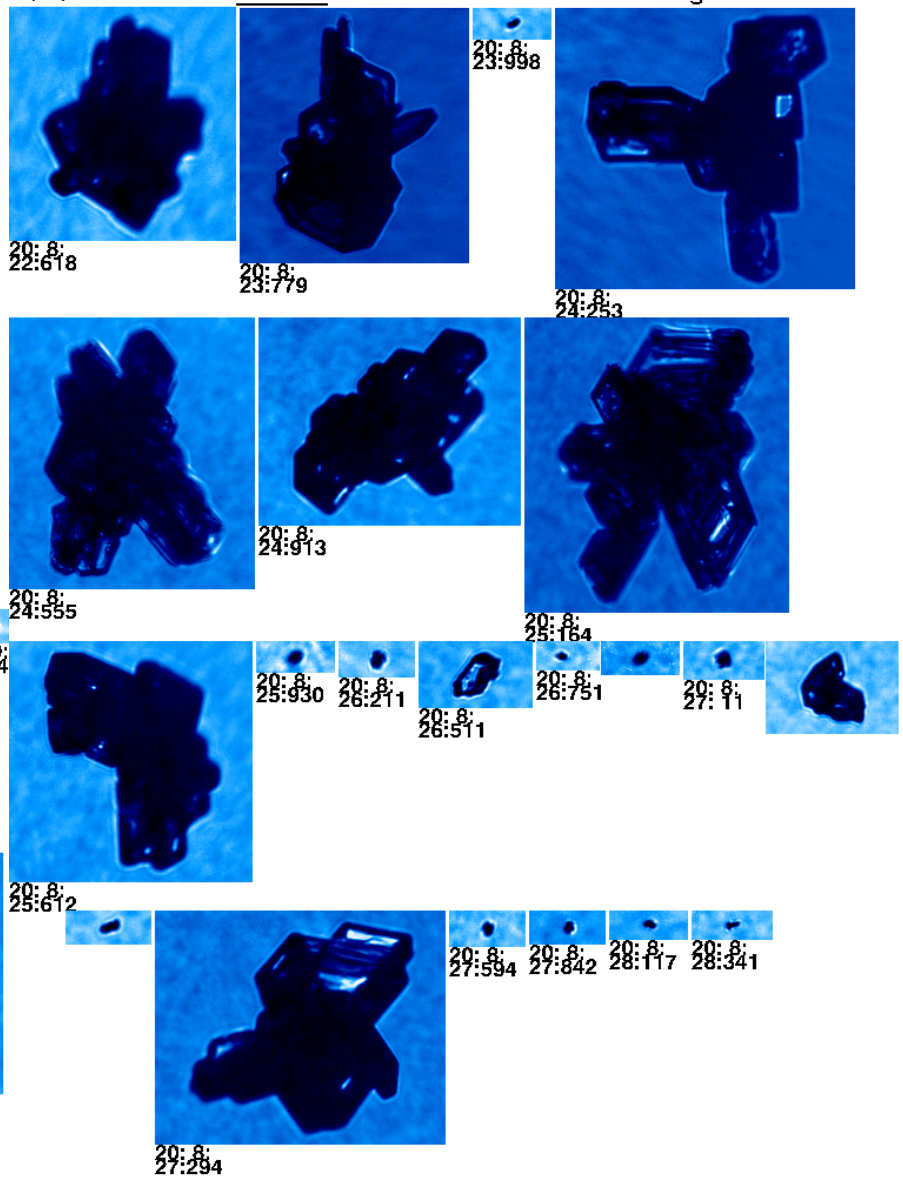

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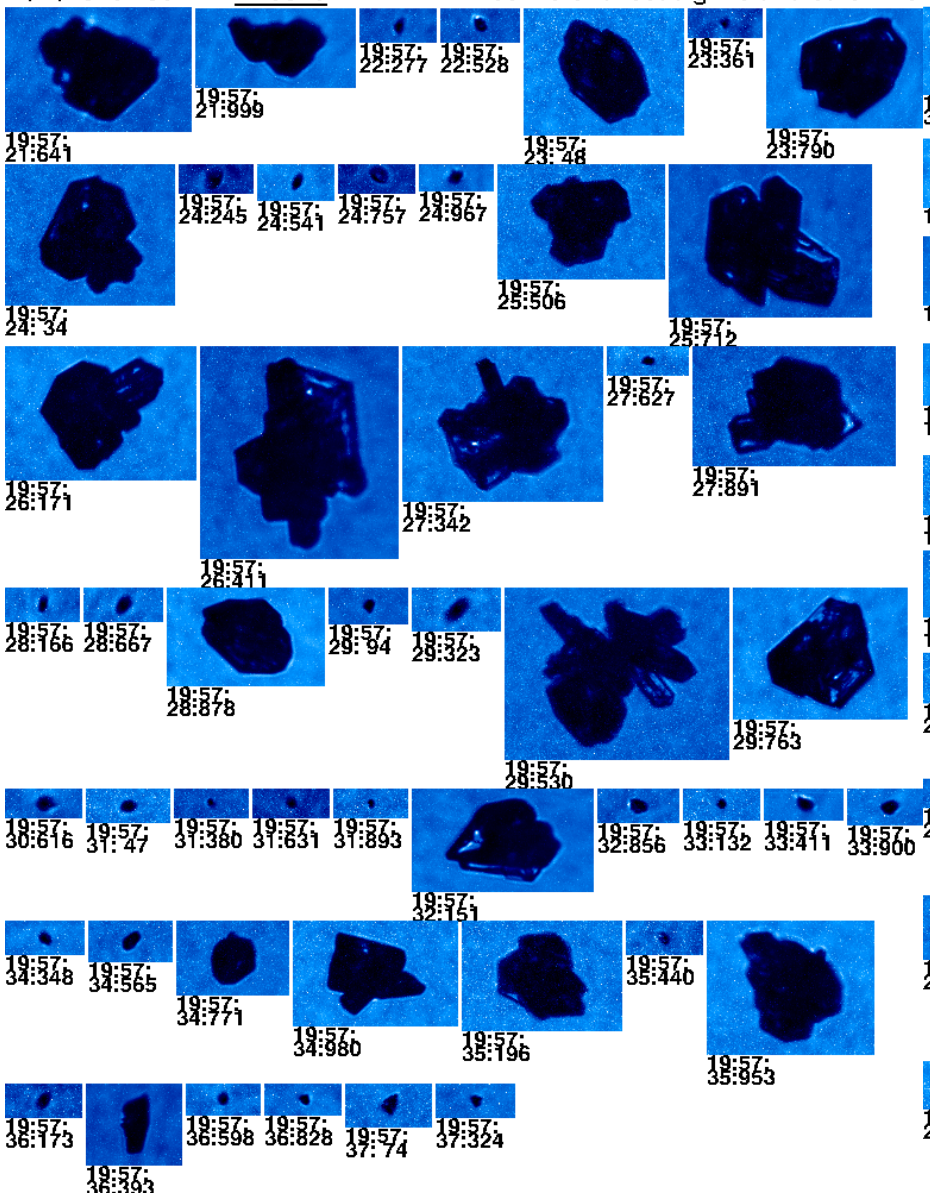
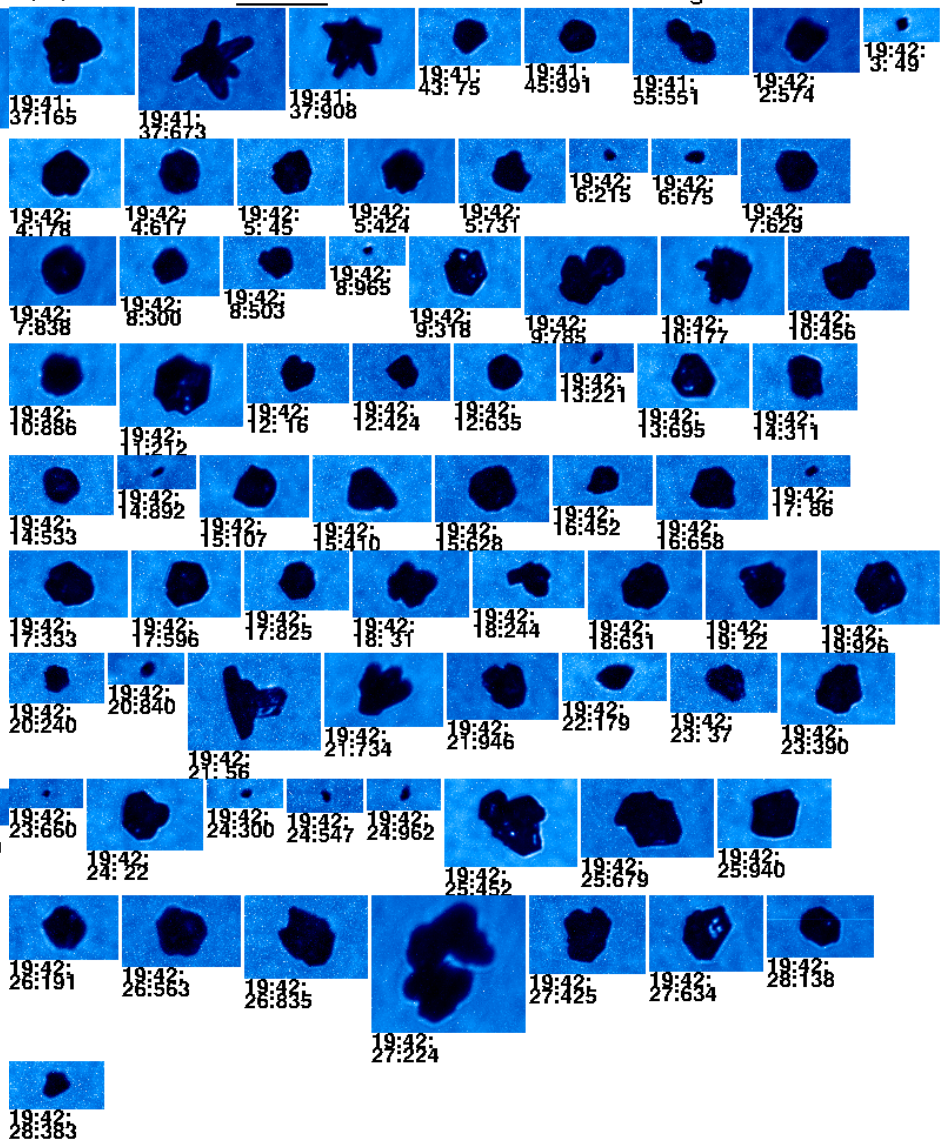


4/ 1/2010 194137-- 194228<----------->200microns focus gt 20 and cutoff lt 6

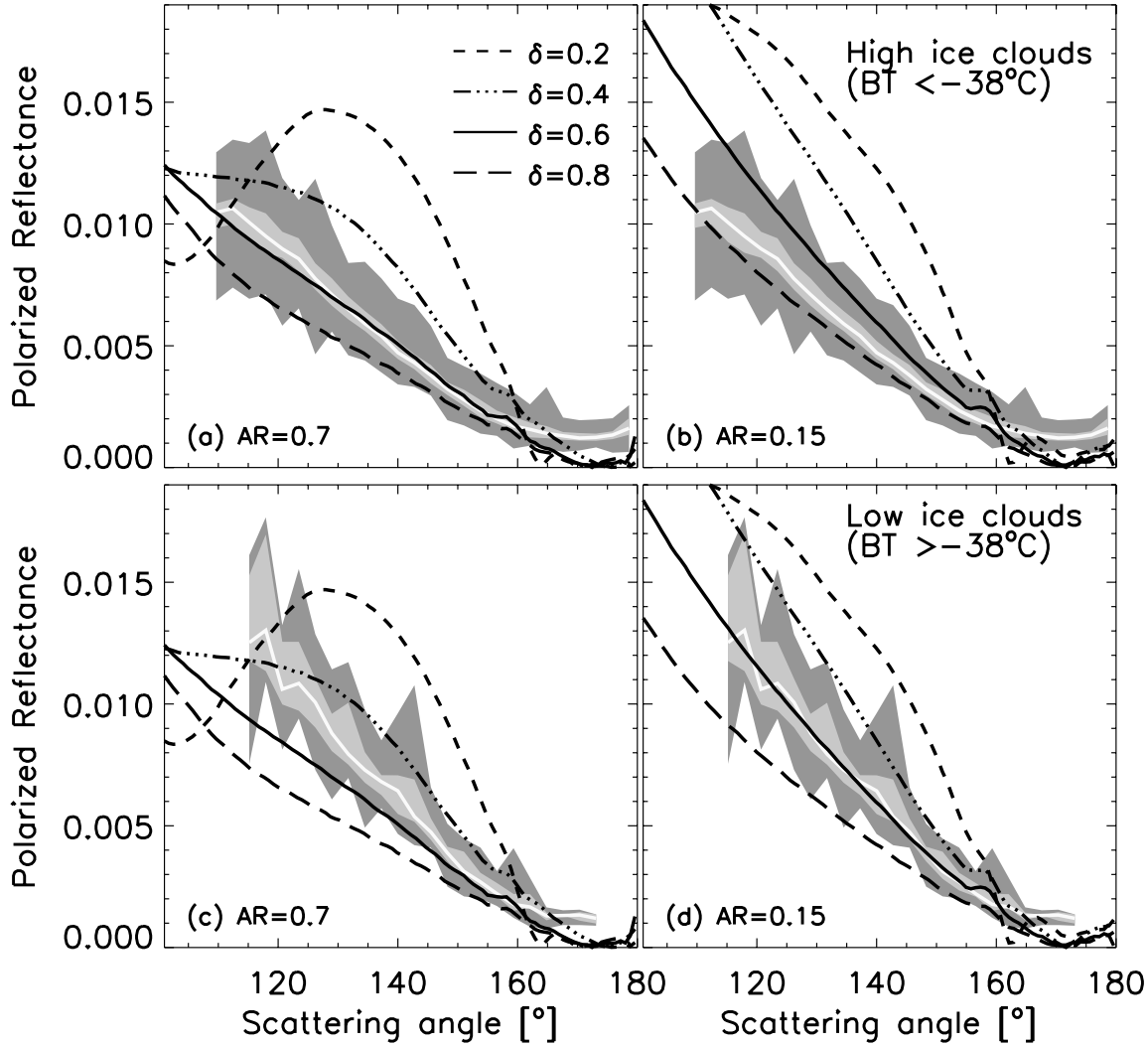


Radiative transfer consistent with microphysics

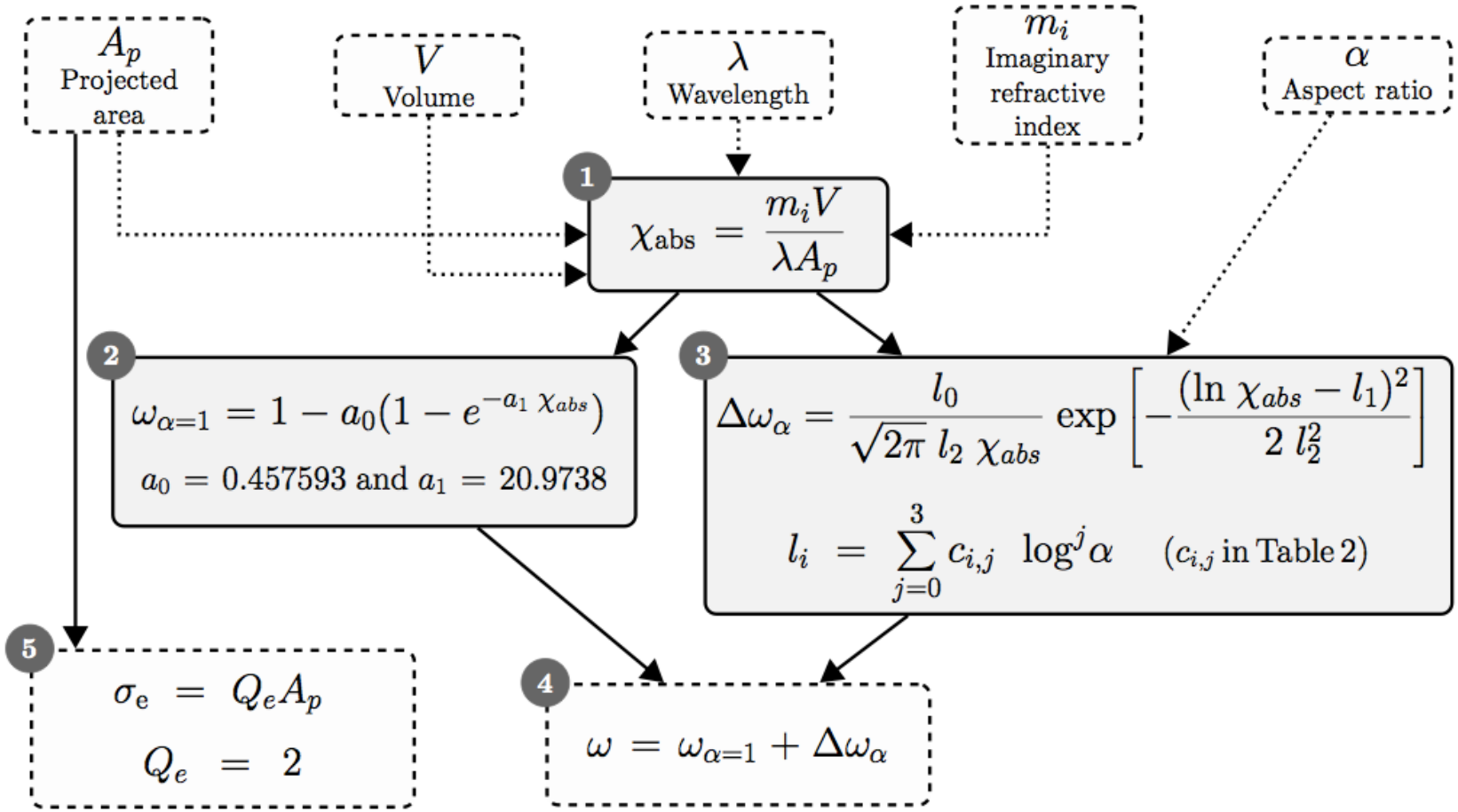
- Optical properties cannot be directly calculated for irregular ice
- Use *2 sets* of hexagonal columns which reproduce CRM's assumptions on
  1. projected area and volume (mass) for scattering and absorption (σ, ω_o)
  2. projected area and aspect ratio for scattering phase matrix (e.g., g) (see Fu, *J. Clim*, 1996; Fu, *JAS* 2007)
- Crystal surfaces roughened to obtain featureless phase functions (Macke et al., *JAS* 1996; Baran & Labonette, JQSRT, 2006)
- Habit mixtures do not allow volume and projected area to be chosen independently

POLDER/MODIS ice aspect ratio, roughness

- Constrain *roughness* using 0.86-µm polarized reflectance with scattering angle [*van Diedenhoven et al. JAS 2012*]



van Diedenhoven et al. (2014) parameterization



Summary

- ice habit is important in Arctic mixed-phase clouds
- non-spherical ice microphysical (and optical) properties are not quantitatively constrained by existing habit ID methods
- non-habit-specific bin model approach in DHARMA (following Böhm) provides internally consistent fall speeds, collision kernels, and optical properties (growth rates currently spheroids, to be integrated)
  - mass
  - maximum dimension and projected area (no analytic relations required)
  - aspect ratio
  - roughness
- SPARTICUS case studies
  - large bullet rosettes and their aggregates and likely precursors
  - irregular particles (the 90%?)
  - model should reflect what is really out there (e.g. informing growth rate integration) but how best is not yet clear