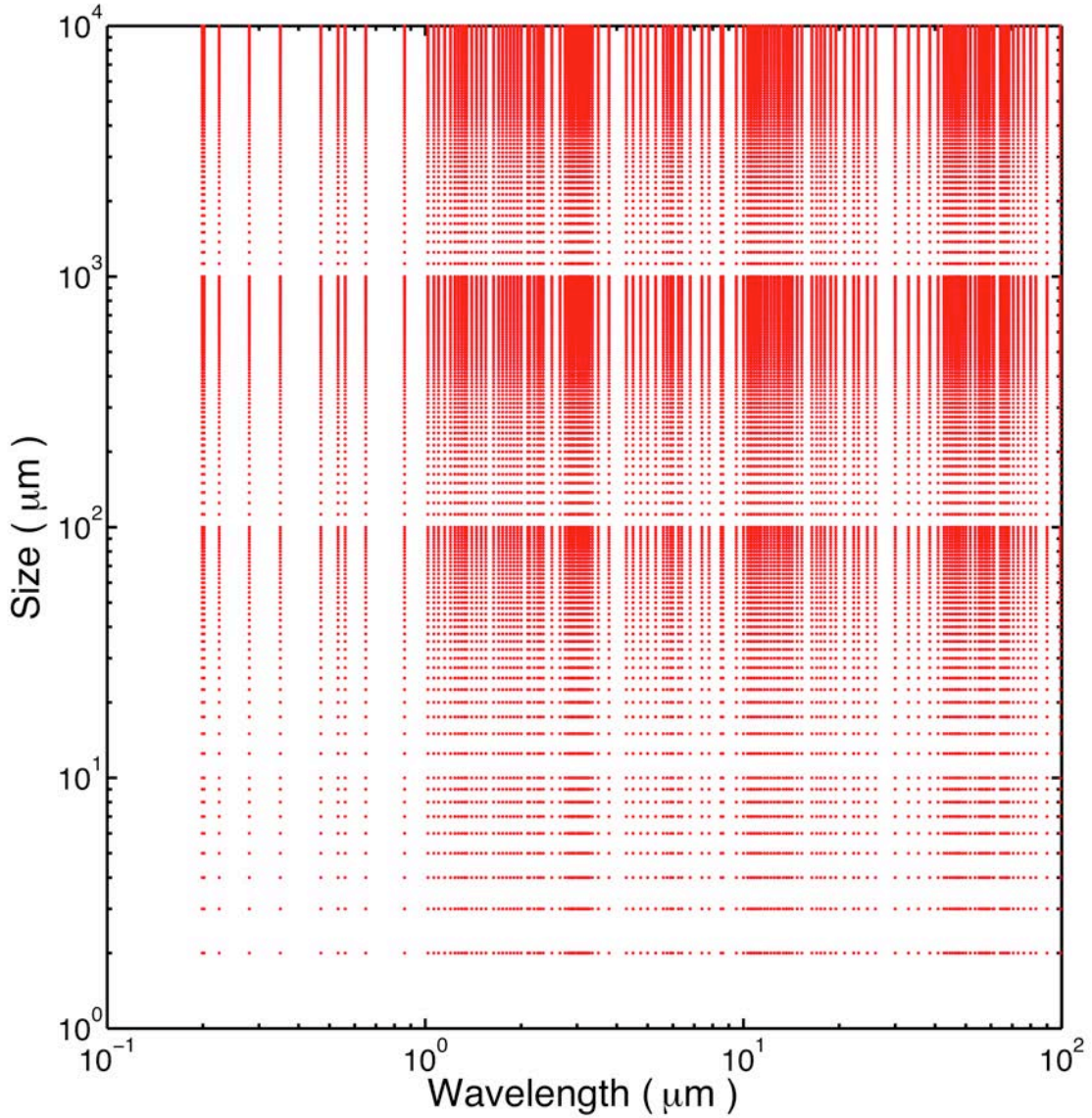
Improved Ice Cloud Models for MODIS retrievals

Ping Yang[1], Bryan Baum[2]
Lei Bi[1], Benjamin Cole[1]
Steven Platnick[3] and Andrew Heidinger[4]

1. Dept. of Atmospheric Sciences, Texas A&M University
2. SSEC/University of Wisconsin
3. NASA Goddard Space Flight Center
4. NOAA/NESDIS Center for Satellite Applications and Resaerch

A spectrally consistent database of ice crystal scattering properties from 0.2 μm to 100 μm

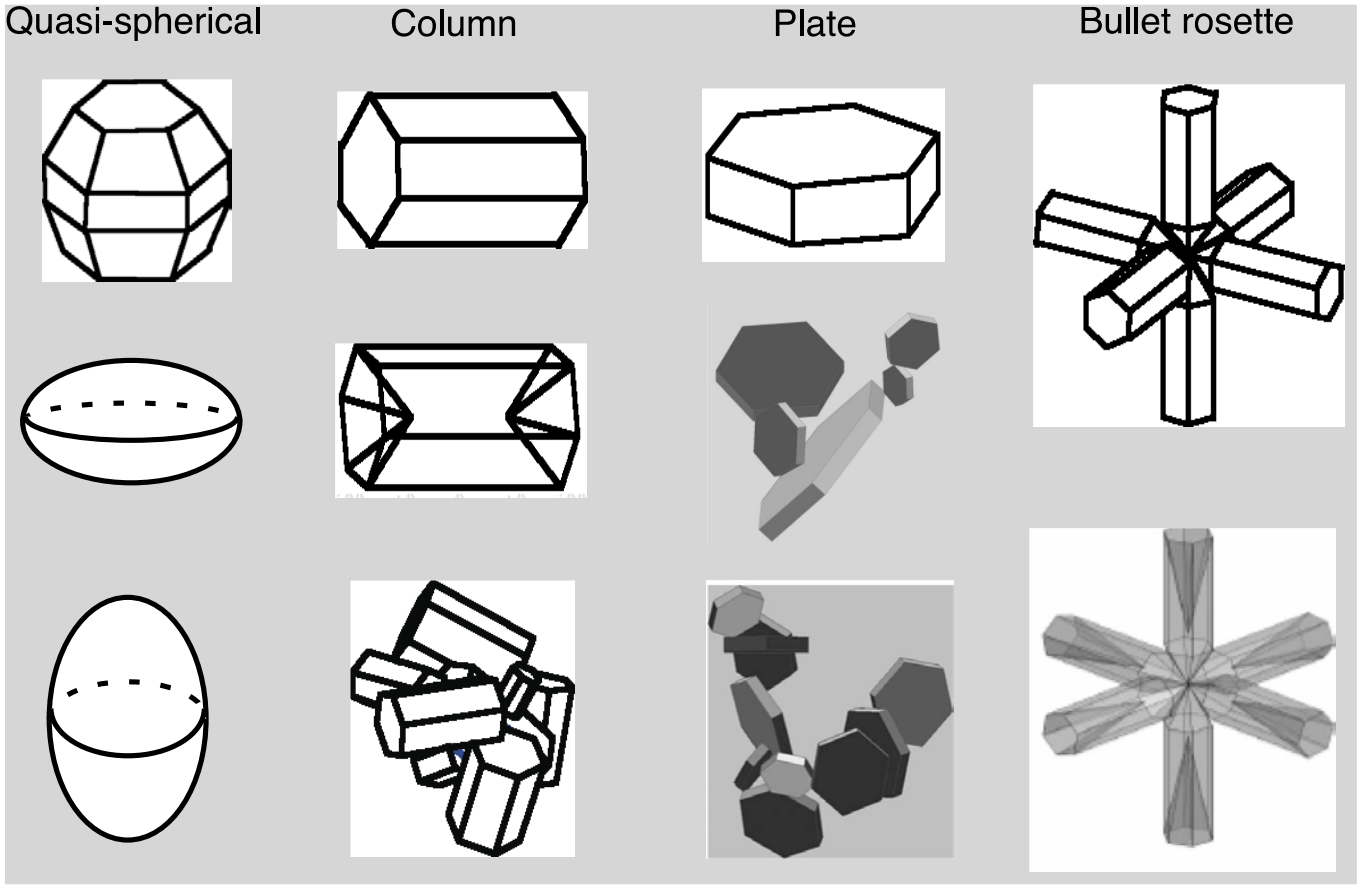


Grid points with respect to particle size and wavelength for computing a scattering database

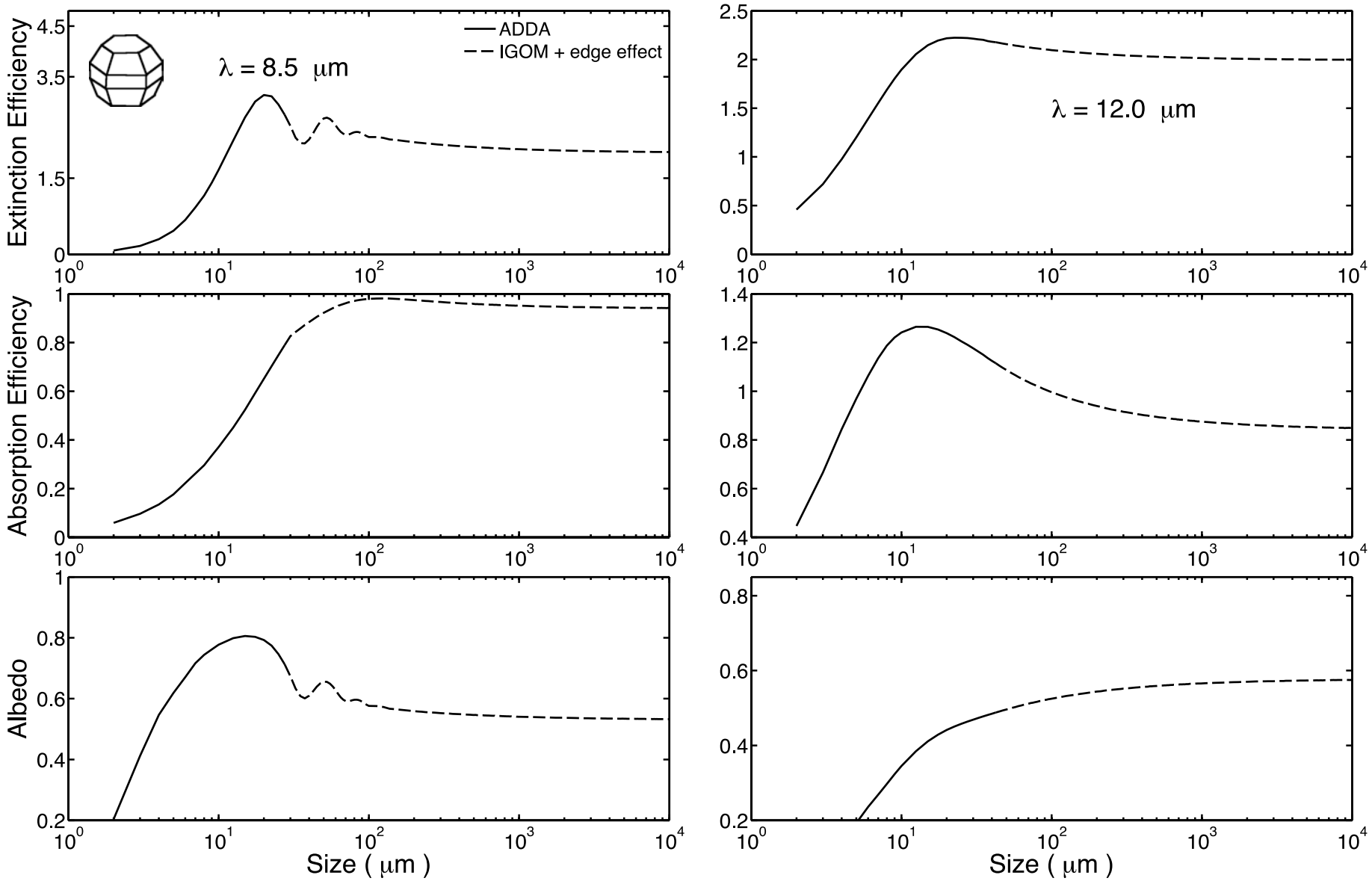
Ic crystal habits included in the database

New additions: hollow bullet rosettes and aggregates of plates

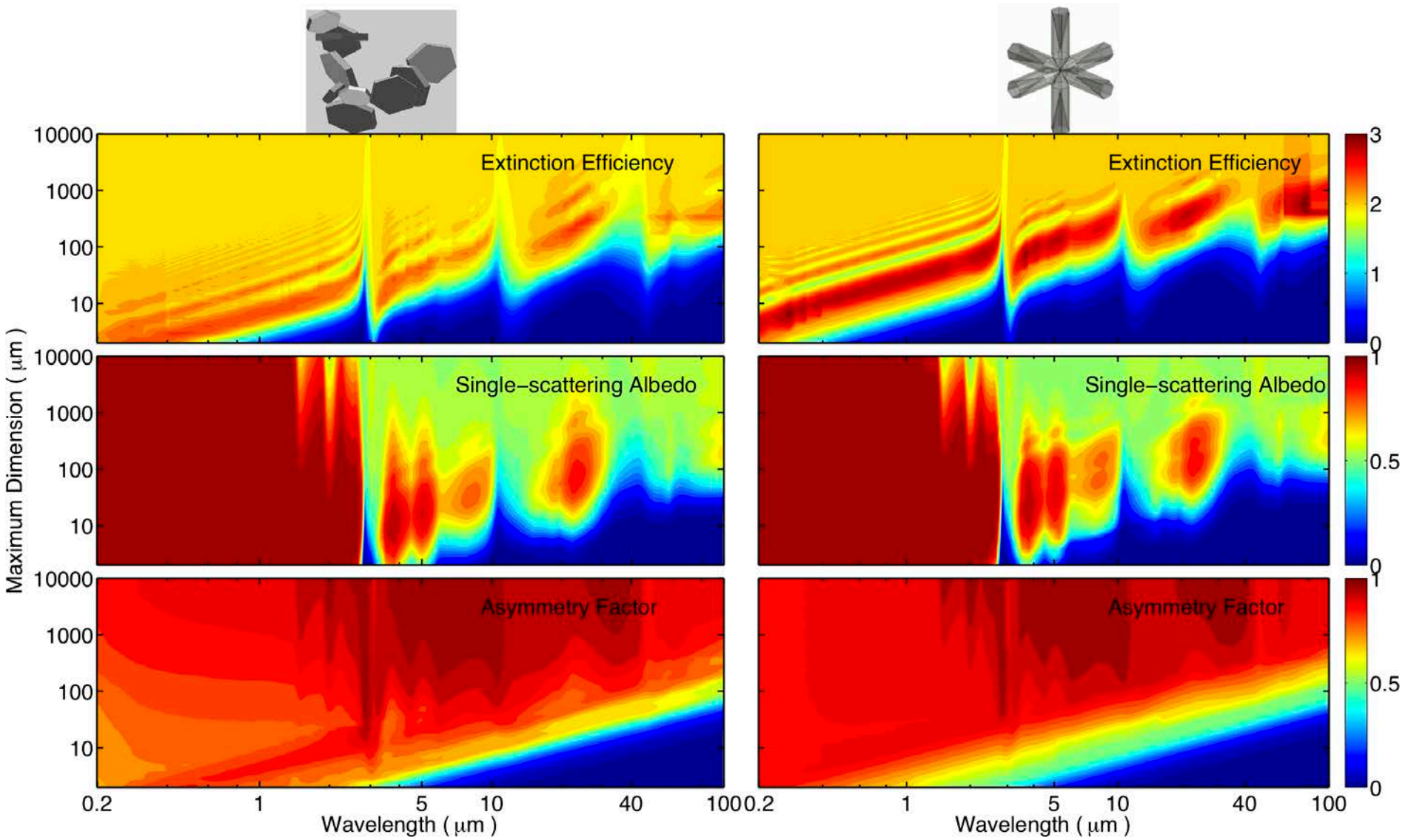
Spheroid may be a good approximation of young contrail particle geometry



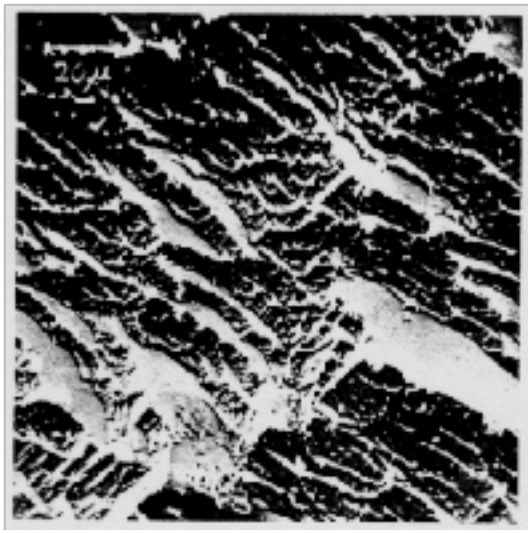
Consistent solutions for small and large particles



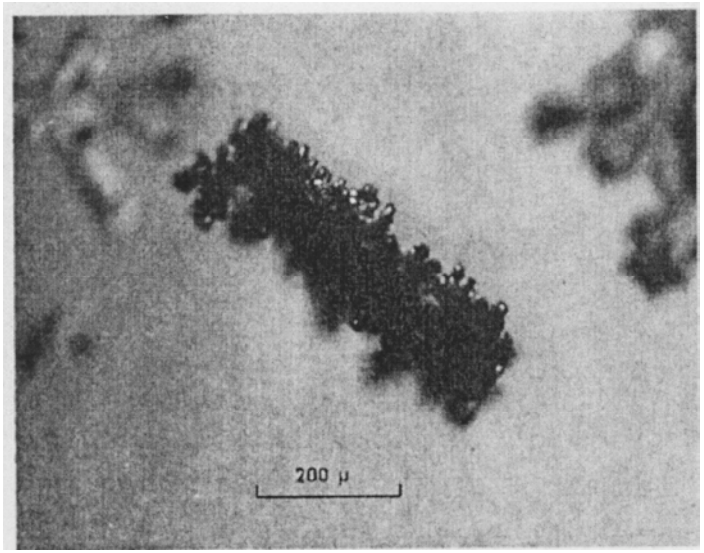
Examples of the database



Roughened ice crystal surface

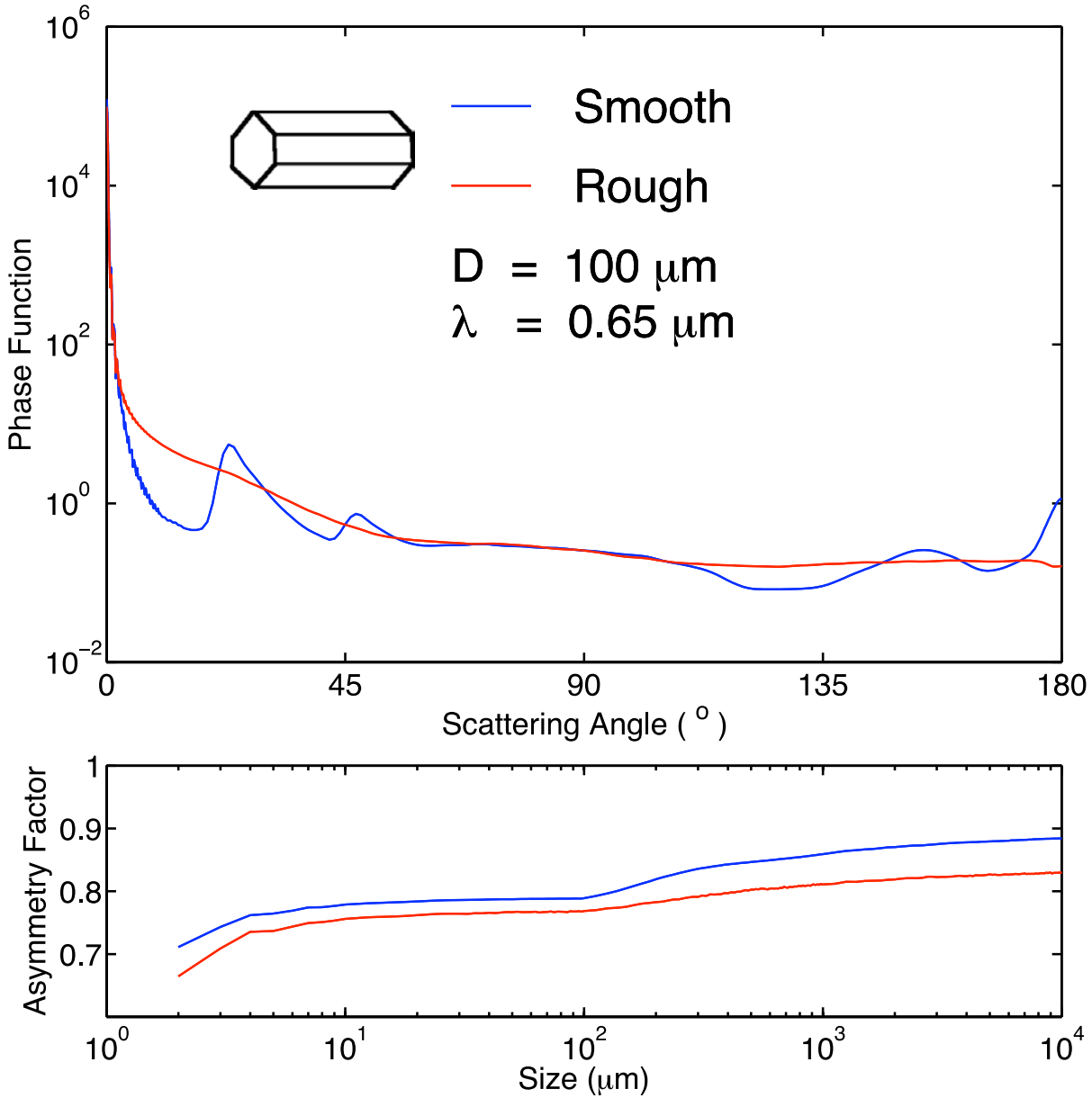


Surface roughness were observed for single crystals and polycrystalline ice by using an electronic microscope. Images adapted from Cross, 1968

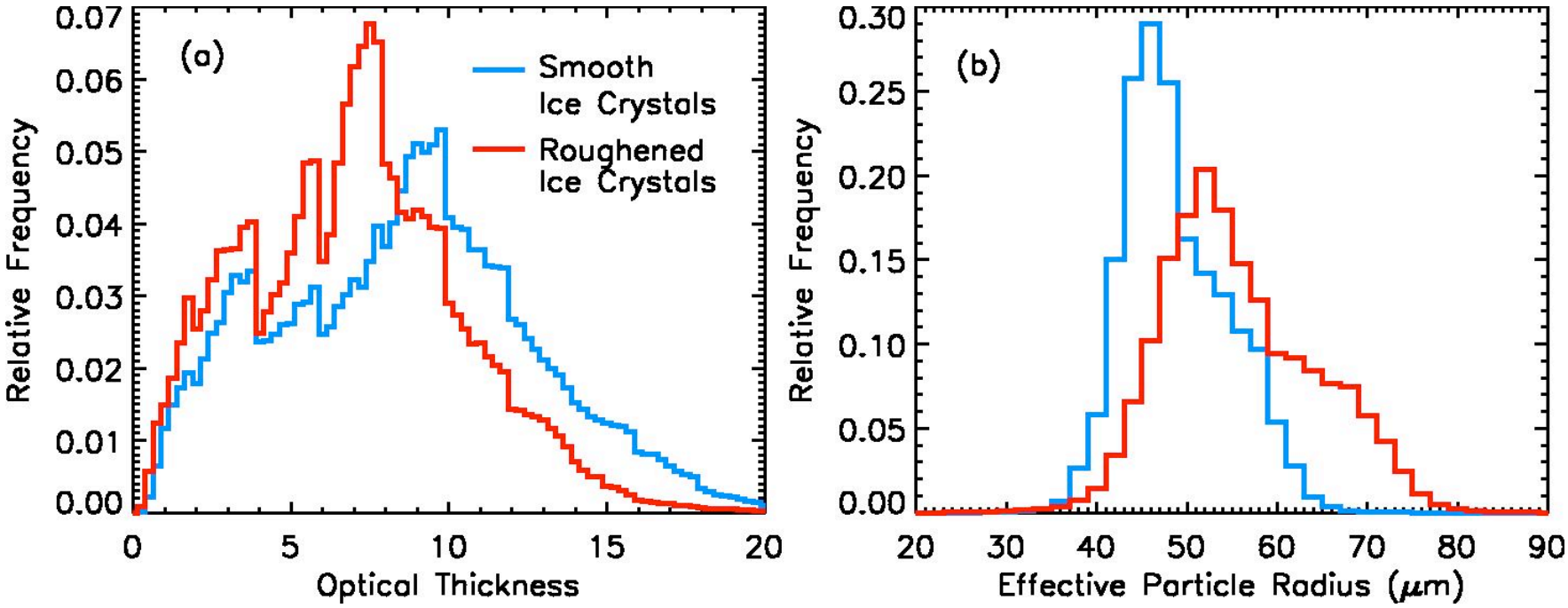


The image of a rimed column ice crystal (adapted from Ono, 1969). The surface roughness of this ice crystal is evident.

Comparison of the optical properties of small and roughened ice crystals

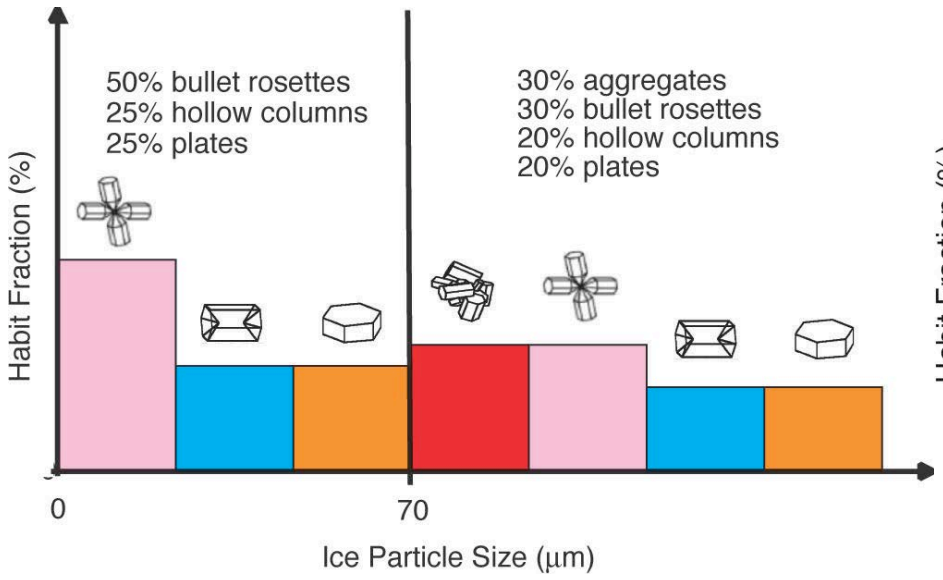


Effect of particle surface roughness on retrievals:Ice cloud optical thickness and effective particle size (Yang et al. 2008)

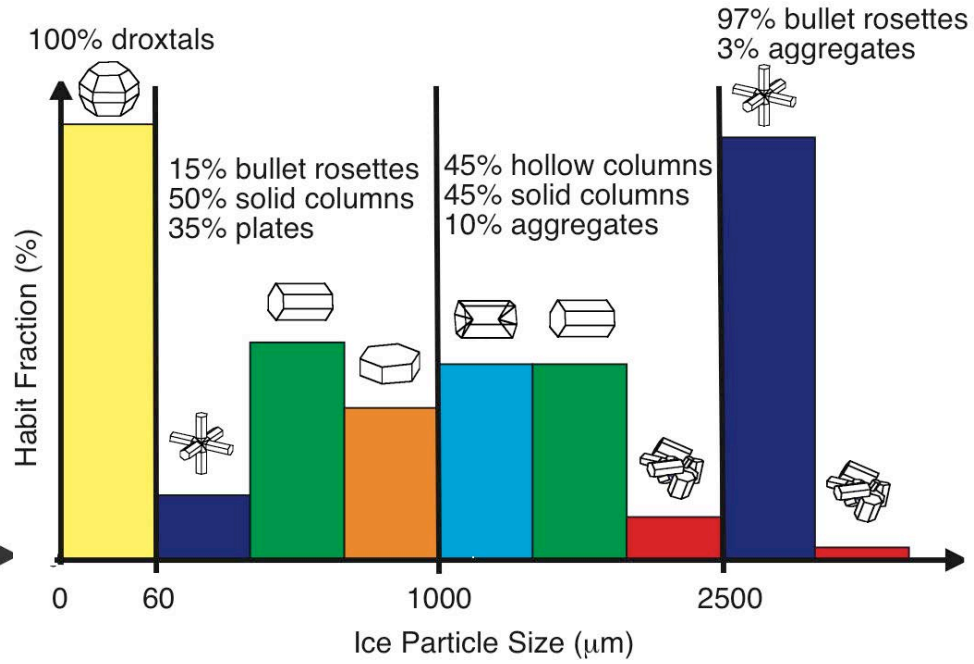


Ice cloud Models (particle habit distribution)

MODIS Collection 4



MODIS Collection 5



Summary of Modifications for C6 Ice Cloud Models

Bryan Baum, Ping Yang, Andy Heymsfield

Microphysical data:

a. more field campaigns (ARM, TRMM, SCOUT, ACTIVE, pre-AVE, midCiX, CRYSTAL-FACE)
b. mitigation of contribution from shattered ice particles
c. data are being provided by new probes; new insight regarding small particles
d. now have ~13,000 individual PSDs, previously had about 1,100
e. IWC now ranges from 1.E-6 to 1 g m^{-3} (lower limit previously 1.E-3 g m^{-3})
f. development of new habit distribution

Ice particle single scattering libraries now include:

a. new habits, e.g., hollow bullet rosette and aggregate of plates
b. both roughened and smooth particles
c. full phase matrix
d. increased resolution in particle size
e. host of improvements to light scattering calculations
f. updated ice index of refraction (Warren and Brandt, JGR, 2008)
g. models will include same properties as before except for delta-transmission energy

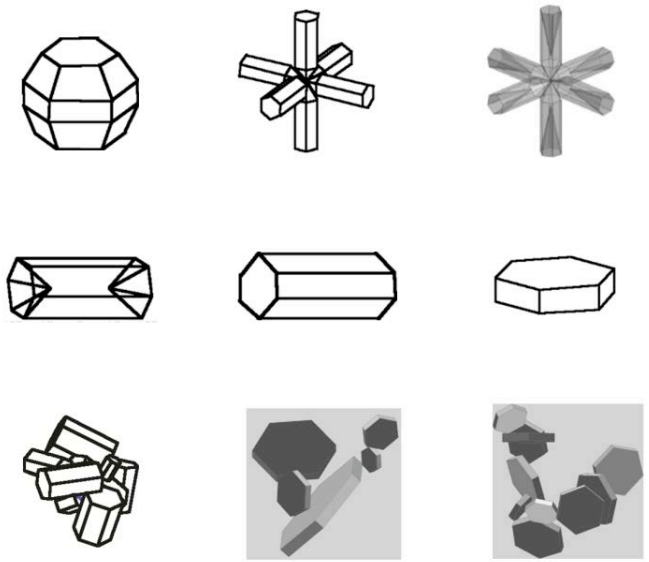
Use of models with particle roughening will result in lower t and higher D_{eff}

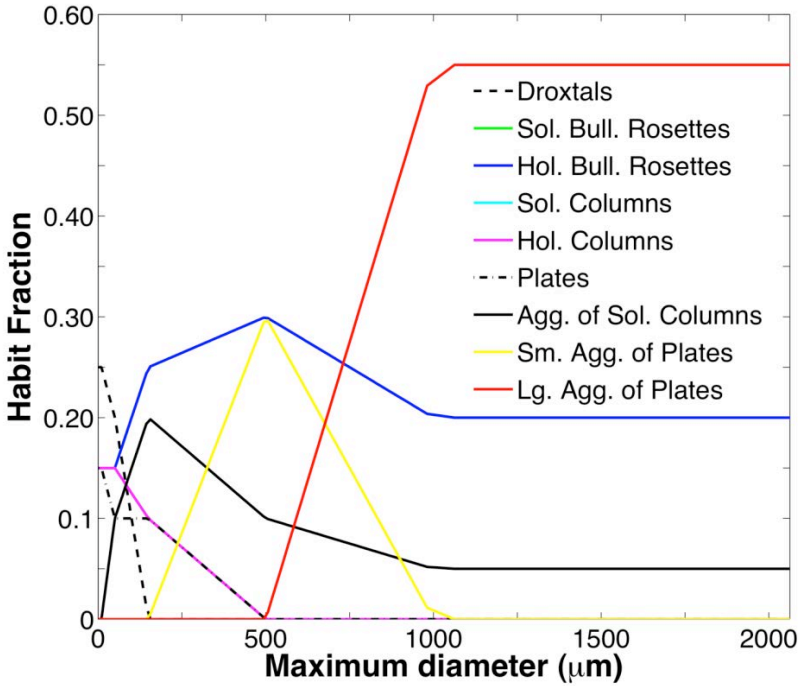
New paper published:

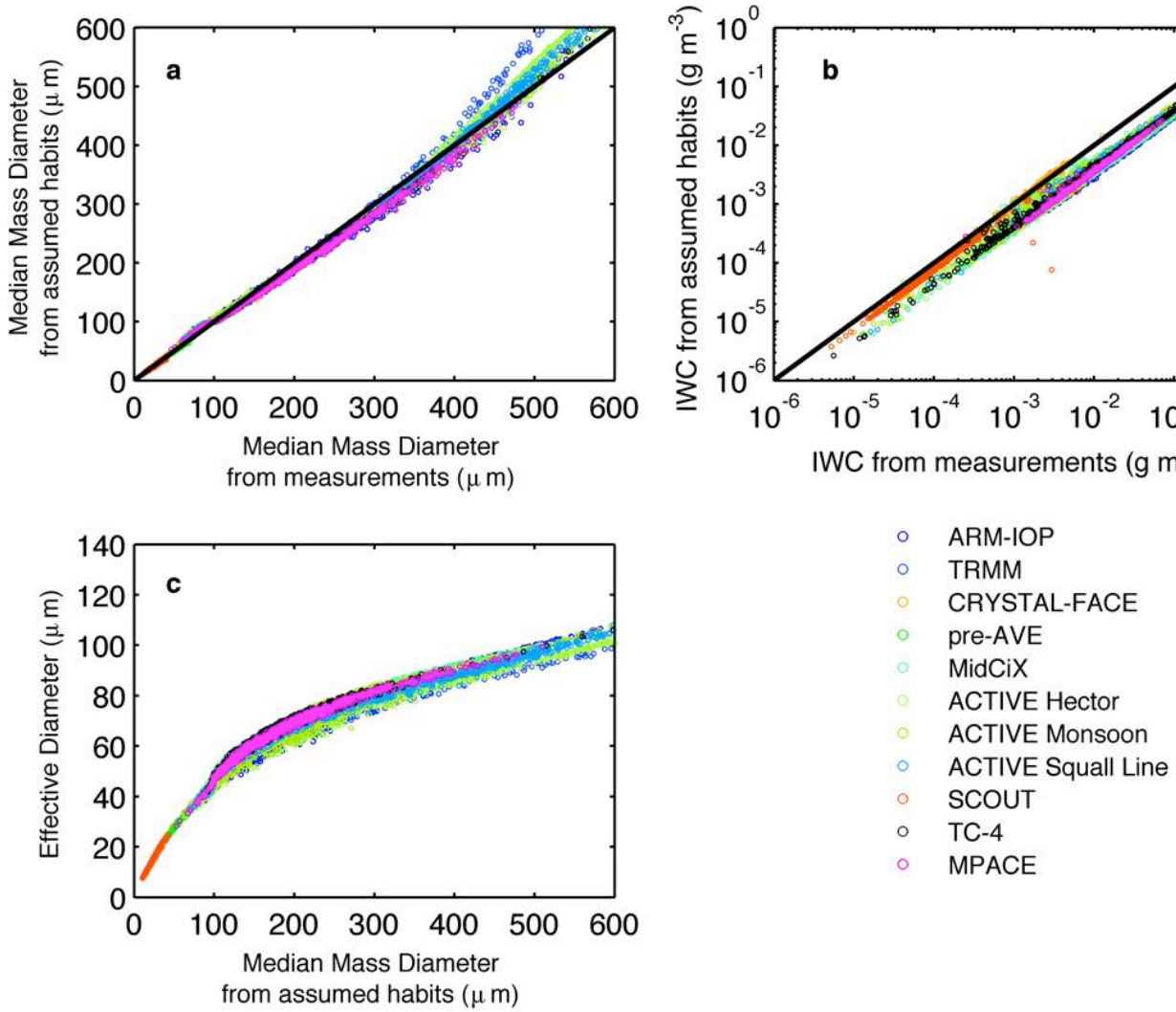
Baum, B. A., P. Yang, A. J. Heymsfield, C. Schmitt, Y. Xie, A. Bansemer, Y.-X. Hu, and Z. Zhang, 2011: Improvements to shortwave bulk scattering and absorption models for the remote sensing of ice clouds. *J. Appl. Meteor. Clim.*, **50**, 1037-1056.

New general habit mix

- 9 total habits, now includes small and large aggregate of plates and hollow 3D bullet rosettes
- Percentage of habits changes linearly as the size changes
- Can contain smooth, moderately rough, or severely rough ice

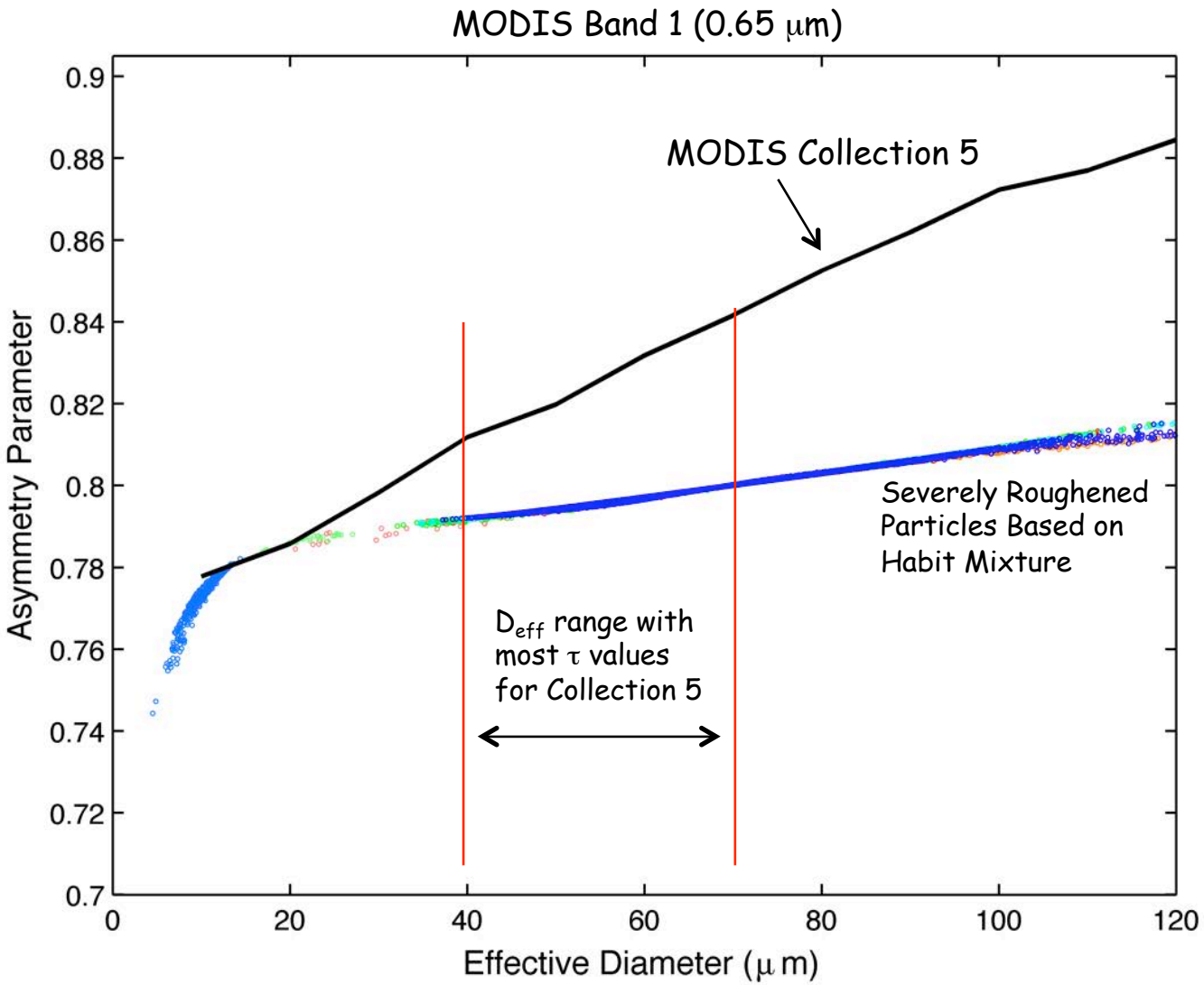






A. Heymsfield & B. Baum

Particle roughening reduces the asymmetry parameter



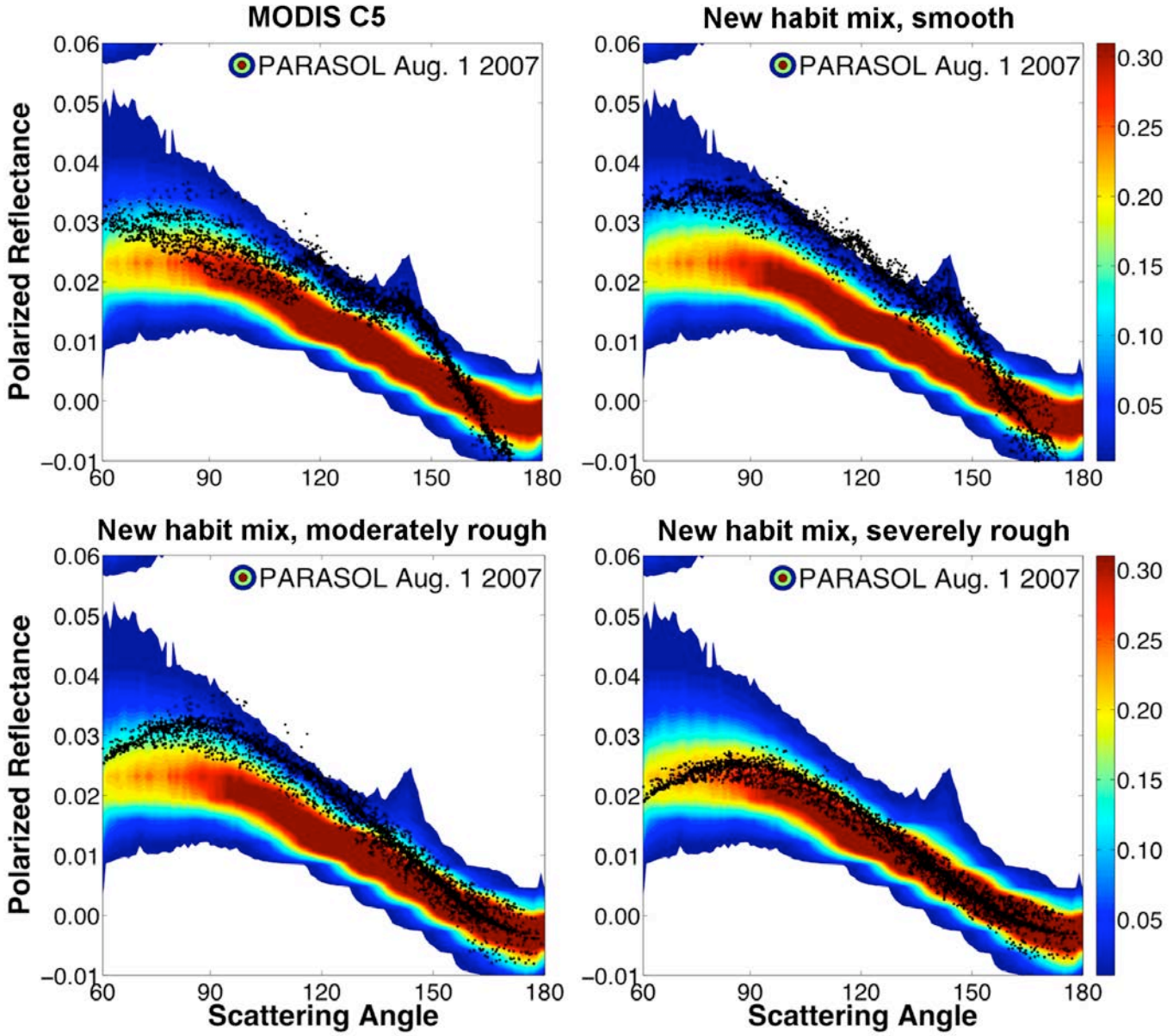
Use of Multiangle & Polarization Observations To Test Ice Clouds Models

POLDER Data

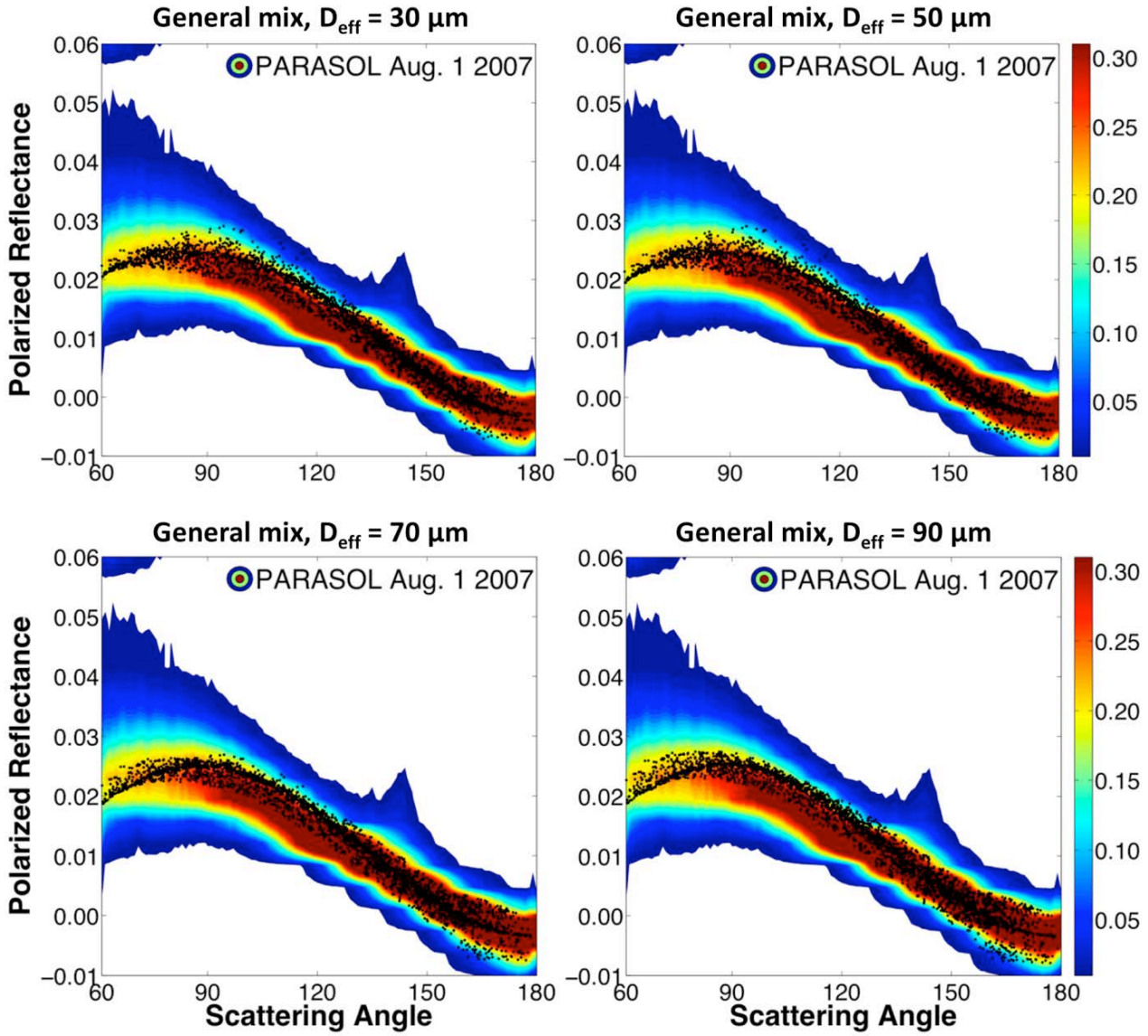
Normalized Polarized Radiance

$$L(\theta_s, \theta_v, \phi_s - \phi_v) = \frac{\pi sgn\sqrt{Q^2 + U^2}}{E_s} \frac{\cos\theta_s + \cos\theta_v}{\cos\theta_s}$$

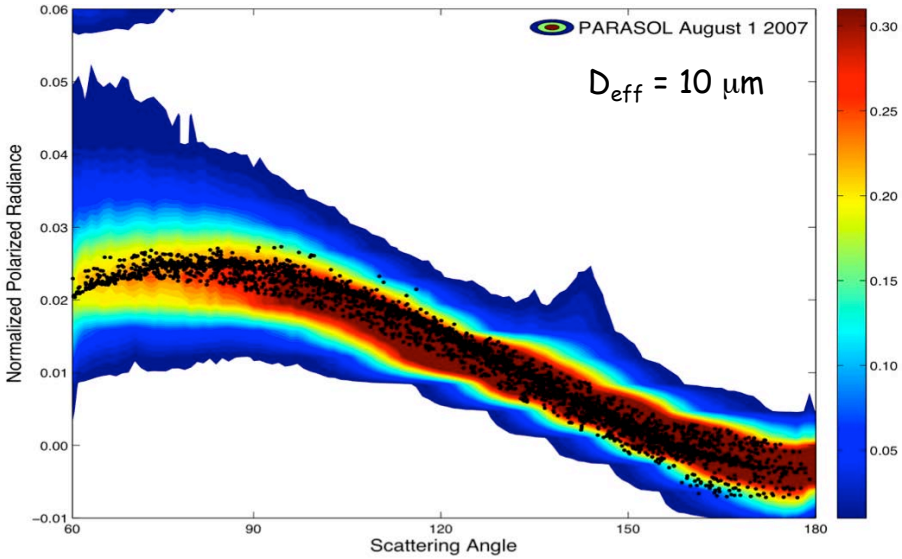
MODIS C5 and new habit mix, D_{eff} = 60 µm

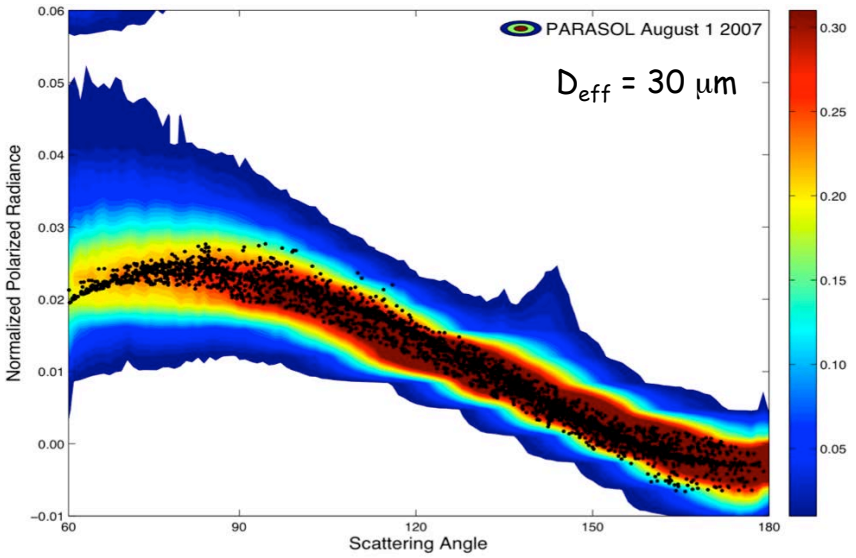


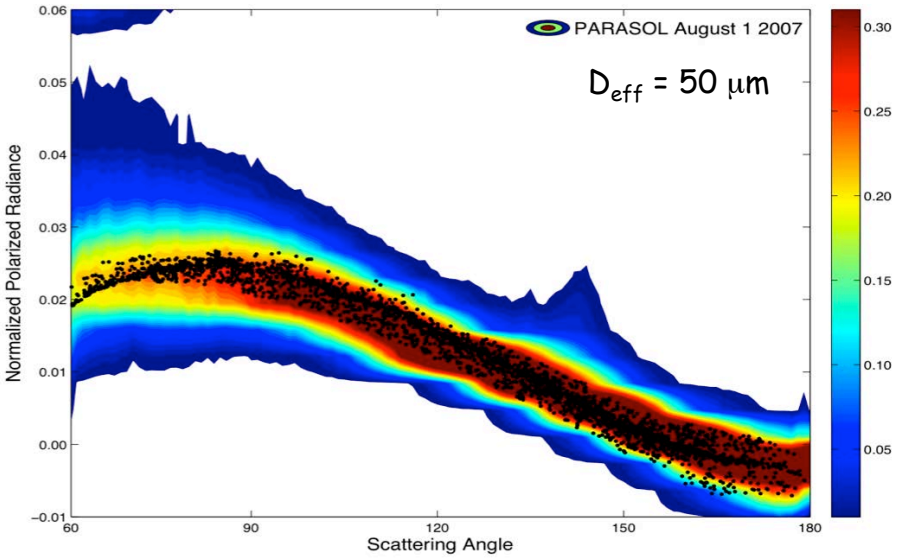
New mix (severely rough), D_{eff} = 30 – 90 µm

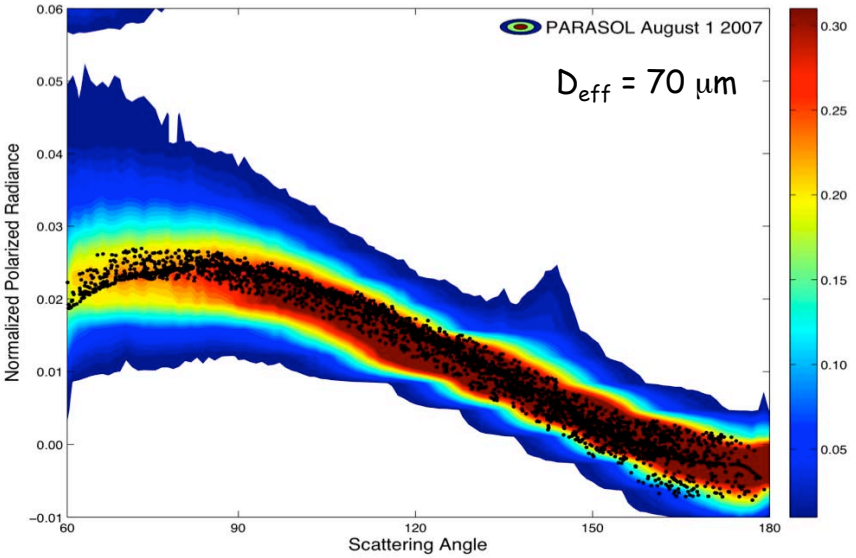


Severely roughened hollow bullet rosettes also compare closely…

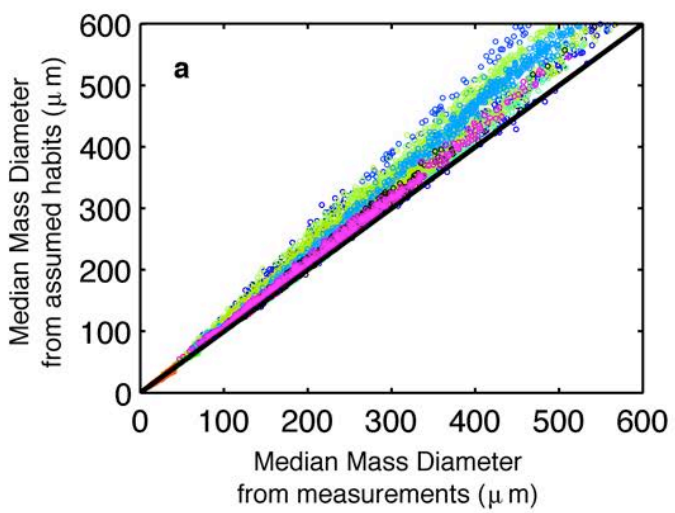


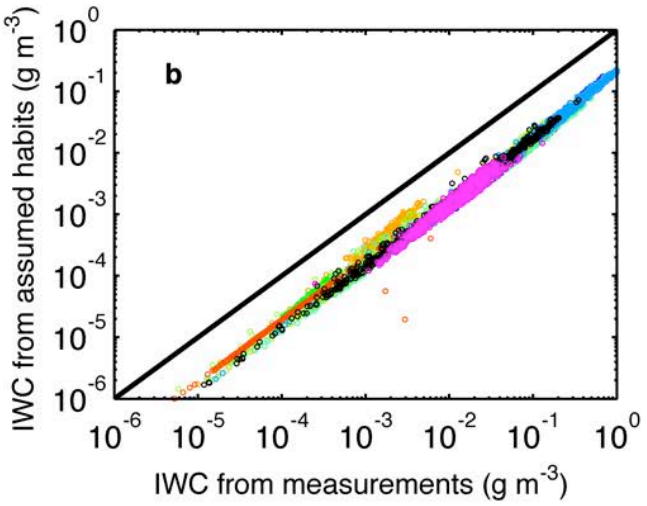


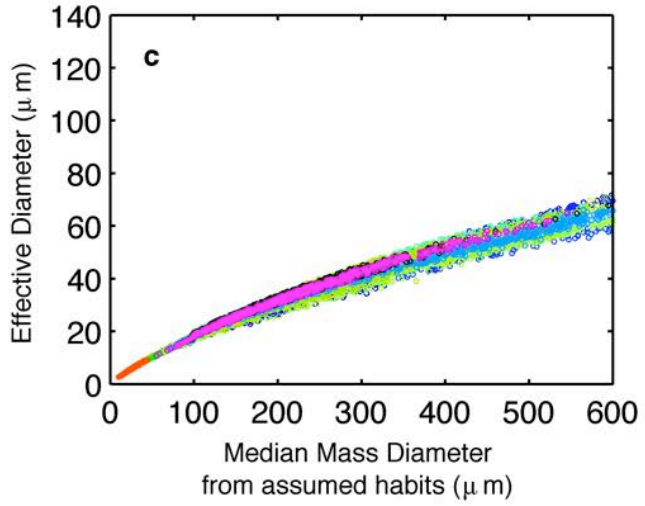




But the microphysical property comparisons are worse than for the habit mixture…







ARM-IOP
TRMM
CRYSTAL-FACE
pre-AVE
MidCiX
ACTIVE Hector
ACTIVE Monsoon
ACTIVE Squall Line
SCOUT
TC-4
MPACE

Version 3 Models Now Available on Web Site

Spectral models are available from 0.4 to 2.5 μm at 0.01 μm resolution that are based on:

- General habit mixture based on 9 habits
- Severely roughened particles
- Over 14,000 particle size distributions from many field campaigns
- Updated ice scattering libraries

Site: http://www.ssec.wisc.edu/ice_models/spectral.html

Imager models are available for 35 polar-orbiting and geostationary sensors that are based on:

- General habit mixture based on 9 habits
- Severely roughened particles
- Best available radiance spectral response functions

Polar Orbiting Imagers	Geostationary Imagers
AVHRR-5 through 19	GOES 8-13
MODIS Terra and Aqua	GOES-R ABI
MISR	MTSAT-1/2
VIIRS	METEO-SG1/SG2
IIR	
ATSR-1/2	
AATSR	

Site: http://www.ssec.wisc.edu/ice_models/imager.html

More models (e.g., full phase matrix) will be added once the documentation is available (this takes time)

Summary

- **Spectrally consistent single-scattering properties have been computed for various ice crystal shapes and sizes at wavelengths ranging from UV to far-IR (0.2 μm -100 μm)**

- **A new habit distribution based on *in situ* microphysical measurements has been developed.**

- **Using the new habit distribution, the bulk optical properties have developed at the spectral bands of various sensors including MODIS.**

- **Comparison between simulated polarized reflectance and the POLDER counterpart suggests that the new ice models are more appropriate than the MODIS C5 ice models.**