Recent Studies in Ice Cloud Models

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MODIS Science Team Meeting
May 18, 2011

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Outstanding Issues

C5 models: assumed smooth particles and were based on limited set of microphysical data and pristine ice particle shapes (habits)

Significant issues (not a complete list):

Differences found between MODIS C5 cirrus optical thicknesses and those from CALIOP V3 products and also with IR retrievals based on IR window bands

Spectral gaps in the ice models that need to be filled for sensors such as the SSFR

Discontinuities in transition in absorption/extinction efficiencies obtained from one scattering model to another (e.g., FDTD/DDA to IGOM)

Updated ice index of refraction published (Warren and Brandt, JGR, 2008)

Seasonal differences found between POLDER and MODIS (Zhang et al 2009)

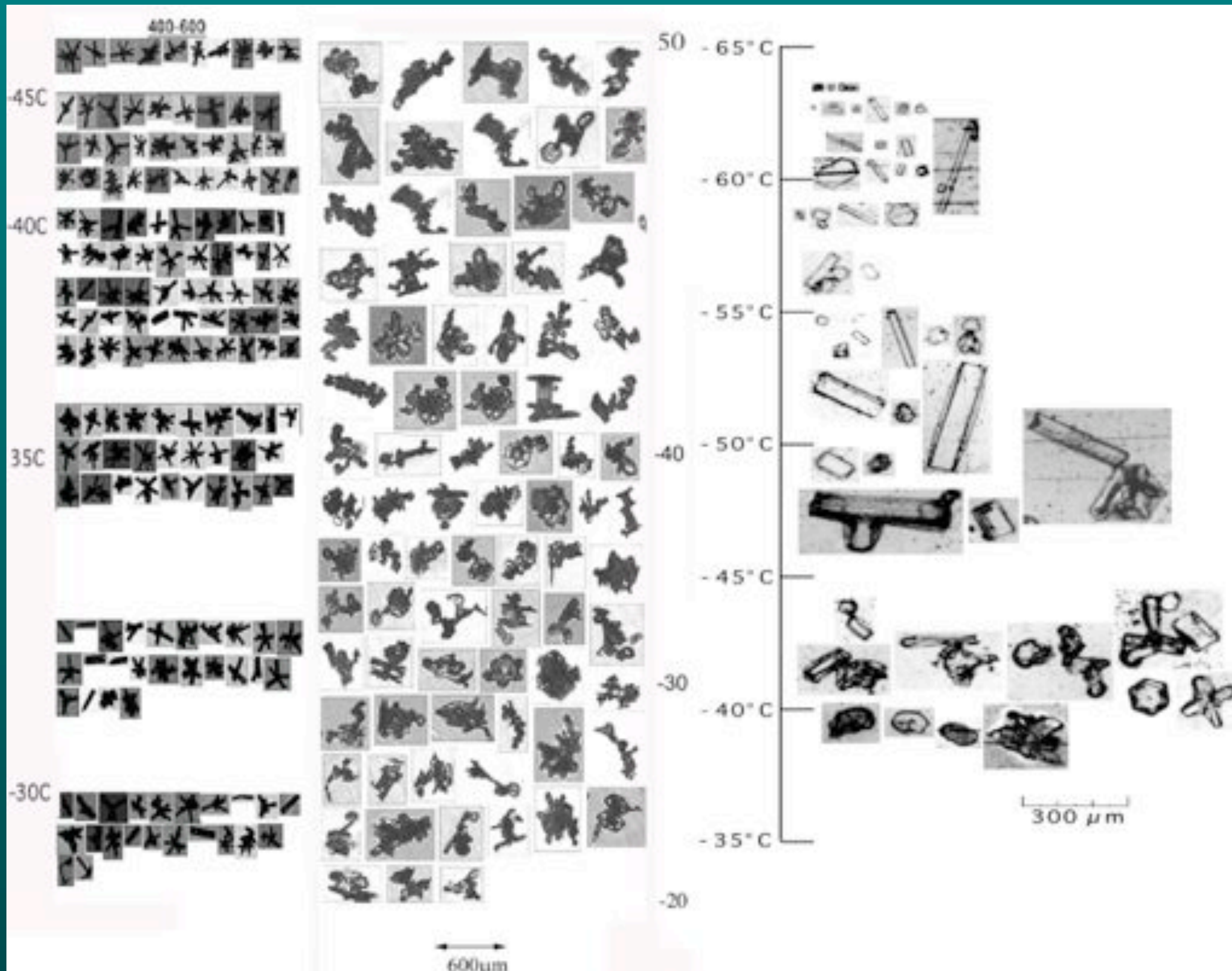
Expanded Set of Microphysical Data Available

IWC range: 1.E-6 to 1 g m^{-3}

Field Campaign	Location	Instruments	# PSDs
ARM-IOP (UND Citation)	Oklahoma, USA 2000	2D-C, 2D-P, CPI, CVI, FSSP	1420
TRMM-KWAJEX (UND Citation)	Kwajalein, Marshall Islands, 1999	2D-C, HVPS, FSSP	201
CRYSTAL-FACE (NSA WB-57F)	SE Florida/ Caribbean 2002	CAPS (CIP, CAS), VIPS	62
SCOUT (Geophysica)	Darwin, Australia 2005	FSSP, CIP	553
ACTIVE - Monsoons (Egrett)	Darwin, Australia 2005	CAPS (CIP, CAS)	4268
ACTIVE- Squall Lines (Egrett)	Darwin, Australia 2005	CAPS (CIP, CAS)	740
ACTIVE- Hectors (Egrett)	Darwin, Australia 2005	CAPS (CIP, CAS)	2583
MidCiX (NASA WB-57F)	Oklahoma, USA 2004	CAPS (CIP, CAS), VIPS, FSSP	2968
Pre-AVE (NASA WB-57F)	Houston,Texas, USA 2004	VIPS, CAPS	20
TC-4	Costa Rica 2007	CAPS, CPI	7663

Number of particle size distributions for each field campaign. The total sample set has been filtered by the requirement that the cloud temperature be colder than –40°C, providing > 20,000 PSDs.

Different Formation Mechanisms for Ice Particles

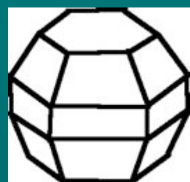


Homogeneous Nucleation

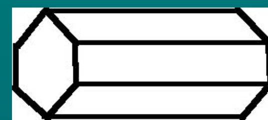
Develop in updrafts of deep convection

Cold-topped synoptic cirrus

Set of Ice Habits Used to Develop Version 2 Single-Scattering Properties

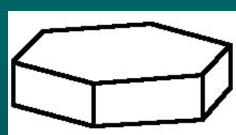


Droxtal

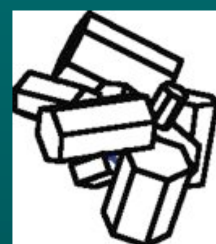


Solid Column

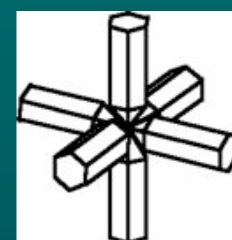
Hollow Column



Plate

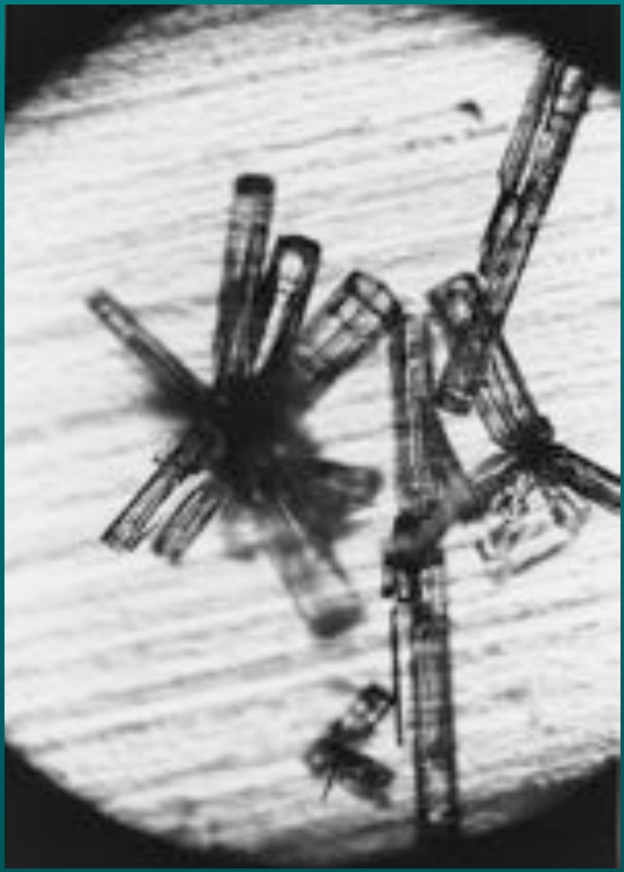


Aggregate of Solid Columns

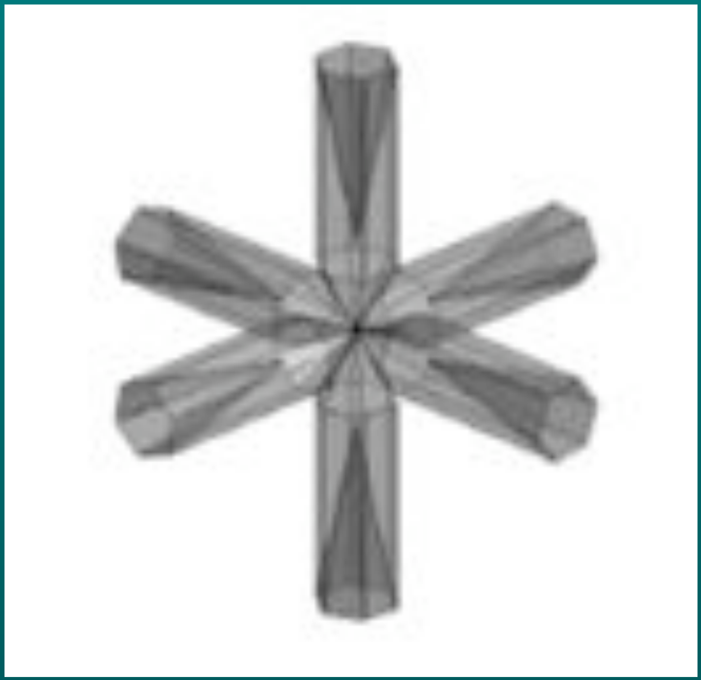


3D Bullet Rosette

New Habits



Photomicrograph of snow particles falling at the South Pole Station, 18 August, 1992, at ambient temperature -54°C. Photograph by Stephen Warren.

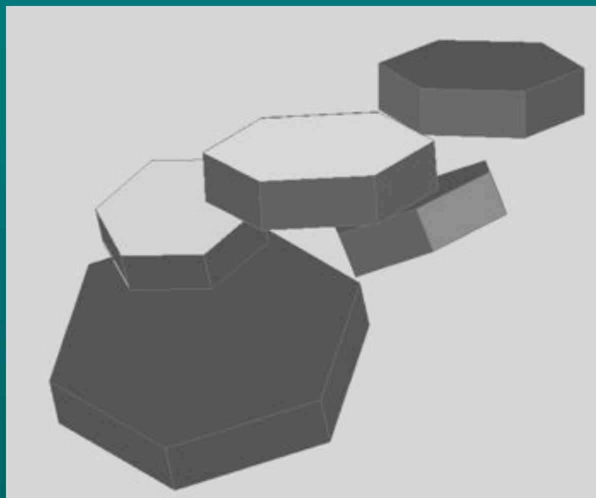


New 3D Hollow Bullet Rosette

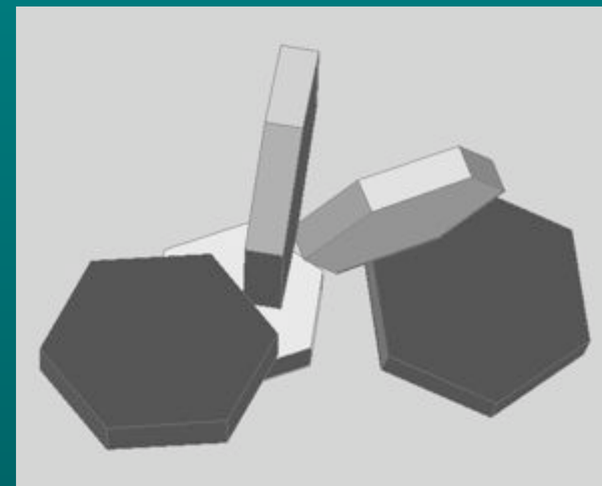
Yang et al., 2008: Effect of cavities on the optical properties of bullet rosettes: Implications for active and passive remove sensing of ice cloud properties. **J. Appl. Meteor. Climatol**. **47**, 2311-2330.

Different Realizations for the Aggregate of Plates

Small Aggregate of Plates

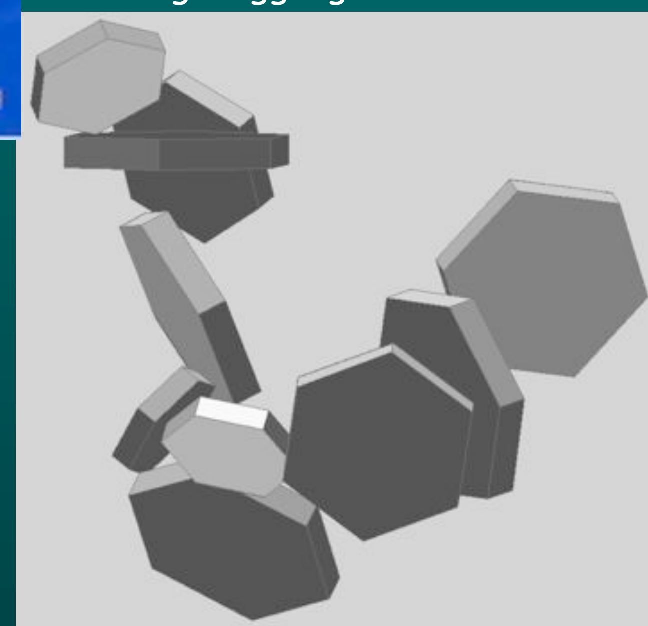


Small Aggregate of Plates



Large Aggregate of Plates

Large Aggregate of Plates



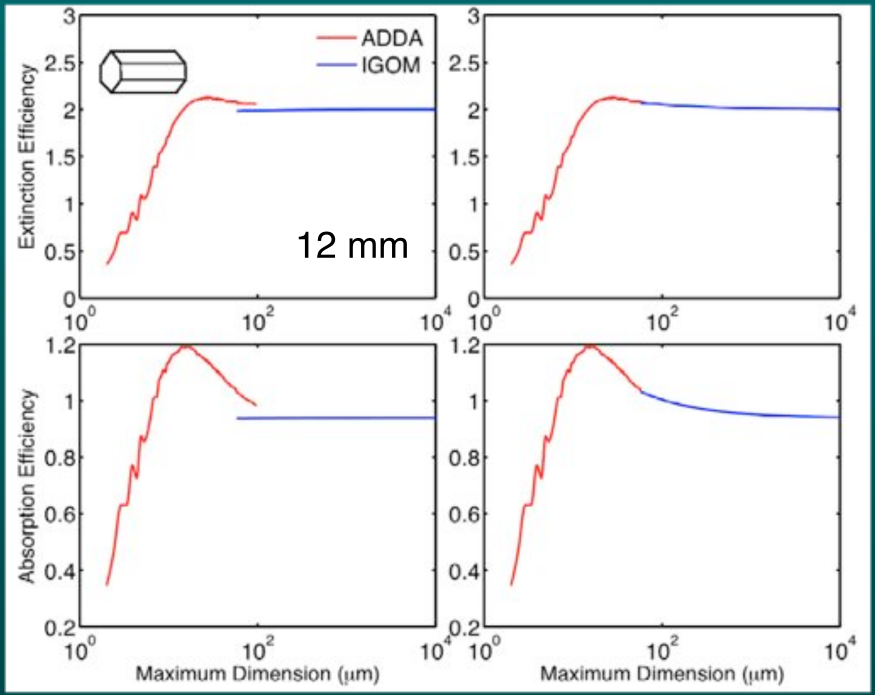
Improvements to Light Scattering Models

New treatment of ray-spreading results in the removal of the term relating to delta-transmission energy at the forward scattering angle.

Improved the mapping algorithm: the single-scattering properties from the new algorithm smoothly transition to those from the conventional geometric optics method at large size parameters.

Semi-analytical method developed to improve the accuracy of the first-order scattering (diffraction and external reflection).

Semi-empirical method is developed to incorporate the edge effect on the extinction efficiency and the above/below-edge effects on the absorption efficiency.



Not considering edge effects   Considering edge effects

Bi et al, 2009: Simulation of the color ratio associated with the backscattering of radiation by ice crystals at 0.532 and 1.064-mm wavelengths. **J. Geophys. Res.**, Vol. 114, D00H08, doi:10.1029/2009JD011759.

New Library of Single–Scattering Properties

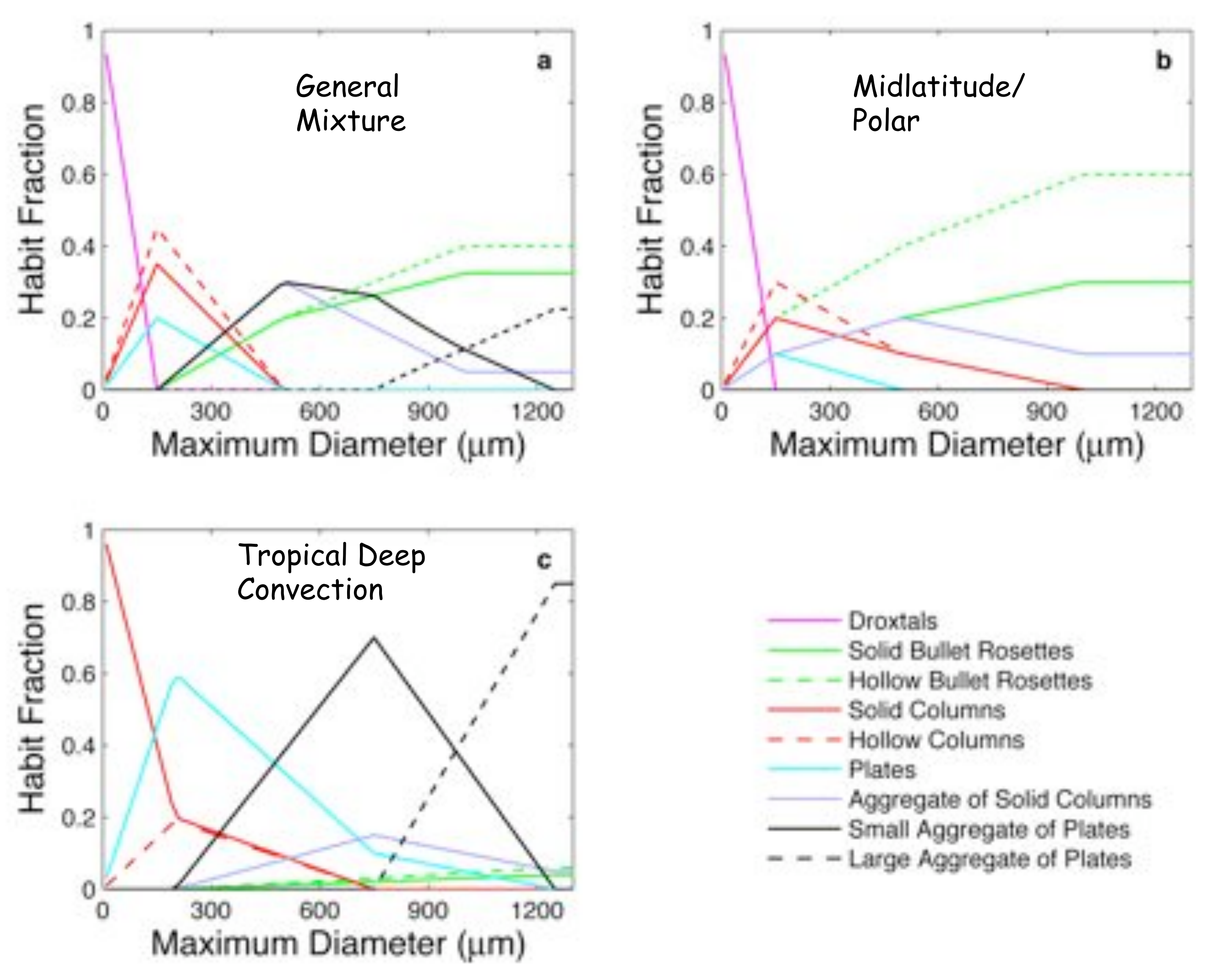
Long-term plan: New database of single-scattering properties that will encompass spectrum from UV through Far-IR with no spectral gaps

Short term: A preliminary set of single-scattering properties provides what is needed for building and testing models for upcoming MODIS Collection 6 effort

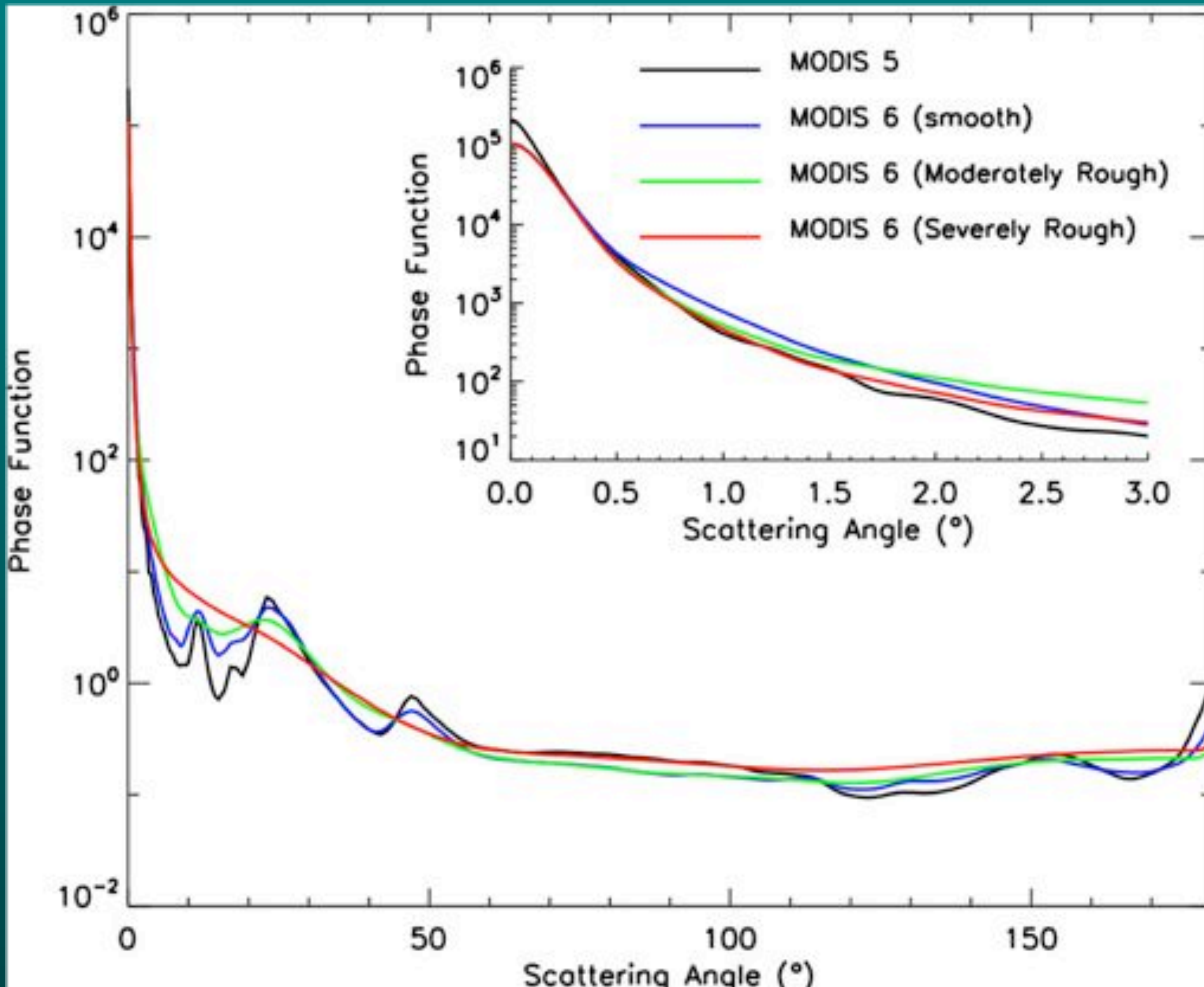
Current library includes:

- 189 particle sizes between 2 – 10,000 mm
- 396 wavelengths between 0.2 and 15.25 mm
- new habits, e.g., hollow bullet rosette and small/large aggregate of plates
- properties for smooth, moderately roughened, and severely roughened particles
- host of improvements to light scattering calculations (e.g., no delta-transmission term)
- use of updated ice index of refraction (Warren and Brandt, JGR, 2008)

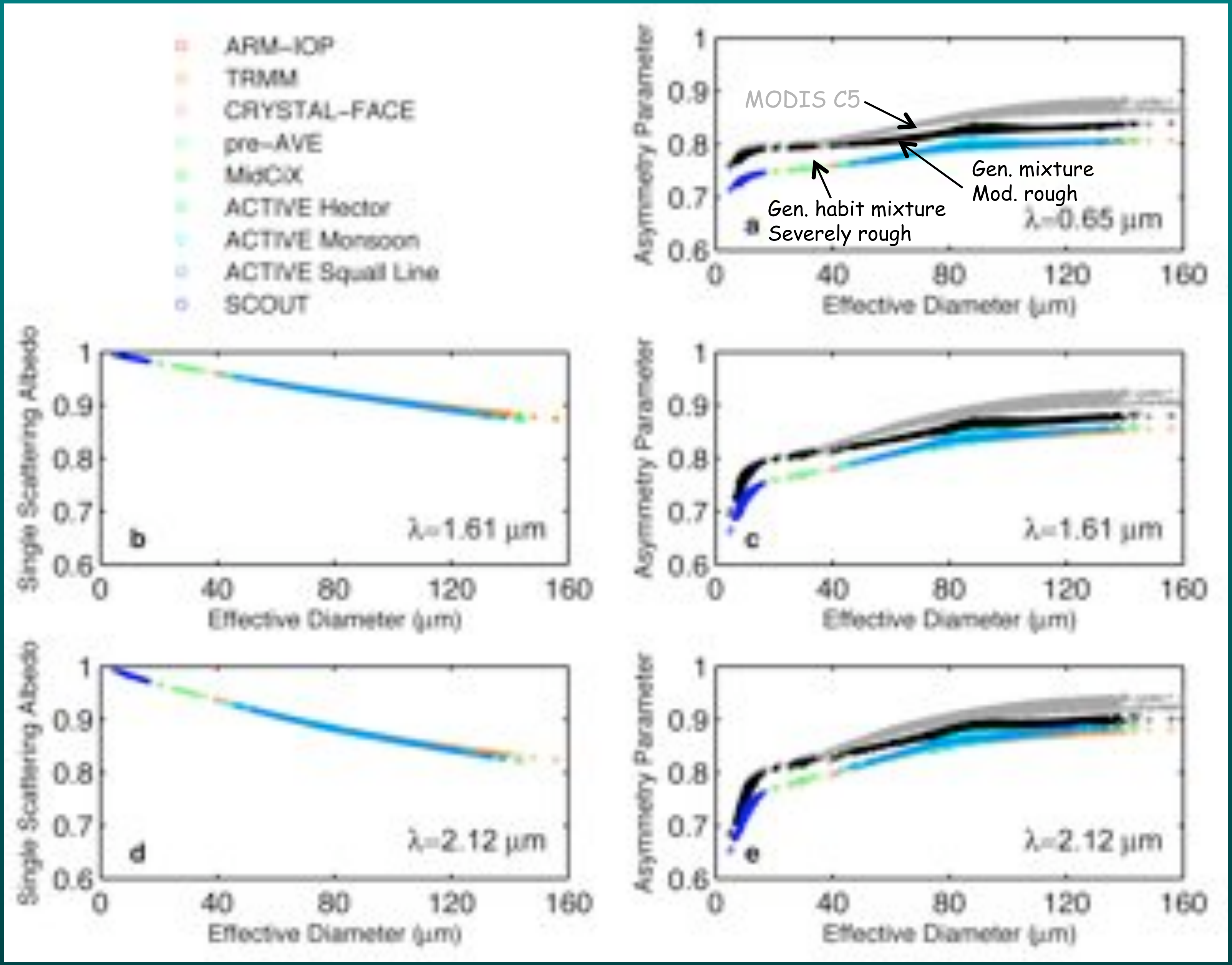
Development of three new habit recipes



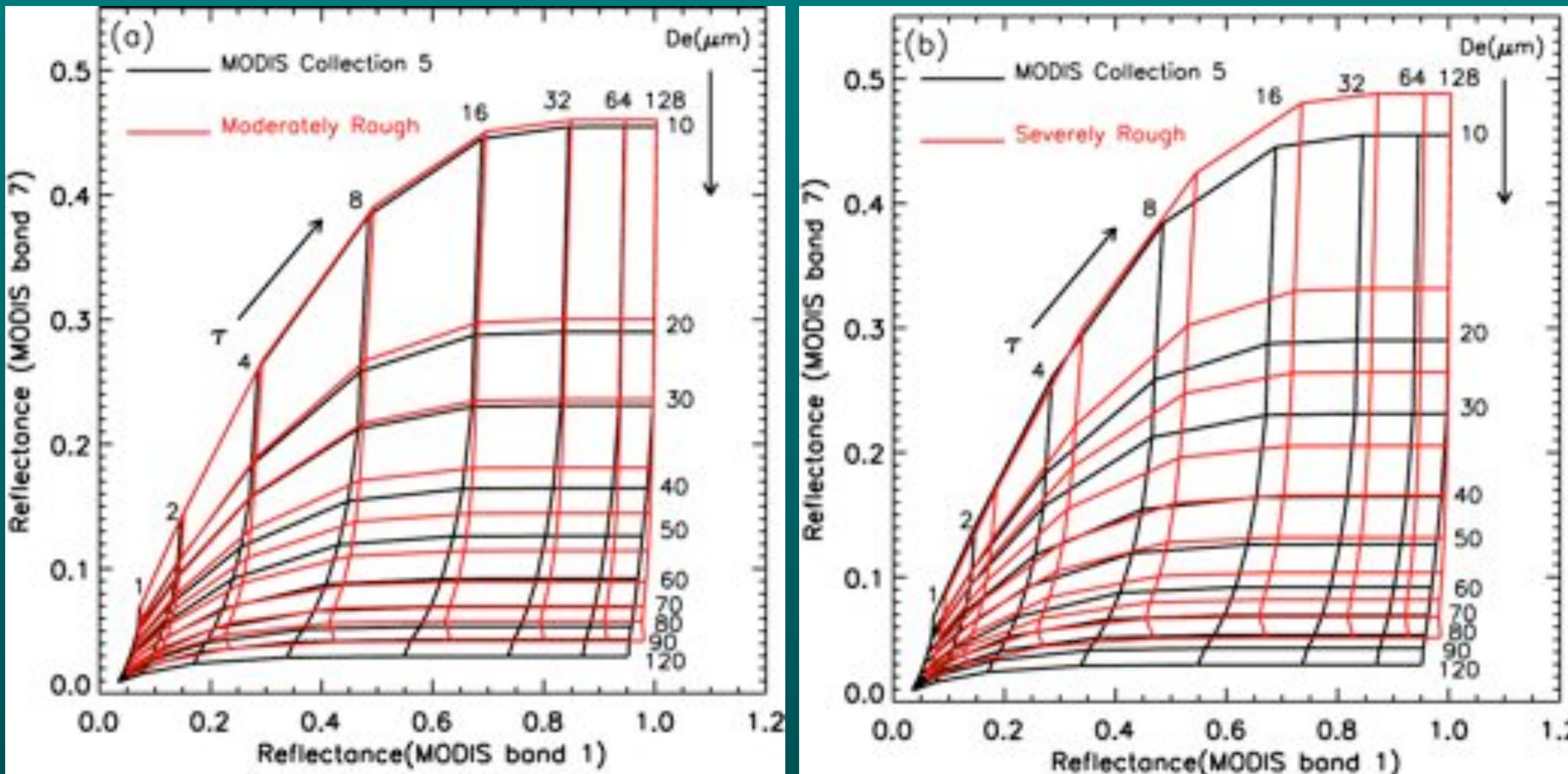
Comparison of MODIS C5 to Potential C6 Phase Functions
MODIS Band 1 (l = 0.65 mm)



Single-scattering albedo and asymmetry factor



Sample LUT showing difference between MODIS Collection 5 and moderately-roughened or severely roughened models



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

In summary…

We are incorporating a wealth of improvements in microphysical data and single-scattering computations

In the solar: use of severely roughened particles has the most impact compared to other changes (new PSDs, habits, etc.)

In the IR: particle roughening will have little impact, but there are two changes that have an influence:

a. use of new Warren-Brandt index of refraction
b. use of realistic PSDs for $D_{eff} \leq 40$ microns

Currently performing some closure studies to study impact of these changes on both solar and IR optical thickness/particle size retrievals