Path Forward Using POLDER/MODIS/CALIOP for Ice Cloud Properties

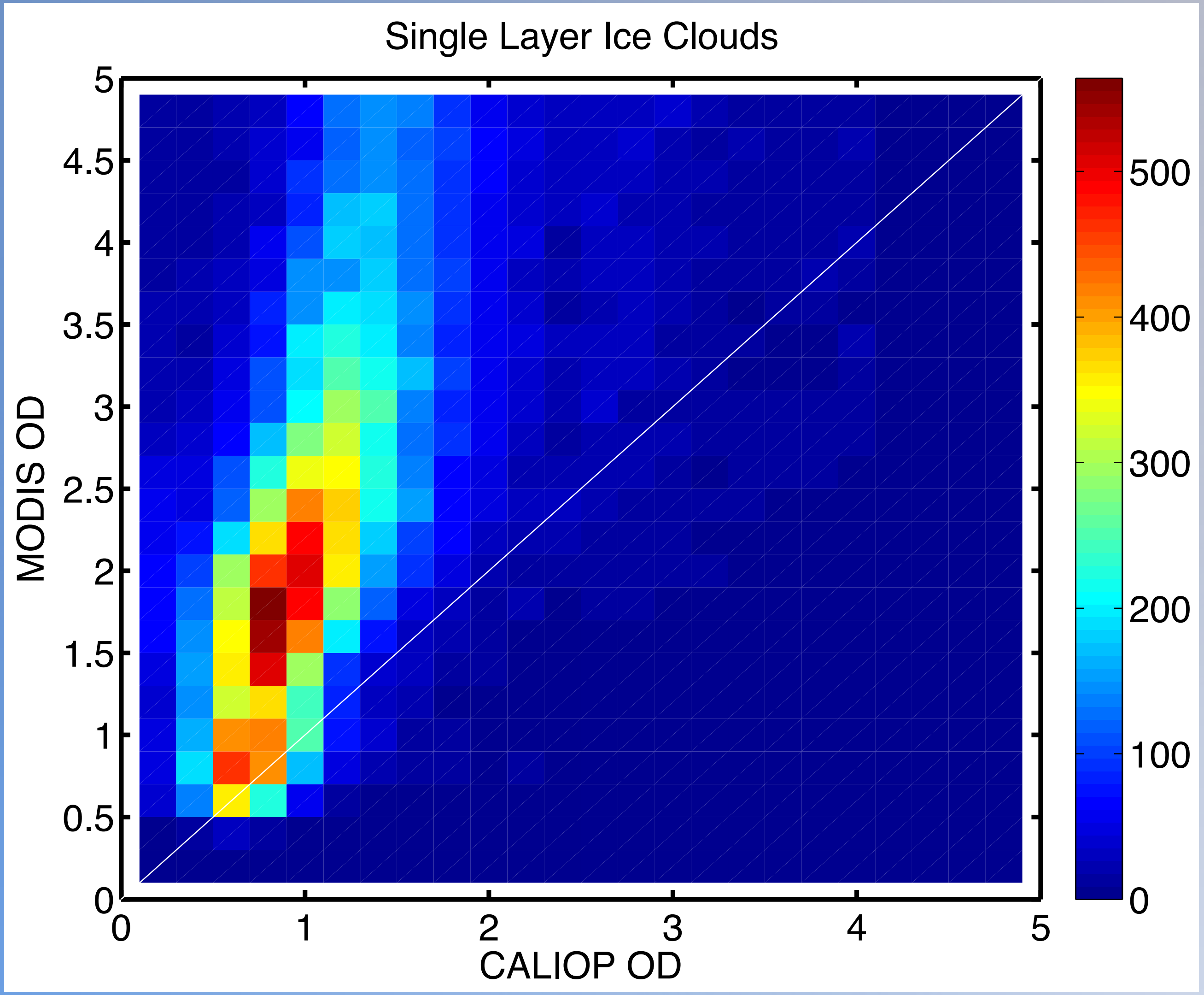
Bryan A. Baum[1], Ping Yang[2], Steve Platnick[3], Jerome Riedi[4], Zhibo Zhang[5]

[1] Space Science and Engineering Center, UW-Madison
[2] Texas A&M University
[3] NASA Goddard Space Flight Center
[4] Universite de Lille, France
[5] Univ. Maryland, Baltimore County

Significant areas of anticipated research in next year:

- Effort to work with sensor teams to investigate differences in cirrus optical thickness (AVHRR, MODIS, CALIOP, POLDER, IIR)
- Building co-located MODIS/POLDER/CALIOP product
- Individual particle and bulk ice cloud single-scattering properties and associated RT modeling
    - Shape of phase function depends on particle roughening and habit

Comparison of MODIS C5 with CALIOP Optical Thickness

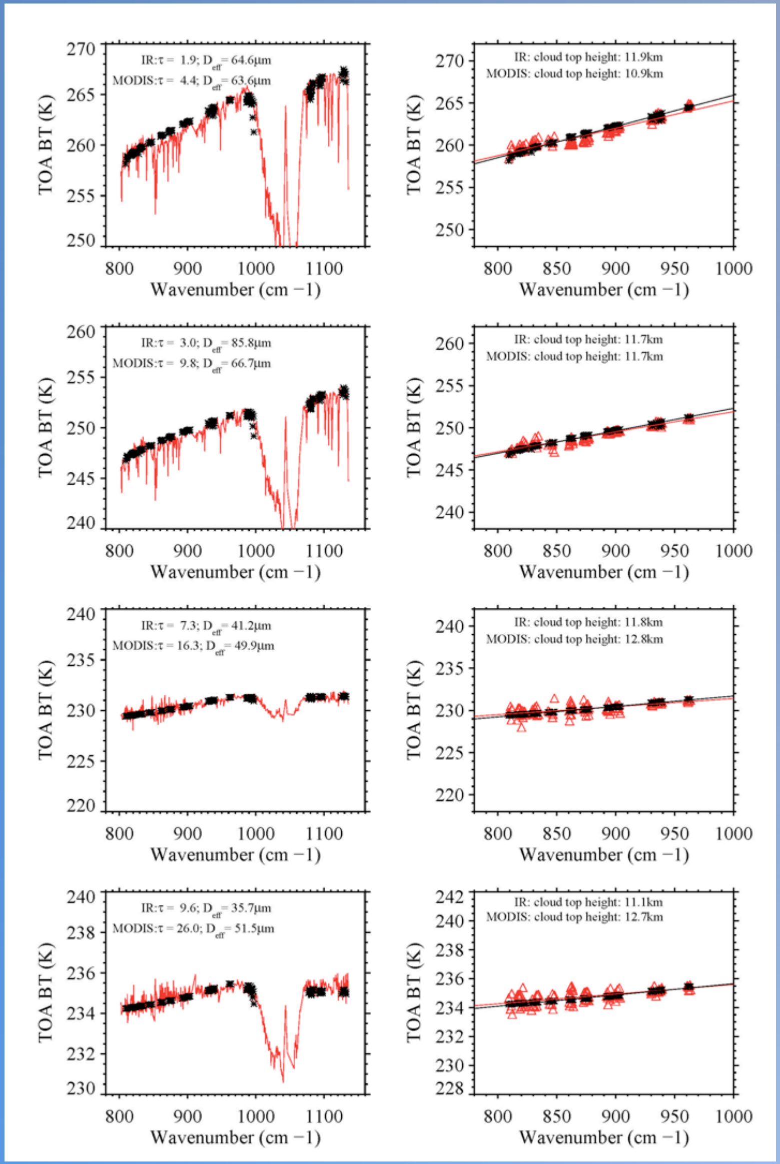


Daytime comparisons of optically thin cirrus with CALIOP reveal a bias, but this is based on unconstrained CALIOP retrievals

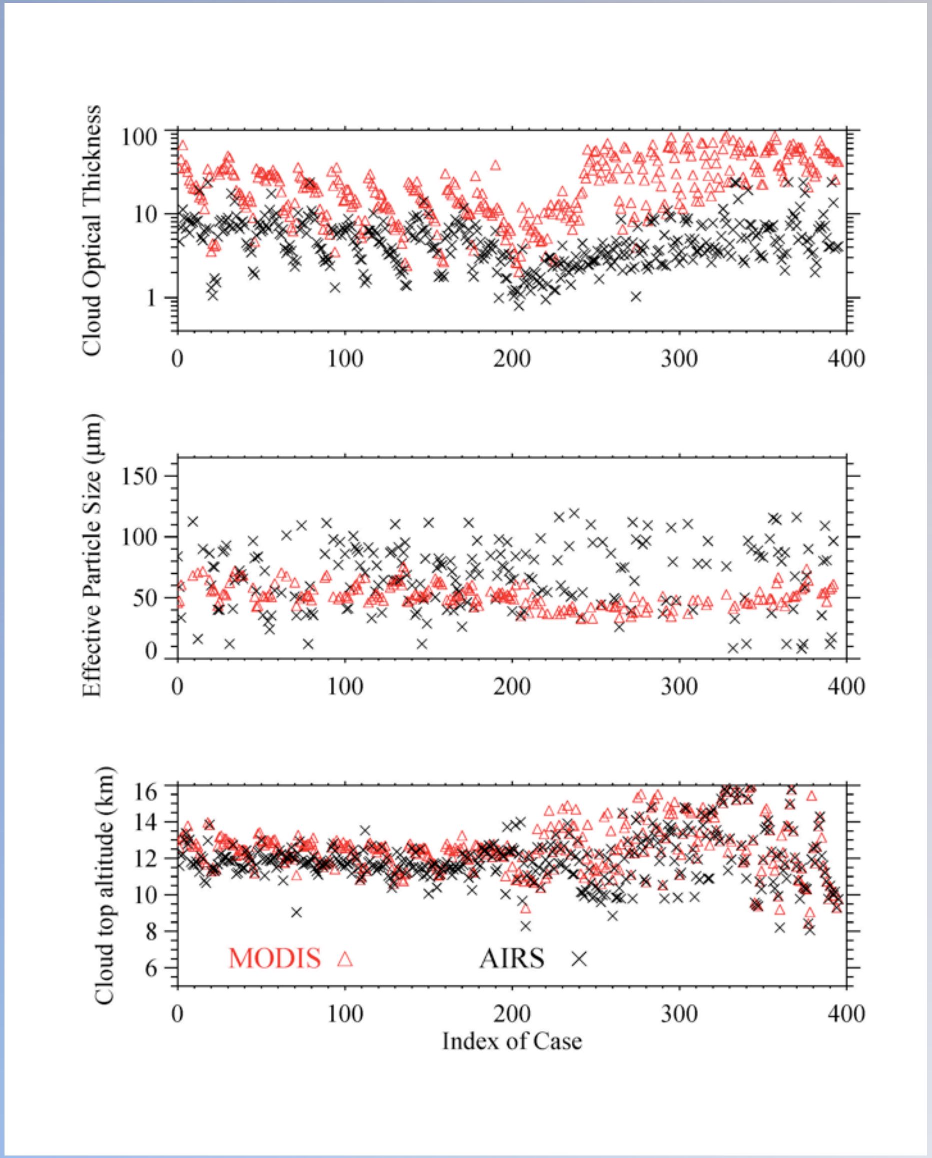
Comparison of MODIS C5 with AIRS-based Optical Thickness

P. Yang - new results

Model Simulation vs. AIRS Obs



Model (C5) vs. AIRS Retrievals



Wang, Yang, Platnick, Heidinger, Baum, Greenwald, and Zhang (in preparation for submittal to JAMC, 2011)

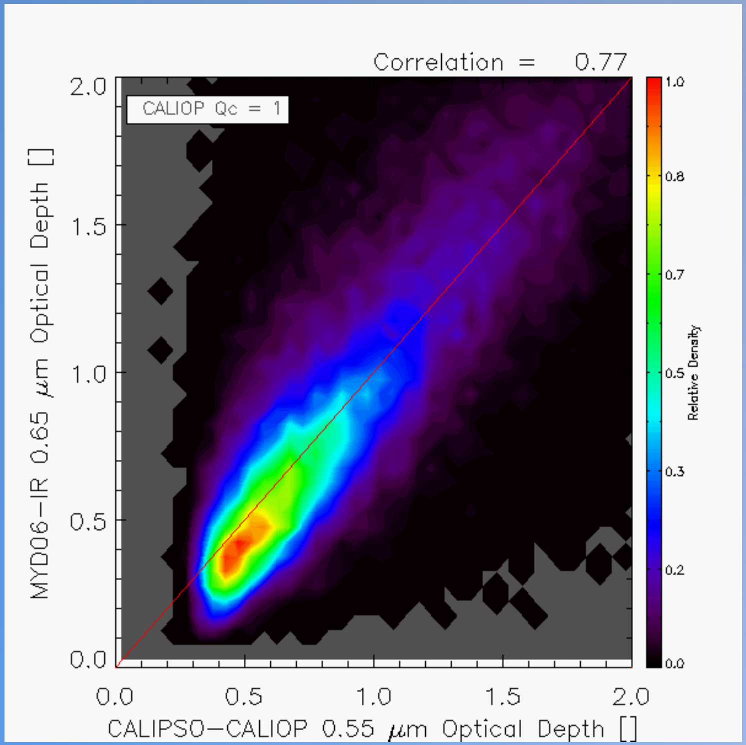
IR-window based ice cloud optical thickness vs. CALIOP

Andy Heidinger (NOAA/NESDIS)

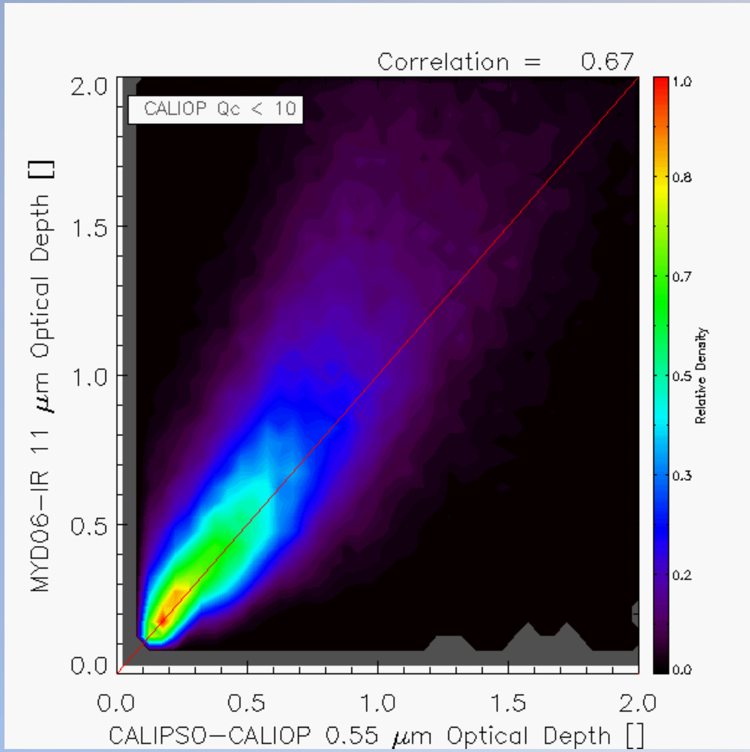
IR window approach based on cloud emissivity ratios implemented by Andy Heidinger (NOAA) for CLAVRR (real time operational NOAA product) and PATMOS-x (cloud climatology product)

PATMOS-x is a 30+ year climatology based on AVHRR, but algorithms easily applied to any sensor with similar channel set (at a minimum)

Results below are based on IR cloud emissivities now provided in MODIS C6 code from SSEC



CALIOP constrained retrievals
Lower optical thickness limit imposed



CALIOP unconstrained retrievals
more points off-axis, lower optical thicknesses

Exploration of differences in ice cloud optical thickness between various A-Train sensors

Two recent meetings held this year to discuss this issue (at MODIS and CALIPSO/CloudSAT STMs)

Principals included Steve Platnick, Ann Garinier, Jacques Pelon, Ping Yang, Bryan Baum, Ralph Kuehn, Robert Holz, Dave Winker, Yong-Xiang Hu, Andy Heidinger, Jerome Riedi, Zhibo Zhang, and others

- 4 different groups performing IR window-based retrievals (Ping Yang, Andy Heidinger, Ann Garinier/Jacques Pelon, Zhang/Platnick)

- Effort underway to intercompare the IR approaches to determine their consistency

- CALIOP has two different retrieval methods: constrained (nighttime) and unconstrained (daytime) but the resulting products are inconsistent.

Exploring the various issues and assumptions related to each sensor and its products

The Atmosphere PEATE and ICARE will provide matchups between sensors (more on this later)

The important idea here is that several teams are working together with the goal of improving consistency between approaches

Current 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 current efforts (MODIS Collection 6; MODIS/AVHRR/IIR/CALIOP/POLDER consistency project)

Current library includes:

- 189 particle sizes between 2 – 10,000 µm
- 396 wavelengths between 0.2 and 15.25 µm
- 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)
- full phase matrix (P_{11}, P_{21}, P_{22}, P_{33}, P_{43}, and P_{44})

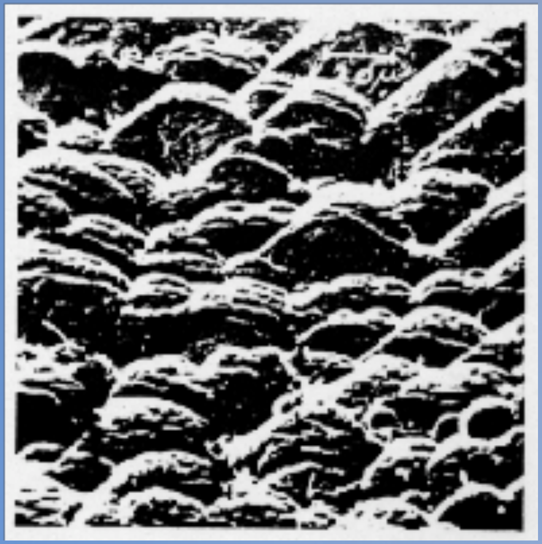
Current List of Microphysical Data Available

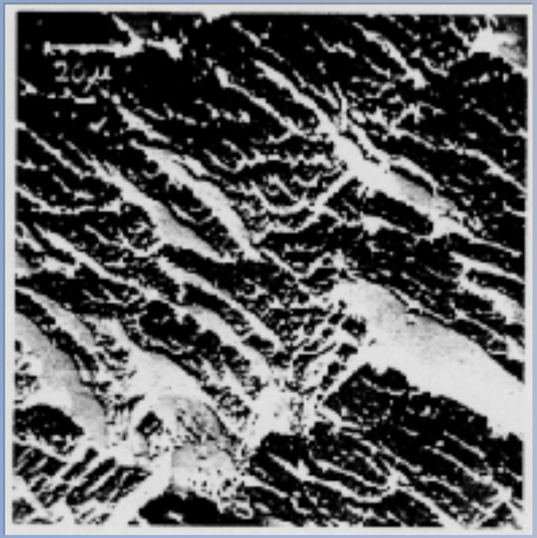
IWC range: 1.E-6 to 1 g m^{-3}

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
MACPEX - Pending	Oklahoma, 2011		

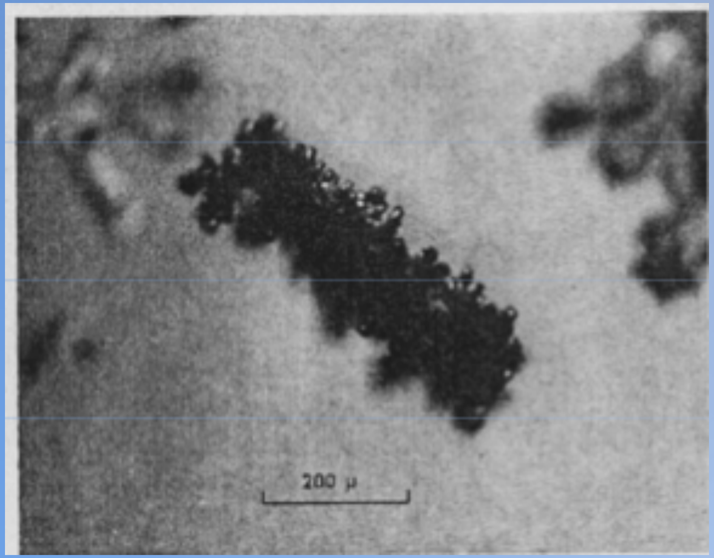
The total sample set has been filtered by the requirement that the cloud temperature be colder than –40°C, providing > 20,000 PSDs.
Note: more data coming from MACPEX campaign where the Small Ice Detector (SID/3) was employed.

Evidence of Ice Particle Roughening



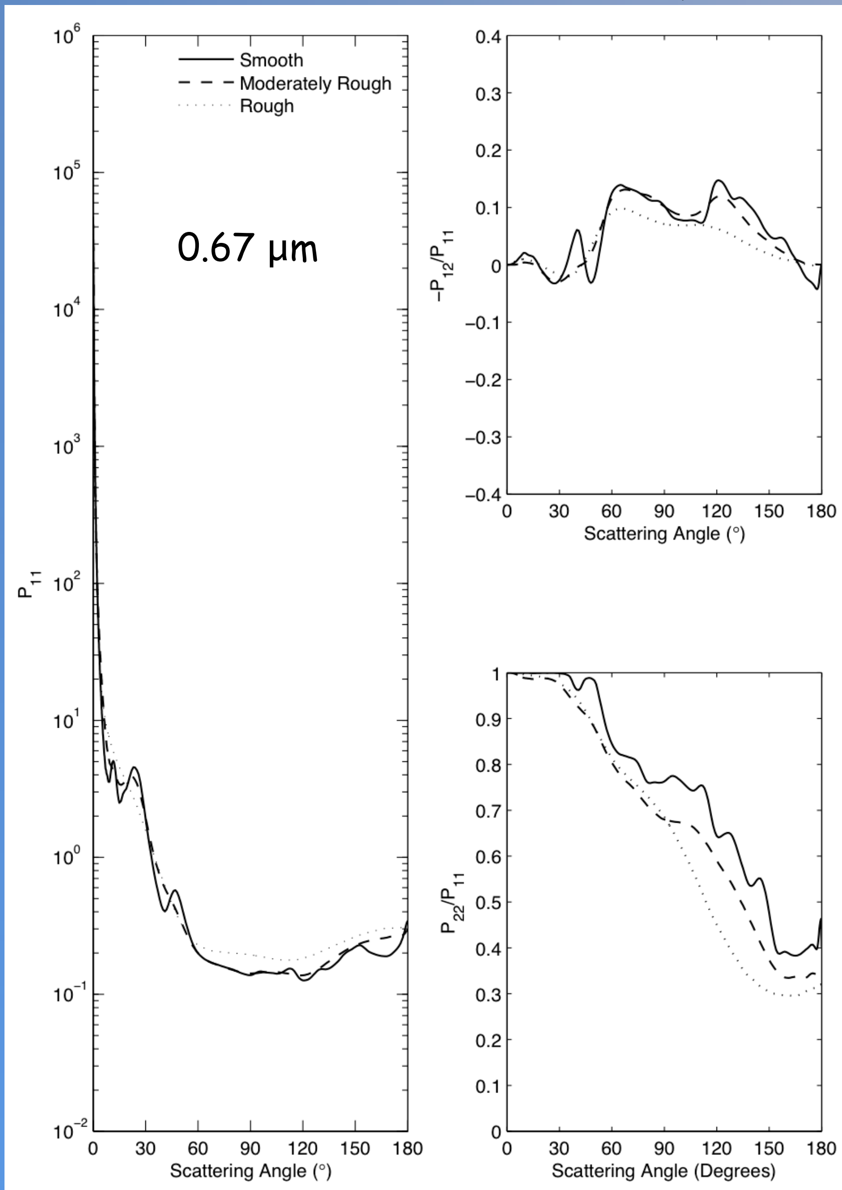


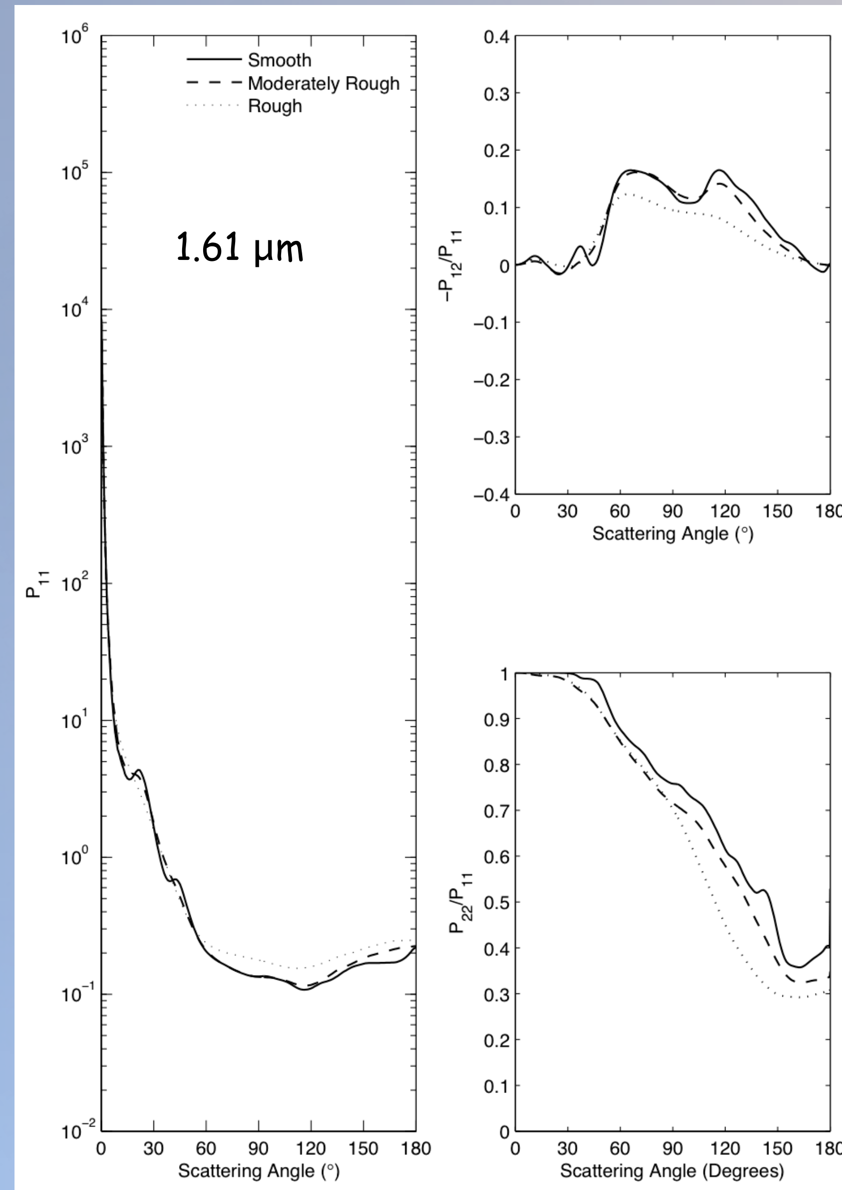
Surface roughness observed for single crystals and polycrystalline ice by using an electronic microscope. Images adapted from Cross, 1968



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

Influence of Ice Particle Roughening on Phase Matrix based on a single particle size distribution (D_{max}≤250 microns) and a habit mixture



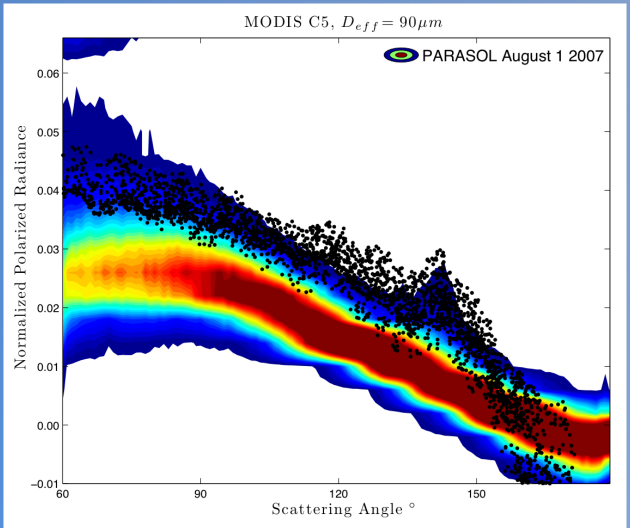


Baum, B. A., P. Yang, Y.-X. Hu , and Q. Feng, 2010: The impact of ice particle roughness on the scattering phase matrix. J. Quant. Spectrosc. Radiant. Transfer, Vol. 111, doi:10.1016/j.jqsrt.2010.07.008, 2534-2549.

Comparison of POLDER data to ice models*

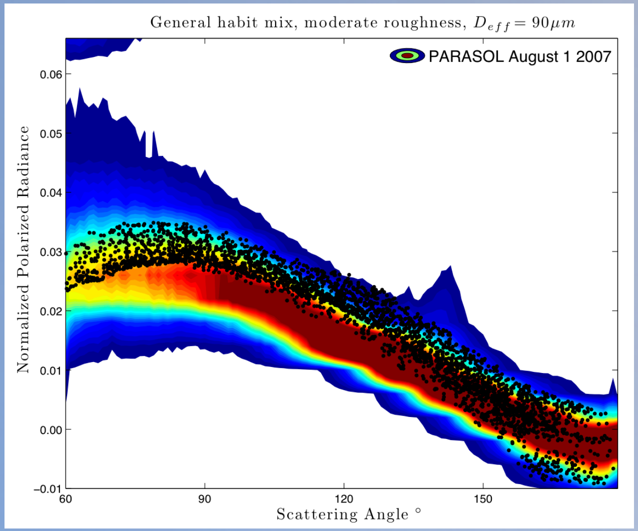
At 865 nm from 1 August 2007; over ocean; 100% cloud cover; ice phase (~70K pixels), D_{eff} = 90 μm

Smooth



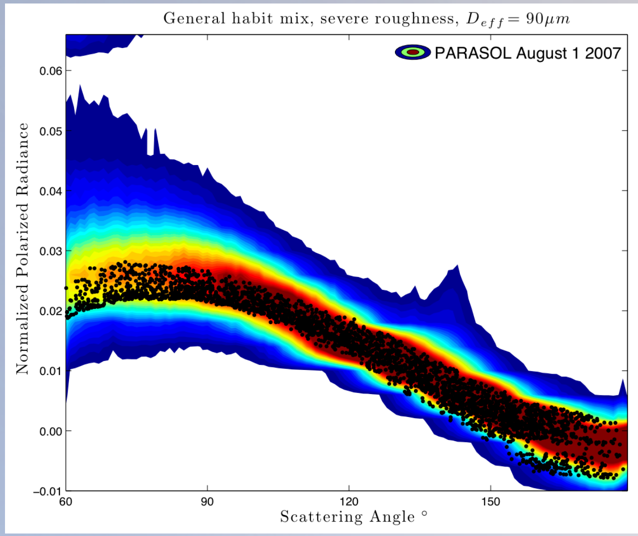
MODIS C5 habit mixture

Moderately Roughened



New general habit mixture

Severely Roughened



New general habit mixture

Normalized Polarized Reflectance:

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

Single scattering approximation:

$$L(\theta_s, \theta_v, \phi_s - \phi_v) \approx L(\Theta) = -\frac{\omega_0 P_{12}(\Theta)}{4P_{11}}$$

* Ben Cole, Texas A&M

Primary Focus: Comparison of POLDER/MODIS/CALIOP

Near-term plan: ICARE will provide full record (~5 years) of POLDER/MODIS/CALIOP matchups

Product will include:

- 3 POLDER pixels with associated cloud parameters
- 10 MODIS pixels with associated cloud parameters
- CALIOP Version 3 Level-2 cloud parameters

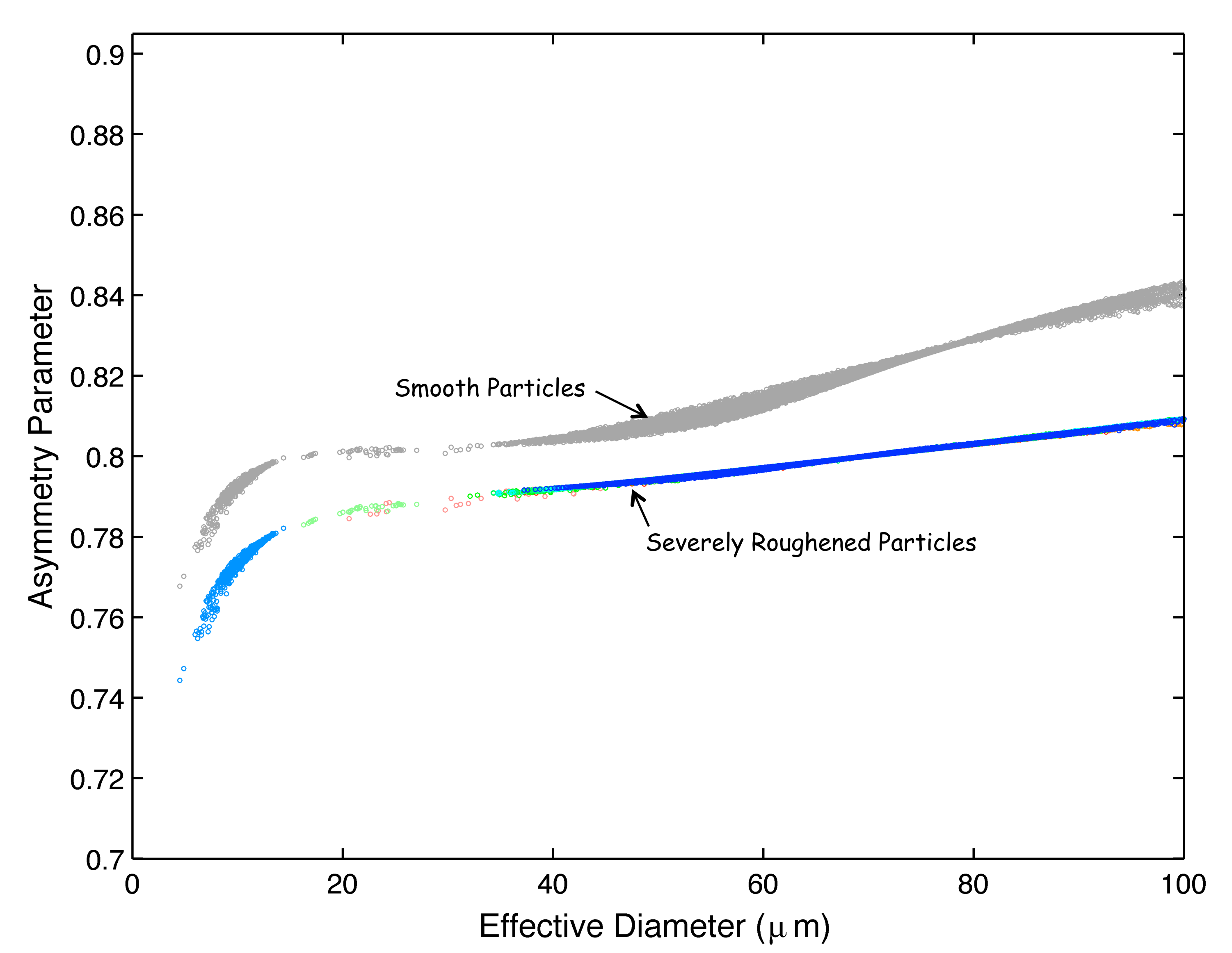
At SSEC, Bob Holz/Fred Nagle will modify this product over time:

- consider parallax in the colocation
- update MODIS products to Collection 6
- test different ice bulk scattering models
- update products as they become available

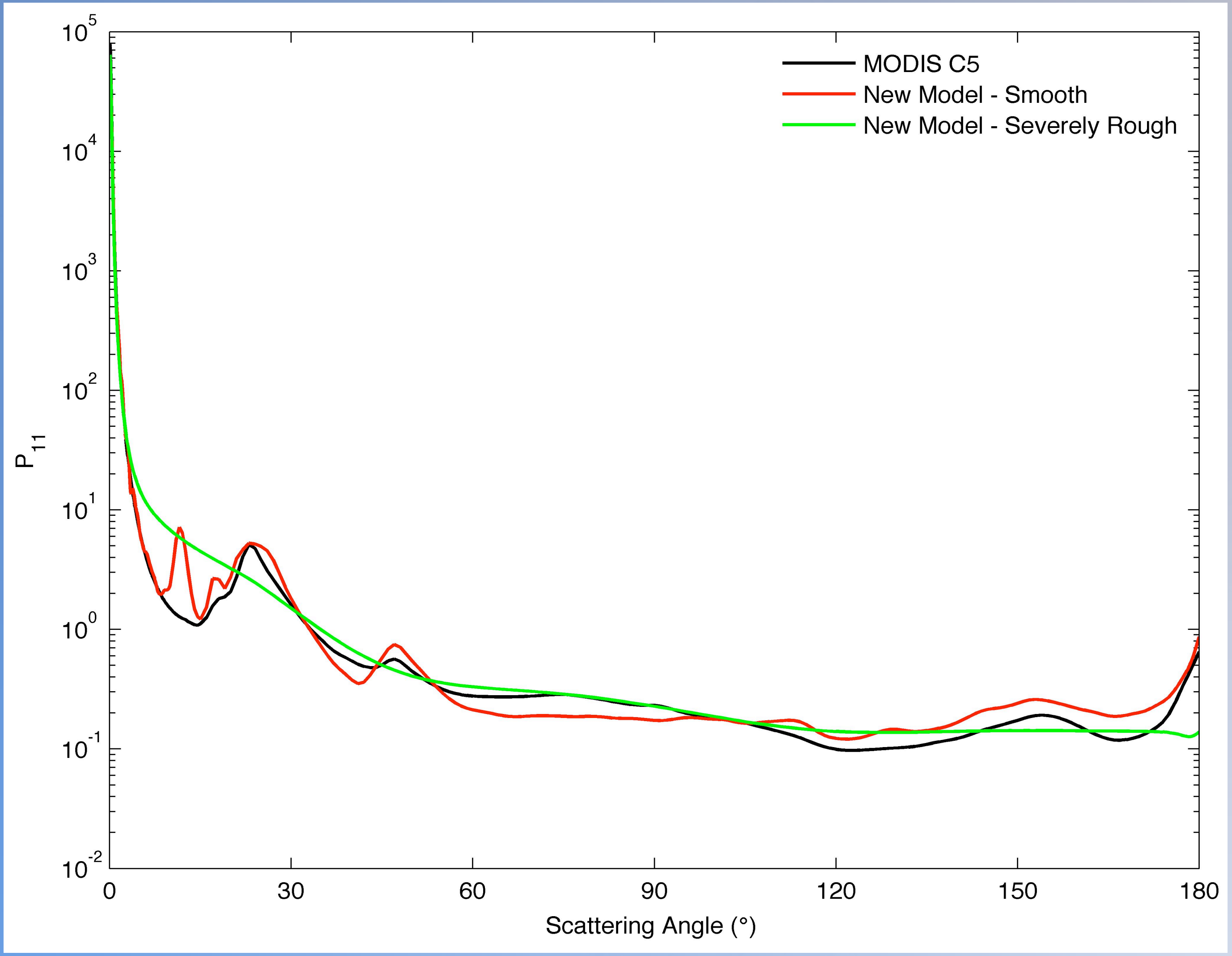
Team will explore regional and seasonal differences between the products

Expect surprises along the way

Effect of particle roughening on asymmetry parameter for a single wavelength at 0.65 μm

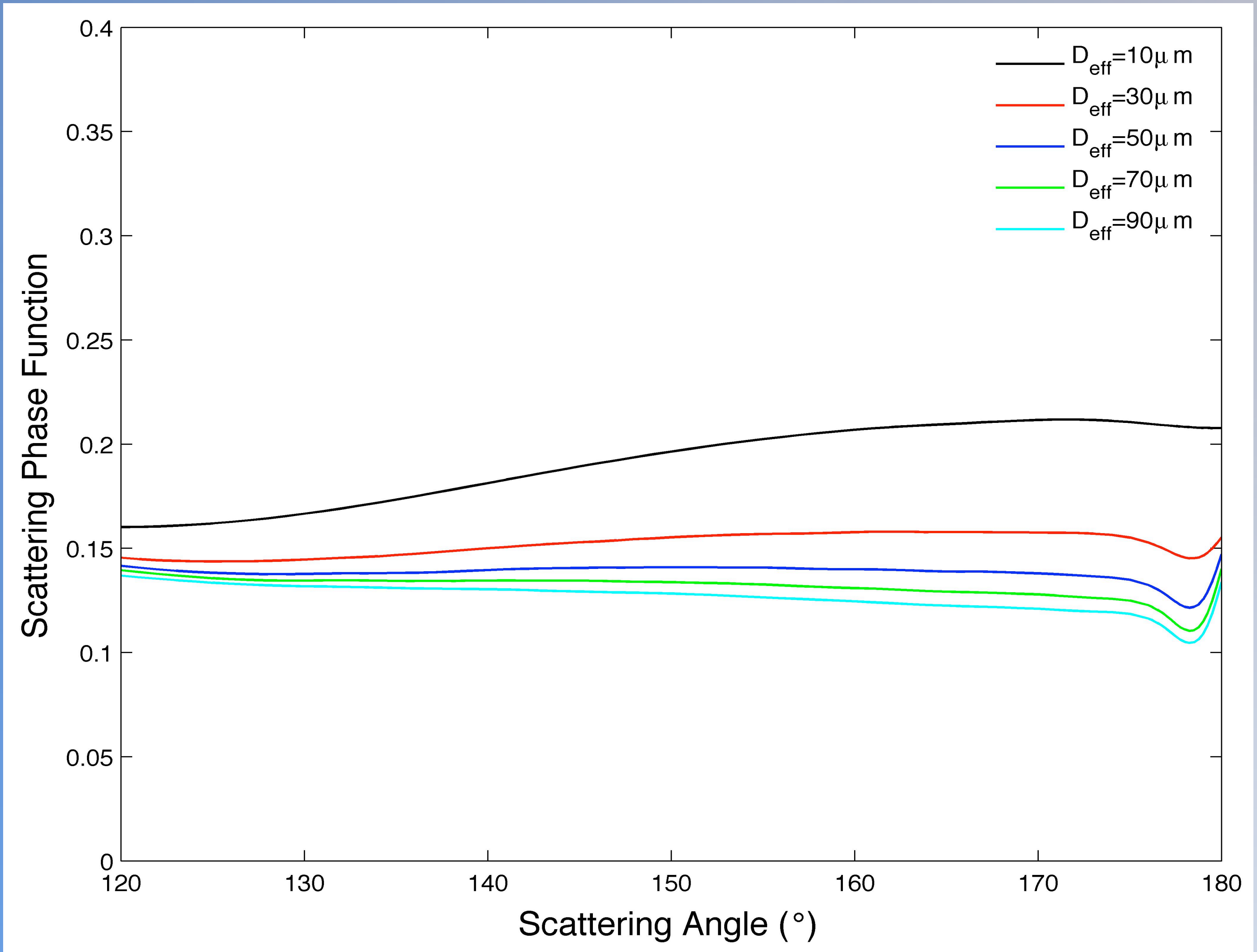


Comparison of MODIS C5 to roughened phase functions for MODIS Band 1 (λ = 0.65 μm); D_{eff} = 40

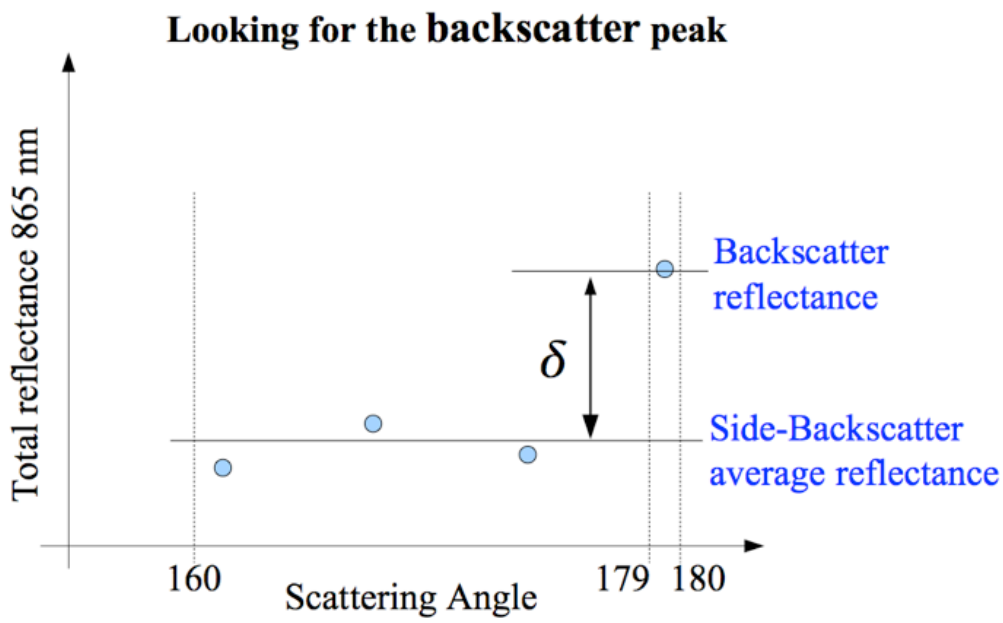


Note that roughening decreases the backscatter peak

Phase functions based on severely roughened particles at 0.53 μm: Note the behavior near backscattering



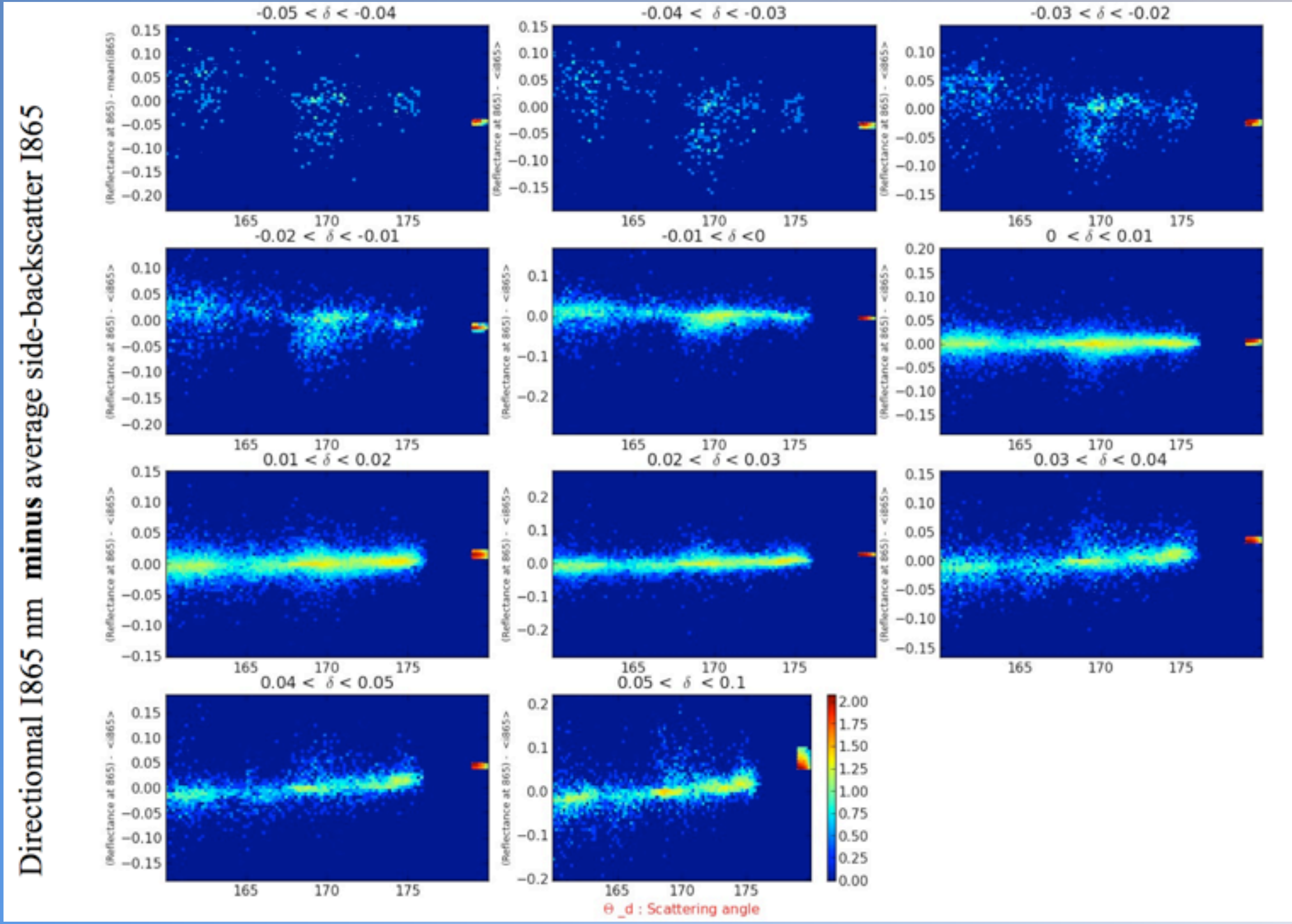
The behavior near backscattering can be tested with POLDER data
Jerome Riedi - preliminary study



Peak intensity is defined as the difference between the exact backscatter and the average side-backscatter reflectance.

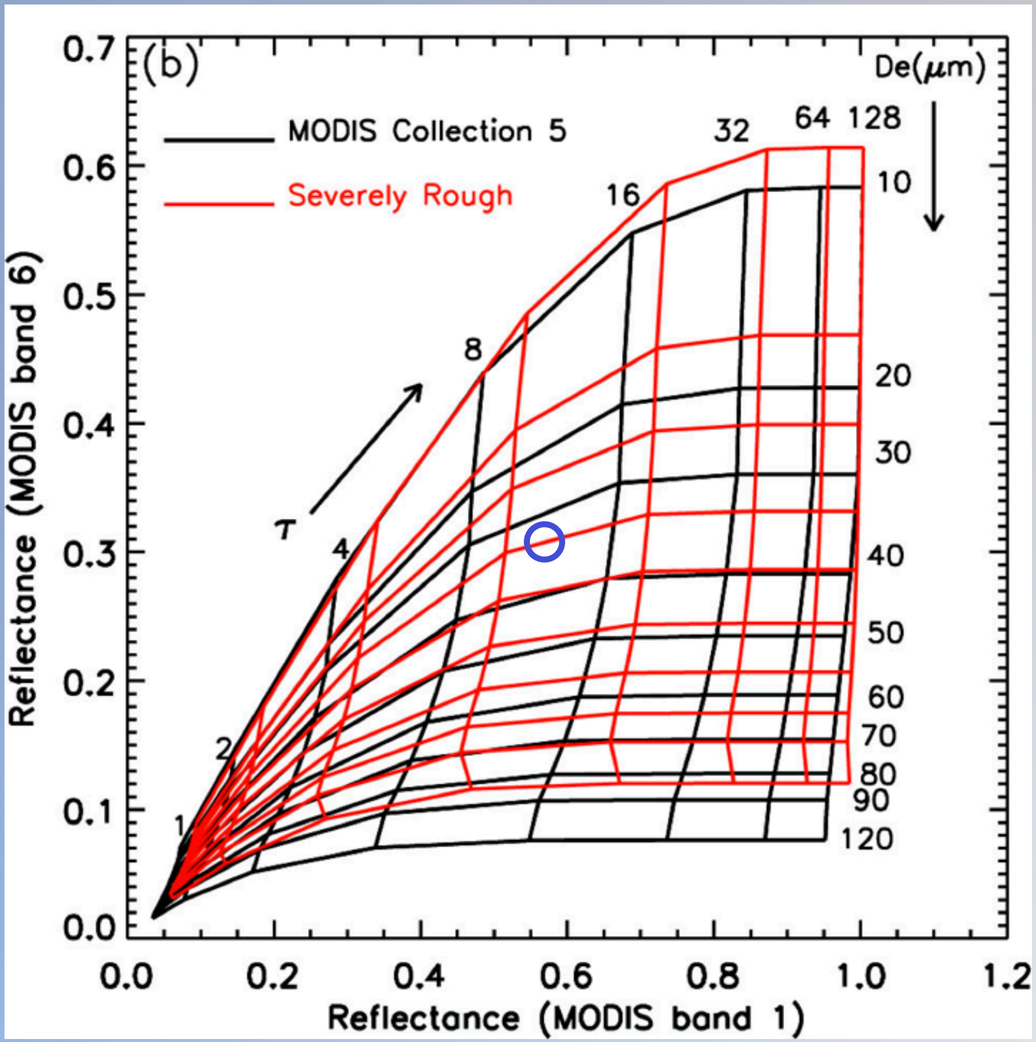
- One week of data
- at least 1 ob. between 179-180°
- at least 3 obs. between 160-179°
- for different ranges of peak intensity in steps of 0.02

A first test of using POLDER to look at peak intensity
Jerome Riedi - preliminary



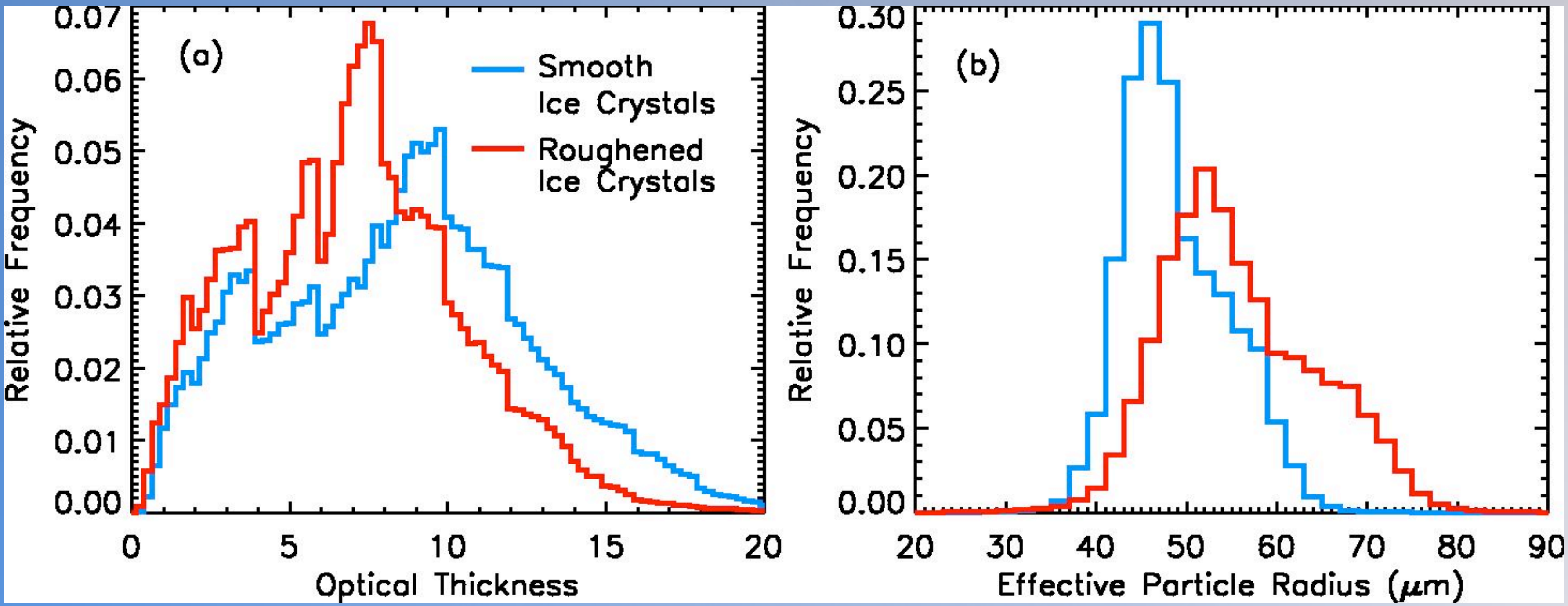
Effect of Particle Roughening on MODIS retrieval of τ_c and r_e

- Simulations imply that use of roughened particle models will result in lower τ_c values and higher r_e values
- Is there a simpler mixture of habits that would provide the correct radiative properties?
- Is there an optimal amount of roughening that should be assumed?
- Should we use a mixture of smooth and roughened particles?



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**, 1037-1056.49.

Effect of particle surface roughness on retrievals: Ice cloud optical thickness and effective particle size



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

General focus for first year activities

Jerome Riedi and ICARE: full record of co-located POLDER/MODIS/CALIOP products

Baum (SSEC): responsible for co-location of CALIPSO/POLDER/MODIS products; incorporation of updated CALIPSO/MODIS C6 products as necessary

Platnick/Zhang (NASA GSFC/UMBC): aid effort to improve consistency between MODIS and other sensors; work with Jerome to supply LUTs that can be used to investigate back/near-backscatter delta reflectances

Yang (Texas A&M): radiance simulator (including polarization) and comparison to POLDER data

The team will investigate POLDER/MODIS/CALIOP matchup files