Impact of Smoke on Ice Cloud Properties in Geostationary Data

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With thanks to Ping Yang, Andrew Heymsfield, Carl Schmitt, Aaron Bansemer, Ben Cole, Chenxi Wang and others

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Grainau, Germany
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New Generation of "Pure" Ice Cloud Scattering Property Models

Spectral models with the full phase matrix are available at 445 discrete wavelengths from 0.2 to 100 μm that are based on:

- General habit mixture, aggregate of solid columns only, and solid columns only
- Severely roughened particles
- Formatted in NetCDF

Site: ***http://www.ssec.wisc.edu/ice_models***

All microphysical data are also available (more than 14000 particle size distributions)

Imager models are available for 35 polar-orbiting and geostationary sensors.

Baum, B. A., P. Yang, A. J. Heymsfield, A. Bansemer, A. Merrelli, C. Schmitt, and C. Wang: Ice cloud bulk single-scattering property models with the full phase matrix at wavelengths from 0.2 to 100 *μ*m. In press, *J. Quant. Spectrosc. Radiat. Transfer, Special Issue ELS-XIV.*

Heymsfield, A. J., C. Schmitt, and A. Bansemer, 2013: Ice cloud particle size distributions and pressure dependent terminal velocities from in situ observations at temperatures from 0˚ to -86˚C. *J. Atmos. Sci.*, **70**, 4123-4154.

Yang, P., L. Bi, B. A. Baum, K.-N. Liou, G. Kattawar, and M. Mishchenko, 2013: Spectrally consistent scattering, absorption, and polarization properties of atmospheric ice crystals at wavelengths from 0.2 *μ*m to 100 *μ*m. *J. Atmos. Sci.*, **70**, 330-347.

New Challenge

What if…the ice clouds are not pristine, but instead have significant loading by absorbing aerosols?

Which brings us to pyroconvection…specifically pyroCumulonimbus

Jaroso, New Mexico

June 11, 2013

Development of a PyroCb on 20 June 2013

Courtesy of Bill Gabbert

12:30 pm local time

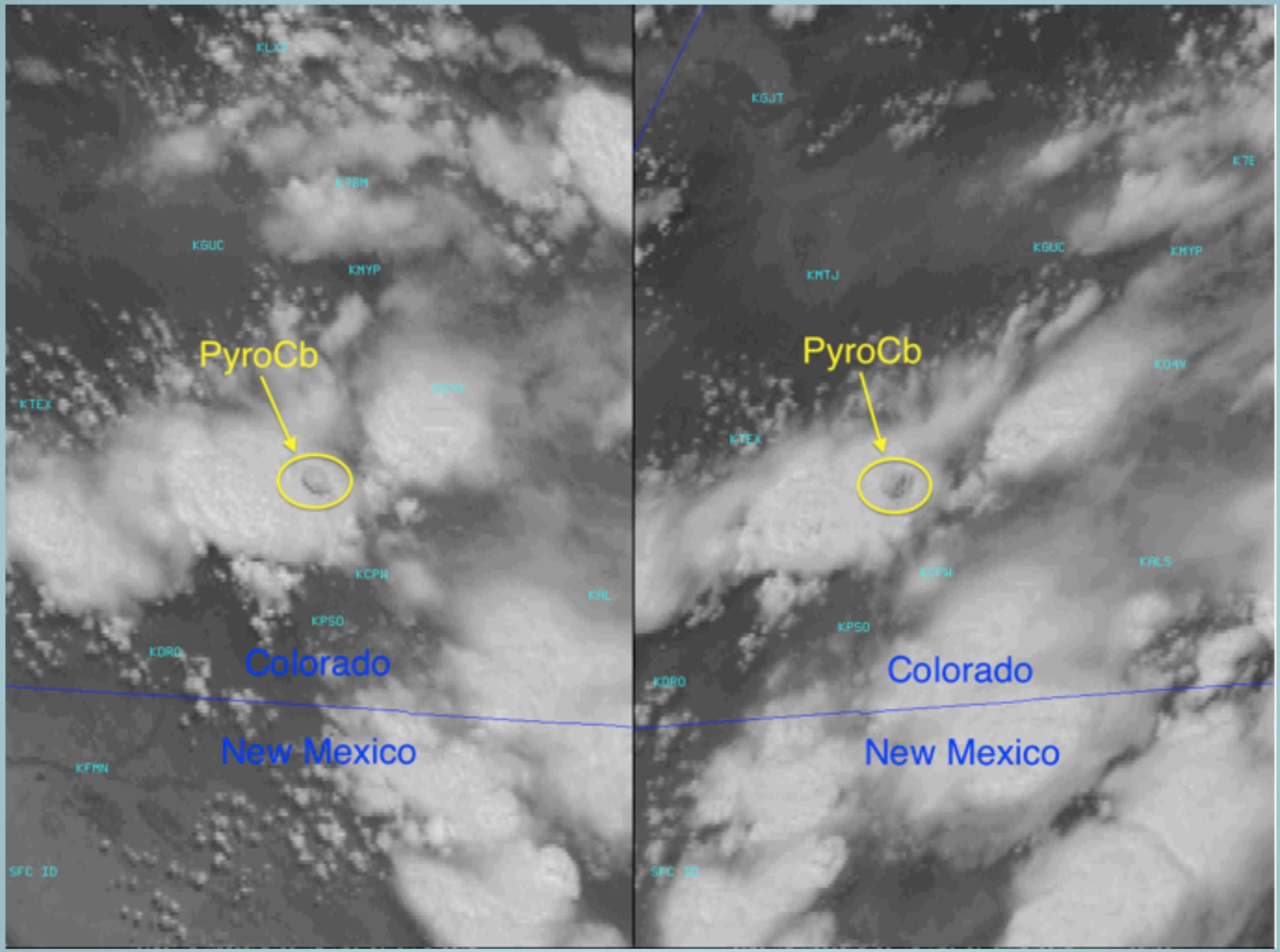
6:00 pm local time

Smoke from West Fork, CO fire from 50 miles away in Durango, CO

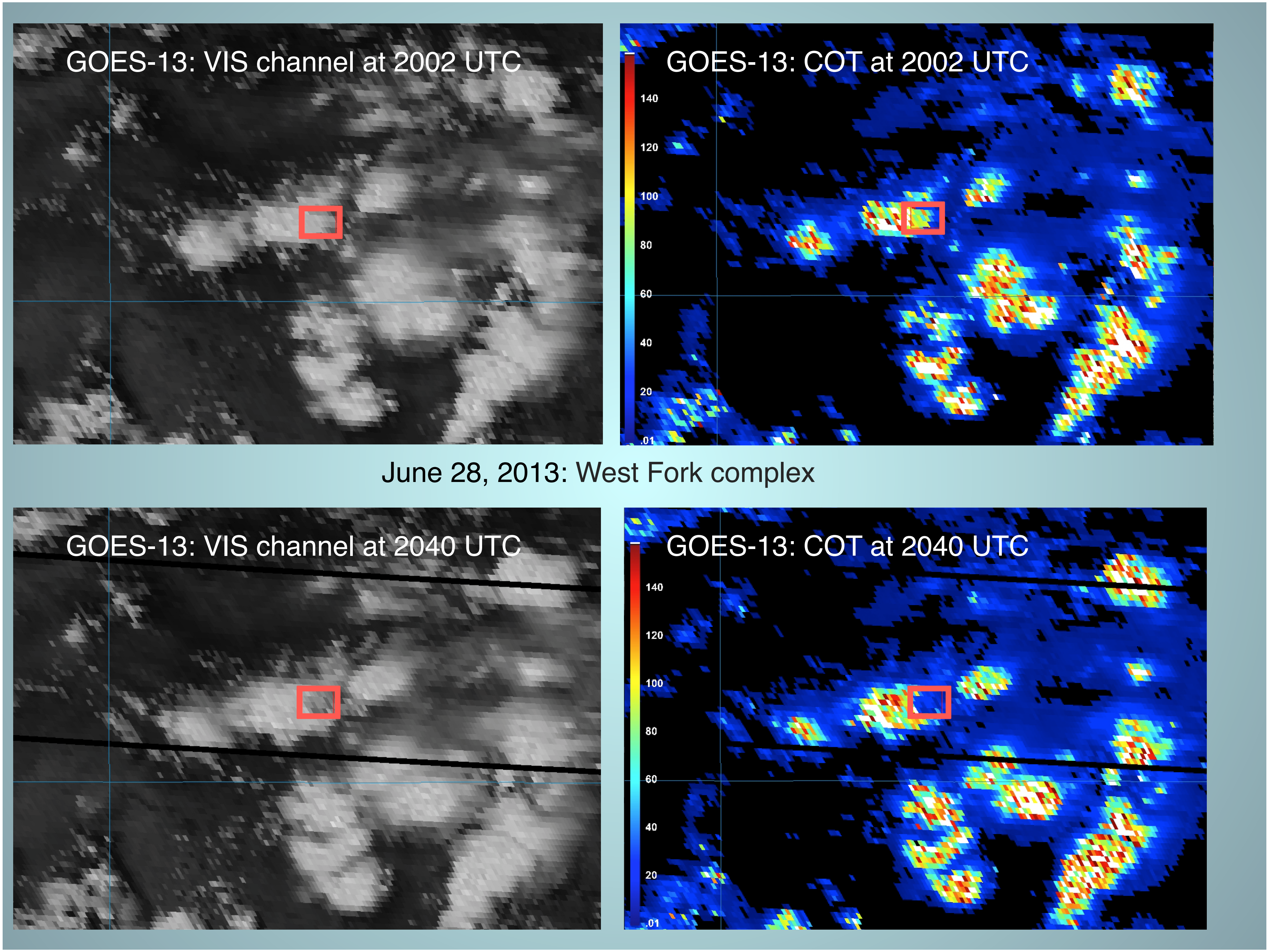
A large and intense wildfire near Durango, CO in the southwest part of the state. It was taken at about 7PM MDT on June 22, 2013, as seen from a commercial airliner flying at 35,000 feet over Colorado. (Photograph courtesy of Luis Rosa, NOAA/NWS)

From Discover Magazine blog by Tom Yulsman on June 24, 2013: A pyroCb cloud from the West Fork Complex of wildfires, as seen from a commercial airliner flying at 38,000 feet over Colorado on June 23, 2013. (Photograph: Courtesy Elizabeth Rothman)

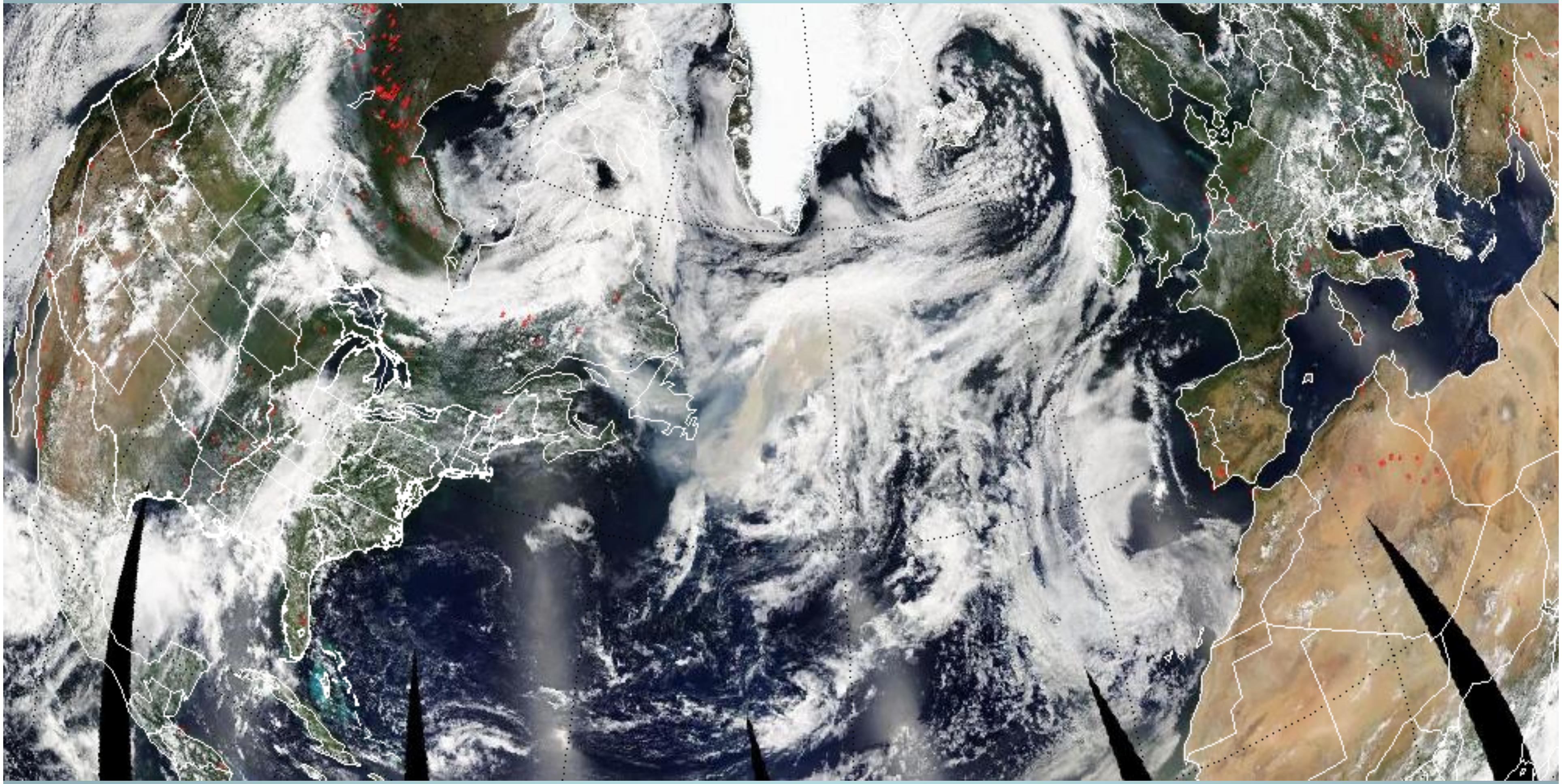
PyroCb impacting existing Cb



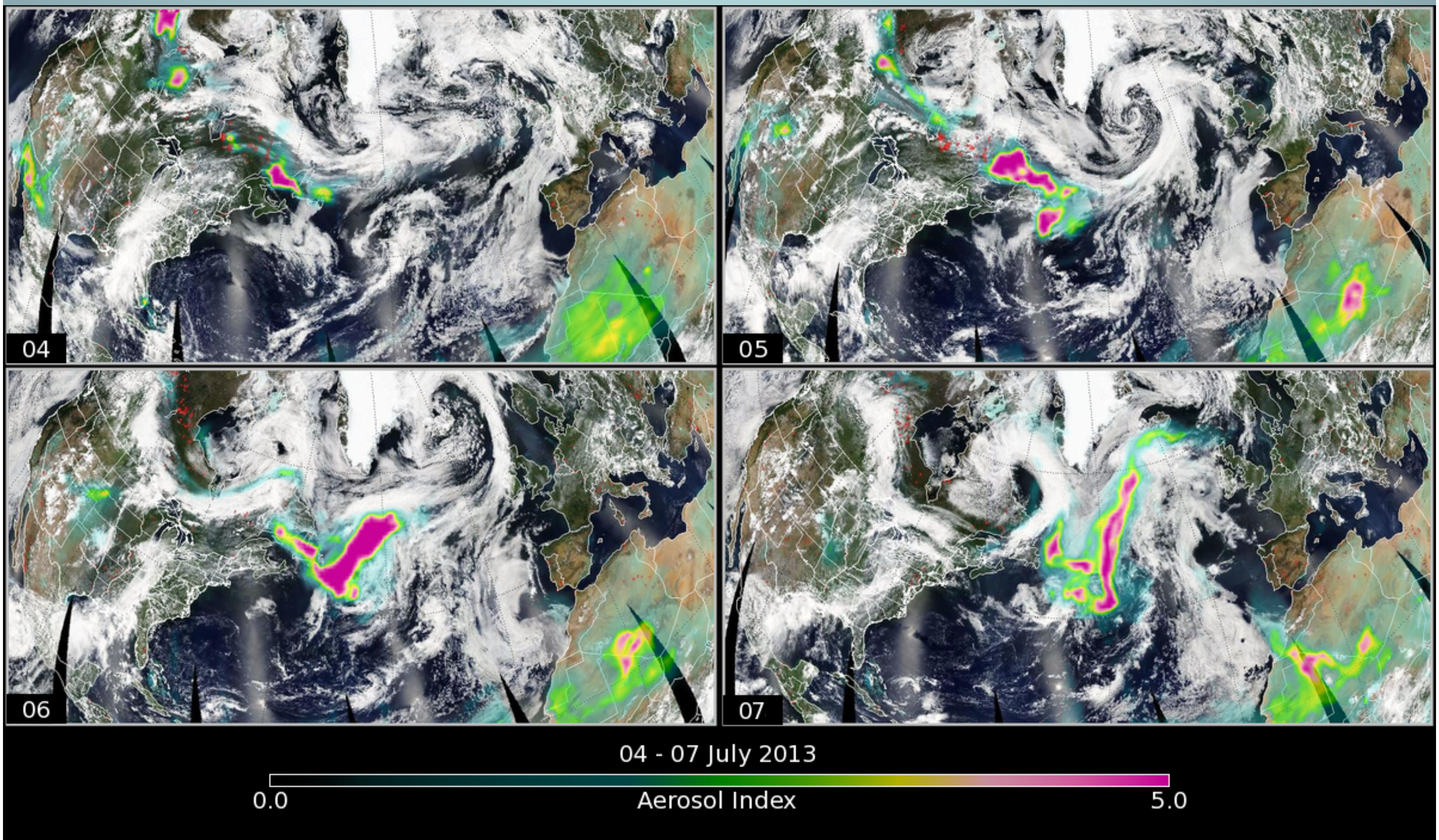
June 28, 2013: From the West Fork complex of wildfires as seen from GOES-15 (left) and GOES-13 (right) 0.63 μm visible channel images.


GOES-13: VIS channel at 2002 UTC
GOES-13: COT at 2002 UTC
140
120
100
80
60
40
20
.01
June 28, 2013: West Fork complex
GOES-13: VIS channel at 2040 UTC
GOES-13: COT at 2040 UTC
140
120
100
80
60
40
20
.01

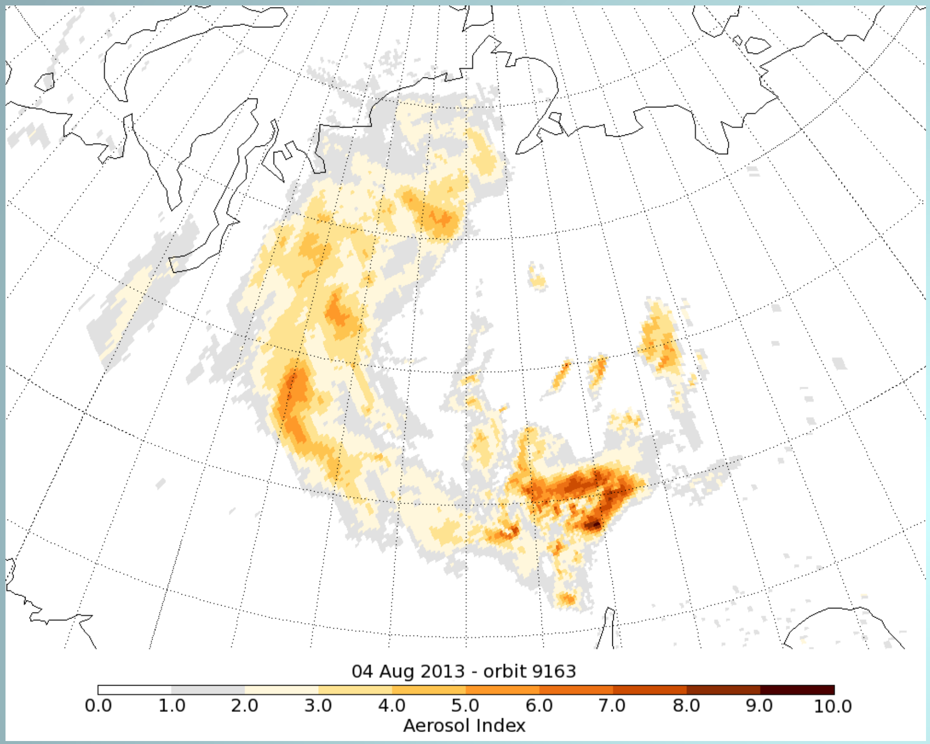
From the Ozone Mapping Profiler Suite (OMPS) blog:
Multiple orbits of MODIS Aqua data on 6 July 2013

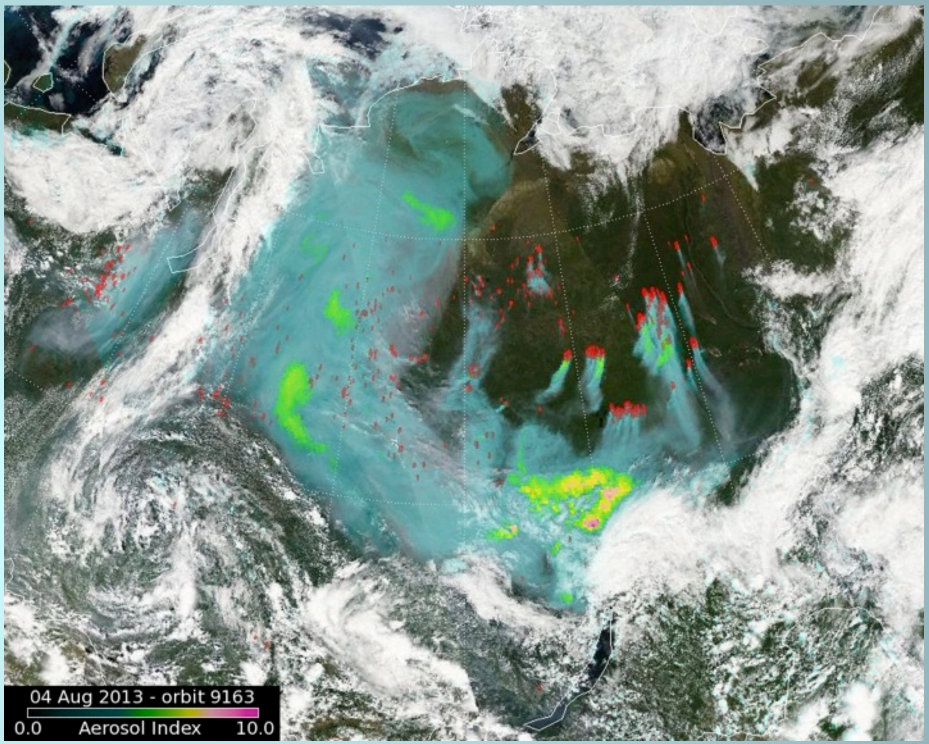


A large smoke plume is noticeable over/within ice clouds over the north Atlantic from the Canadian fires in Quebec


04
05
06
07
04 - 07 July 2013
0.0
Aerosol Index
5.0

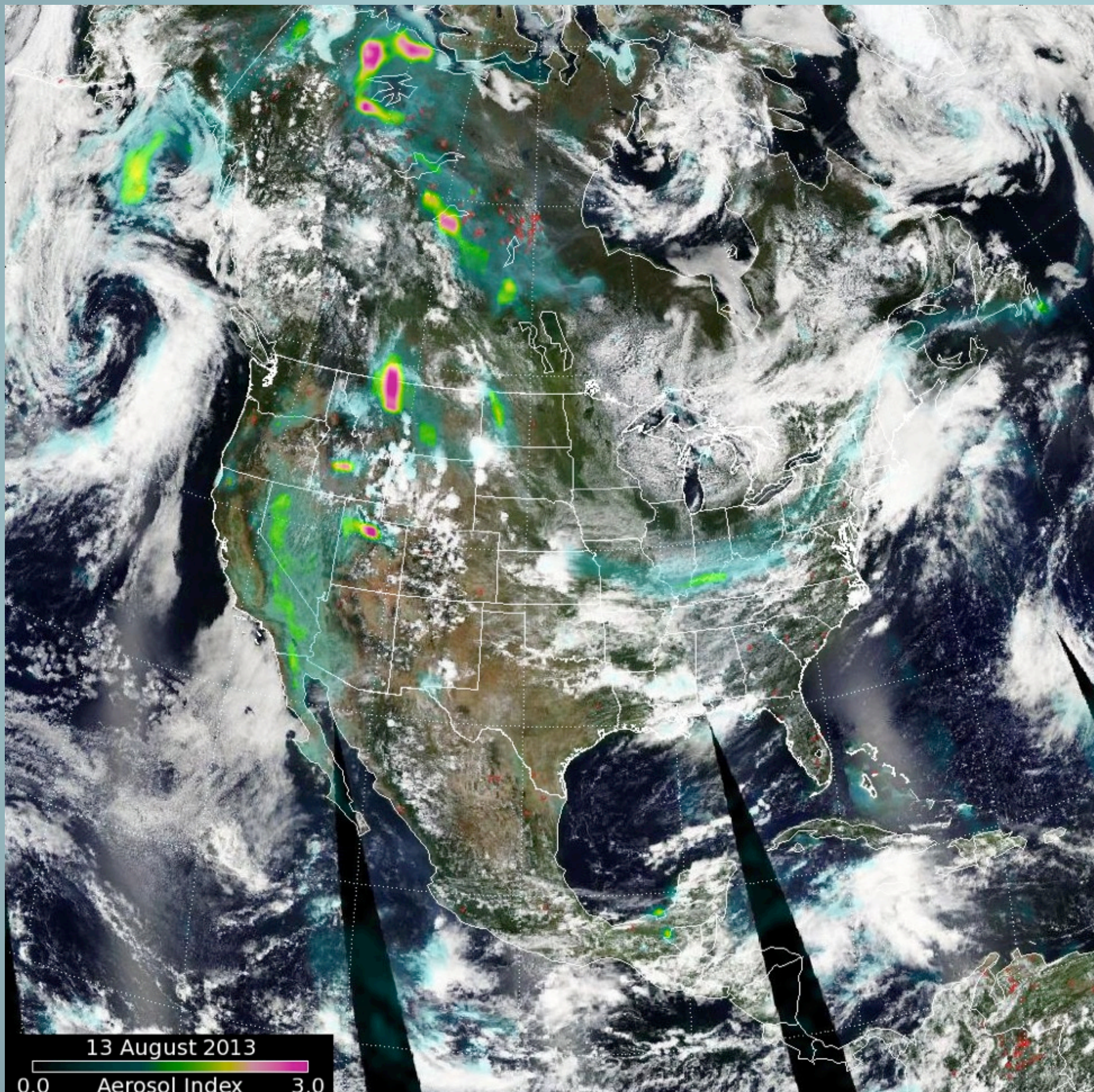
From the OMPS blog on 4 August 2013
Intense smoke over Russia





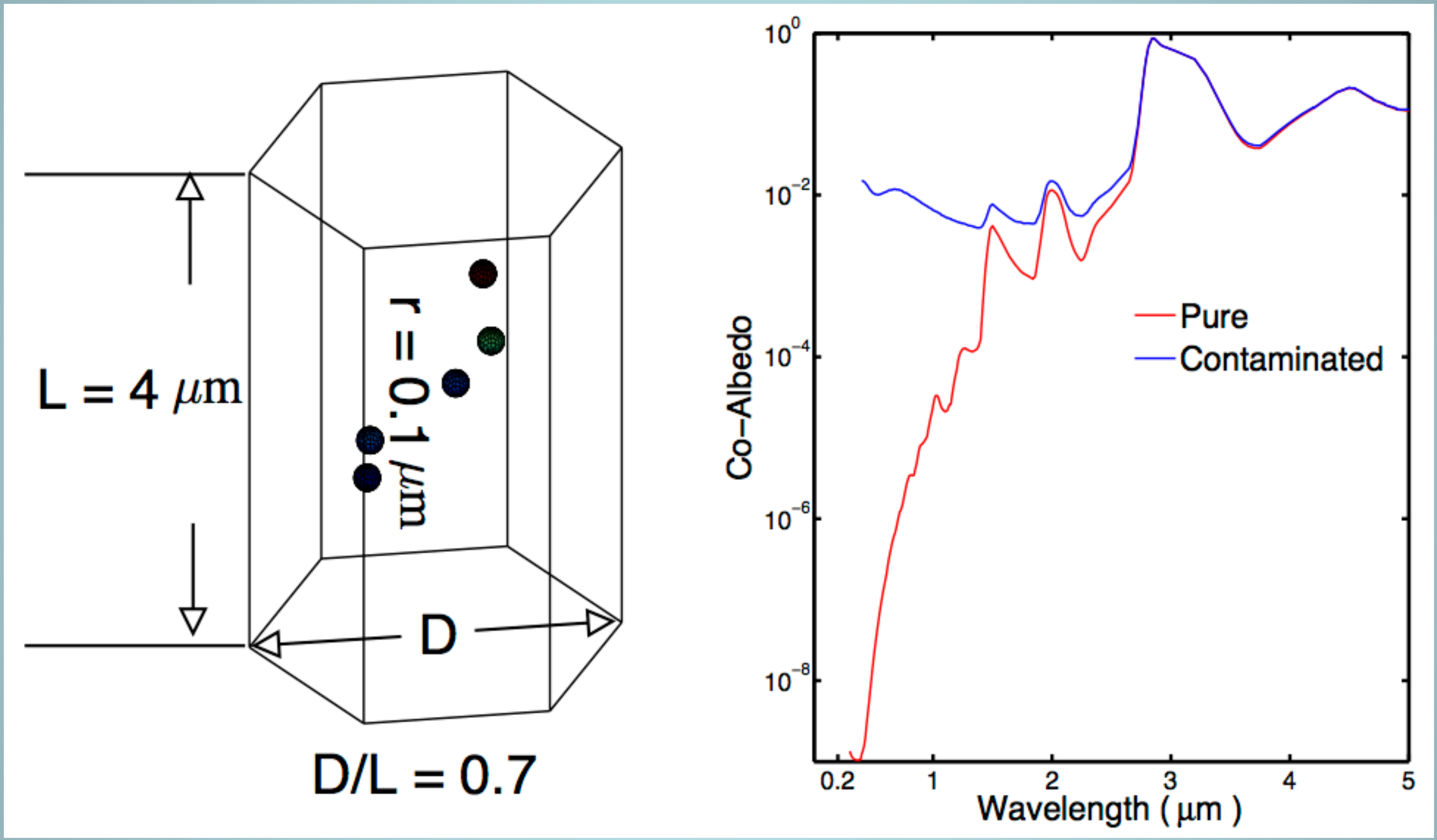
These images were made using only one (orbit 9163). This orbit provided the most nadir-looking data (the data with the smallest footprint, or highest resolution). Note the detail and information that the high resolution provides. Also note the scale; some of this smoke is quite intense, and some of it might be quite high in altitude. You can also track the most intense AI signal back to the fires that produced the smoke.

From the OMPS blog on 13 August 2013
http://ozoneaq.gsfc.nasa.gov/omps/blog

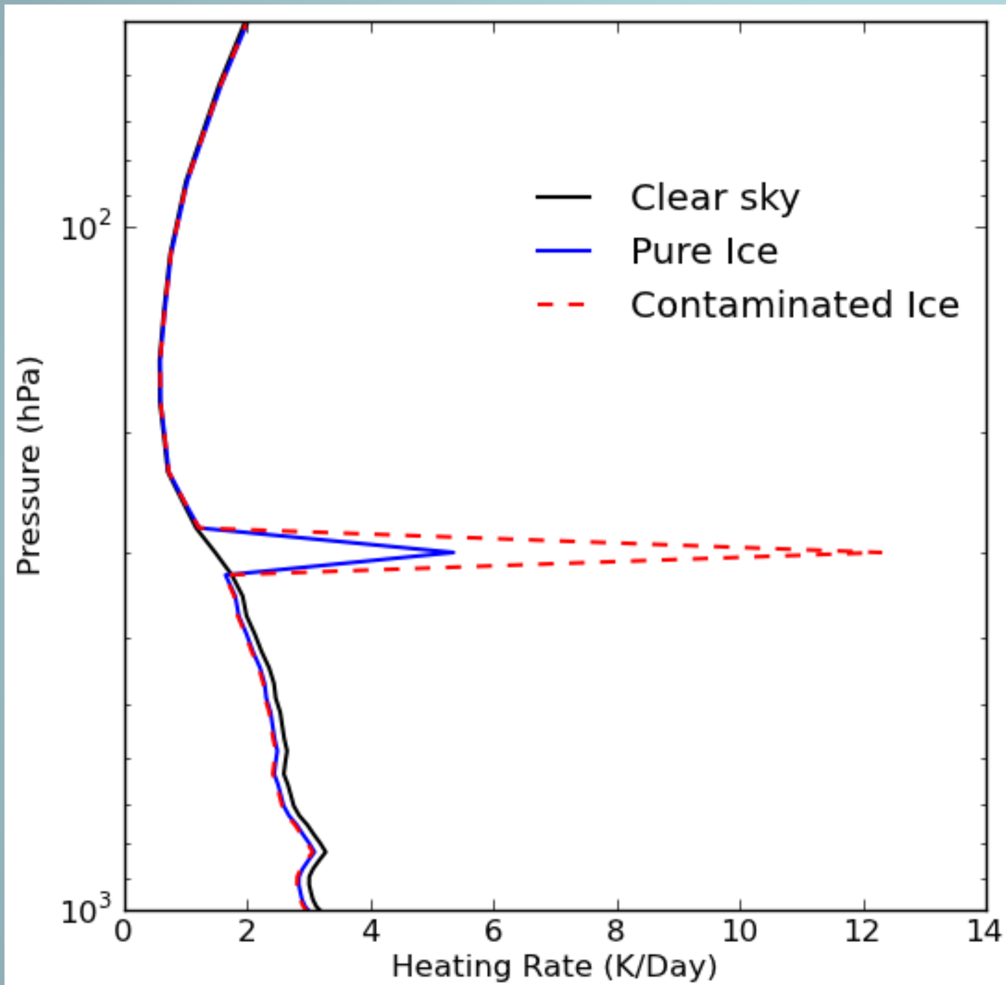


You can see the smoke outline a cold front as it pushes down from northwestern Canada, all the way down into the U.S. Mid-Atlantic, and then back up through New England and off the Candadian coast. The AI signal in California and Nevada is a combination of smoke (especially in northwest and east-central California) and some dust.

Ice particle with black carbon inclusions (e.g., aviation-induced contrail particles)



Radiative effect of black carbon inclusions on the heating rate



Ice particles: $D_{eff} = 20\ \mu m$

Ice particles include 10 spherical soot particles with a radius of 0.5 µm.

Cloud height = 276 hPa, and has a visible optical thickness of 0.5.

Standard tropical atmospheric profile

Solar zenith angle = 60°

Surface albedo is 0.1

Similar findings have been reported by Liou et al. (2013, GRL)

Instantaneous atmospheric and cloud heating rates associated with the clear-sky and ice clouds simulated with RRTMG.

Final thoughts

Bulk scattering property models now available from 0.2 to 100 μm for “pure” ice clouds

There will be times when heavy aerosols impact the ice clouds; models and retrievals do not capture this yet

We would like to build bulk scattering models for ice clouds impacted by absorbing aerosols (e.g., smoke, dust).

PyroCb blog: http://pyrocb.ssec.wisc.edu

Summary: New models will improve consistency of optical properties inferred from different sensors

Severe roughening is important for consistency between solar and IR retrievals

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

For IR retrievals: particle roughening should have little impact, but the small particle models will change from what was available previously due to use of PSDs measured at low IWC values (i.e., for $D_{eff} \leq 40$ μm)

Impact of roughened particle models on SW fluxes much greater than for LW fluxes

Pyro - CU over Yellowstone Park, USA 18 Aug 2013 / 17 Aug UTC

17 Aug 21: 56

17 Aug 21: 57z

17 Aug. 22:19

A consistent approach for the radiative properties of ice clouds and their application in remote sensing and climate models

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With thanks to Ping Yang, Andrew Heymsfield, Ben Cole, Chenxi Wang, Shaima Nasiri, Andrew Heidinger, Steve Platnick, Yu Xie, Zhibo Zhang, and others

LASP
CU-Boulder
October 23, 2013

Goal is better consistency

Can we provide ice cloud single-scattering and microphysical properties that will result in more consistent radiance calculations and satellite-based retrievals from the UV to the Far-IR?

Topics touched upon:

- bit of history related to one program, MODIS
- progress in improving the models based on different sensor comparisons
- development of consistent models from 0.2 to 100 μm
- beginning to explore impact on broadband RT models

Single Scattering and Microphysical Properties

Model parameters are a function of effective diameter and include:

- Total volume and projected area
- Ice water content (IWC)
- Single scattering albedo
- Asymmetry parameter
- Extinction efficiency
- Extinction coefficient divided by the ice water content
- Full phase matrix (P_{11}, P_{21}, P_{22}, P_{33}, P_{43}, P_{44})

Baum et al. 2011

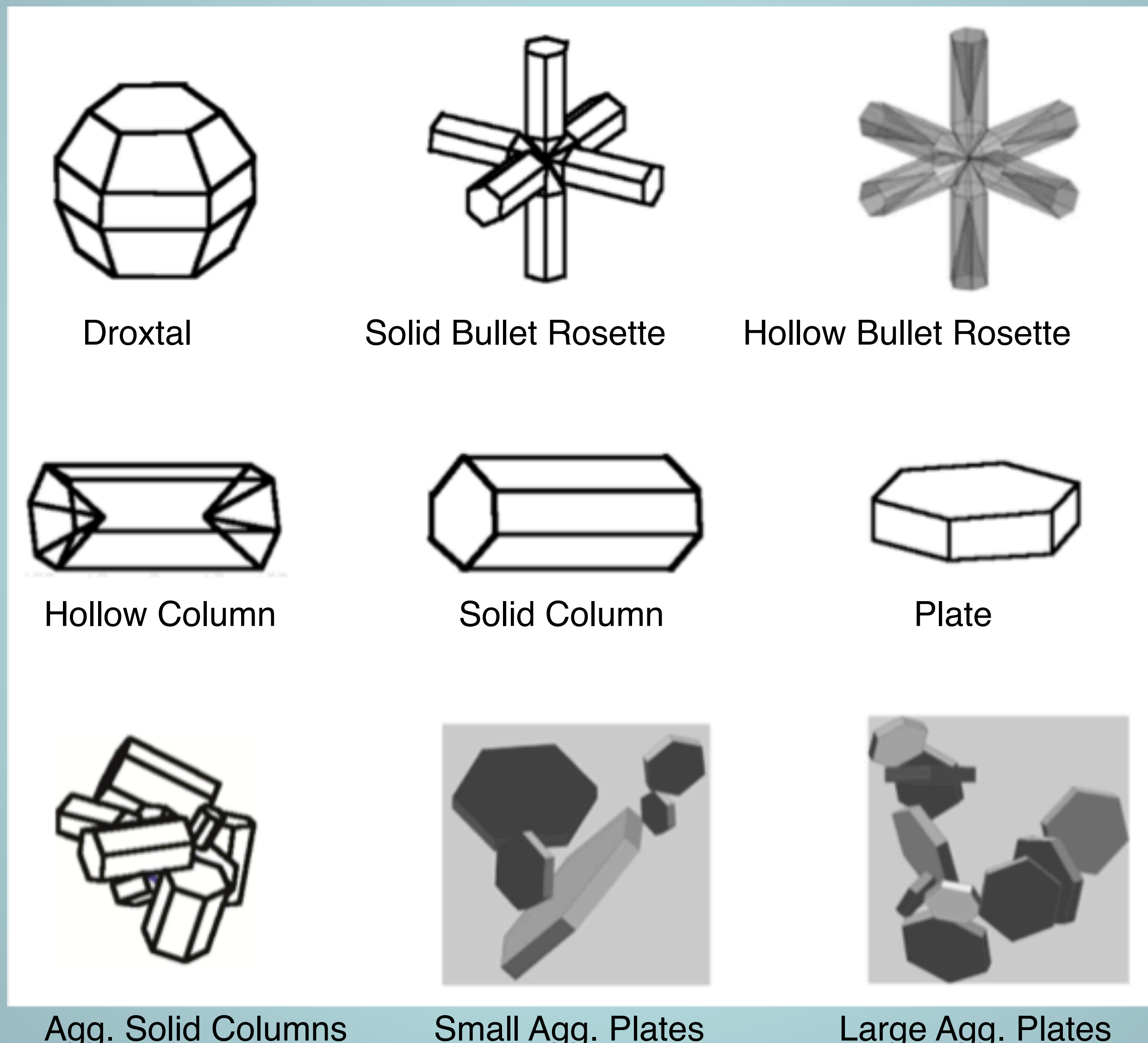
Microphysical Data

http://www.ssec.wisc.edu/ice_models/microphysical_data.html

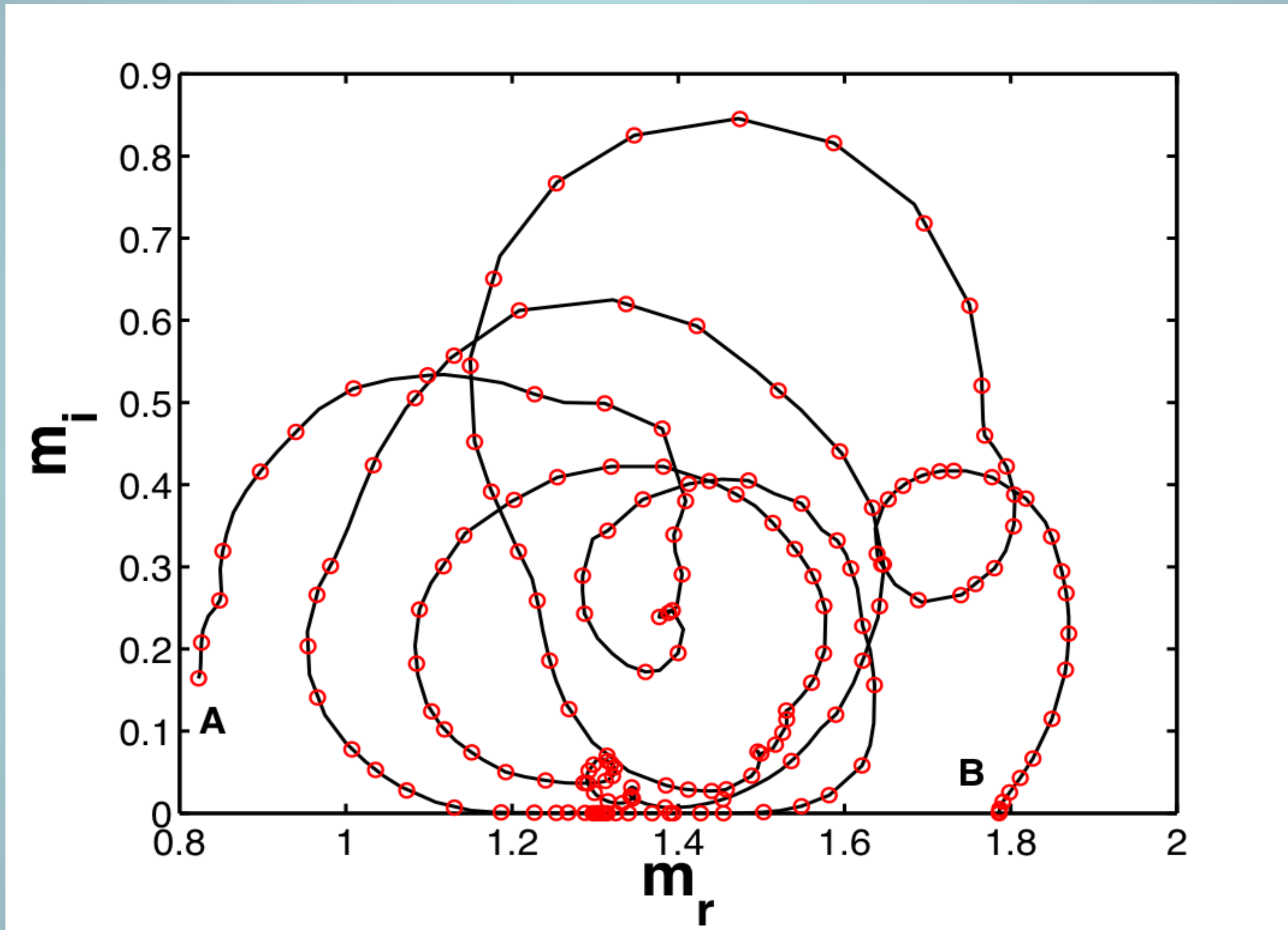
Field Campaign	Location	Instruments	# PSDs
ARM-IOP (UND Citation)	Oklahoma, USA 2000	2D-C, 2D-P	1420
TRMM-KWAJEX (UND Citation)	Kwajalein, Marshall Islands, 1999	2D-C, HVPS	201
CRYSTAL-FACE (NSA WB-57F)	SE Florida/Caribbean 2002	CAPS (CIP, CAS), VIPS	221
SCOUT (Geophysica)	Darwin, Australia 2005	FSSP, CIP	358
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	2968
Pre-AVE (NASA WB-57F)	Costa Rica 2004	VIPS	99
TC-4	Costa Rica 2007	CAPS, PIP	877
MPACE	Alaska	2D-C	671

Heymsfield, et al. 2013. *In press, J. Atmos. Sci.*

Initial set of Ice Habits Used to Develop Single-Scattering Properties



Development of spectrally consistent scattering database



445 wavelengths from 0.2 to 100 μm (data taken from Warren and Brandt, JGR, 2008)

Some comparisons and results…

For the 445 wavelengths, results will be shown for the

a. general habit mixture (GHM, the way we think makes sense)

b. solid columns (similar to the CERES team)

c. aggregate of solid columns (similar to MODIS Collection 6)

Compare:

a. microphysical properties: models to measurements

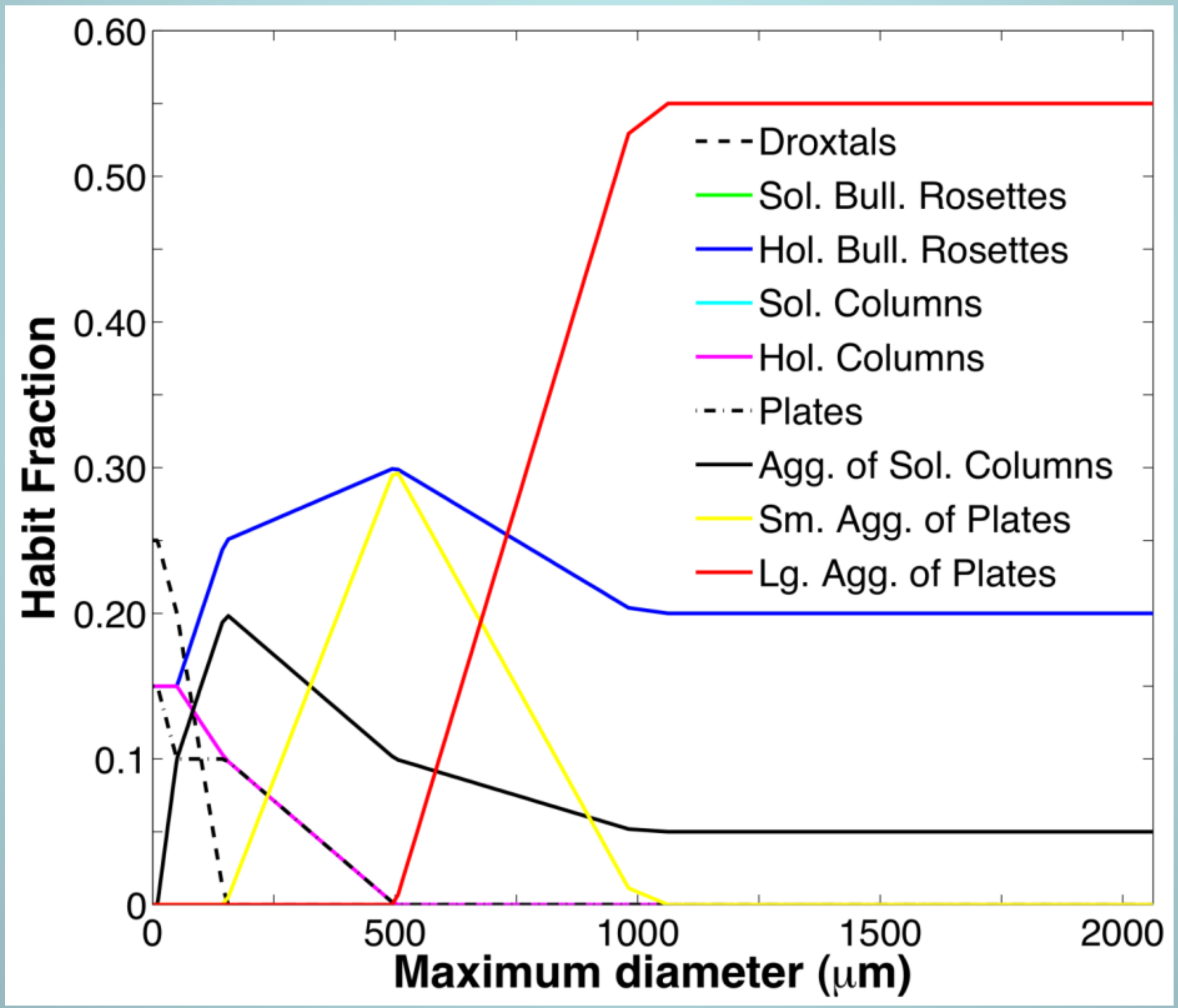
b. polarized reflectances: models to PARASOL/POLDER

c. single-scattering properties (GHM, columns, aggregate of columns)

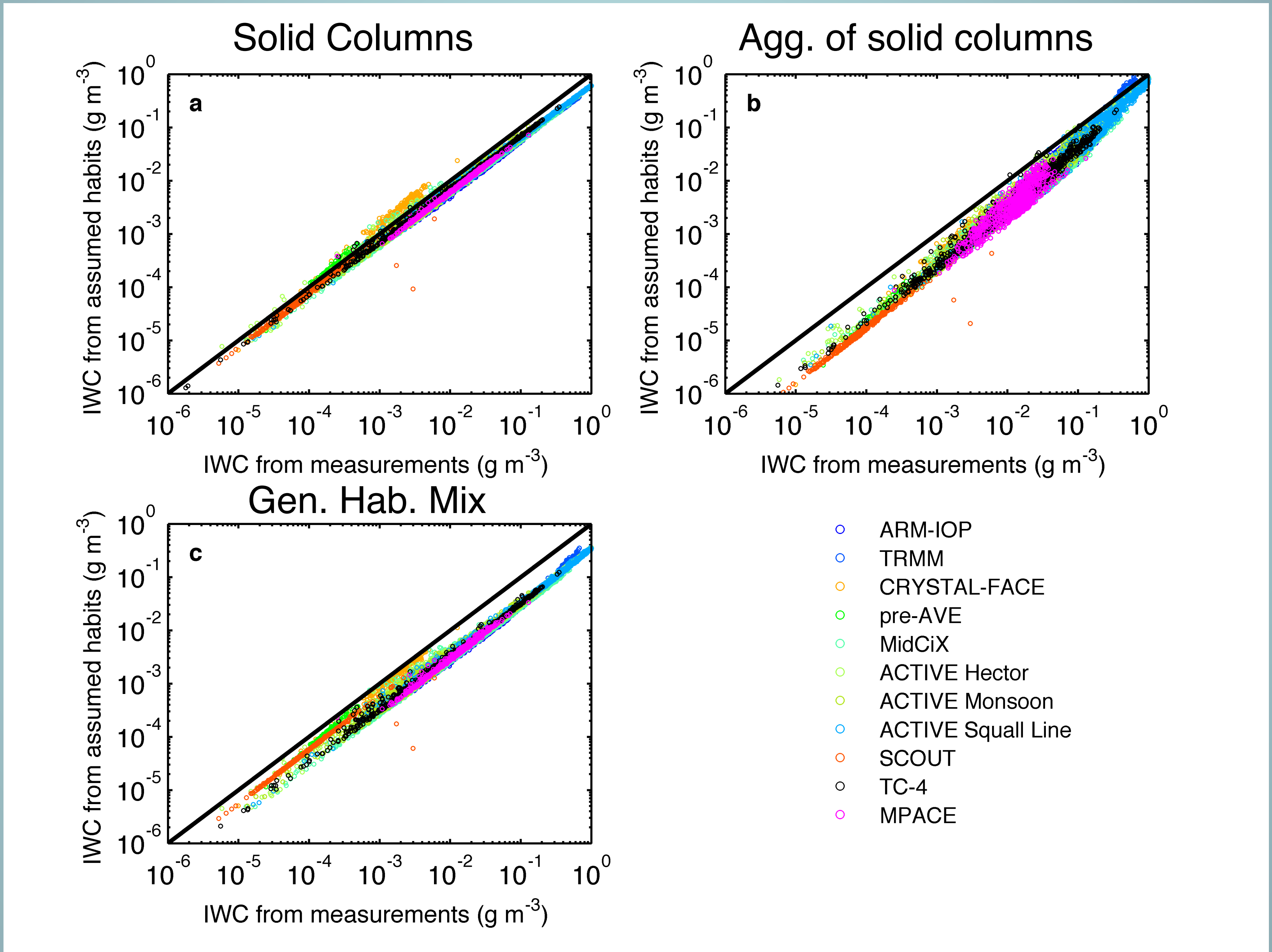
d. broadband properties, smooth vs. roughened particle models

General habit mixture

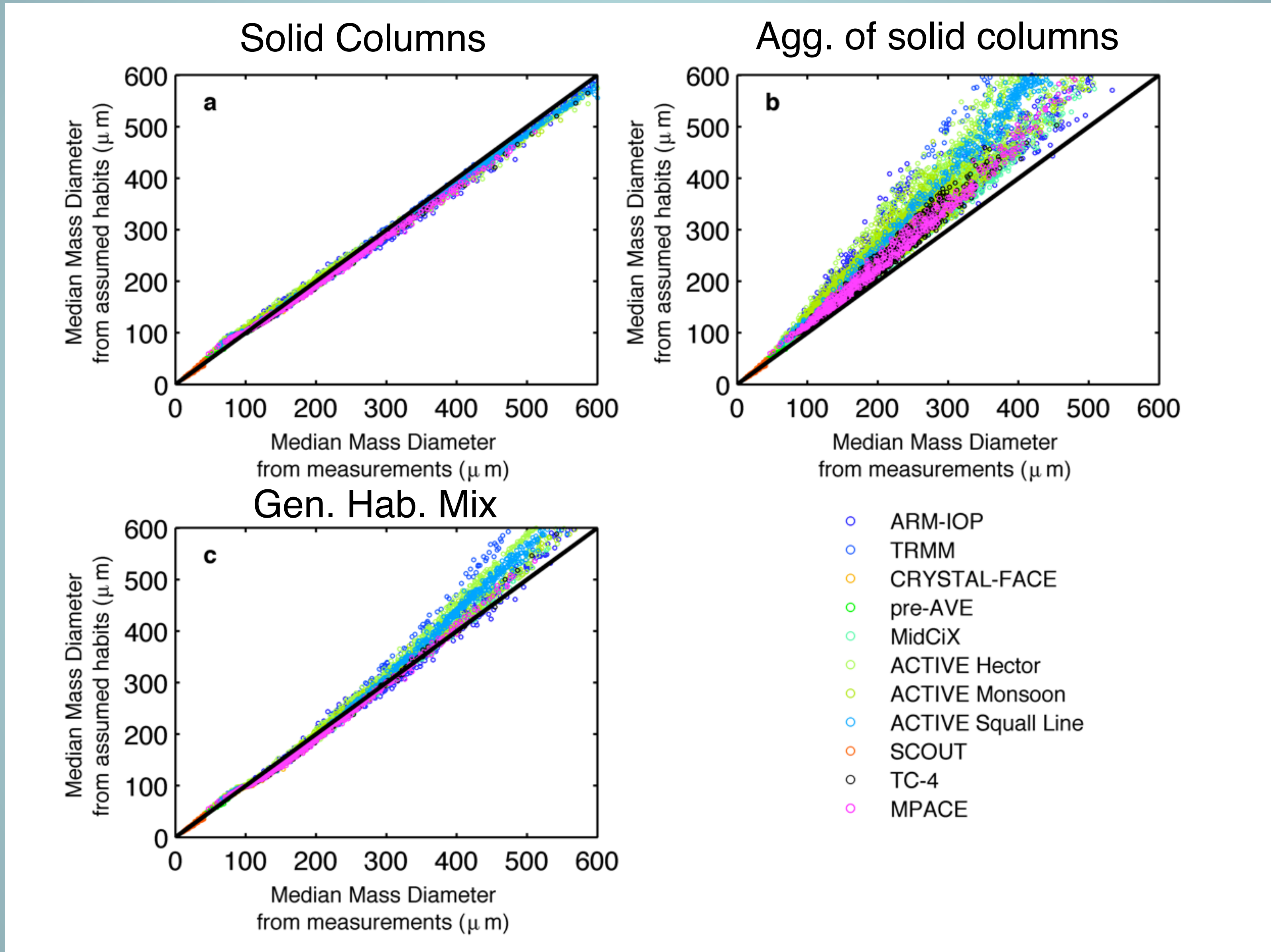
- Percentage of habits changes linearly as the size changes
- Developed by Schmitt and Heymsfield (NCAR)



IWC comparison between different habit models and measurements…

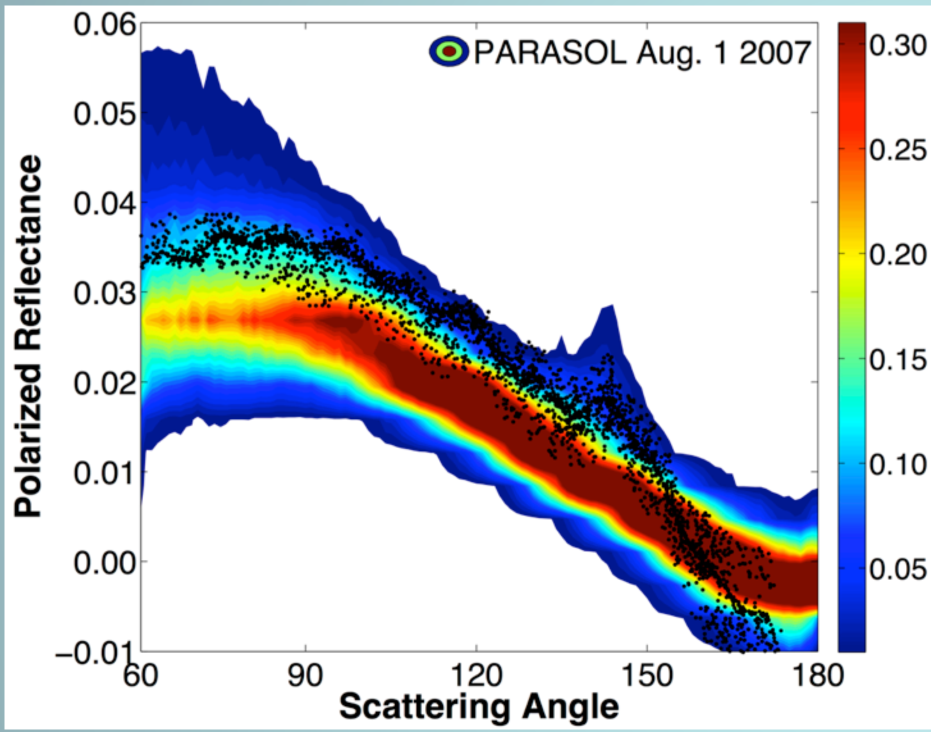


Median mass diameter comparison between different habit models and measurements

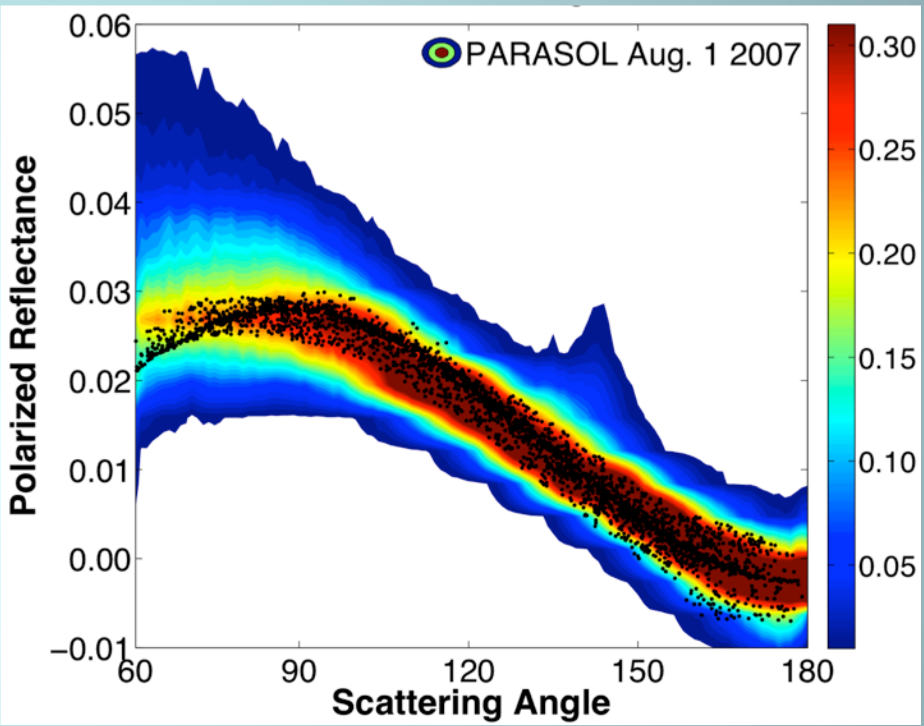


Comparison of PARASOL polarized reflectances over ocean to simulations using a habit mixture for D_{eff} = 70 μm

Smooth



Severely Roughened



Normalized Polarized Reflectance

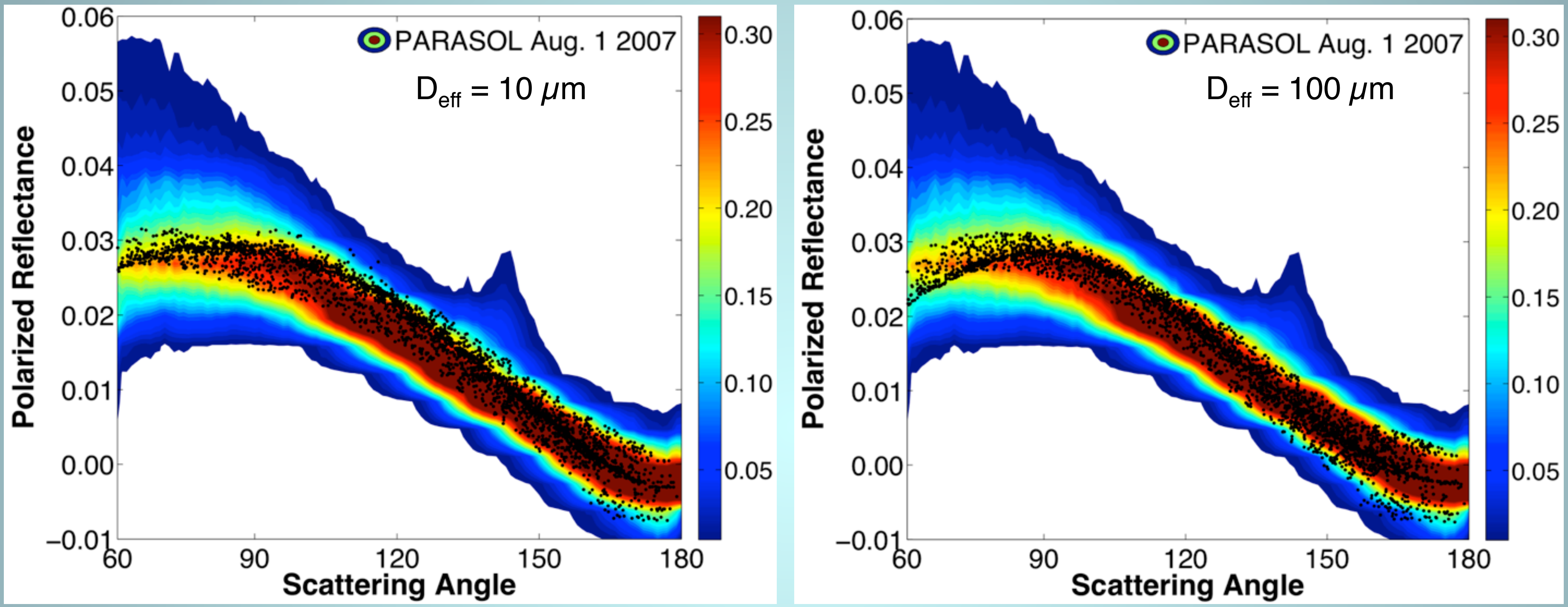
$$L(\theta_s, \theta_v, \phi_s - \phi_v) = \frac{\pi sgn\sqrt{Q^2 + U^2}}{E_s} \frac{\cos\theta_s + \cos\theta_v}{\cos\theta_s}$$

Single scattering approximation

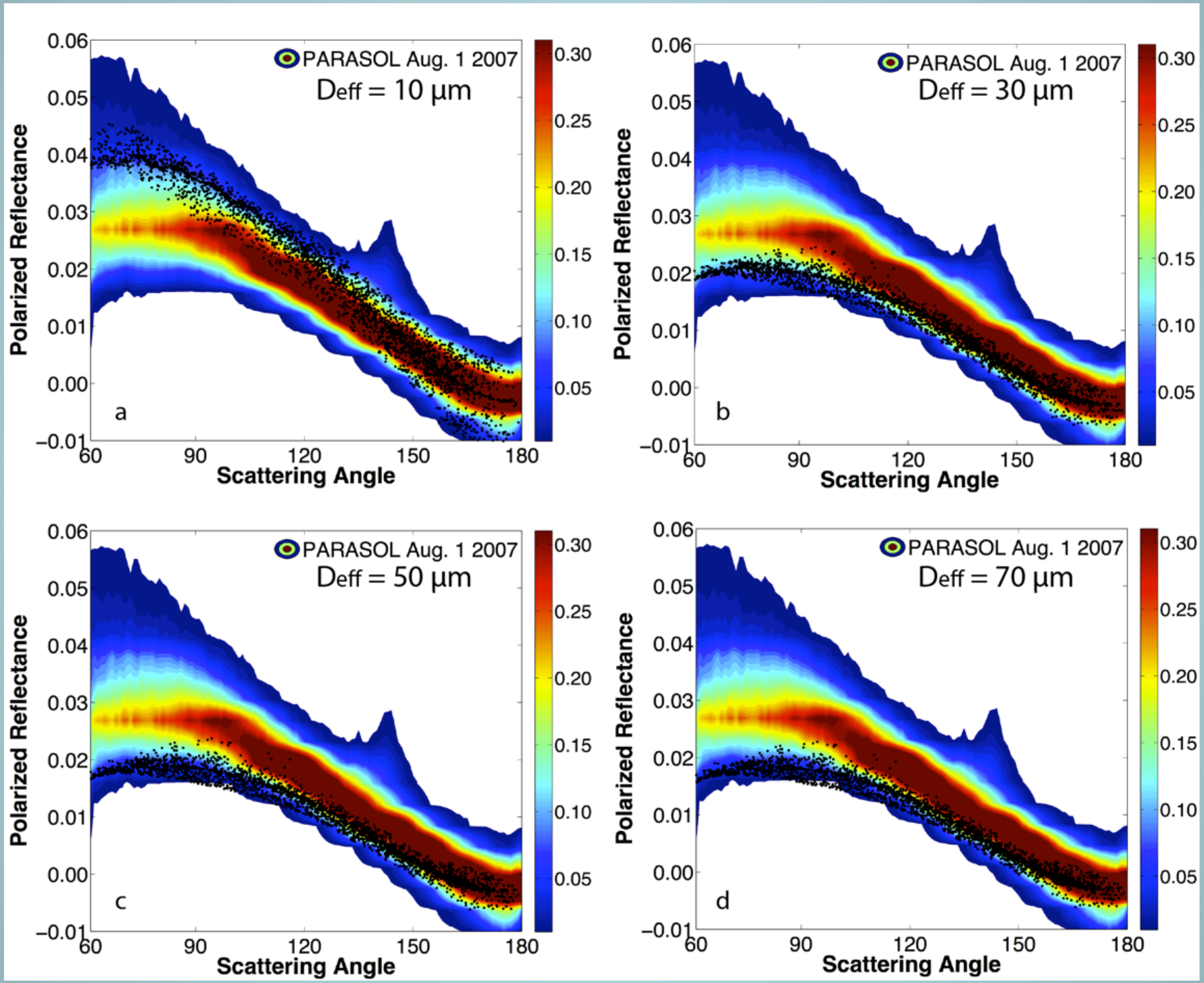
$$L(\theta_s, \theta_v, \phi_s - \phi_v) \approx L(\Theta) = -\frac{\omega_0 P_{12}(\Theta)}{4P_{11}}$$

Cole et al. 2013

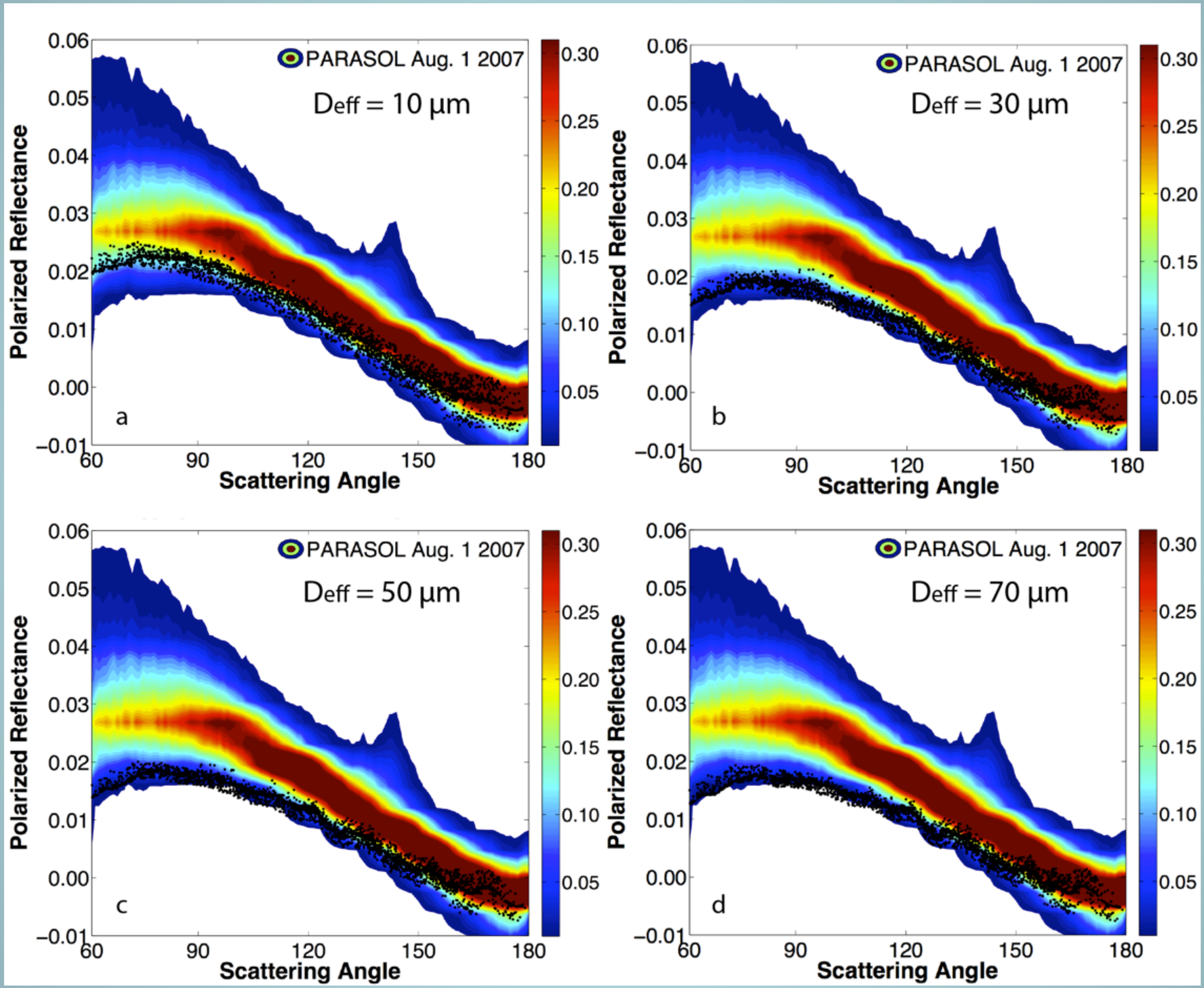
Does the GHM consistency hold for all D_{eff}?



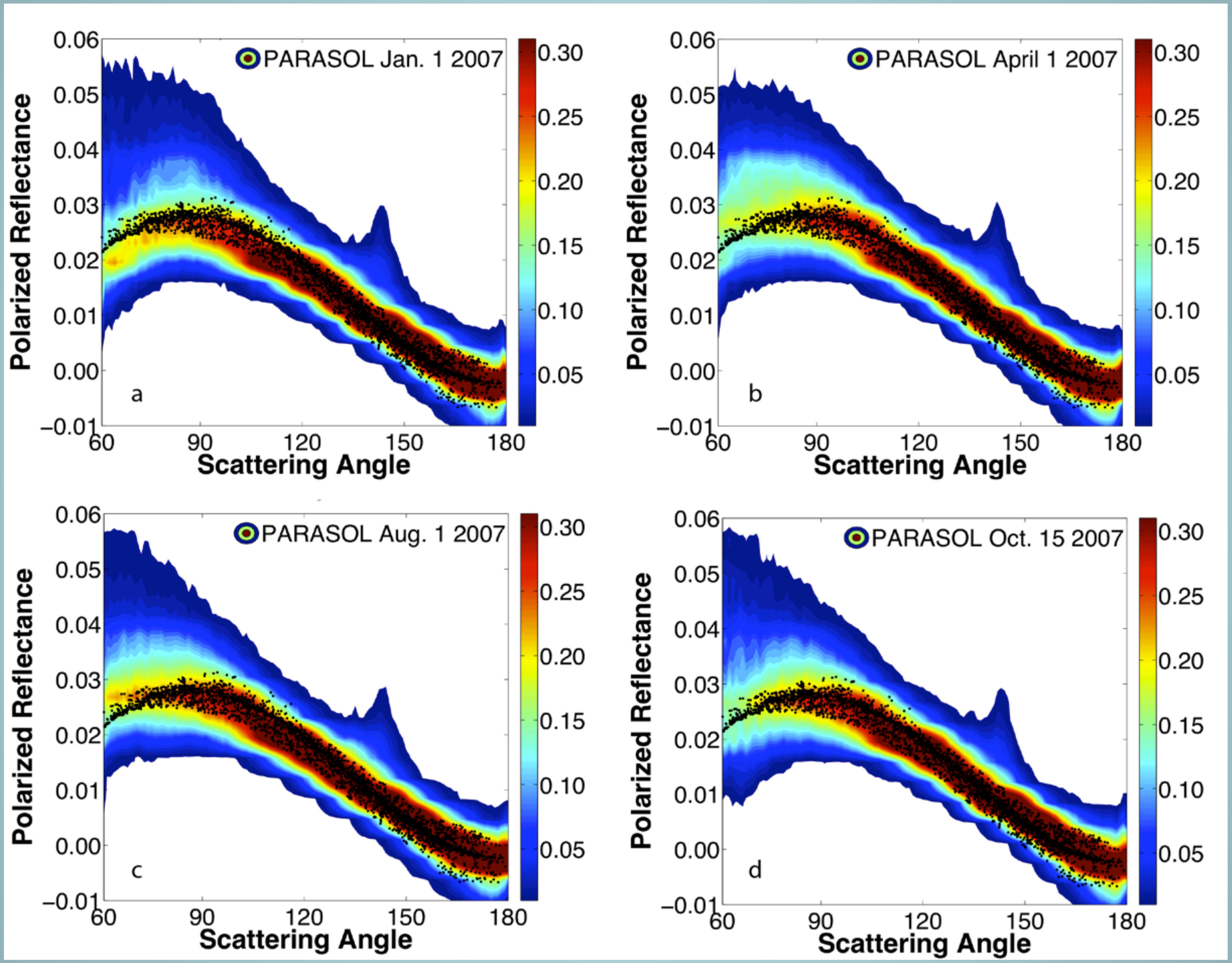
Severely roughened solid columns do not compare as closely…



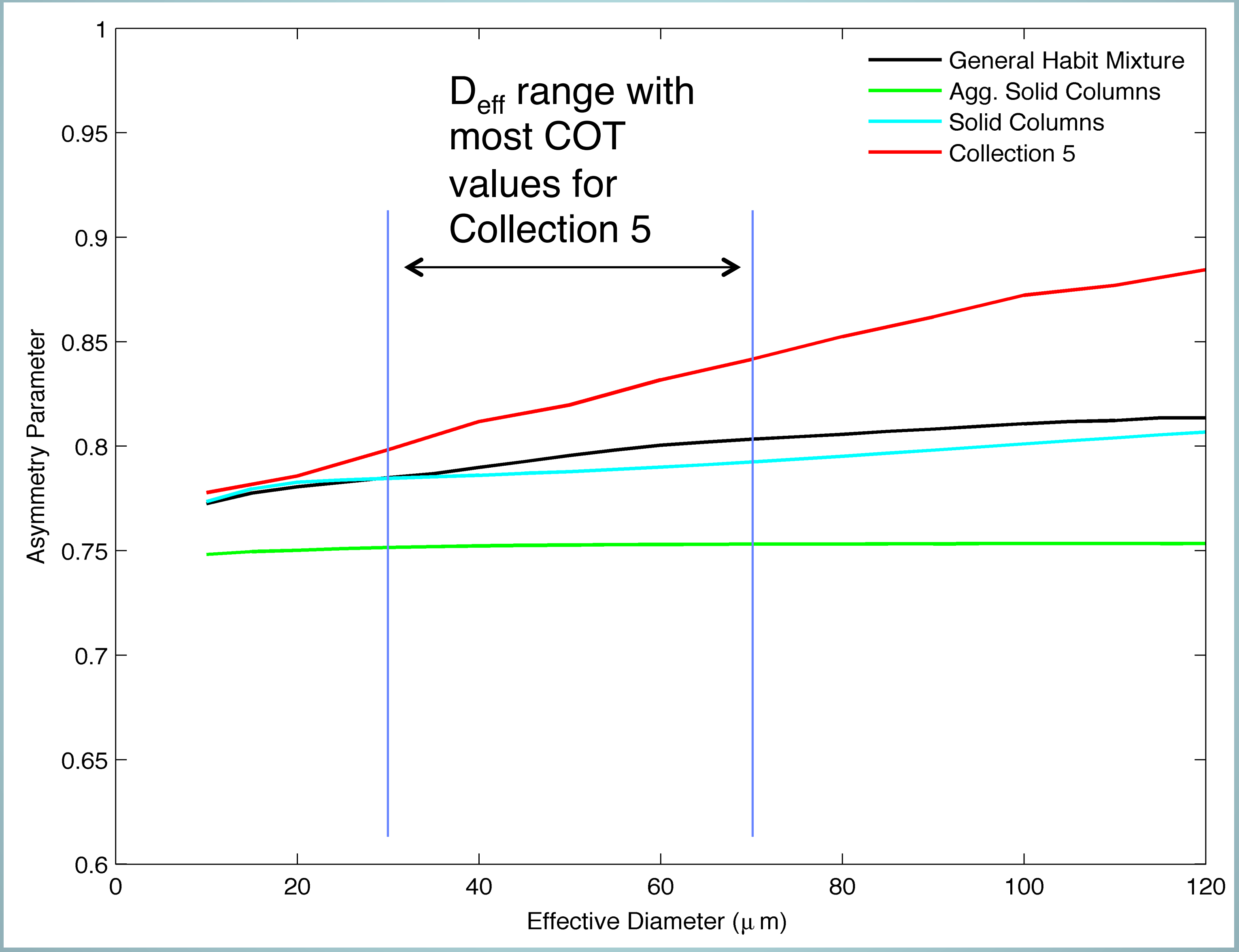
Severely roughened aggregate of solid columns does not compare well either…



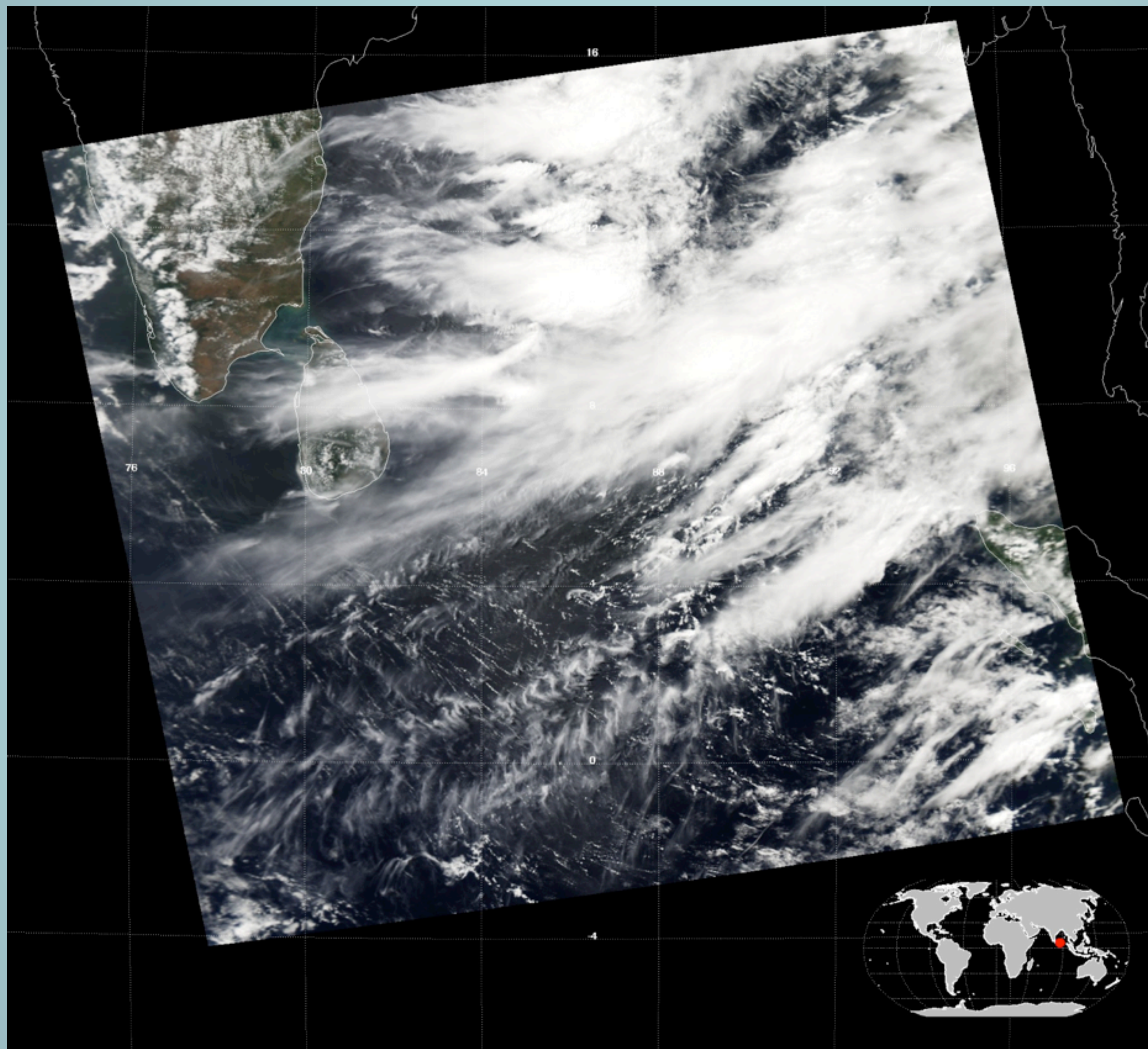
Severely roughened GHM compares closely for all sizes, and also seasons…



Impact of habit and particle roughening on the asymmetry parameter at 0.65 μm

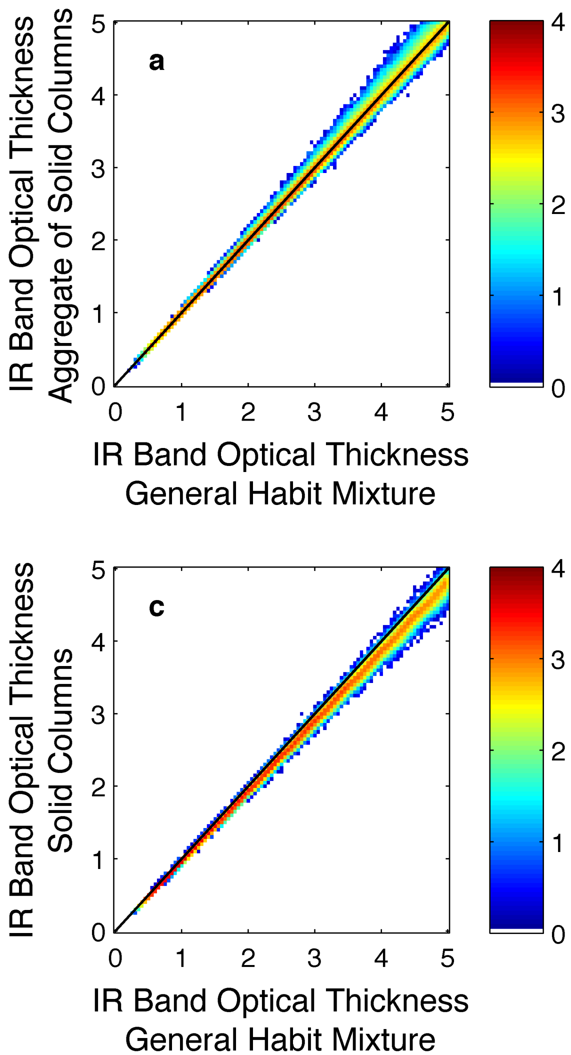


Test whether consistency improves between solar and IR retrievals…



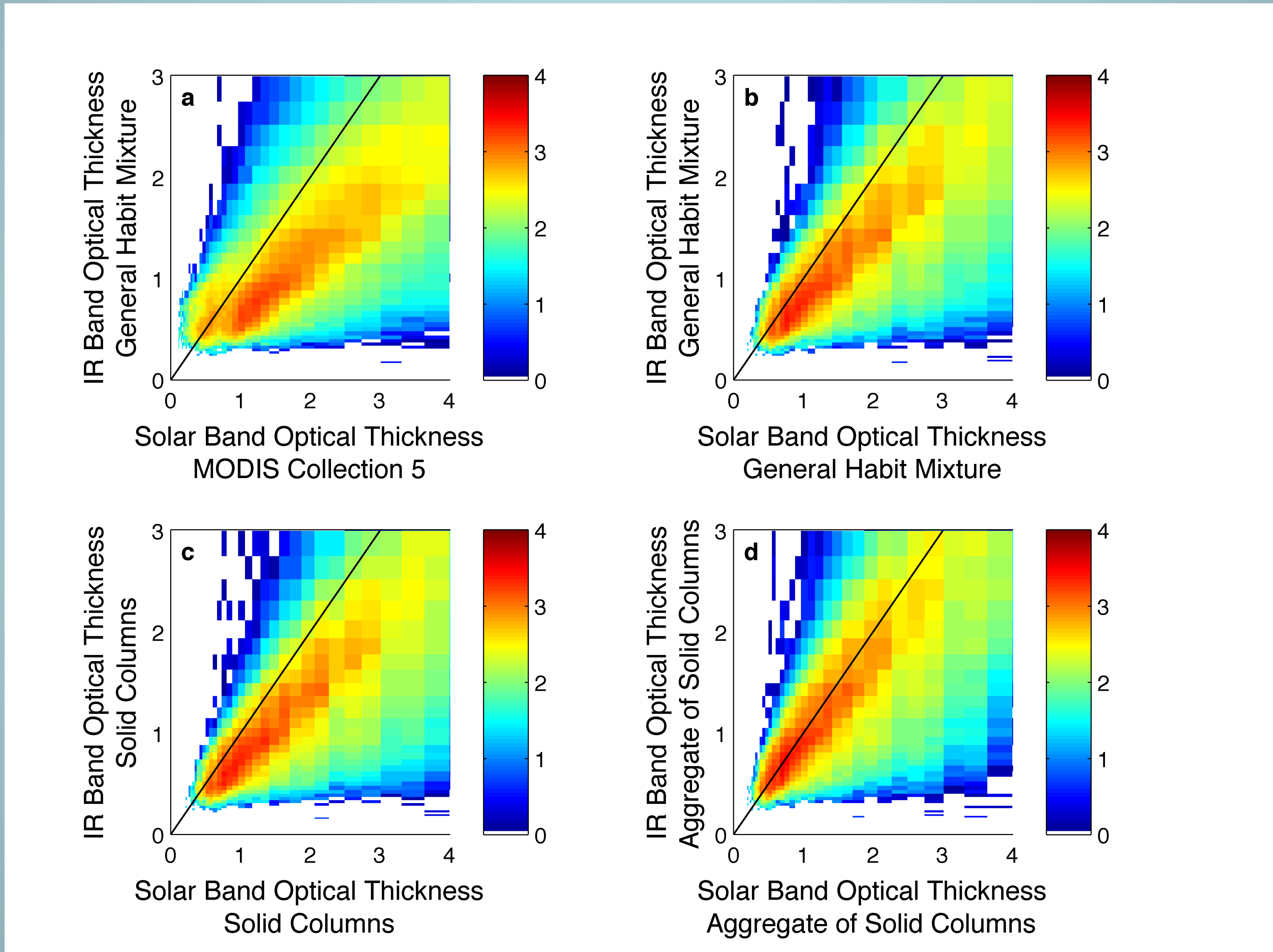
MODIS Aqua scene from 2 August 2010 at 0745 UTC; Bay of Bengal

Particle roughening has little influence on IR optical thickness retrievals…



Baum et al. 2013

Particle roughening decreases the differences between solar and IR optical thickness retrievals…



Courtesy of Chenxi Wang; based on Wang et al. 2011; 2013