Comparison between simulated cloud radiative forcing and CERES measurements

Souichiro Hioki, Ping Yang

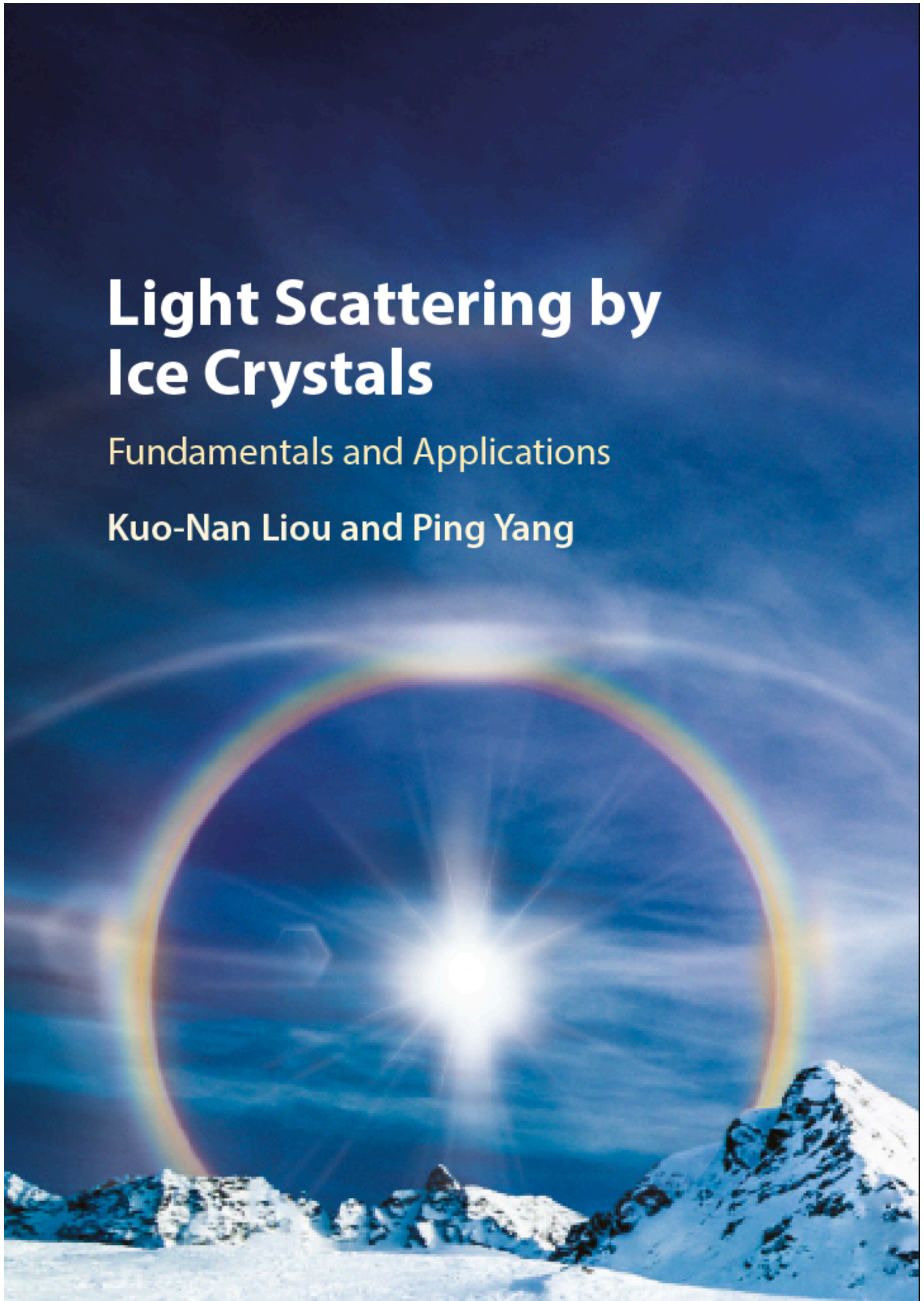
Department of Atmospheric Sciences, Texas A&M University, Texas, USA

In collaboration with

Patrick Minnis, Norman Loeb, Seiji Kato,
Gang Hong and Sunny Sun-Mack

Improved Light Scattering Computational Capabilities

- Small to moderate size parameters: the invariant imbedding T-matrix method (II-TM)
- Large size parameters: the Improved Geometric Optics Method (IGOM) with the incorporation of improvements of inhomogeneous waves inside ice crystals at infrared wavelengths
- Incorporation of the Edge effect (photon tunneling) in the transition from the II-TM to IGOM results

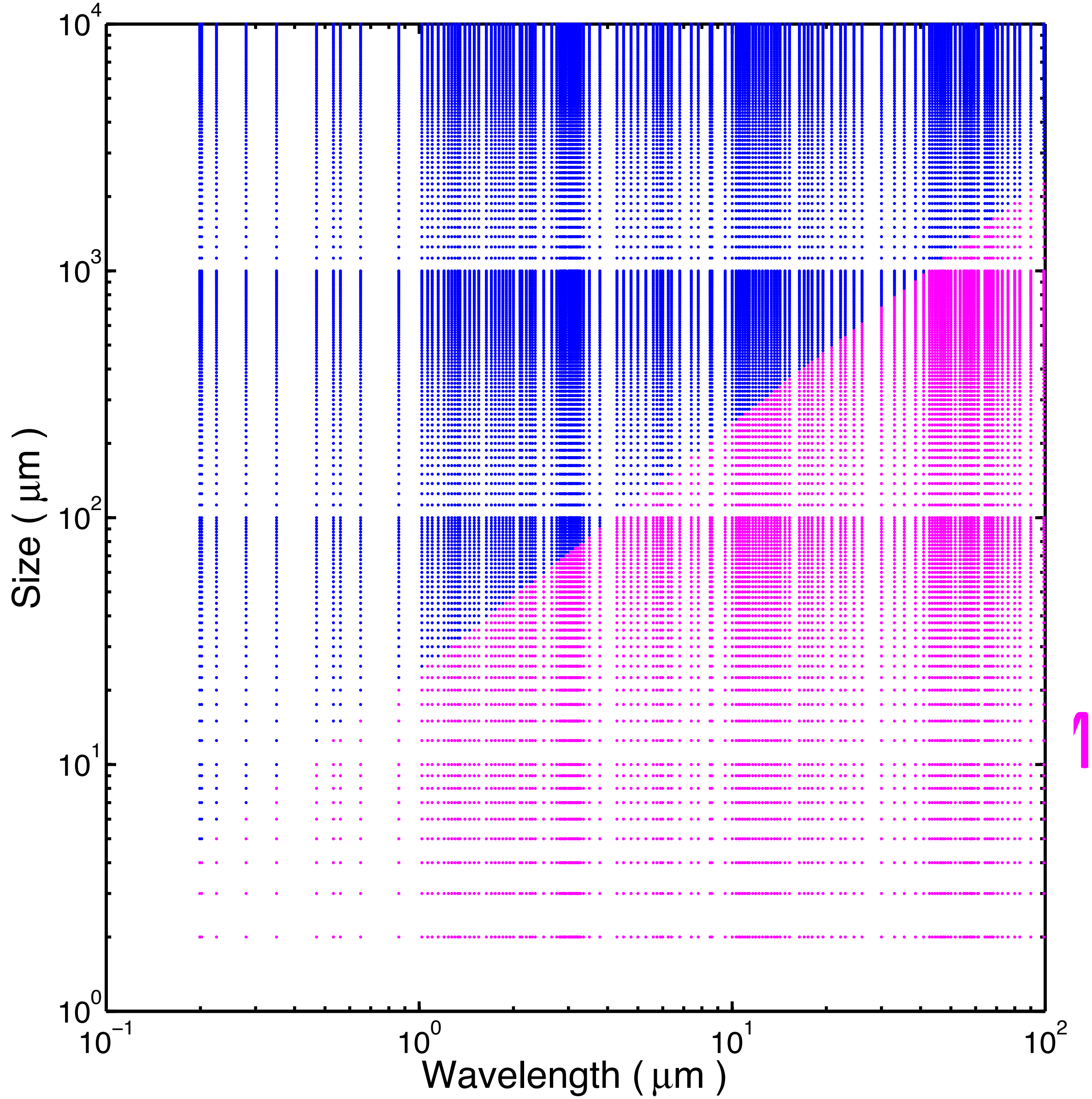


To all the happy ice crystals in planetary atmospheres.

Let there be light.
Let there be beautiful ice crystals in the air and
    mountain ranges.
And here come the reindeers and Santa Claus
    carrying Maxwell's equations, and light rays
    are shining in the wonderlands.
Let the glory of Geometric Optics for ice crystals,
    Newton's optics, and sun's light rays rise
    again from the horizon.
Let ice crystals' old friends - black carbon and
    dust - be not forgot for Auld Lang Syne.
And ice crystals are carried by the ceaseless
    winds; and
After travelling thousands of miles up and down,
    the sky looks very blue.
Let there be space missions to tender ubiquitous
    light rays in the sky,
And all things considered, let light scattering by
    ice crystals in remote sensing and climate
    change be a delight.

-- Liou & Yang

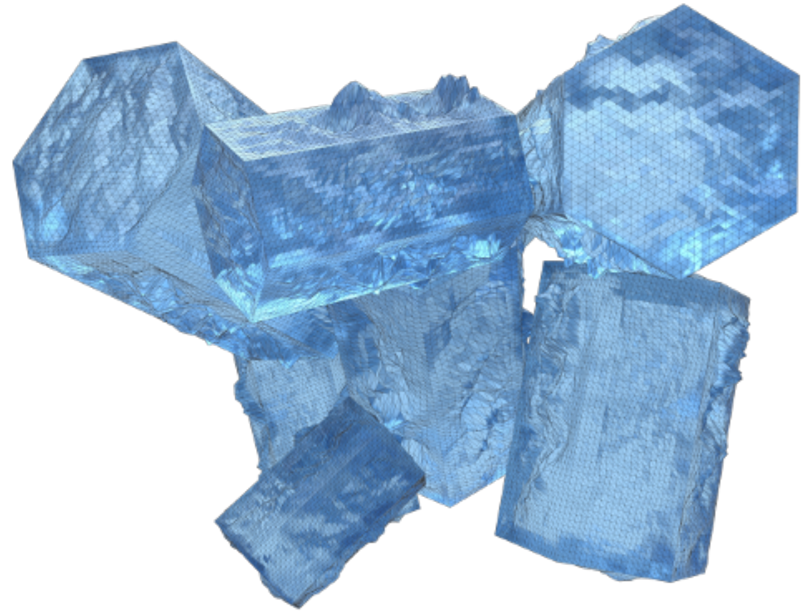
Ice Particle Optical Property Simulation

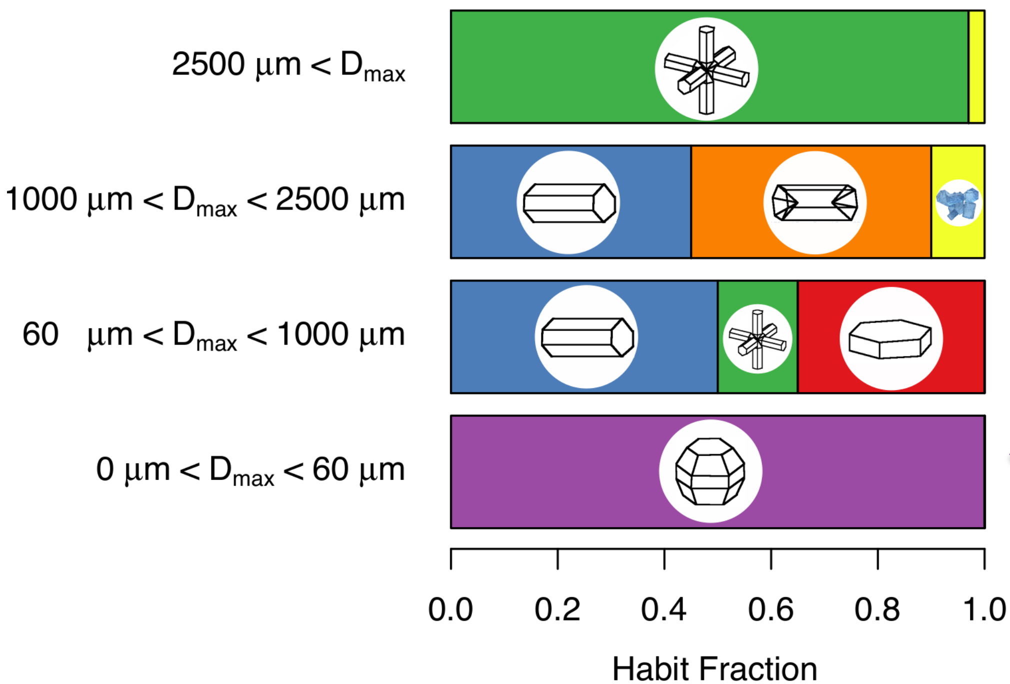


Ice models in MODIS Collection 5 and 6

MODIS Collection 6

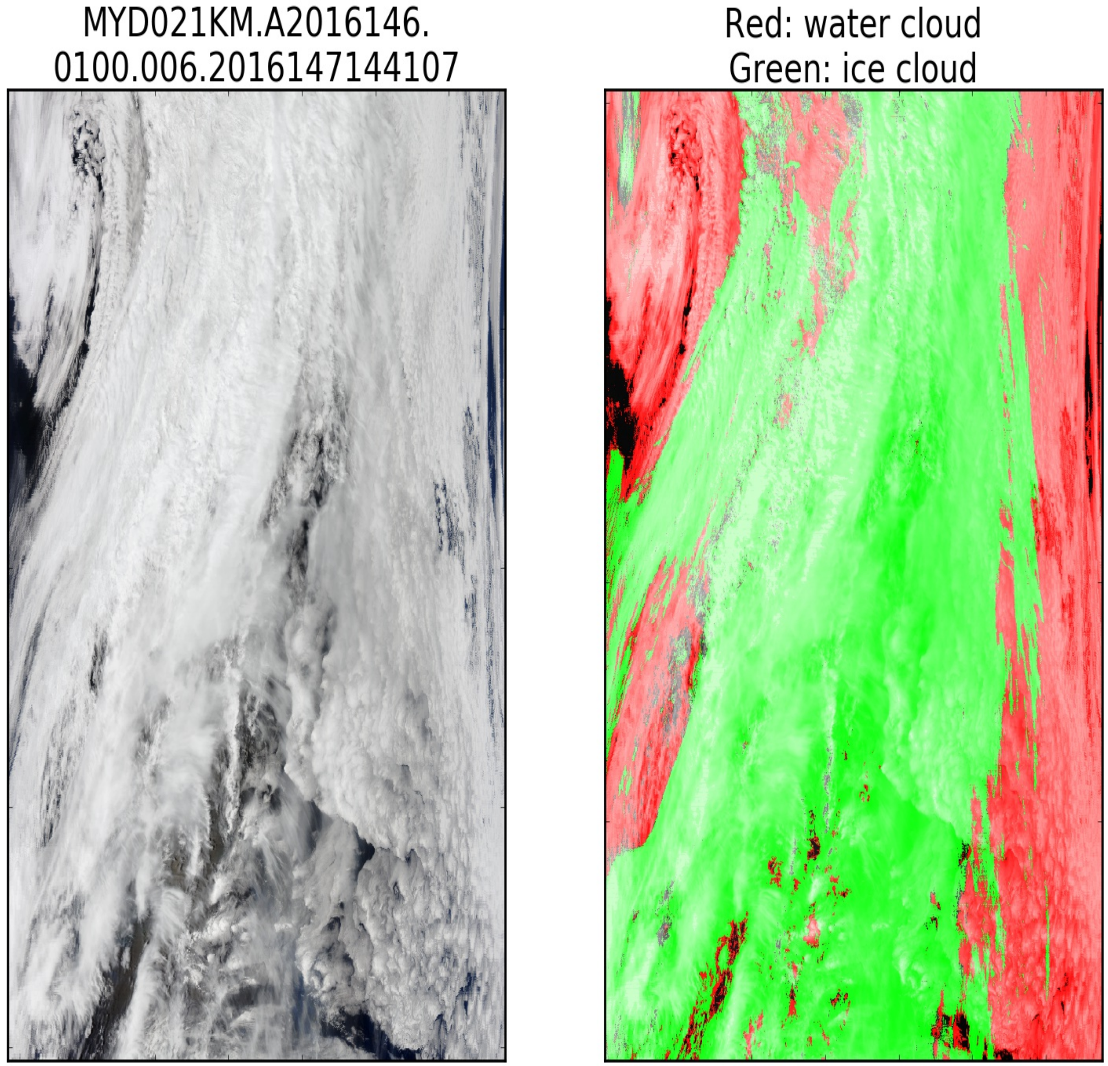
100 % Column Aggregate





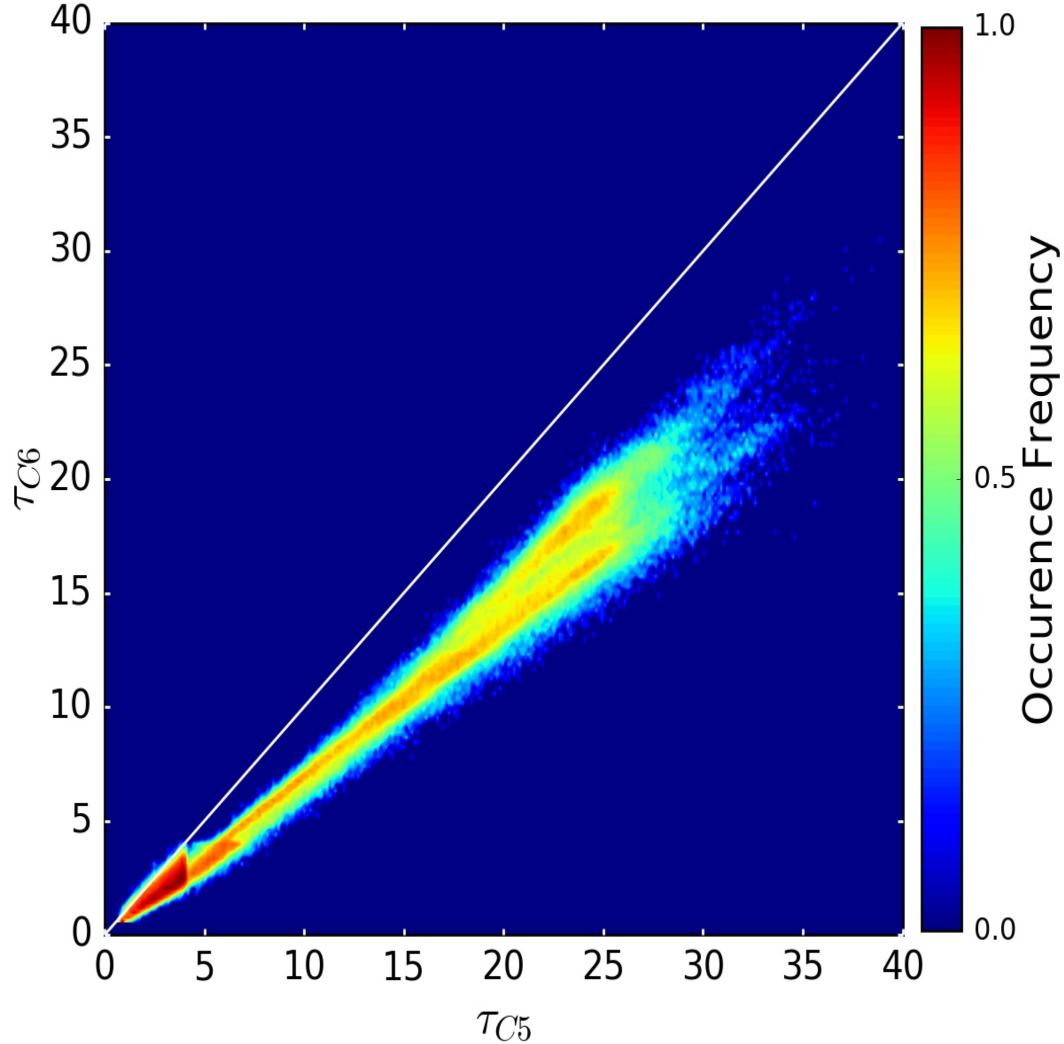
MODIS Collection 5

Mixture of Smooth Particles



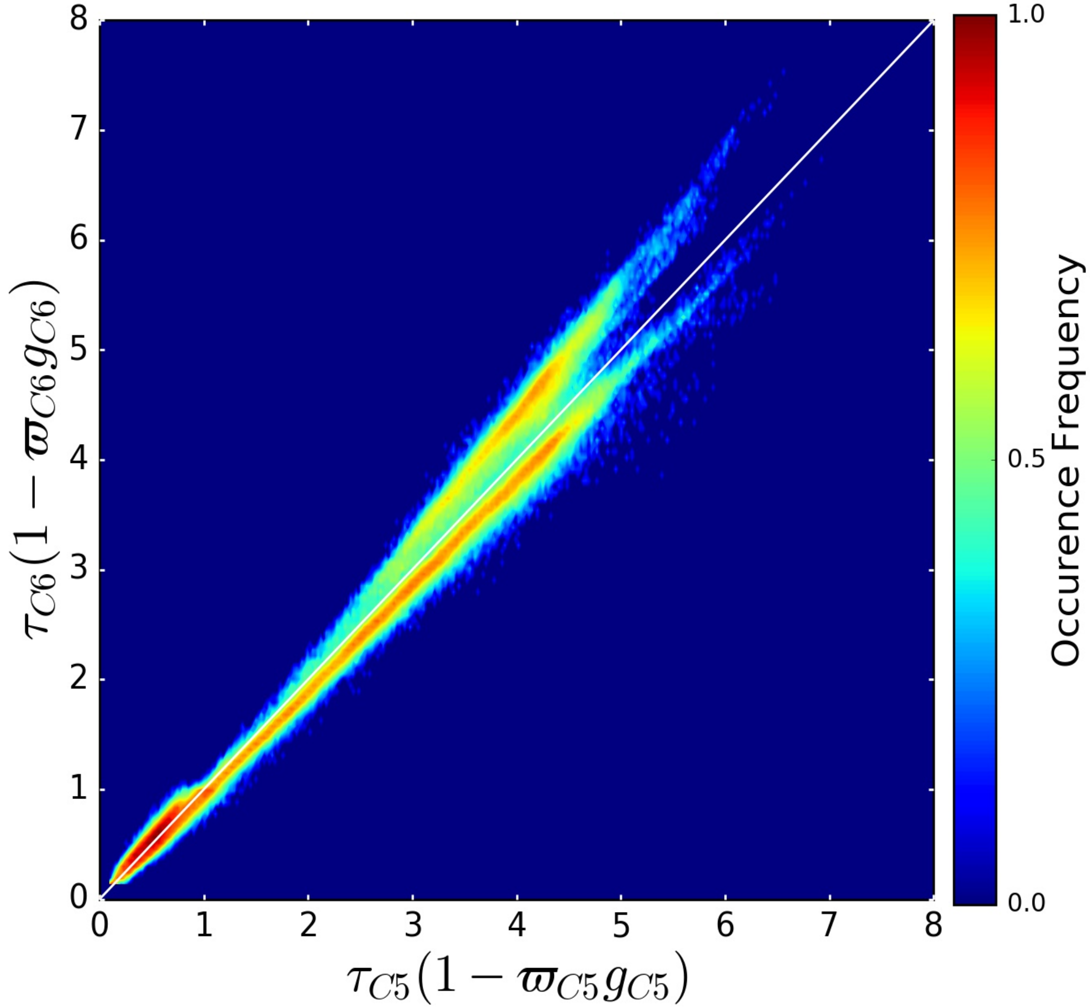
Left: RGB image of Aqua MODIS Level 1B reflectance data (MYD021KM.A2016146.0100.006.2016147144107) **Right:** Distribution of cloud phases (from MODIS C6 Level 2 data) in the granule overlapped on band 2 gray-scale image (courtesy of J. Ding)

Cloud Optical Thickness



Comparison of C5 and C6 ice cloud optical thickness at 0.55 μm wavelength. The white straight line is the one-to-one ratio line (courtesy of J. Ding)

Scaled Cloud Optical Thickness

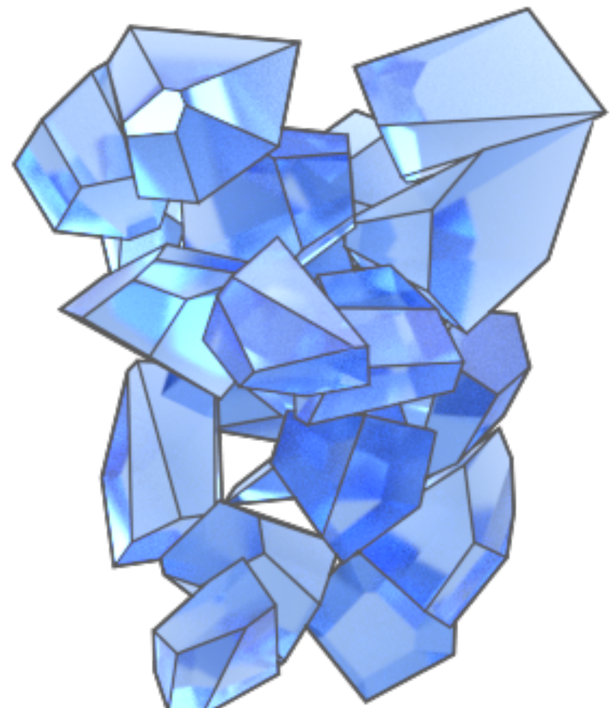


Comparison of $\tau(1-\varpi g)$ for C5 and C6 ice cloud optical thickness data in MODIS Level 2 Cloud Products. The white straight line is the one-to-one ratio line (courtesy of J. Ding)

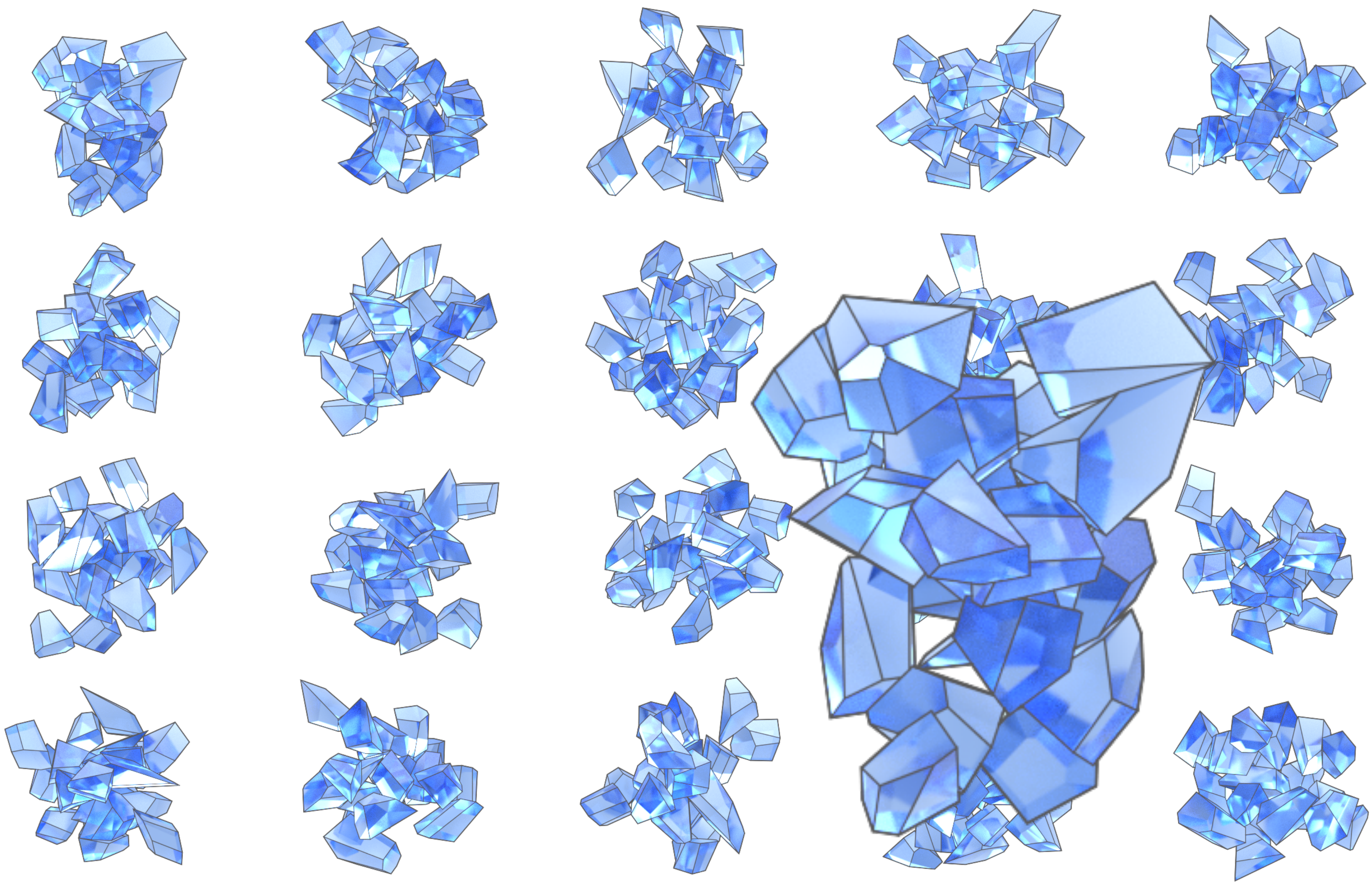
The New Two-habit Model

Roughened
Single Column

Aggregate of
Distorted Columns



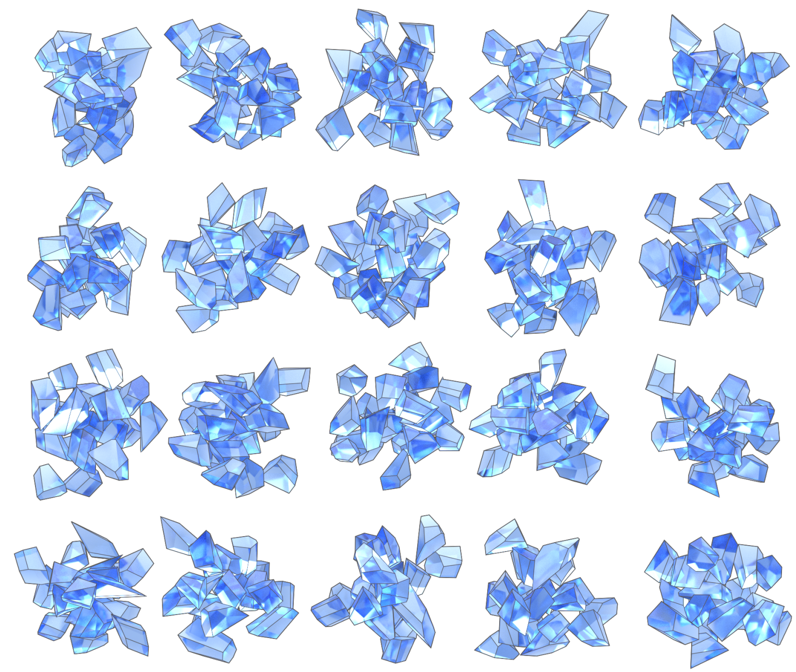
The New Two-habit Model



The New Two-habit Model

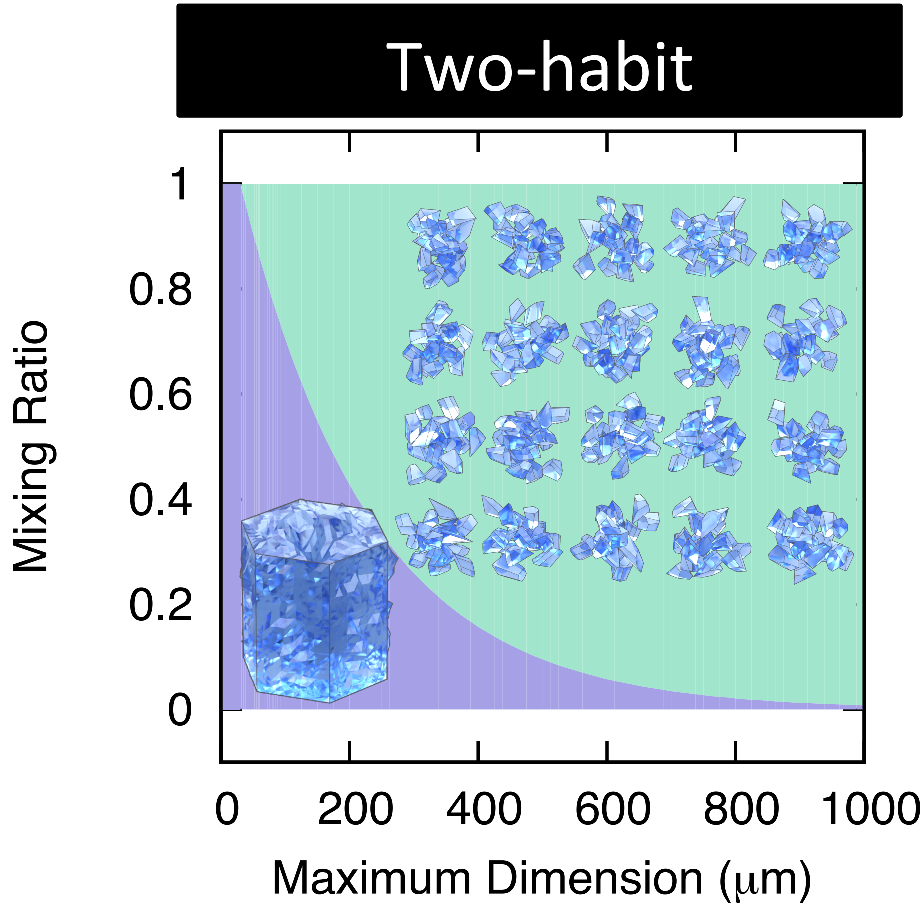
Roughened
Single Column

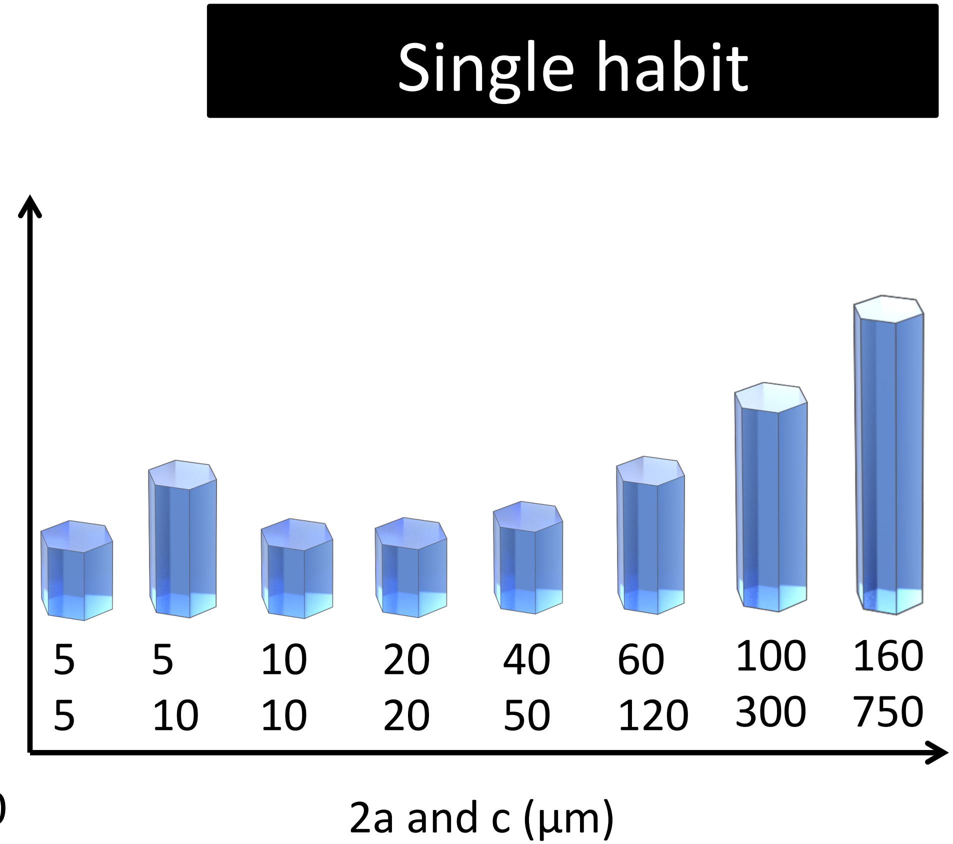
20 Aggregates of
20 Distorted Columns



The new Two-habit Model

has 189 size bins and compatible with various particle size distributions





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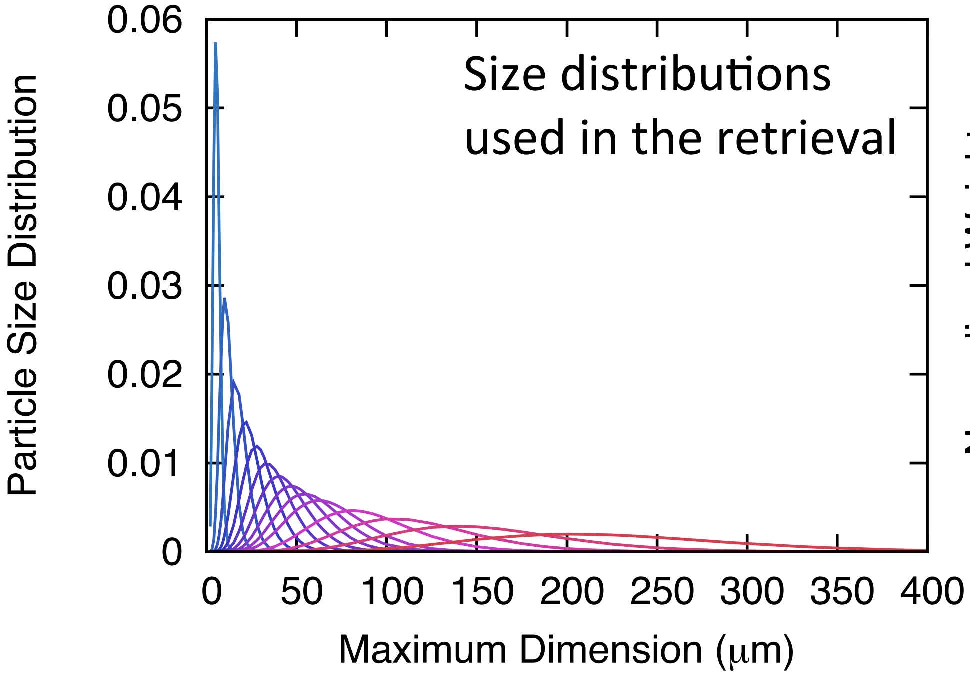
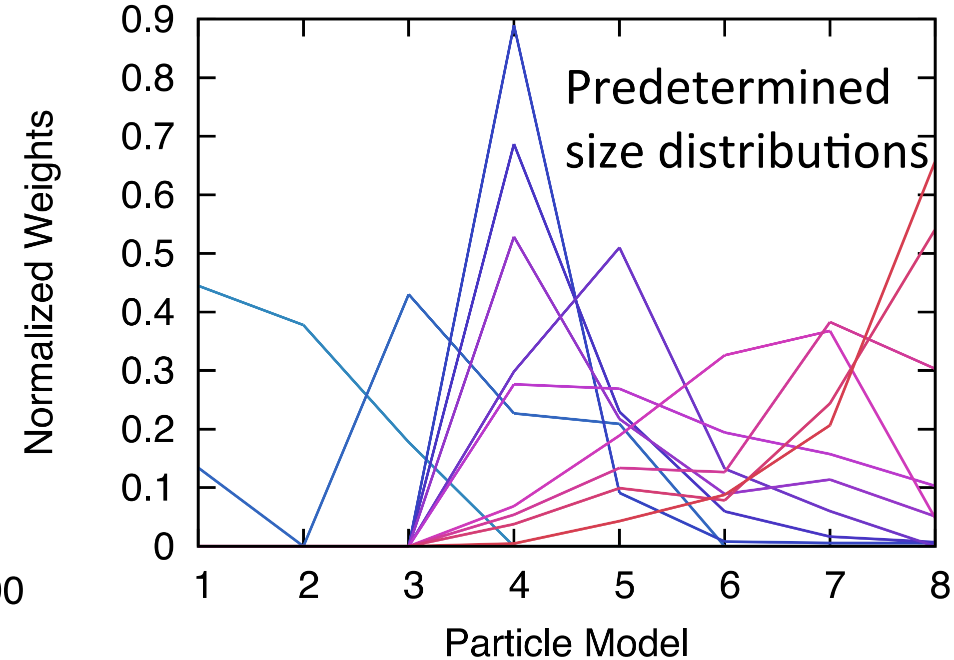
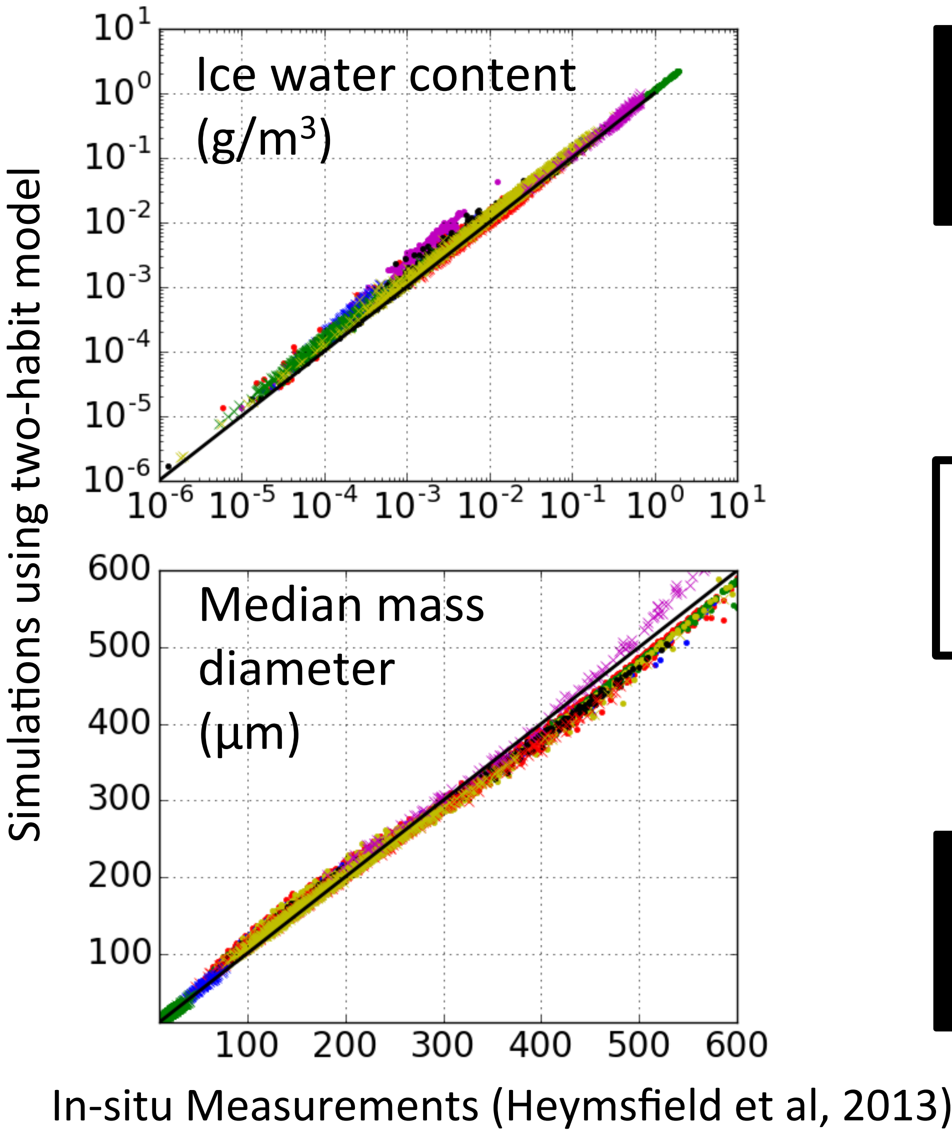
Two-habit



Single habit



Validation with in-situ Measurements



In-situ Measurements

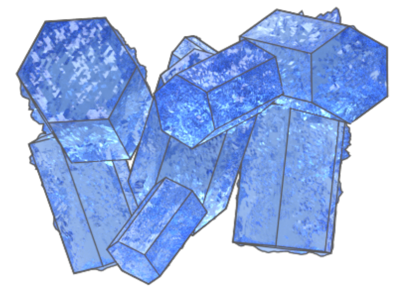
Particle Size Distributions

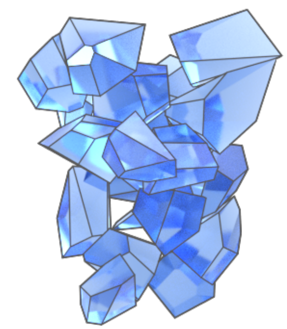
The New Two-habit Model

Ice Water Content

Median Mass Diameter

Shortwave Retrieval Test

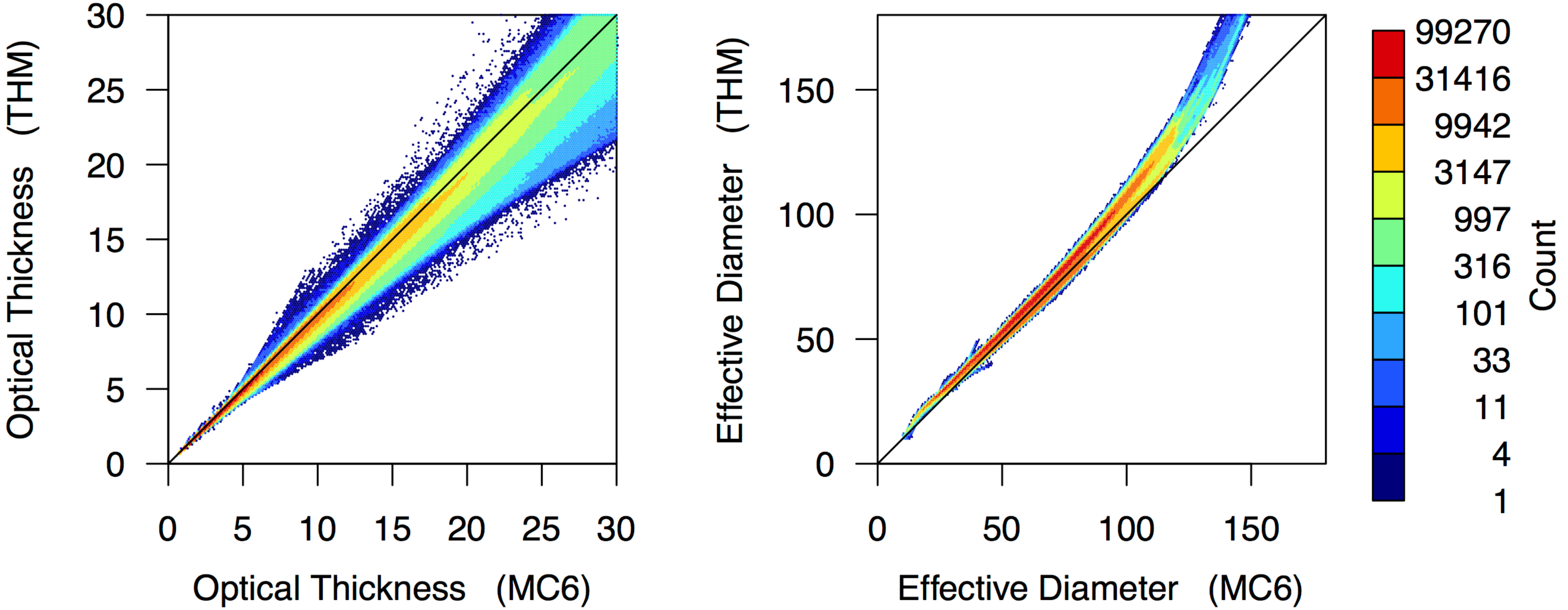




- **Three Particle Shapes**
  - Column Aggregate
  - Single Habit Model
  - Two-habit Model
- **One-day of MODIS Terra Data**
  - September 15, 2013
  - Level 2 Reflectivity with Atmospheric Correction
- **Shortwave Bi-spectral Retrieval**
  - Band 2 (0.86 μm) + Band 7 (2.13 μm)
  - Optical thickness + Effective diameter

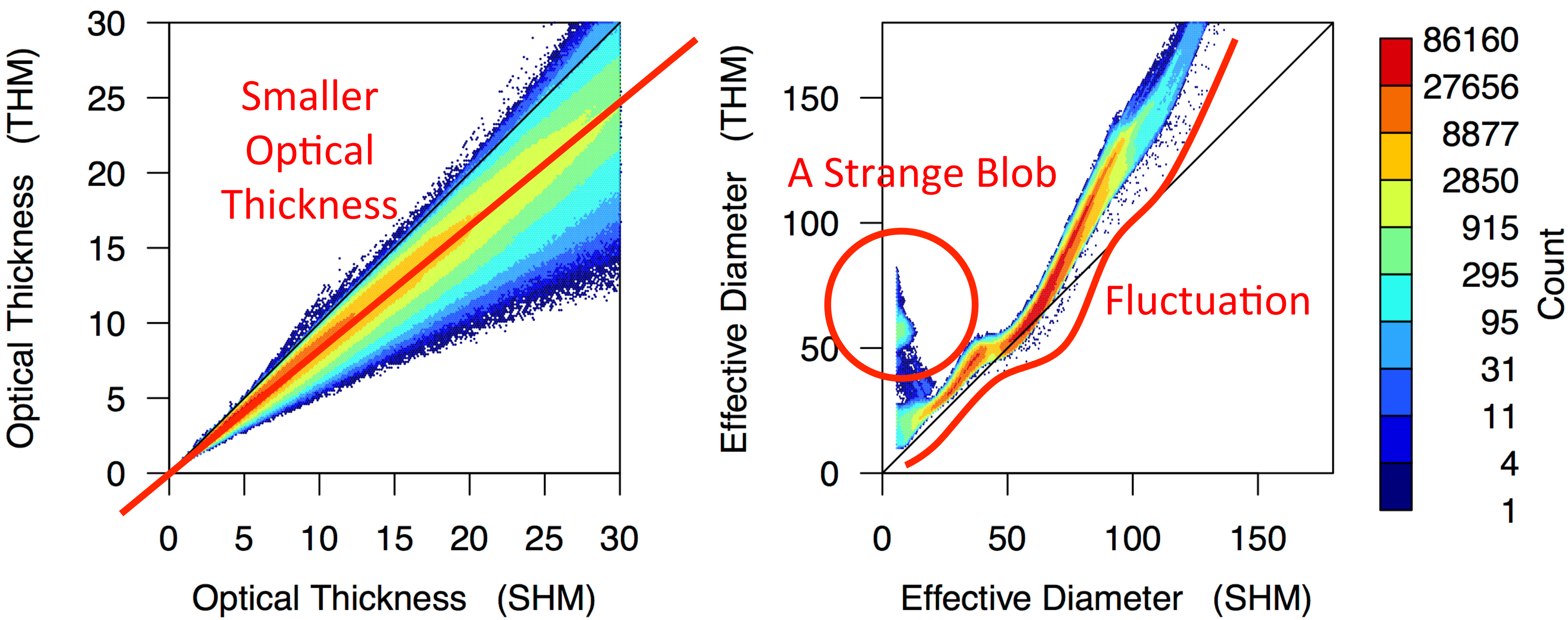
Shortwave Retrieval Test

Optical thickness and effective diameter are both consistent with retrievals using column aggregate model

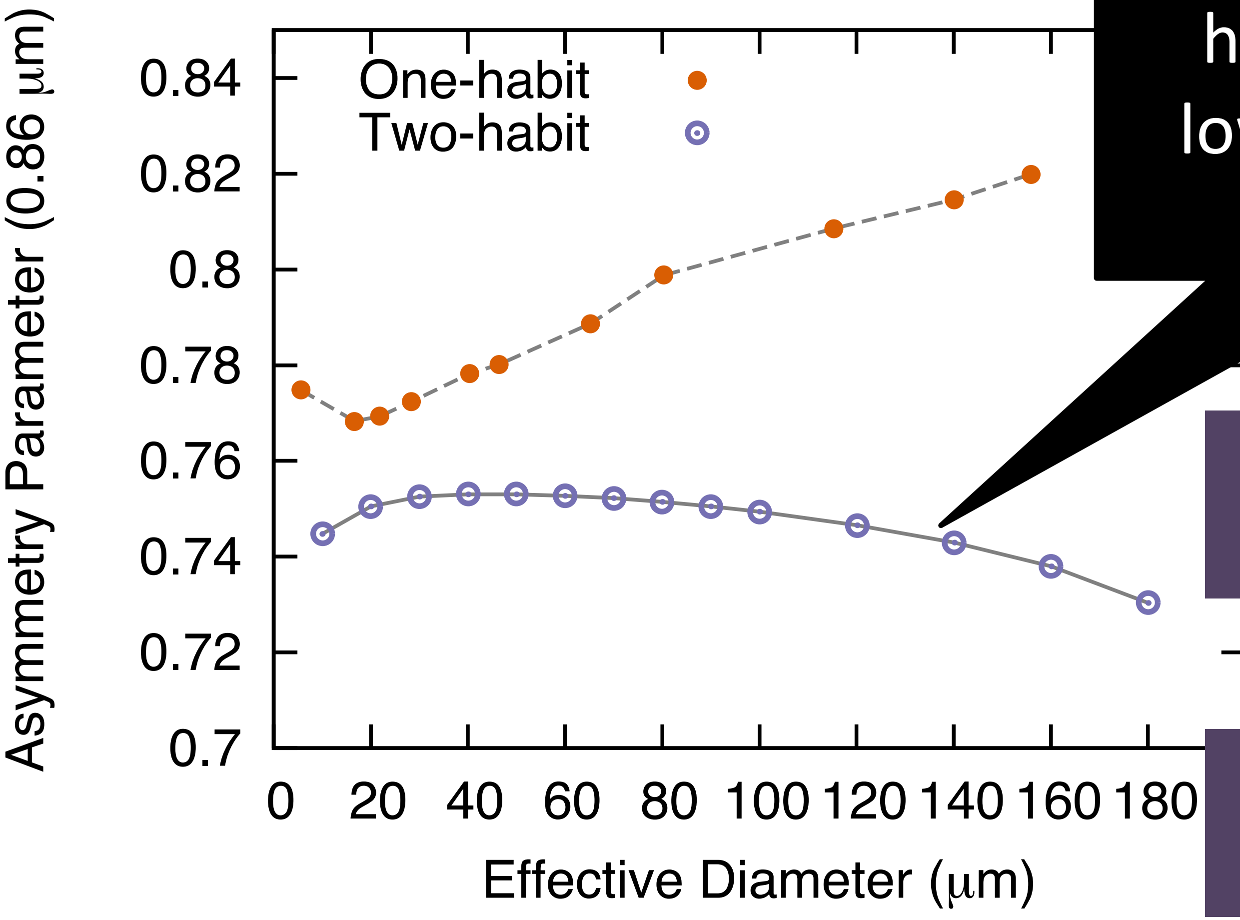


Shortwave Retrieval Test

Lower optical thickness than single habit model (SHM)
Fluctuating, smaller effective diameter at populated sizes



Smaller Optical Thickness



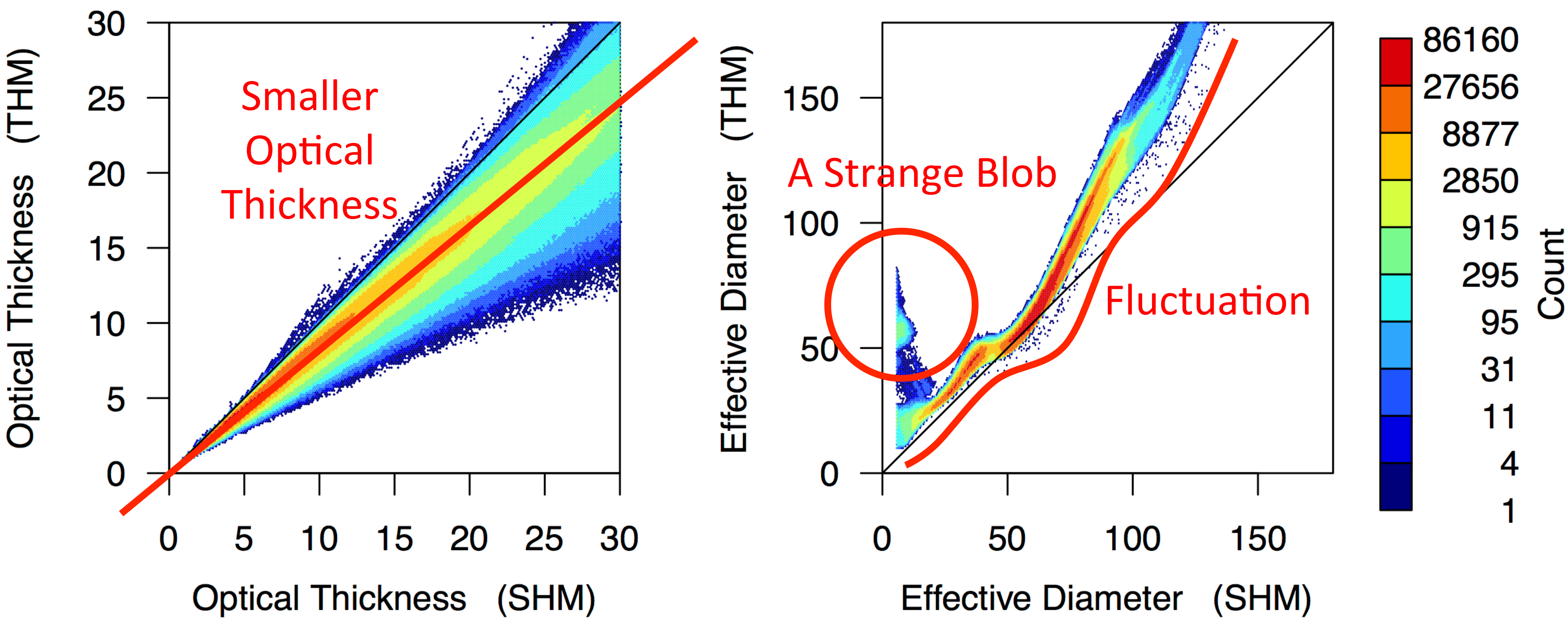
The two-habit model has consistently lower asymmetry parameter

stronger backscattering

smaller optical thickness

Shortwave Retrieval Test

Lower optical thickness than single habit model (SHM)
Fluctuating, smaller effective diameter at populated sizes



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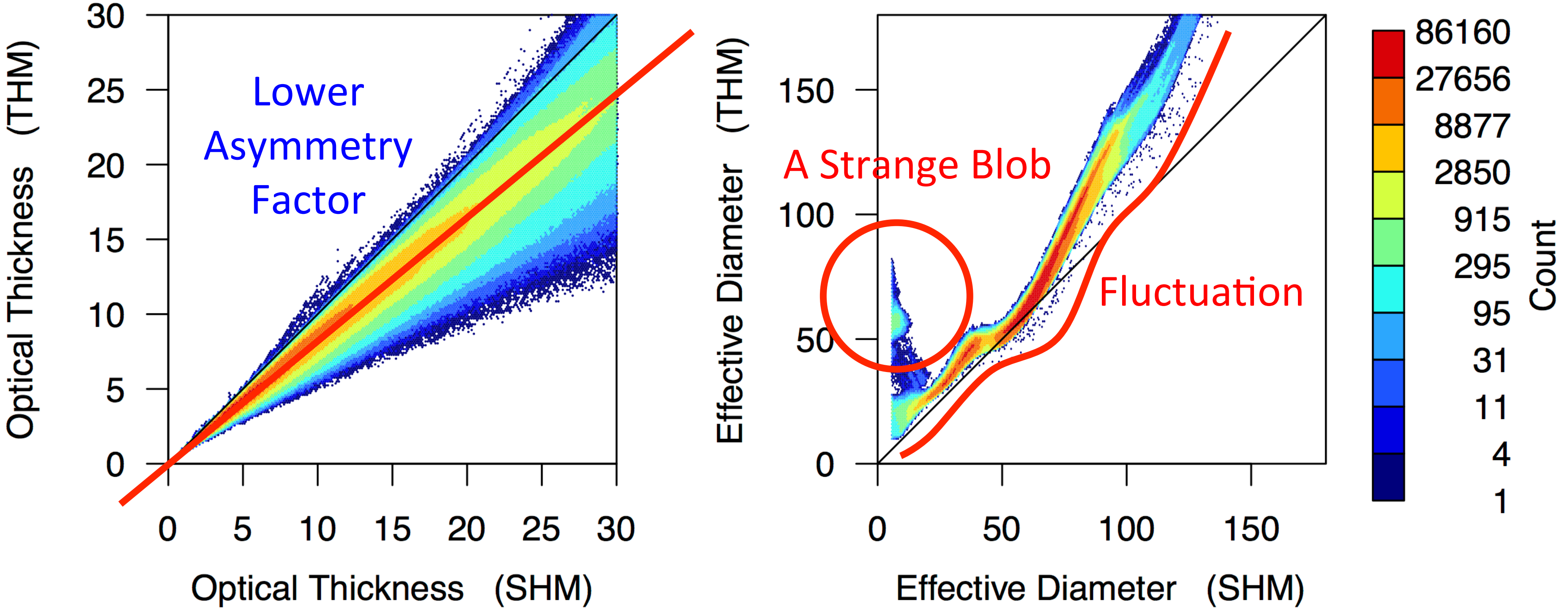
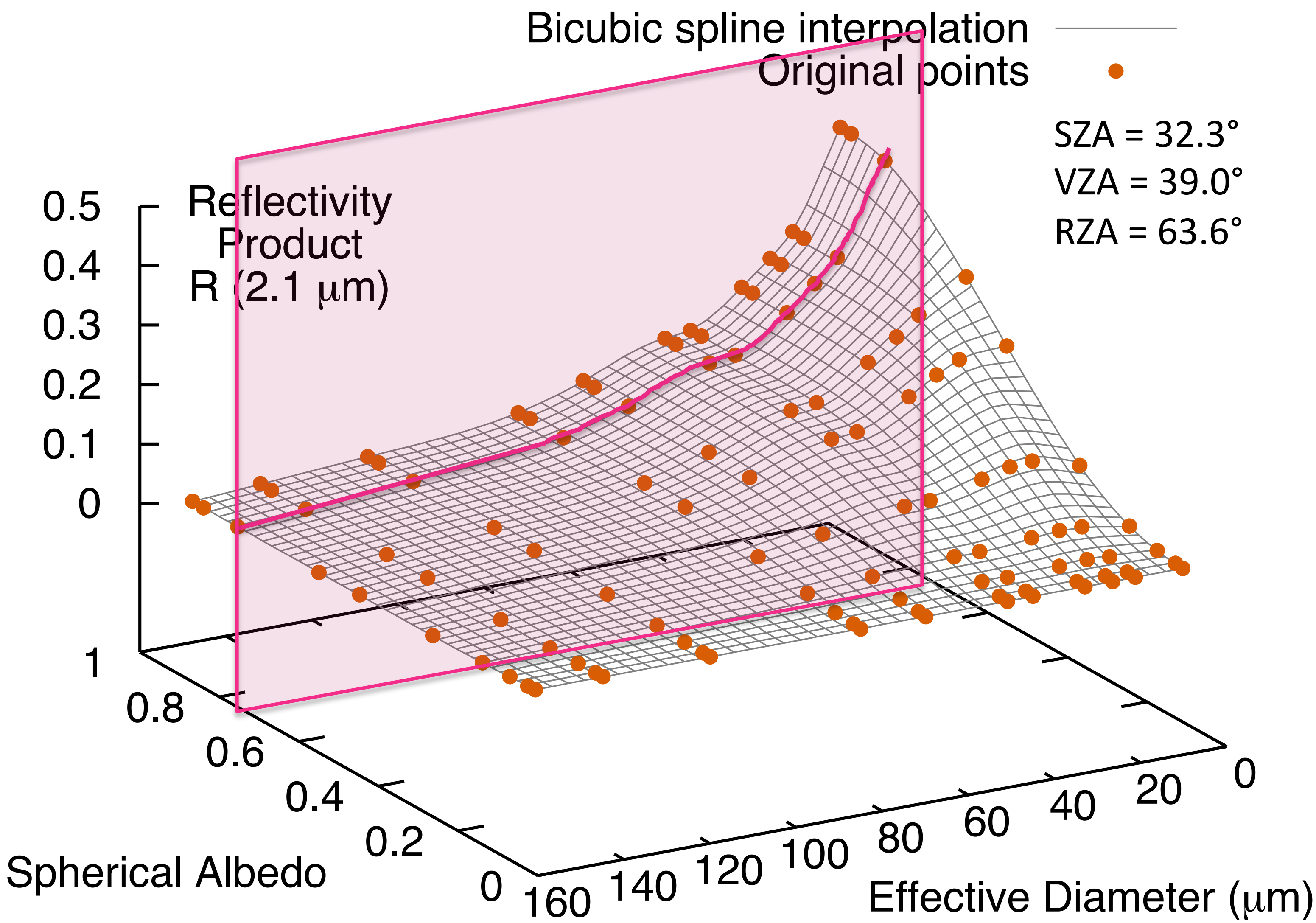


Fluctuating Effective Diameter



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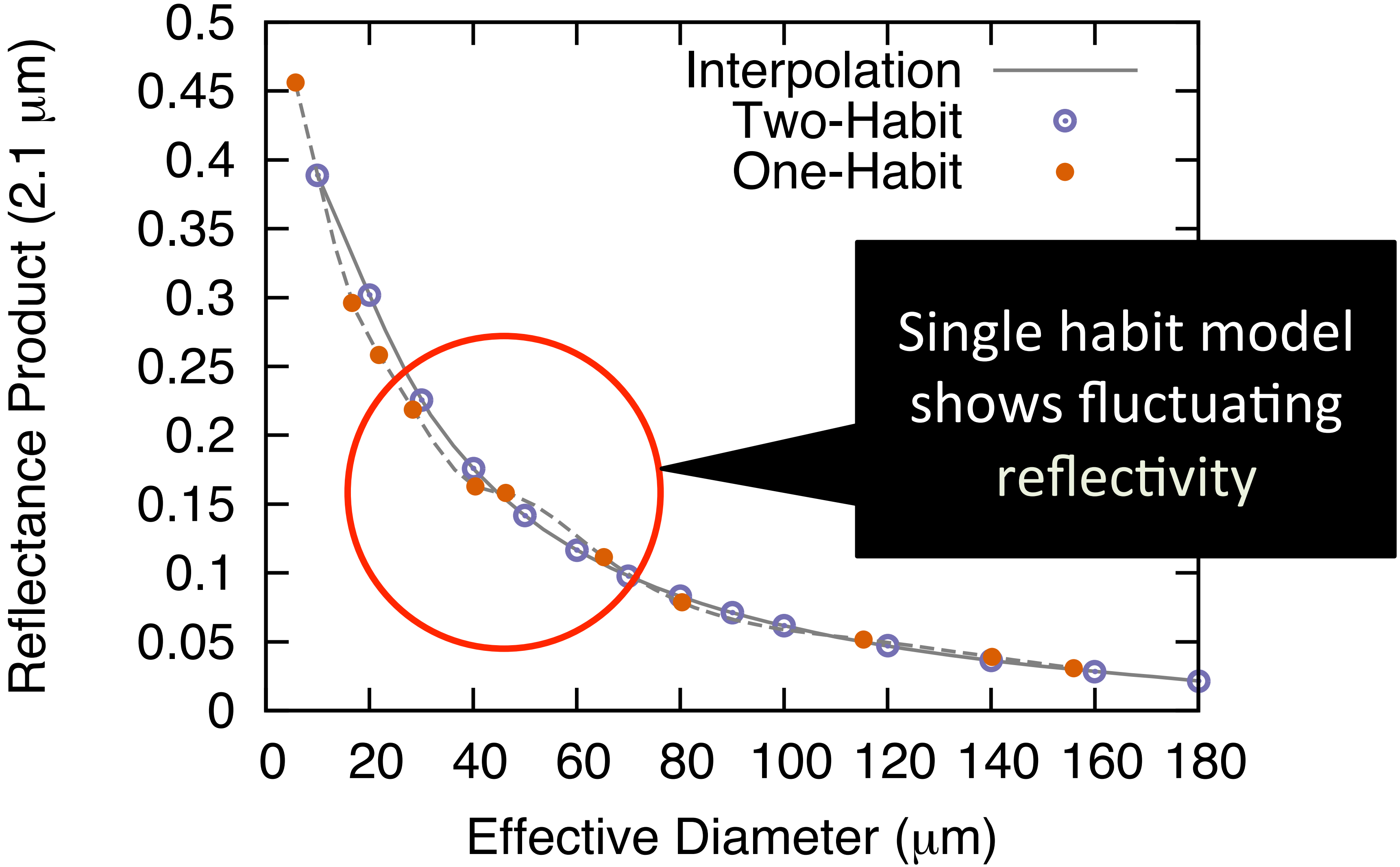

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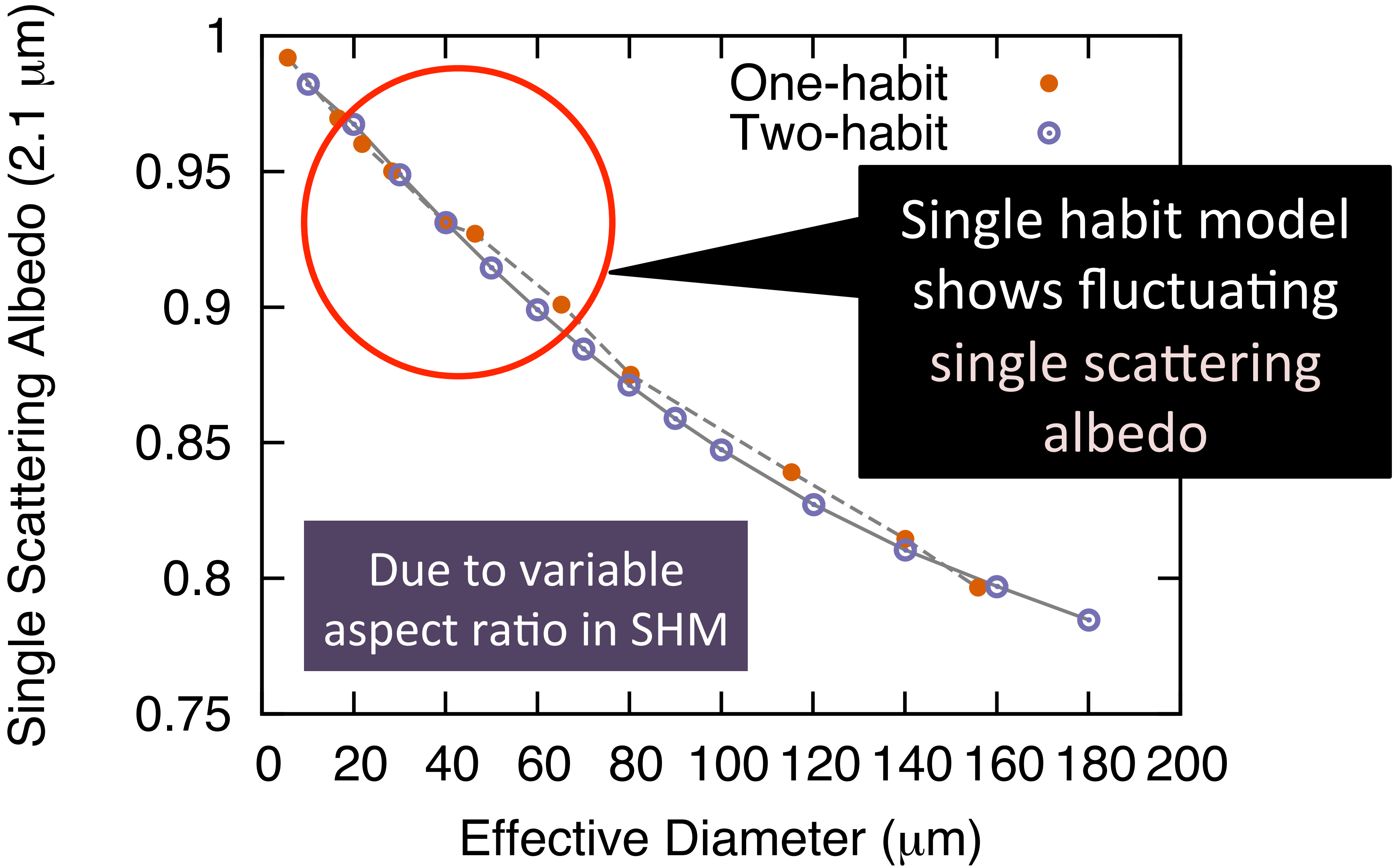

Shortwave Retrieval Test

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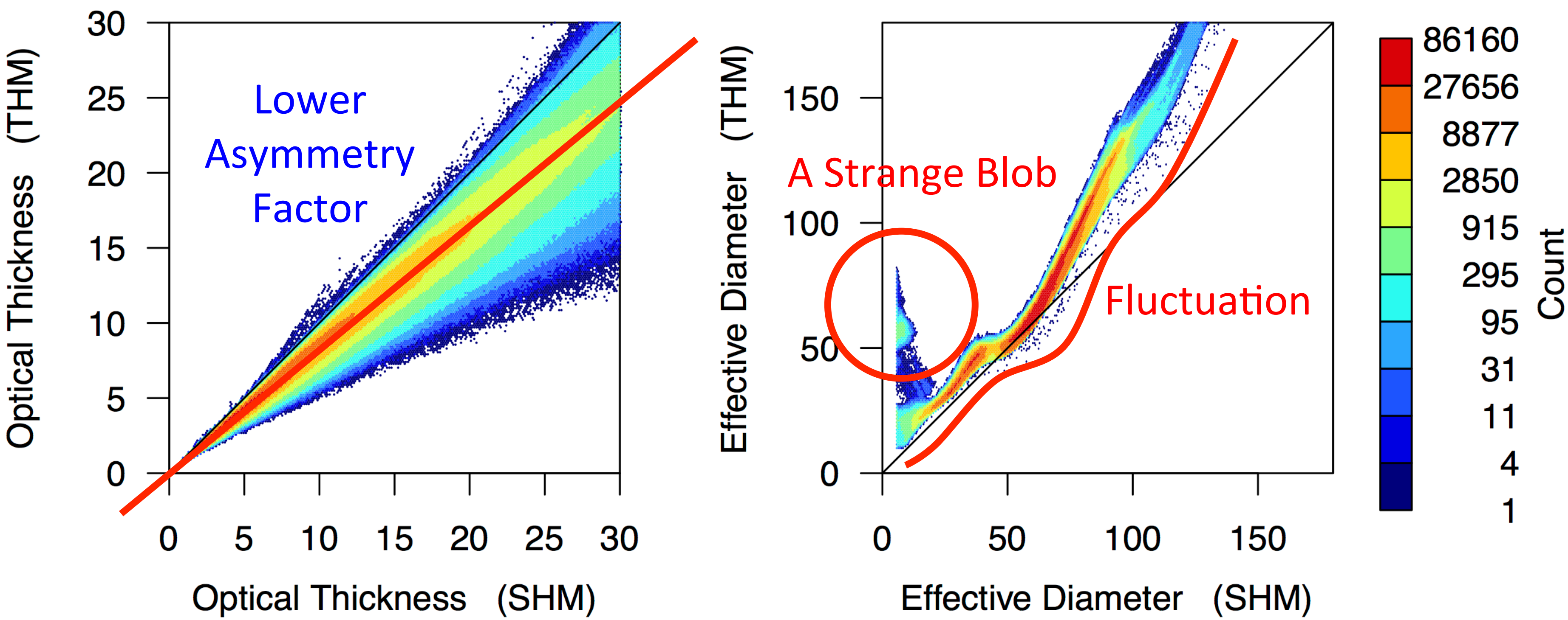

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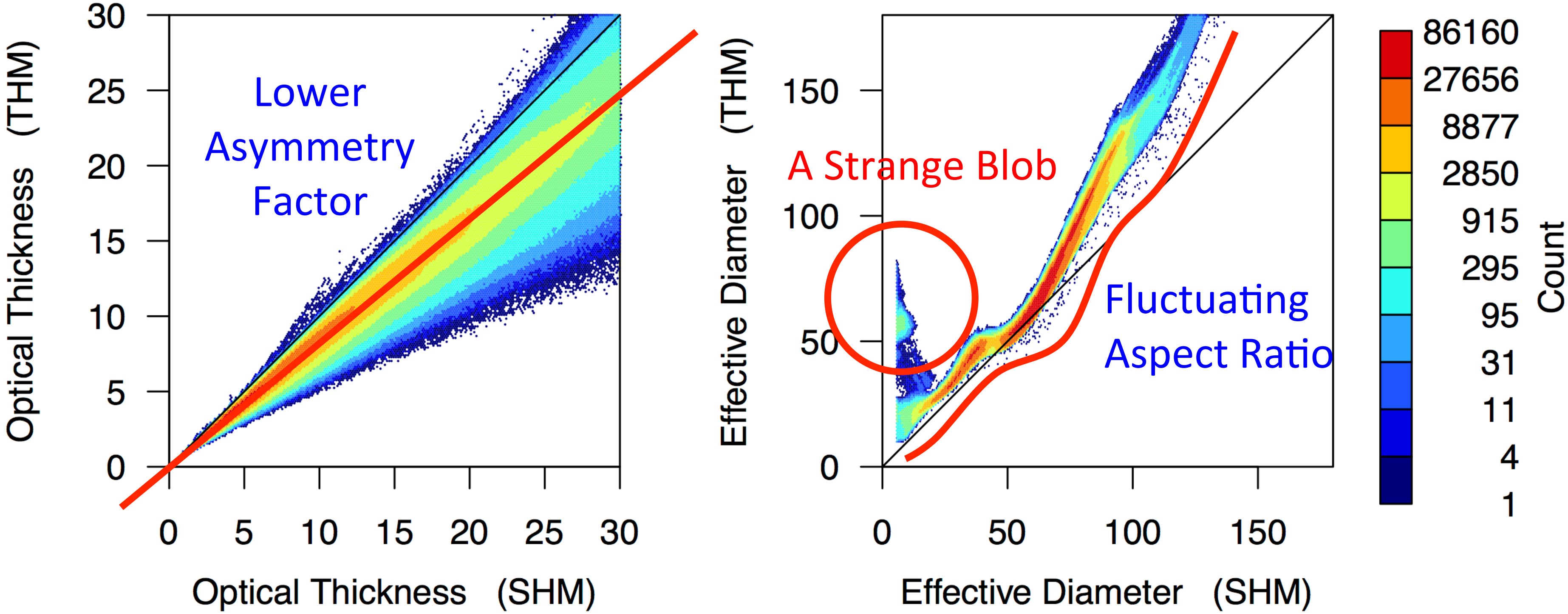
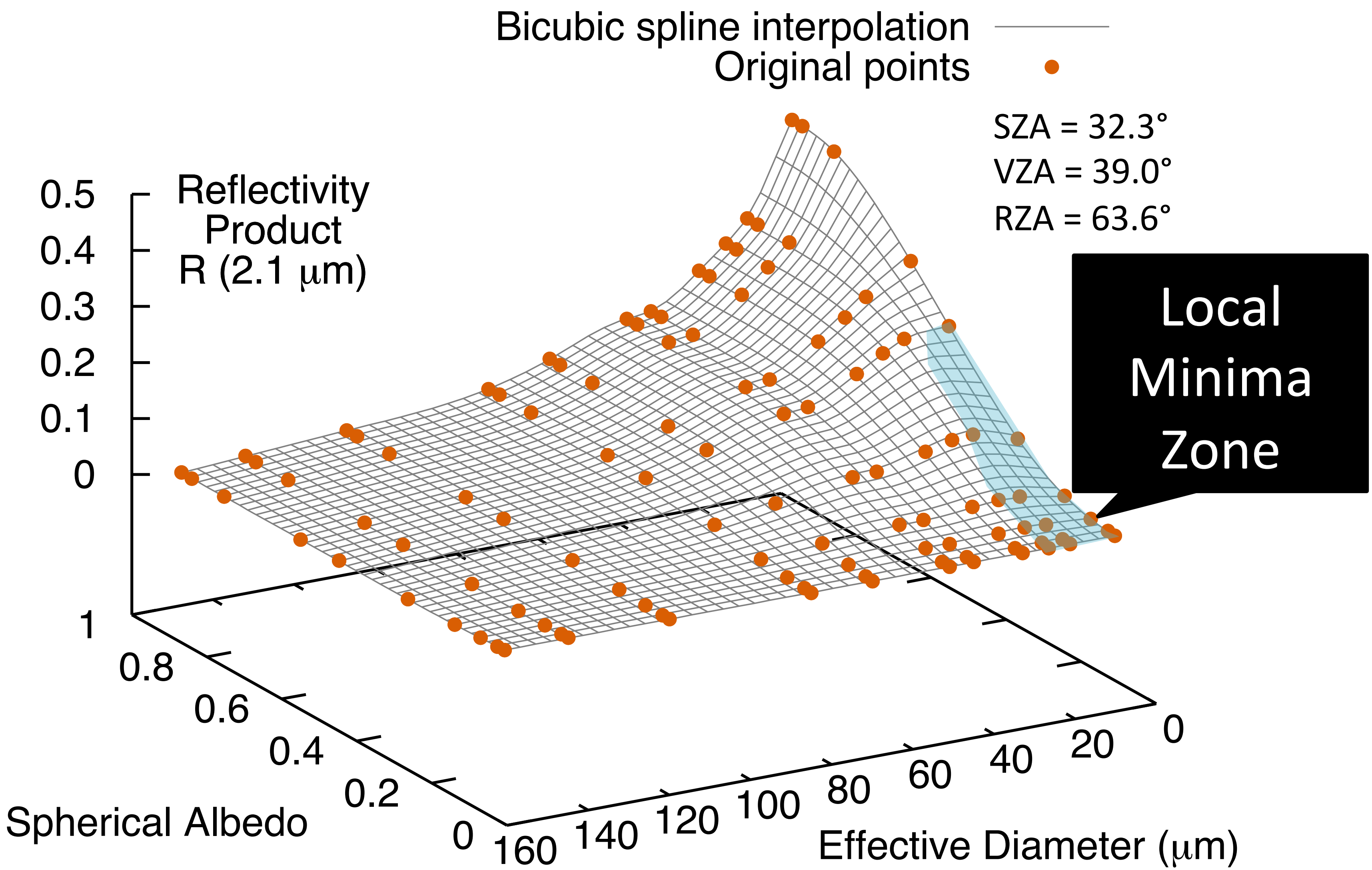


Local Minima



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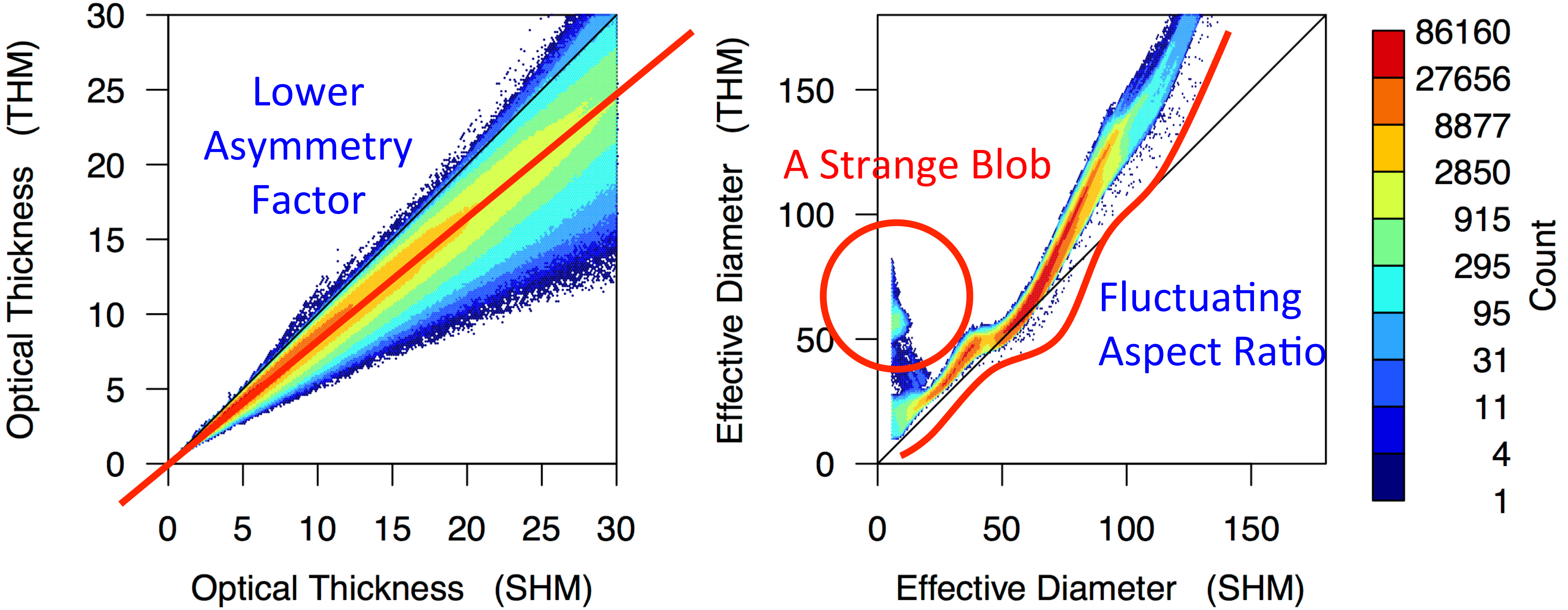

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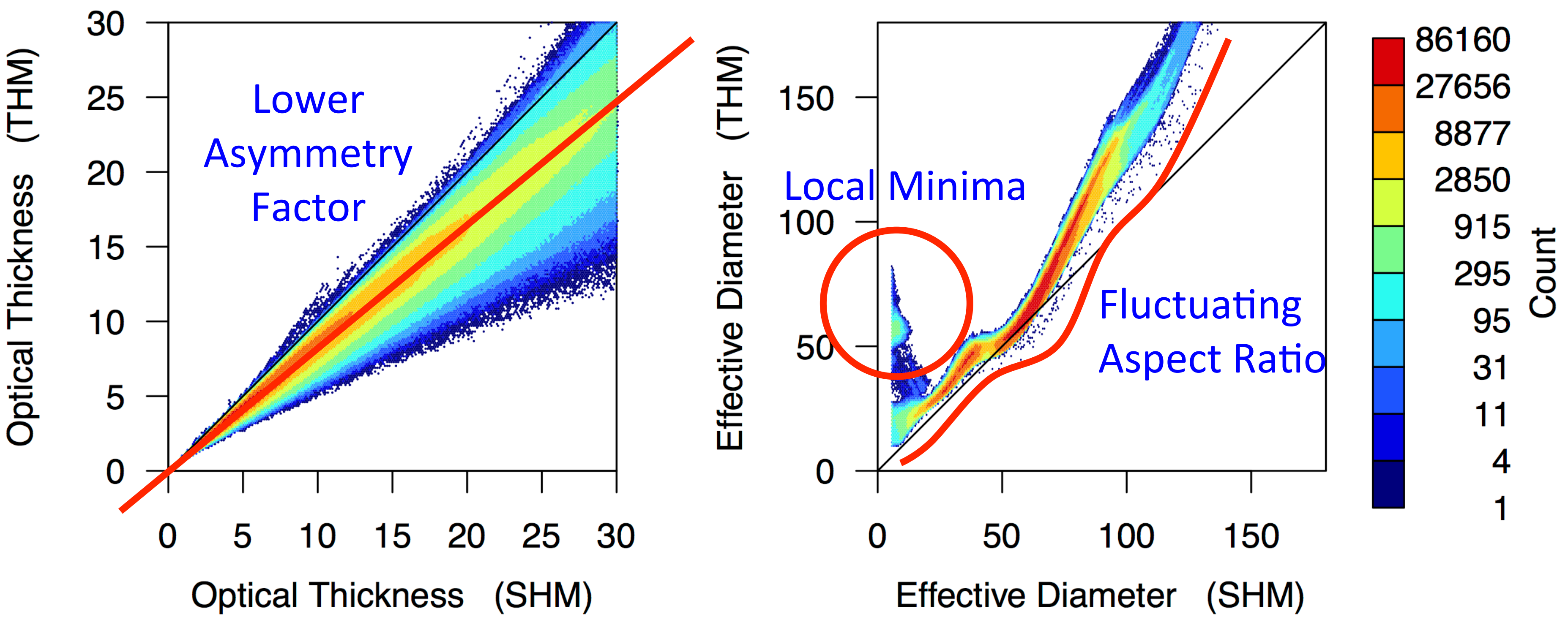


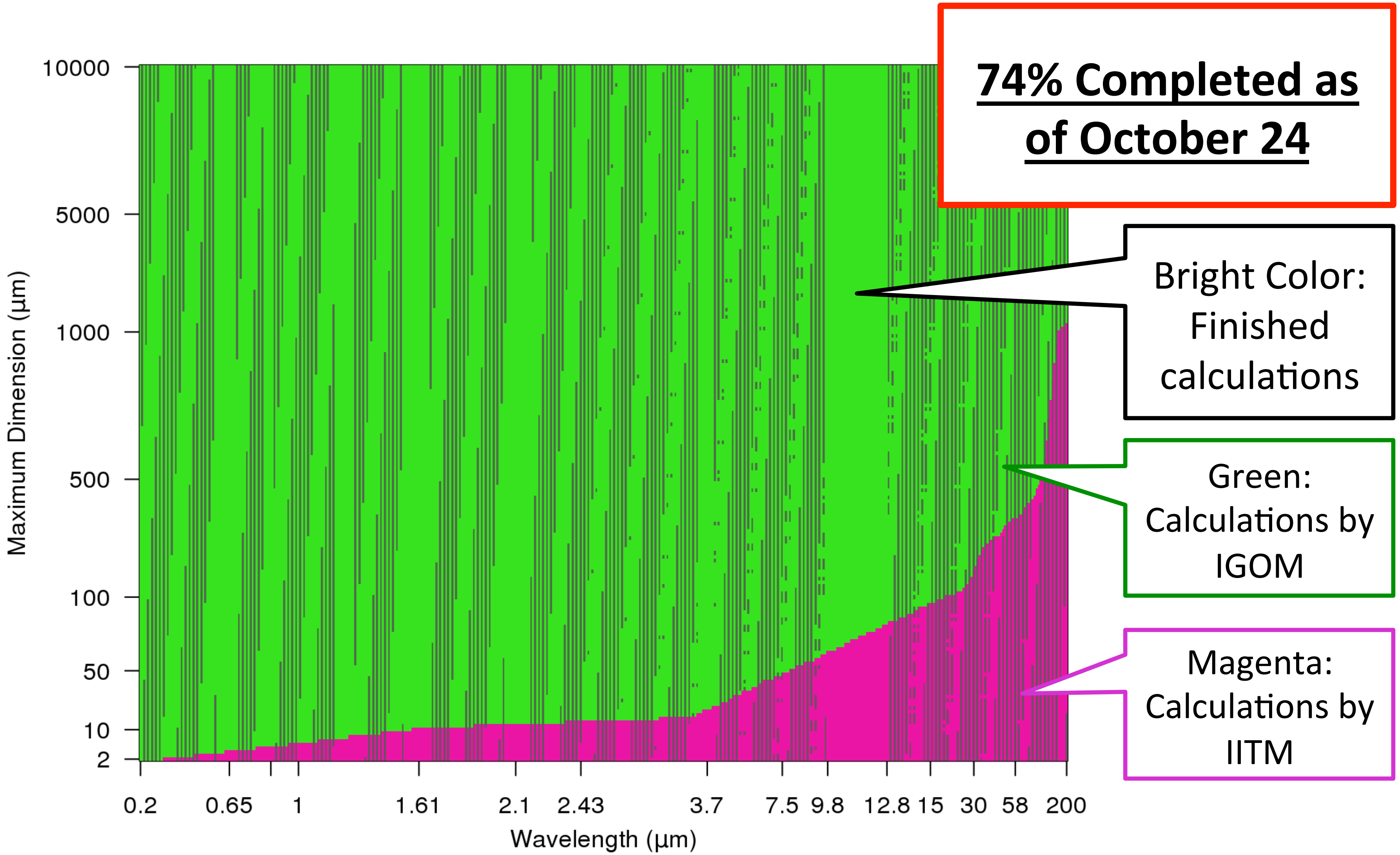
Delivery of Ice Cloud Models (A&M)

As of October 21, 2016	SW BRDFs + Bulk Prop. (VIIRS)	IR Bulk Properties (VIIRS)	SW BRDFs + Bulk Prop. (MODIS)	IR Bulk Properties (MODIS)	Spectral Scattering Properties
MODIS Collection 6 (r050_c8)	Delivered May 7, 2016				
One-Habit (Roughened) (CERES4, 1H-PM, shm1_yx)	Previous LUT		Delivered Sep. 22, 2016	Delivered Sep. 27, 2016	Delivered July 6, 2016
One-Habit (Smooth) (CERES2, shm2_yx)			Delivered Sep. 27, 2016	Delivered Sep. 27, 2016	Delivered Sep. 27, 2016
Old Two-Habit (2H-PM, thm1_cl)	Delivered Apr. 27, 2015				
New Two-Habit (thm1_gt)	Delivered Sep. 21, 2016	Delivered Sep. 21, 2016	Delivered Sep. 26, 2016	Delivered Sep. 26, 2016	Calculation in Progress

Red: Habit names by CERES team (Dr. Gang Hong)
Blue: Habit names used by Souichiro Hioki

RSR of VIIRS is from Dr. Hong, and RSR of MODIS is that of Aqua.

Progress of broadband calculations



Conclusions

- Scaling optical thickness by (1-ϖg) gives **consistent results with both** MODIS Collection 6 particle model and MODIS Collection 5 model
- **The shortwave retrieval** with the new two-habit model is **consistent** with MODIS Collection 6
- Compared to the current single habit model, the new two-habit model retrieves
  - **Smaller optical thickness**
  - **Smaller effective diameter at populated sizes**
- Broadband calculation of the new two-habit model is **in progress**