A-TRAIN SYMPOSIUM

NEW ORLEANS October 25-28, 2010

International Symposium on the A-Train Satellite Constellation

Sheraton Hotel
New Orleans, La USA
October 25-28, 2010

meeting link available from *atrain.nasa.gov*

MODIS (Science Team) – Topic 2
Cloud Optical/Microphysical Retrievals

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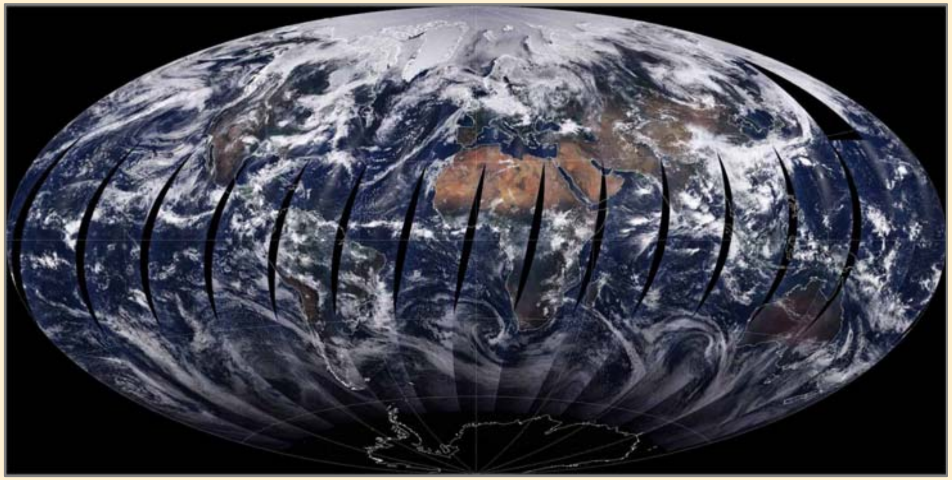
GEWEX Cloud Assessment Workshop
Berlin, Germany
22-25 June 2010



MODIS true-color daily composite

Outline

- Summary/key points (mine) from July 2008 NYC workshop
- What we've "learned" since (about issues related to data product comparisons)
  - issues with ice clouds
  - geometric sensitivities/biases
  - effective radius sensitivity to choice of spectral band(s)

Comparing Cloud Optical Data Products

Many cloud retrievals considered basic and fundamental are ill-defined

- What is a cloud (depends on the part of the spectrum as well as the application)? What is the function of a cloud mask (for what user community/science purpose)?
- Which cloud-top height (radar vs. lidar vs. IR vs. polarization vs. molecular absorption vs. Raman scattering line filling)?
- Cloud phase: For which layer(s)? Mixed phase?
- Cloud effective particle size at what level (local quantity, not vertically integrated as with τ)?

What model assumptions (e.g., ice cloud models) are used?

What ancillary data sets are used?

What QA (Quality Assessment), uncertainties, or other choices are made to screen or weight retrievals?

Every instrument technique/algorithm has a particular part of the solution space for which it is "useful" – no approach covers the entire PDF.

MODIS Cloud Optical, Microphysical Product (MOD06)

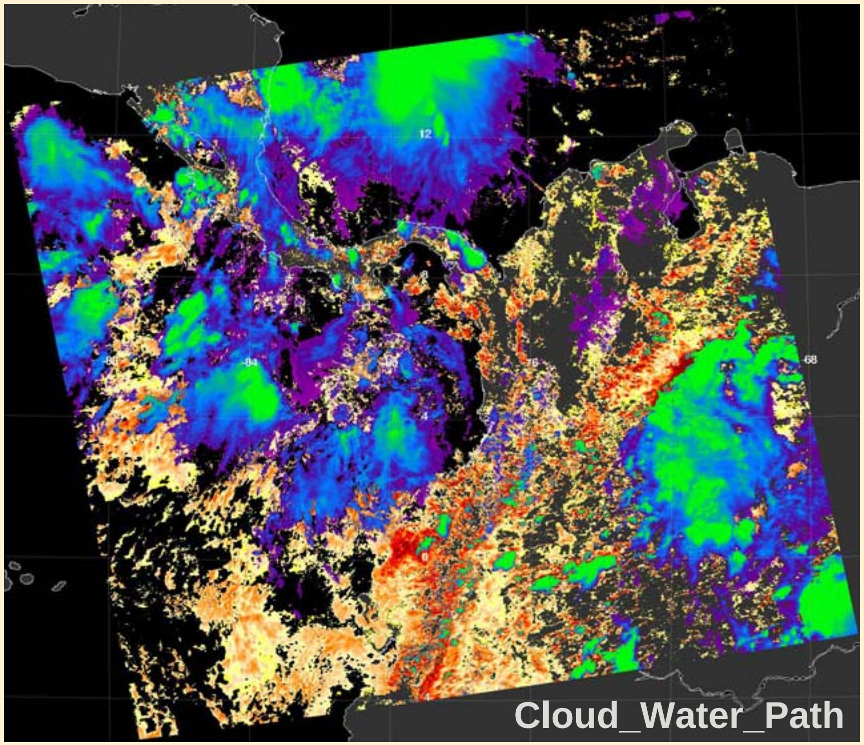
Collection 5 Algorithm Highlights

- Primary r_e from band combinations w/2.1 µm, but L2 also includes 1.6 and 3.7 µm retrievals (given as differences w/2.1 µm). L3 aggregations for 2.1 µm retrieval only.
- Ice cloud radiative models from Baum, Yang, et al. (2005)
- Various QA including:
  - "Clear Sky Restoral" (CSR): spatial (edge removal, 250m cloud mask over water surfaces) and spectral tests, used to help eliminate cloudy pixels not suitable for retrievals or incorrectly identified cloudy pixels. MOD35 pixels eliminated via CSR are not processed.
  - multilayer/phase cloud detection (separate aggregation in L3)
- Pixel-level baseline uncertainties
- Multilayer detection
- Land and snow/ice spectral surface albedo: gap-filled BU C4 product, Moody et al. (2005)

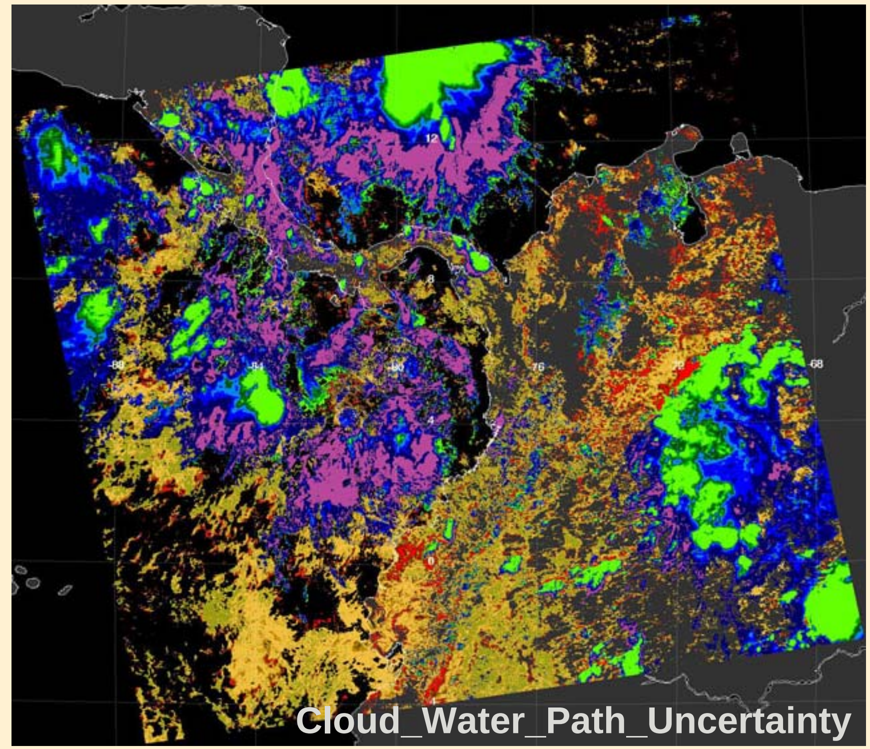
MODIS Cloud Optical, Microphysical Product (MOD06)

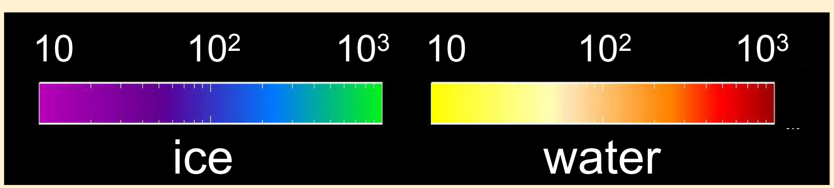
Example of MOD06 Estimated Baseline WP Uncertainties

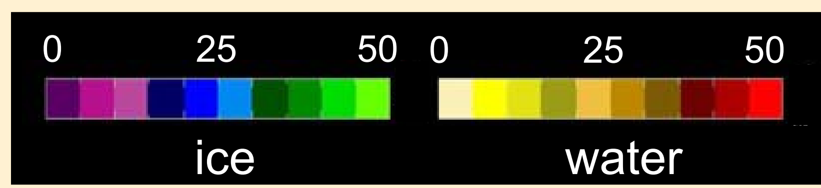
WP (gm^{-2})



Δ*WP*/*WP* (%)





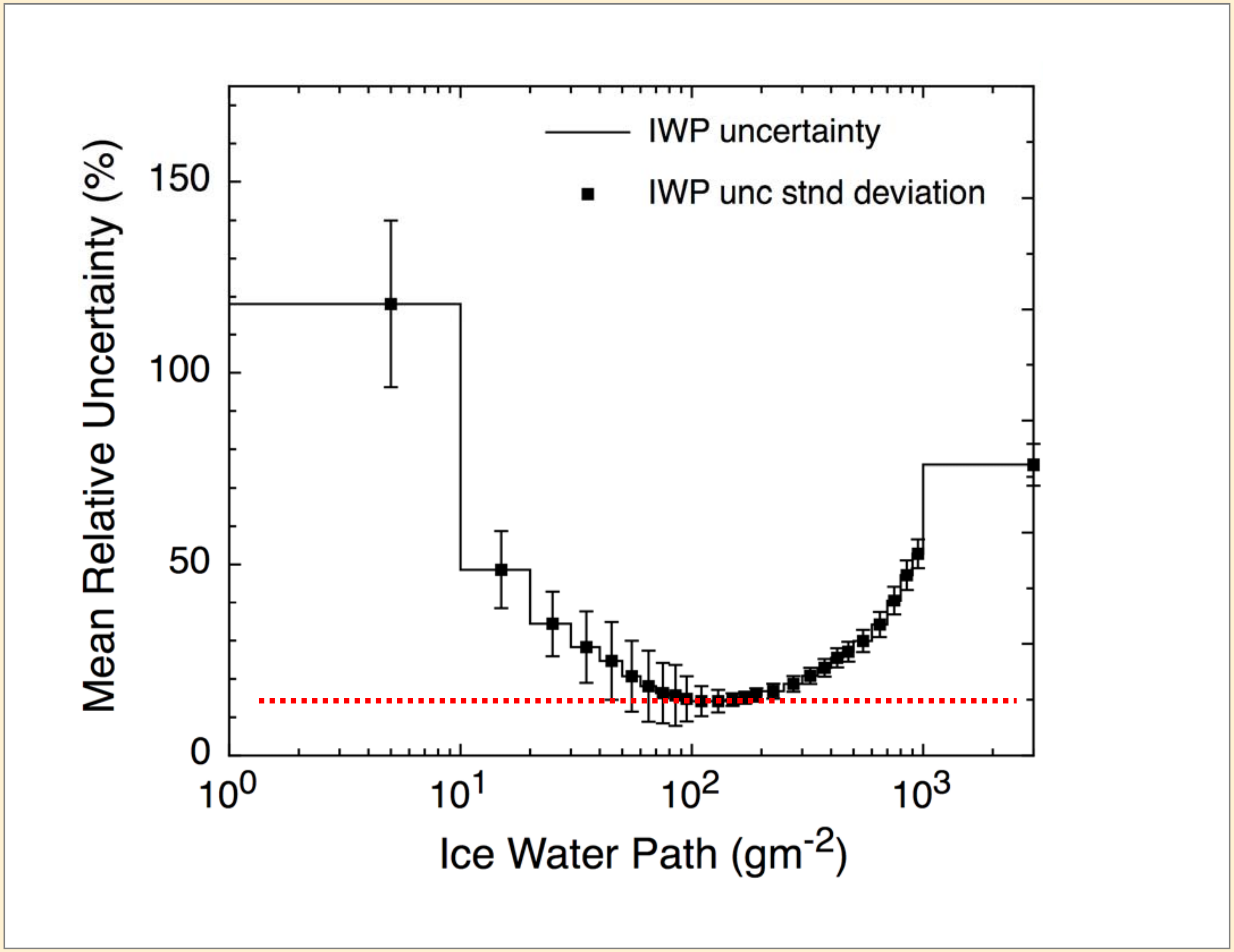


MODIS Aqua

Error sources: calibration/forward model, surface albedo, atmospheric correction

MODIS Aqua Example, cont.

Uncertainty vs. IWP: Ocean Pixels Only



Things Worth Pondering (ice cloud specific)

Same as for water clouds plus …

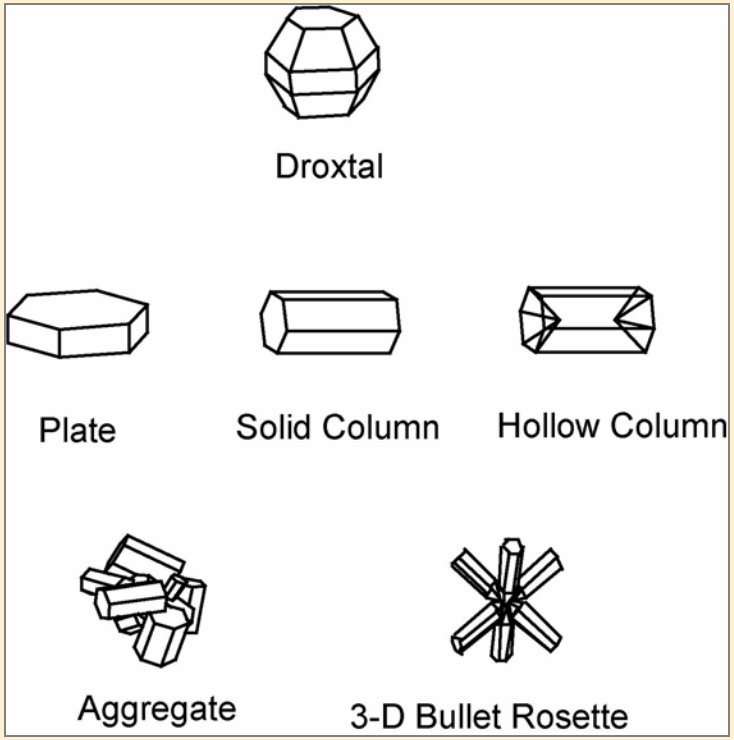
- What cloud size/habit distributions to use? Is the "truth" out there (i.e., Is it possible to "accurately" measure particle scattering parameters in situ? Can you achieve closure by comparing retrievals from different techniques?
- What is the skill in assessing thin cirrus properties? What is the detection limit? Sensitivities to lower cloud (multilayer scenes and surface spectral albedo)?

Once again … Every instrument technique/algorithm has a particular part of the solution space for which it is "useful" – no approach covers the entire PDF.

MODIS Collection 5 Ice Cloud Models

Baum, B. A., P. Yang, A. J. Heymsfield, S. Platnick, M. D. King, Y.-X. Hu, and S. Thomas: JAM, 2005.

Collection 5: Ice particle habit mixtures derived from in situ observations



Max length < 60 µm
100% droxtals

60 µm < Max length < 1000 µm
15% bullet rosettes
35% hexagonal plates
50% solid columns

1000 µm < Max length < 2500 µm
45% solid columns
45% hollow columns
10% aggregates ("severely" roughened)

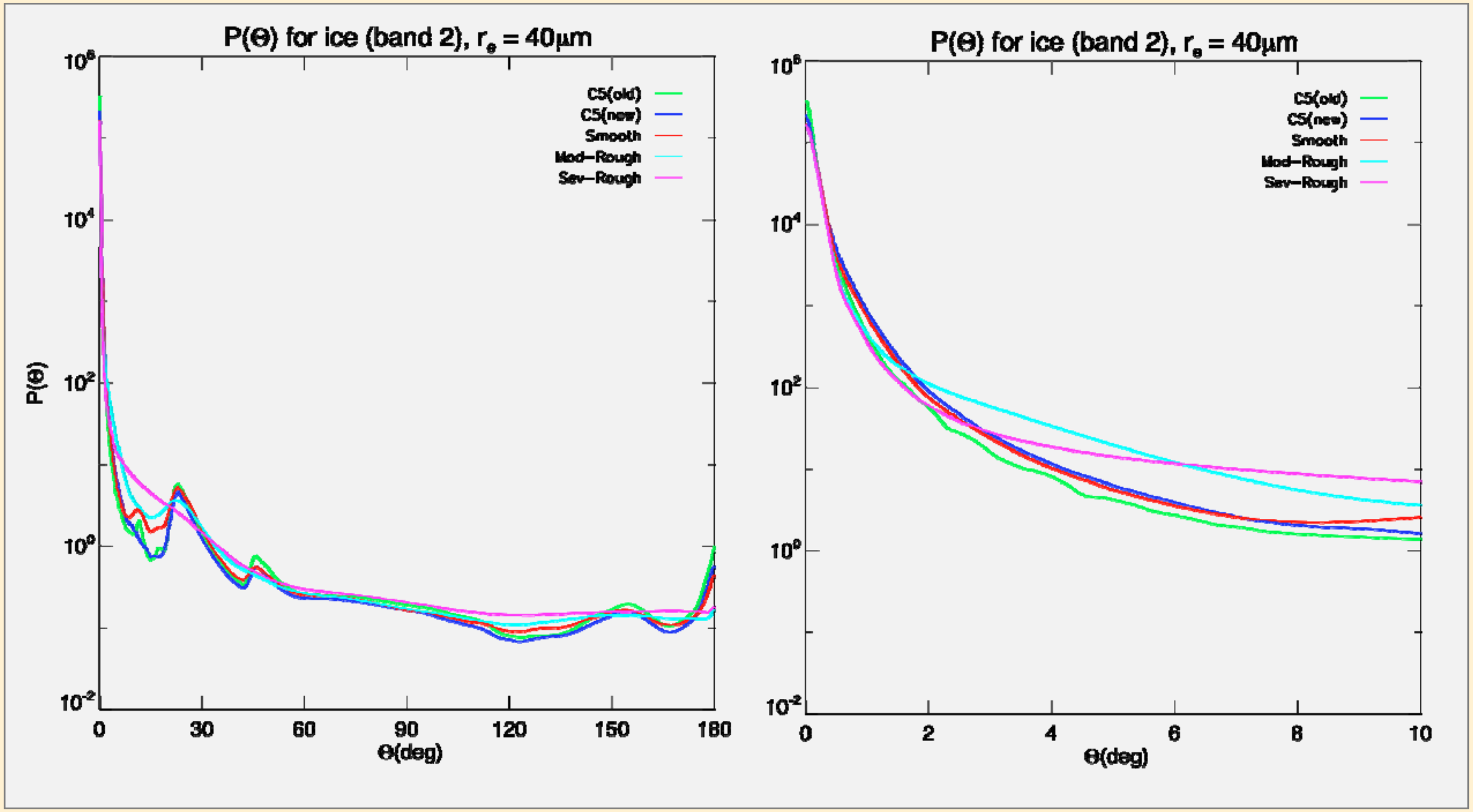
Max length > 2500 µm
97% bullet rosettes
3% aggregates ("severely" roughened)

Collection 6 investigation (Yang, Baum, et al.): C5 habits + hollow bullet rosettes, small and large aggregate of plates, all with smooth, moderate, and severely roughened surfaces.

Effect of Ice Cloud Model Uncertainties

particle scattering uncertainties due to model size distribution/habit

- effect of additional habits + surface roughening MODIS bd2 (P. Yang, B. Baum)



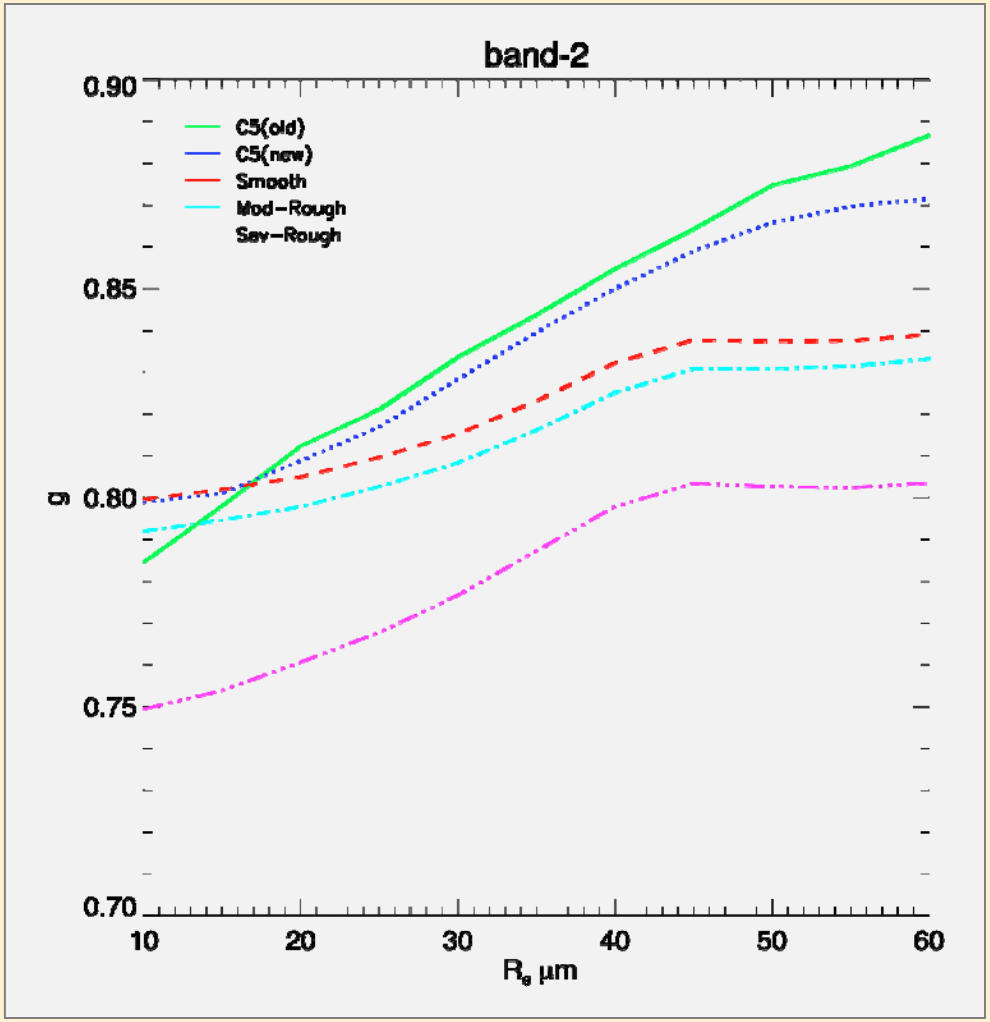
C5 (new): exact same habit mixture as that used for the C5 models; all particles are smooth except for the aggregate of columns, which is severely roughened (same as C5). Delta Transmittance calculated numerically.

Others: C5 habits + hollow bullet rosettes, small aggregate of plates and the large aggregate of plate.

Effect of Ice Cloud Model Uncertainties, cont.

Reflectance ~ $\tau^{*} = \tau\ [1\text{-}g(r_e)]$

$\Rightarrow$If g too large, then
τ too large on average

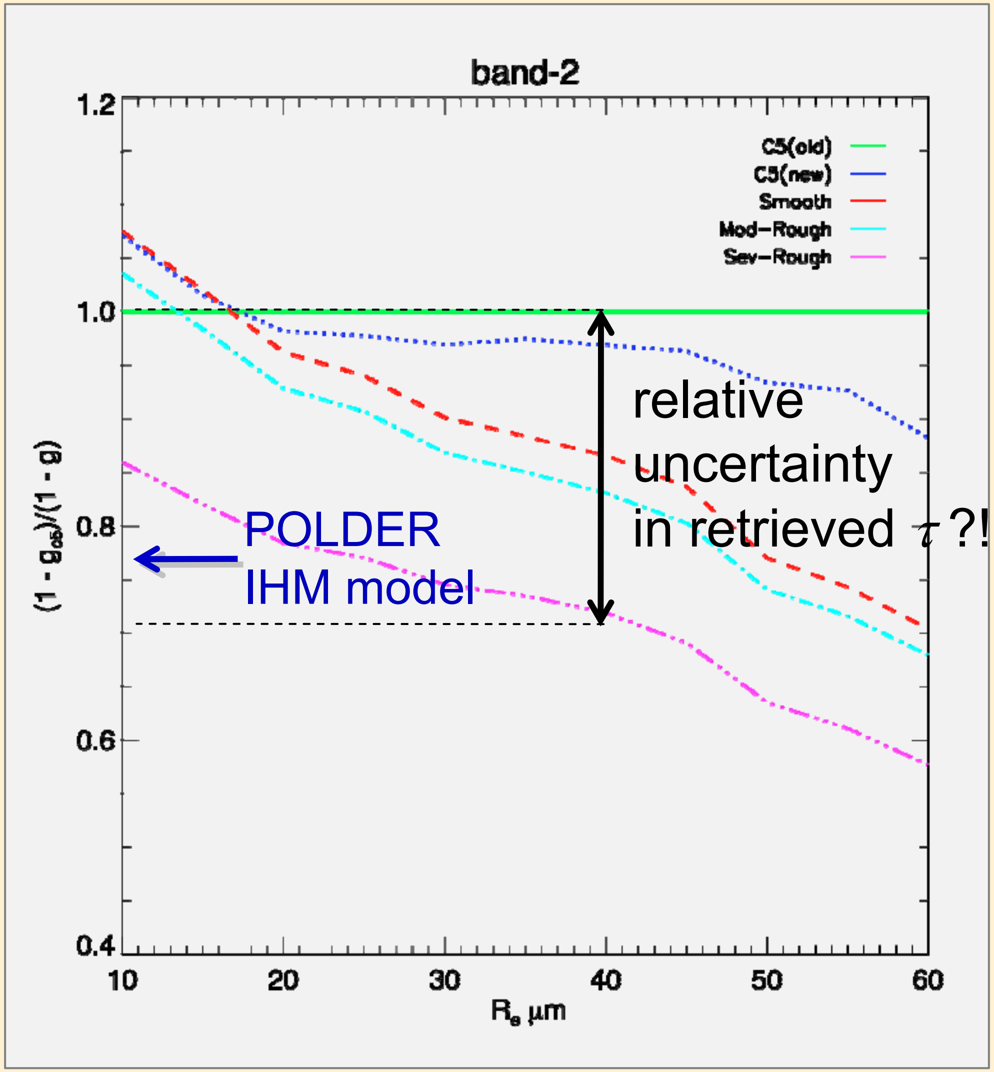


Effect of Ice Cloud Model Uncertainties, cont.

back-of-envelope look at τ retrieval impacts

$R \sim \tau^{*} = \tau\ [1-g(r_e)]$

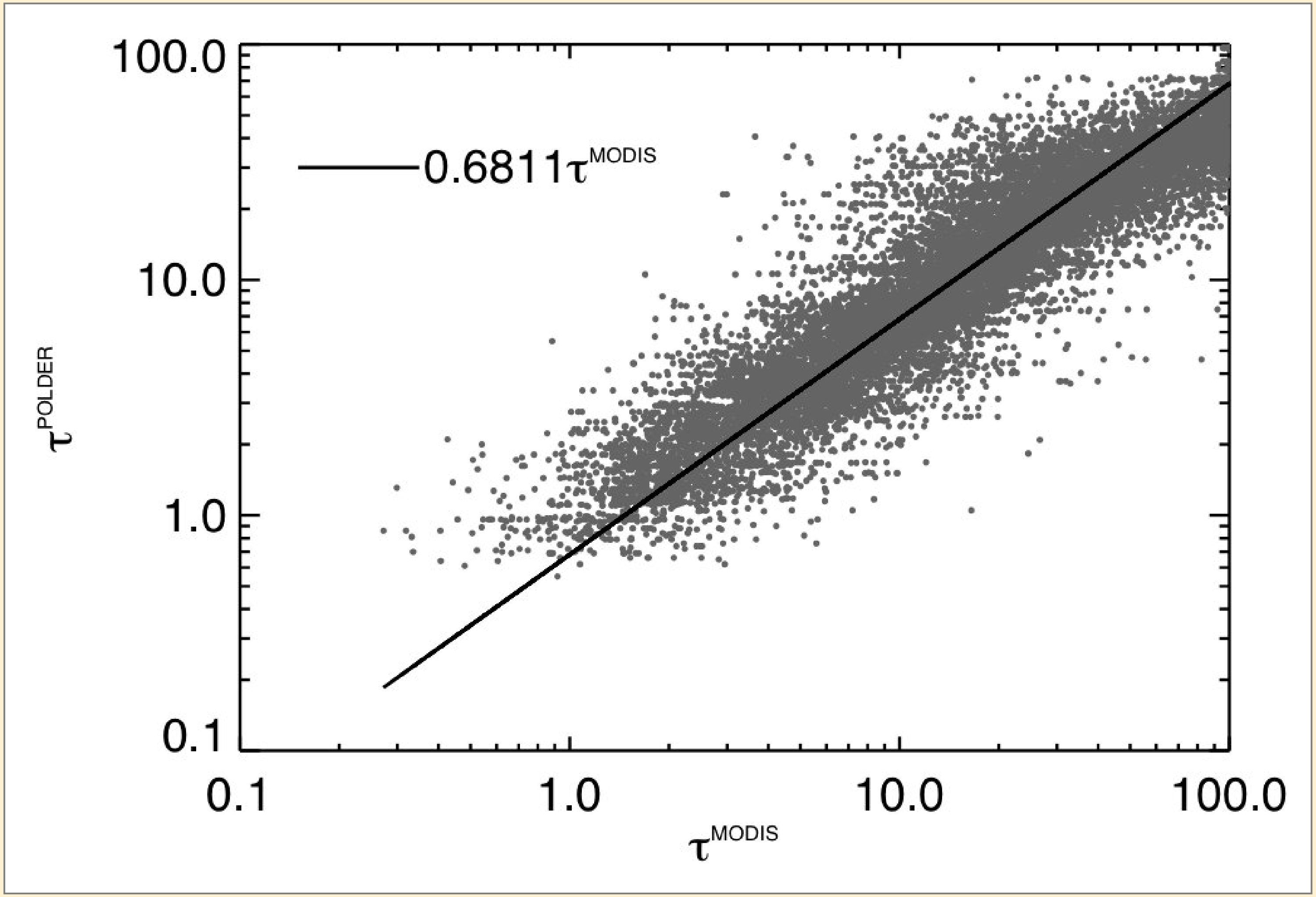
$\tau/\tau_{C5} \sim [1-g_{C5}(r_e)]\ /\ [1-g(r_e)]$



POLDER vs. MODIS C5 Ice Cloud τ – Cent. America Granule Comparison

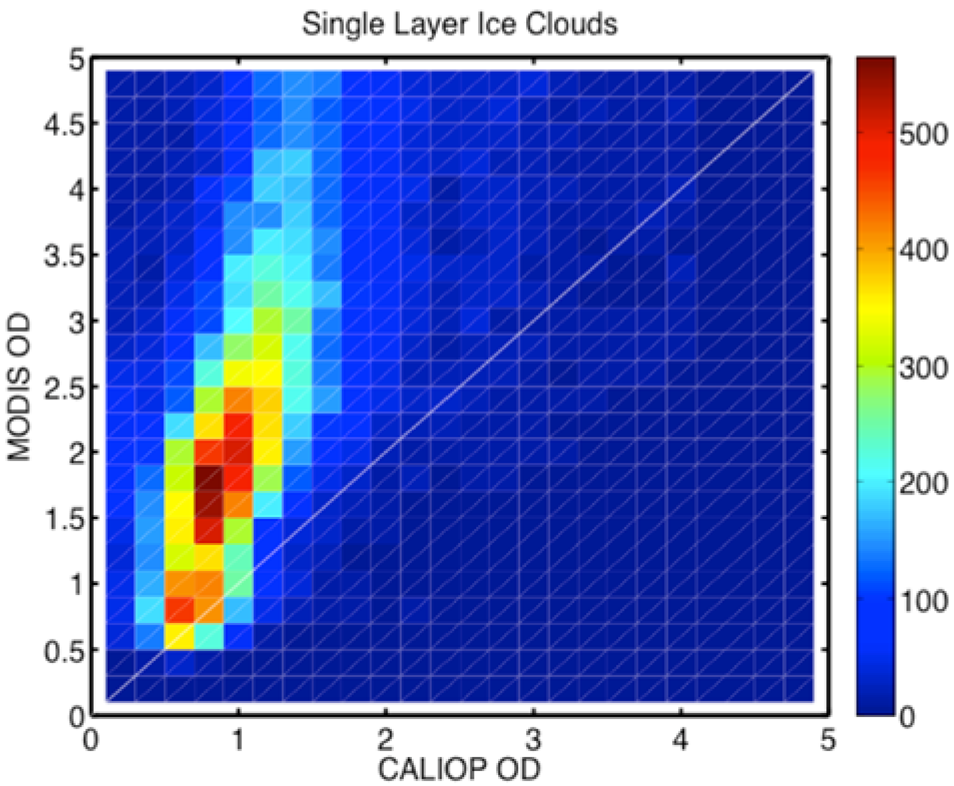
POLDER: IHM model (g≈0.77), randomly oriented hexagonal crystals w/air bubbles

Zhibo Zhang, et al. (ACP, 2009)

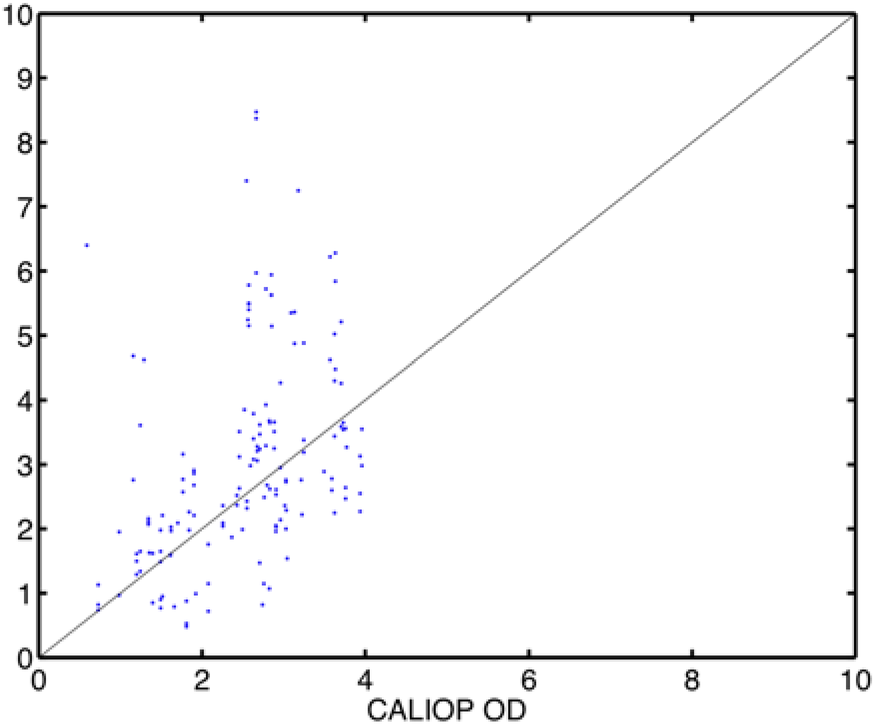


CALIOP (v3) vs. MODIS C5 Single Layer Cirrus τ Comparisons

Global analysis, February 2007, Bob Holz et al.



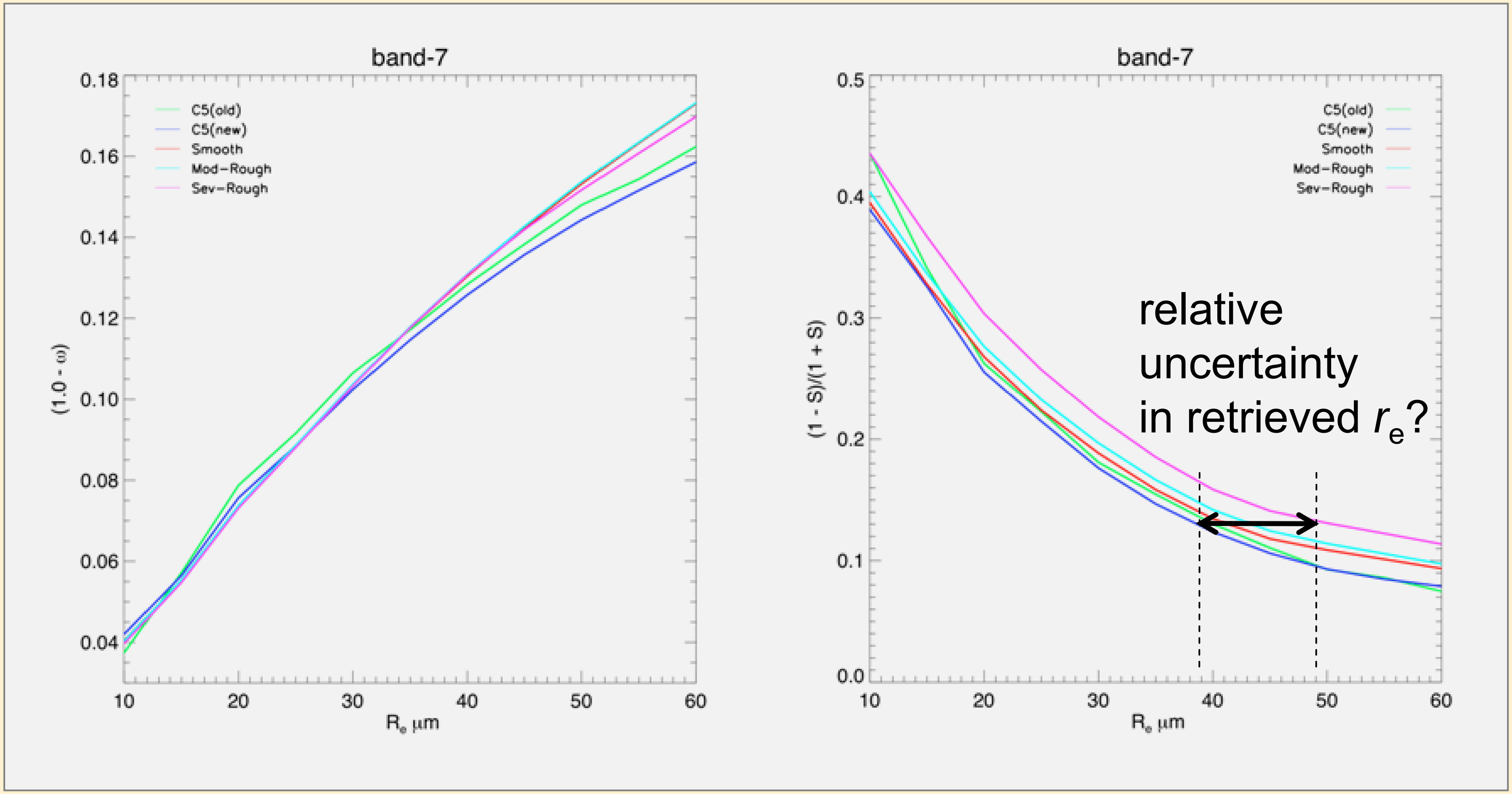
All CALIOP cirrus retrievals
(vast majority from lidar ratio assumption)



CALIOP “constrained” cirrus retrievals
(only ~150 match-ups for the month)

Effect of Ice Cloud Model Uncertainties, cont.

back-of-envelope look at r_e retrieval impacts (from 2.1 µm band)



$$R_\infty \sim (1-S)/(1+S)$$

$$S = [(1-\varpi)/(1-\varpi g)]^{1/2}$$

Summary for Ice Clouds

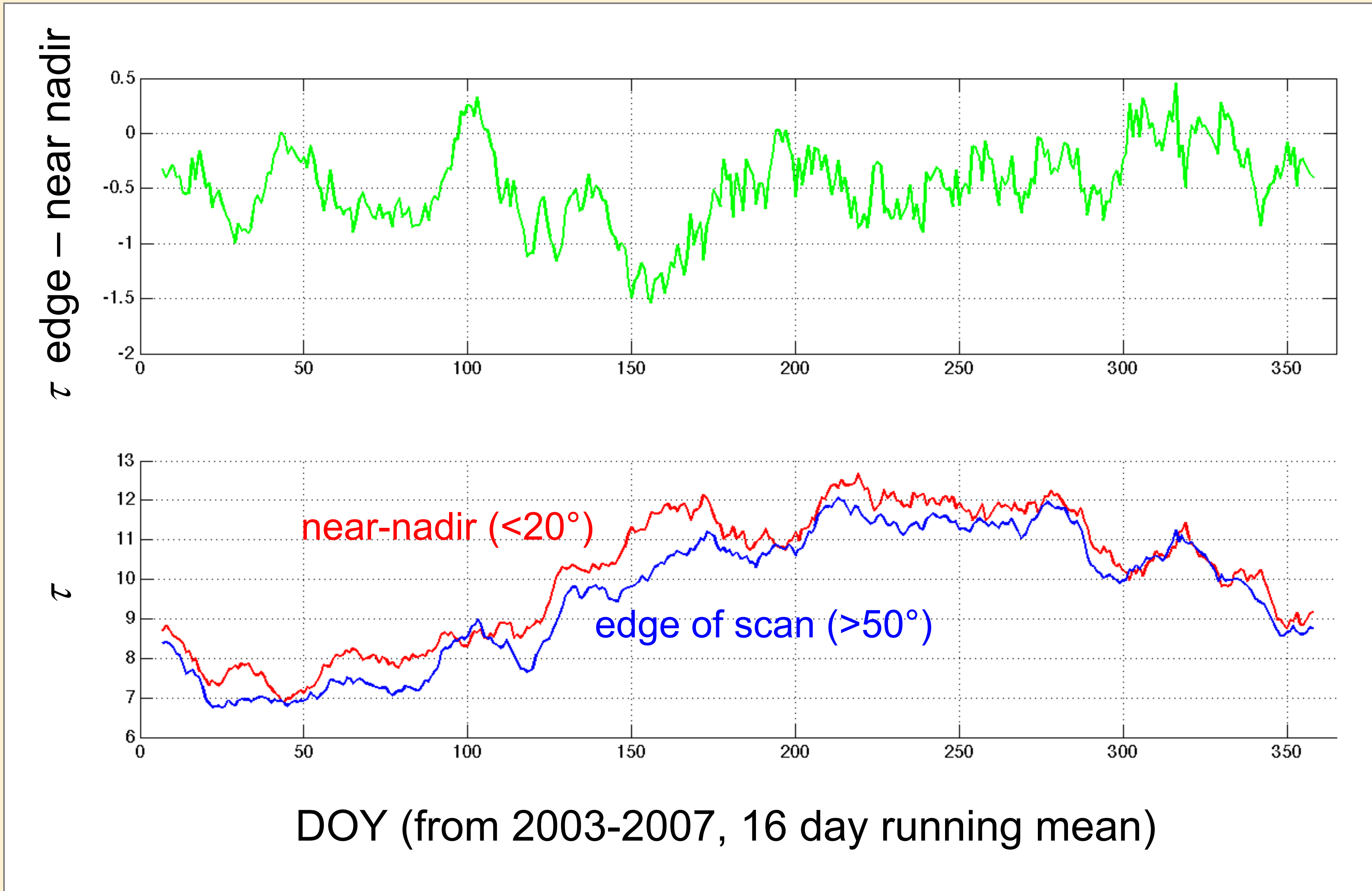
For ice clouds, so far …

- Collection 5 MODIS was an attempt to use in situ habits and IWC constraints to synthesize physically-based ice cloud models.
- Empirical studies (POLDER IHM, Labonnote et al. 2000) find that models with smooth phase functions better match view angle observations.
- Implications of preliminary CALIOP analysis being explored.
- Ultimately, want to understand/merge physically-based data/calculations with empirical results.
  - Physical approach: Adding roughening and/or adjusting habit recipes is a large dimensional and non-unique space.
  - Empirical approach: Launch of Glory (Nov. 2010) should be extremely valuable.

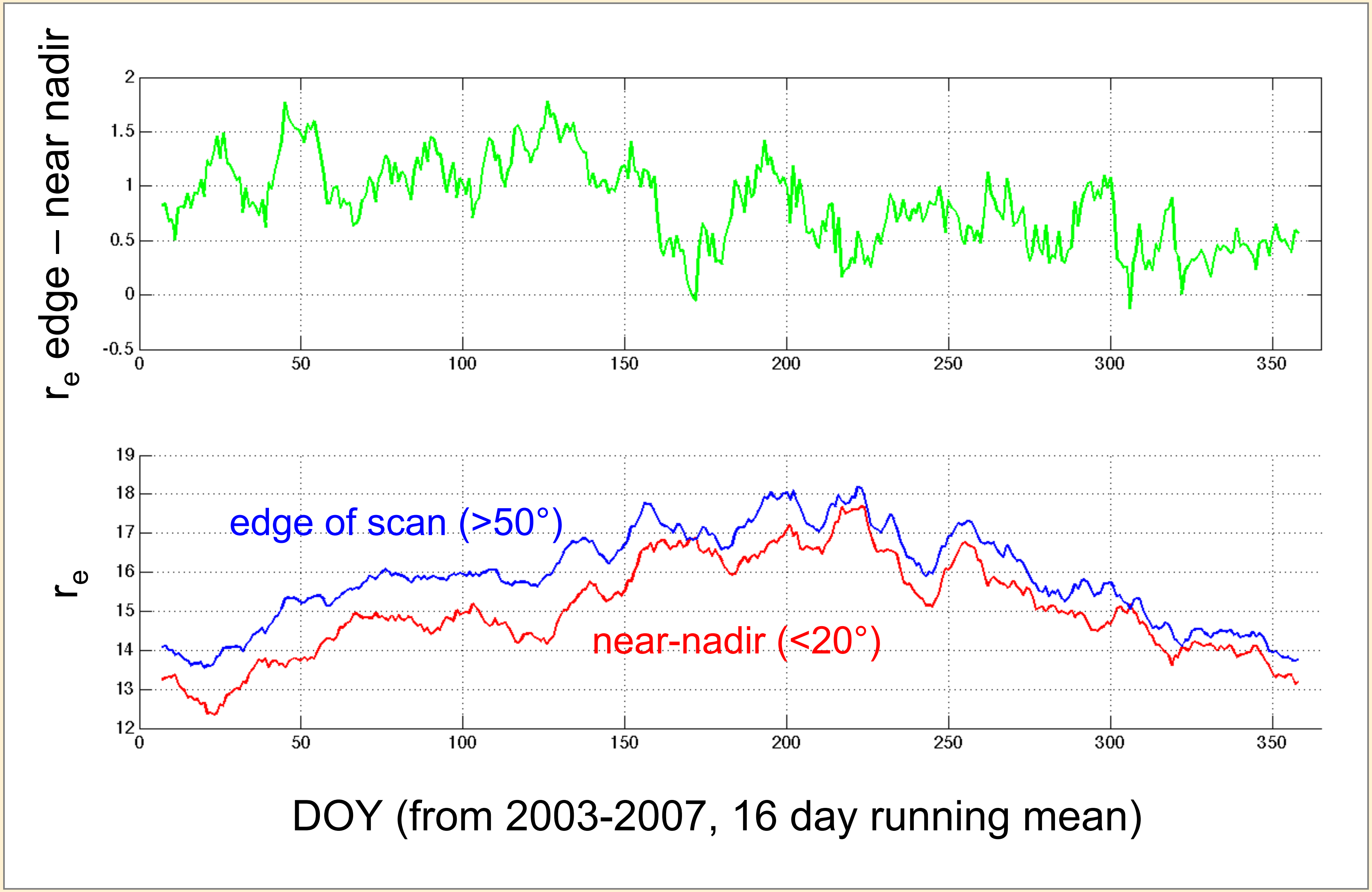
MODIS Cloud Optical, Microphysical Product (MOD06)

View Angle Sensitivities

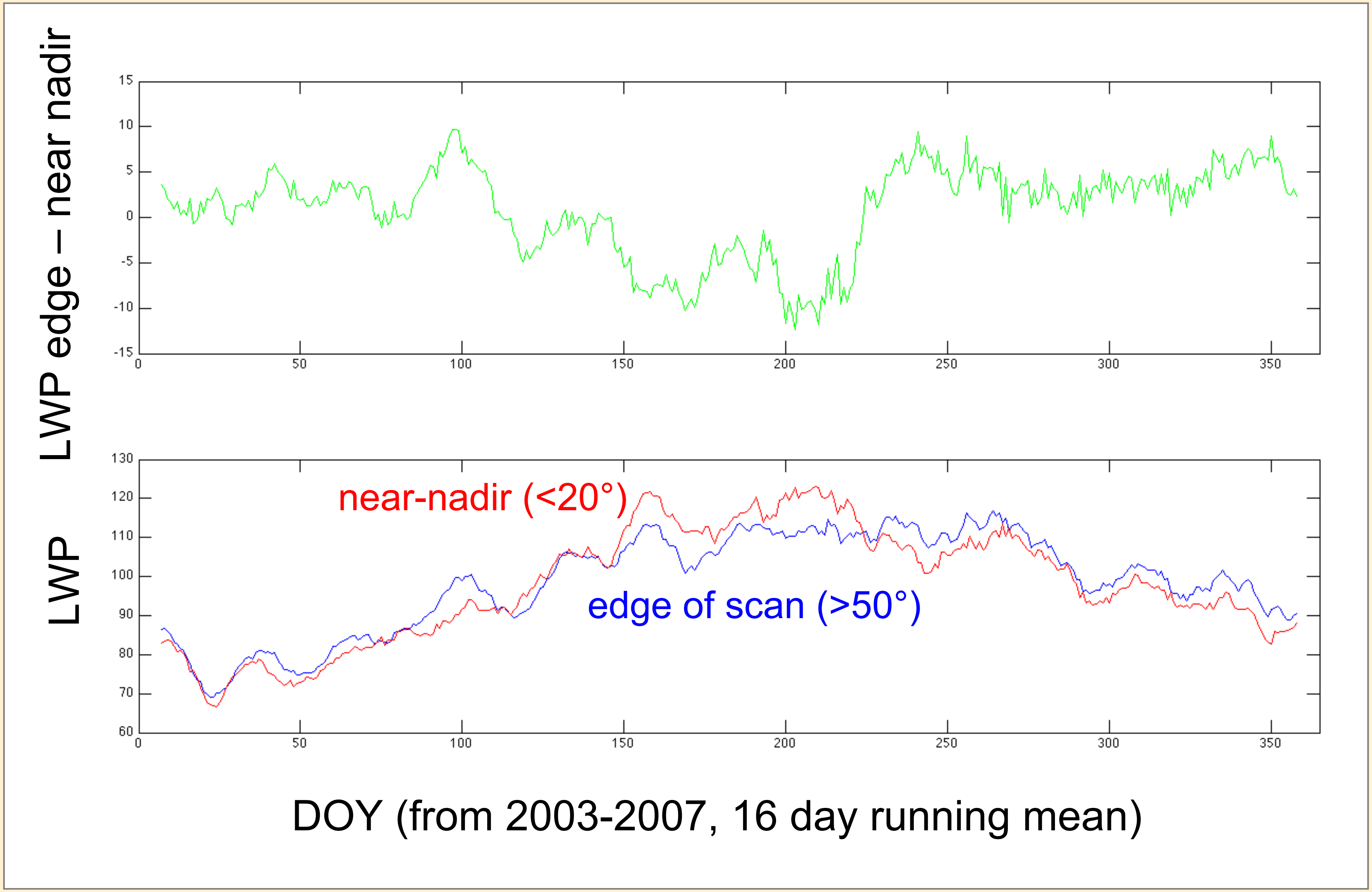
Optical Thickness Terra (10S-20S,80W-90W)



Effective Radius Terra (10S-20S,80W-90W)

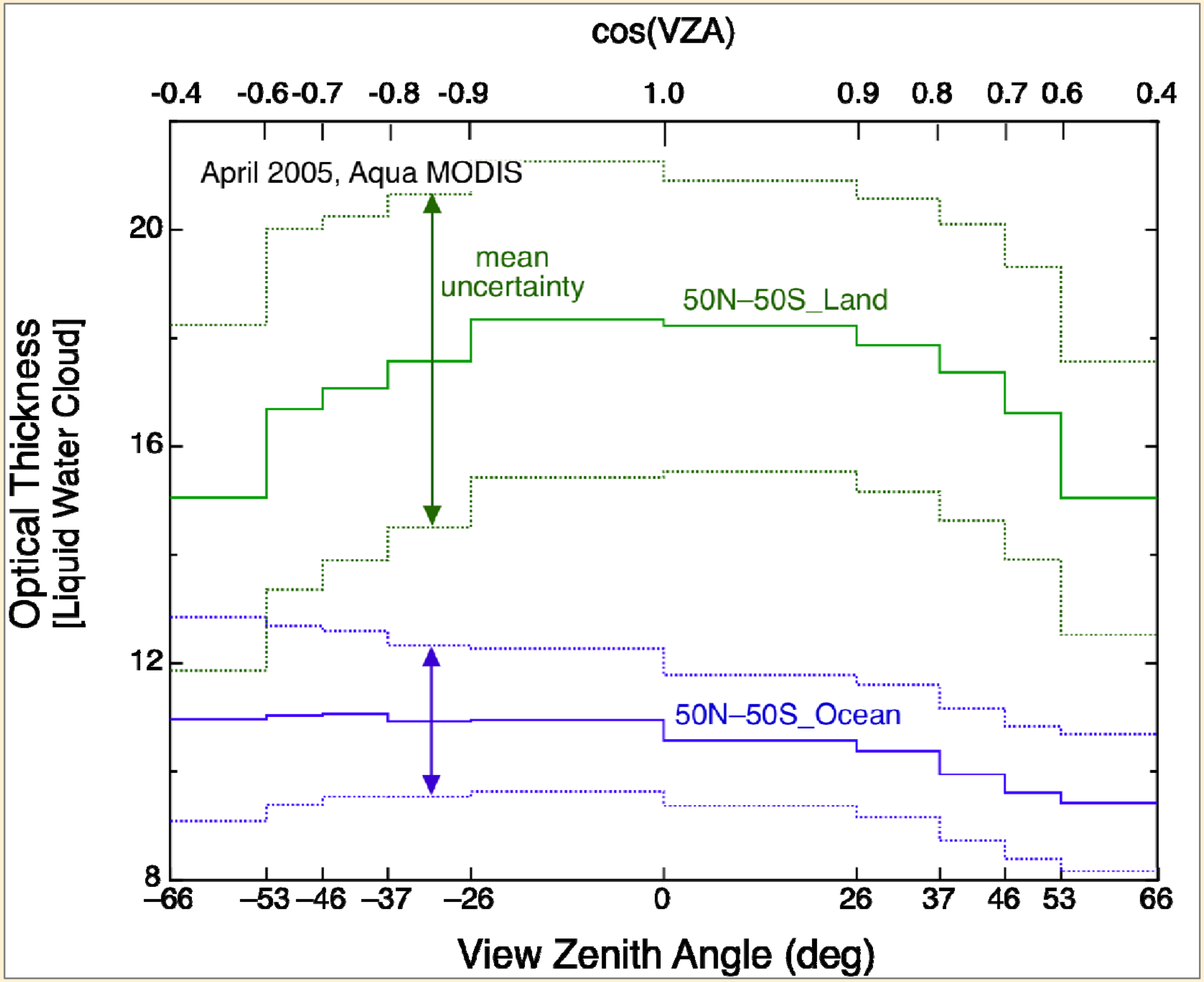


LWP Terra (10S-20S,80W-90W)



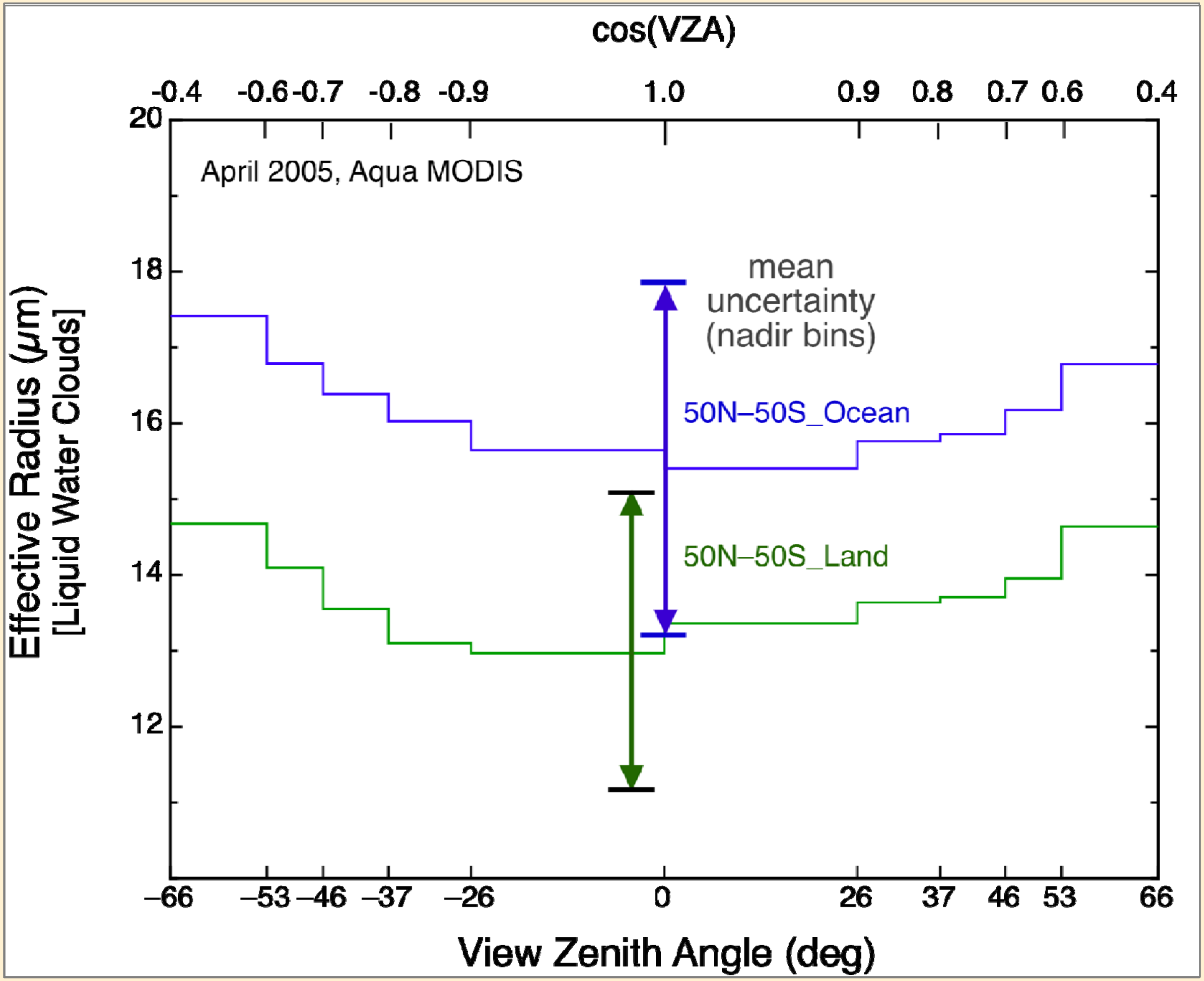
L3 Statistical Uncertainty Study: Zonal Retrieval Statistics vs. VZA

Optical Thickness, water clouds



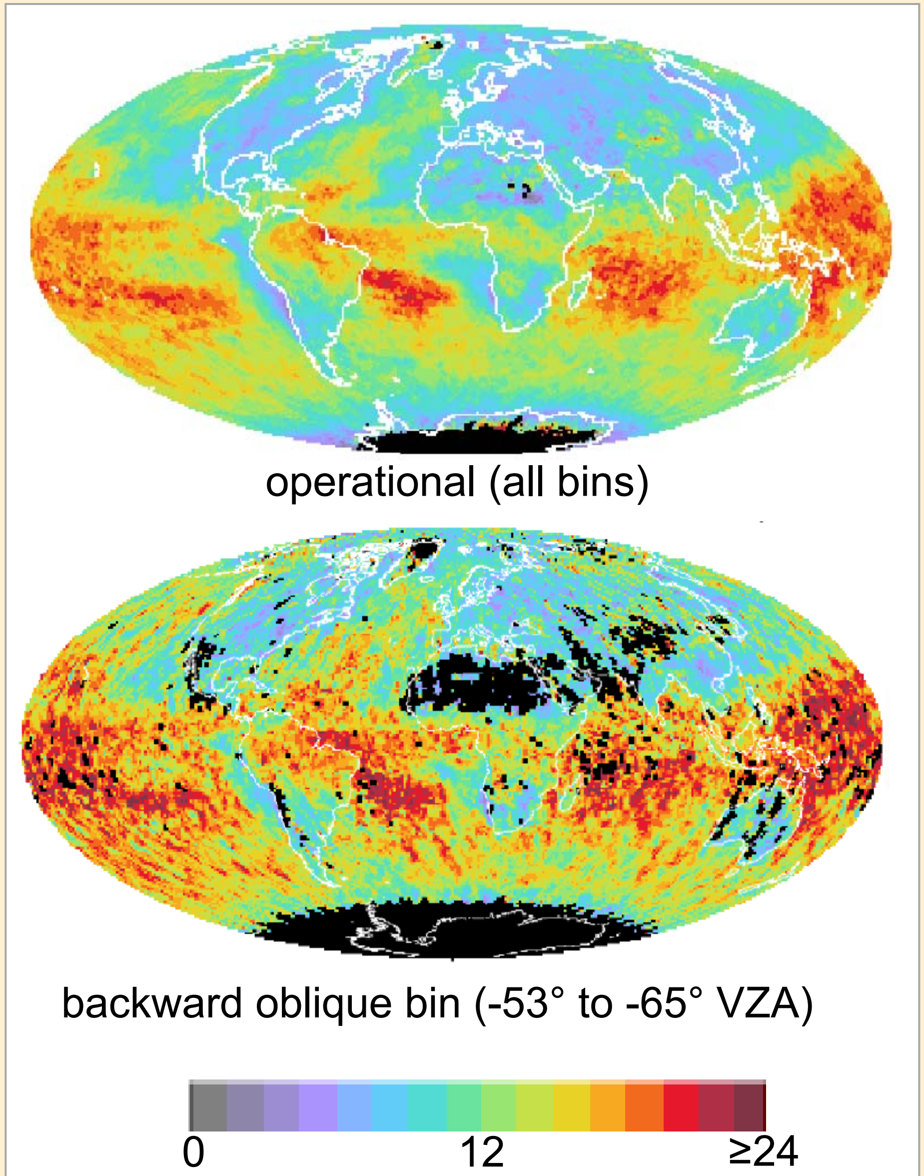
L3 Statistical Uncertainty Study: Zonal Retrieval Statistics vs. VZA

Effective Radius, water clouds



L3 Statistical Uncertainty Study: Global Retrieval Statistics vs. VZA

Effective Radius, water clouds, MODIS Aqua, April 2005



operational (all bins)

backward oblique bin (-53° to -65° VZA)

Summary of VZA Results

For water clouds:

- Can have significant regional effects
- Zonal mean statistics: at all latitudes (land and/or ocean) VZA dependencies for τ and r_e are within product's mean instantaneous uncertainties
- Optical Thickness zonal means:
  – ocean clouds show some asymmetry (slight indication of shadowing on sun view side of scan?)
  – land clouds symmetric.
- Effective Radius:
  – no obvious shadowing effect (symmetric), both zonal and some regional analysis

MODIS Cloud Optical, Microphysical Product (MOD06)

2.1 vs. 3.7 µm-based Effective Radius Retrievals

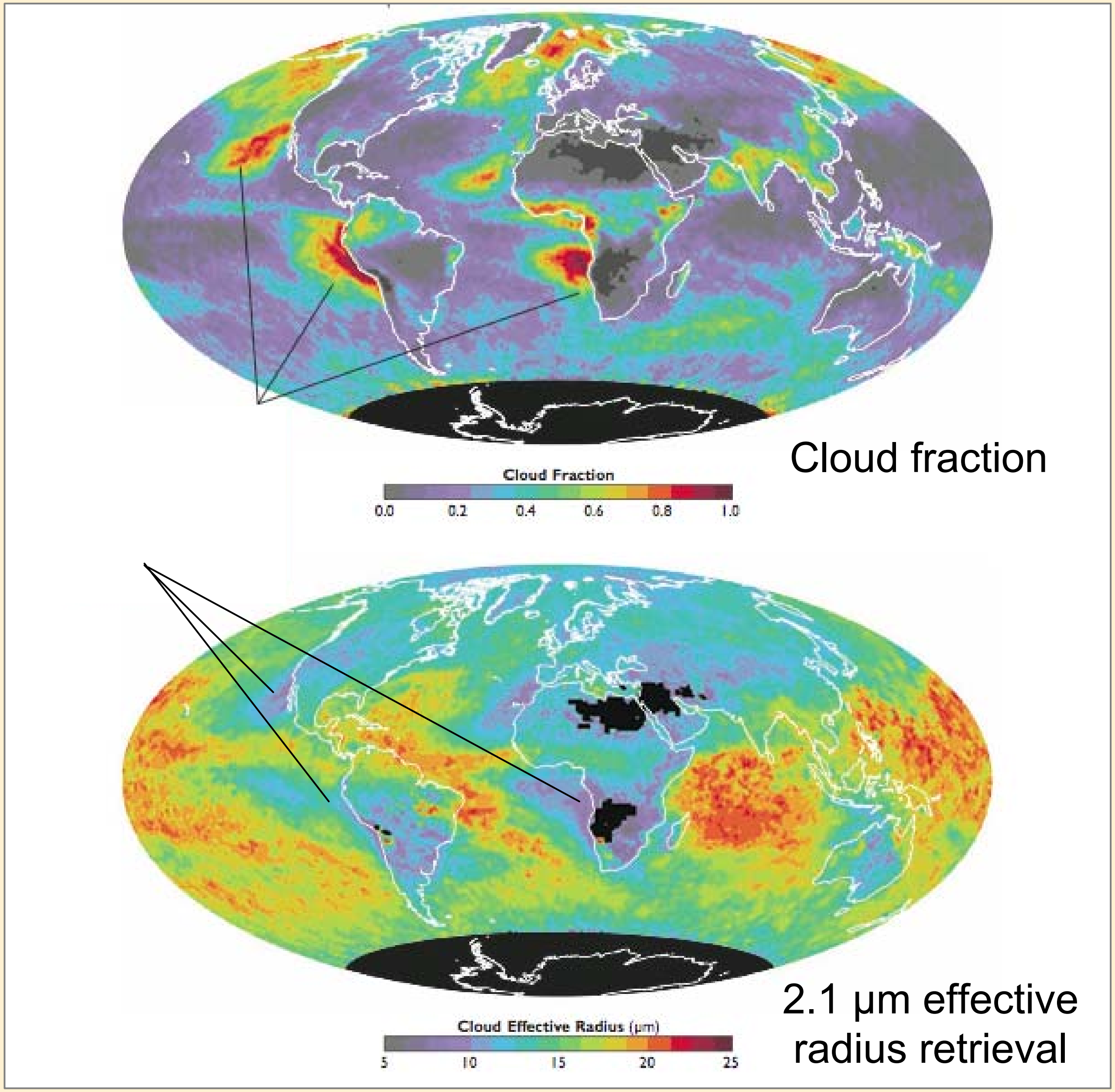
Summary of 2.1 µm vs. 3.7 µm r_e Results

For water clouds, so far …

- Global r_e statistics between 2.1 and 3 7 µm retrievals are significantly different.
  - <u>Don't directly compare MODIS standard retrieval (2.1 µm) with AVHRR or MODIS/CERES 3.7 µm derived data sets</u>.
  - Differences between these data sets are due to choice of bands uses, not algorithmic.
  - Oceanic differences correlated with cloud fraction
  - From CloudSat comparisons (e.g., Bennartz and Maddux; Takashi Nakajima et al., 2010), most dramatic differences appears to be related to drizzle/precip which may also be correlated with broken clouds.
  - Some/more significant positive (2.1–3.7) bias with VZA (beyond pixel level uncertainties) in broken oceanic regions.
- Pursuing MOD06 retrievals from marine BL LES runs

MODIS L3

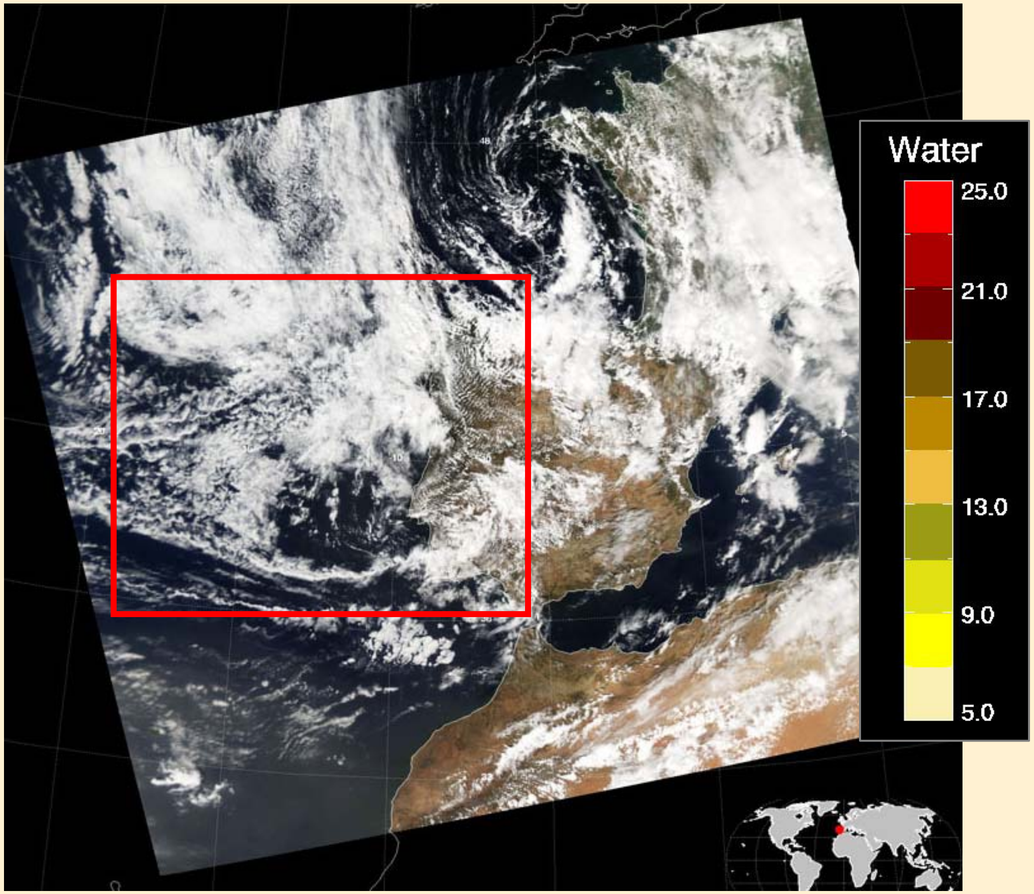
liquid water clouds
Terra, July 2006

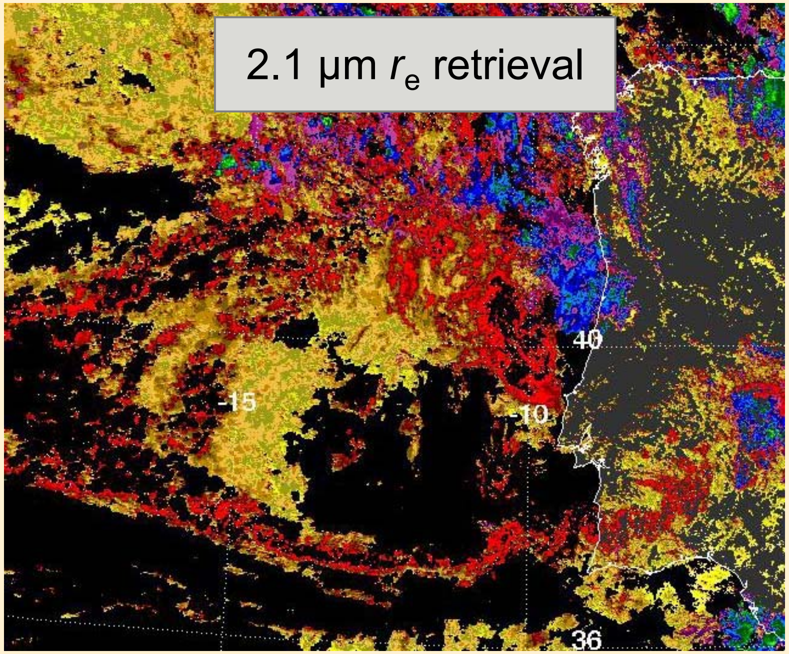


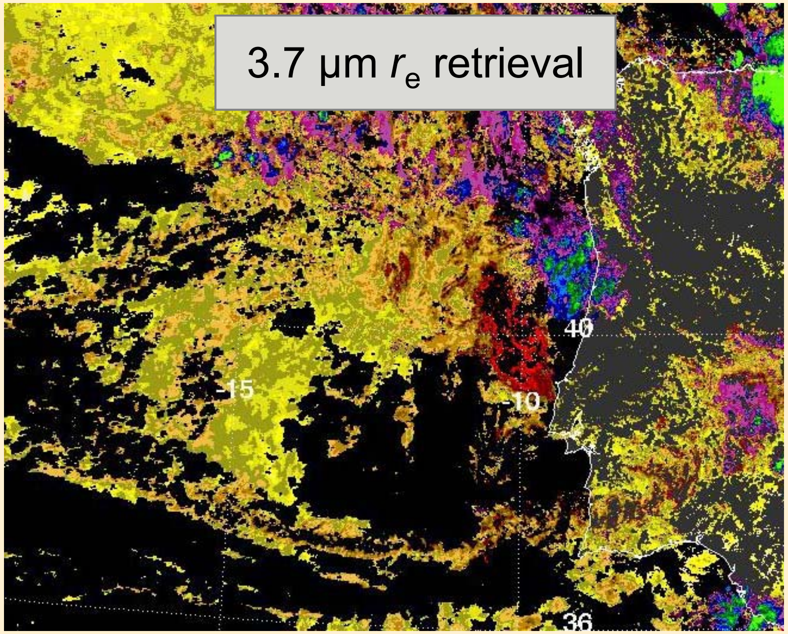
Cloud fraction

2.1 μm effective radius retrieval

MODIS Aqua, Collection 5
9 September 2005

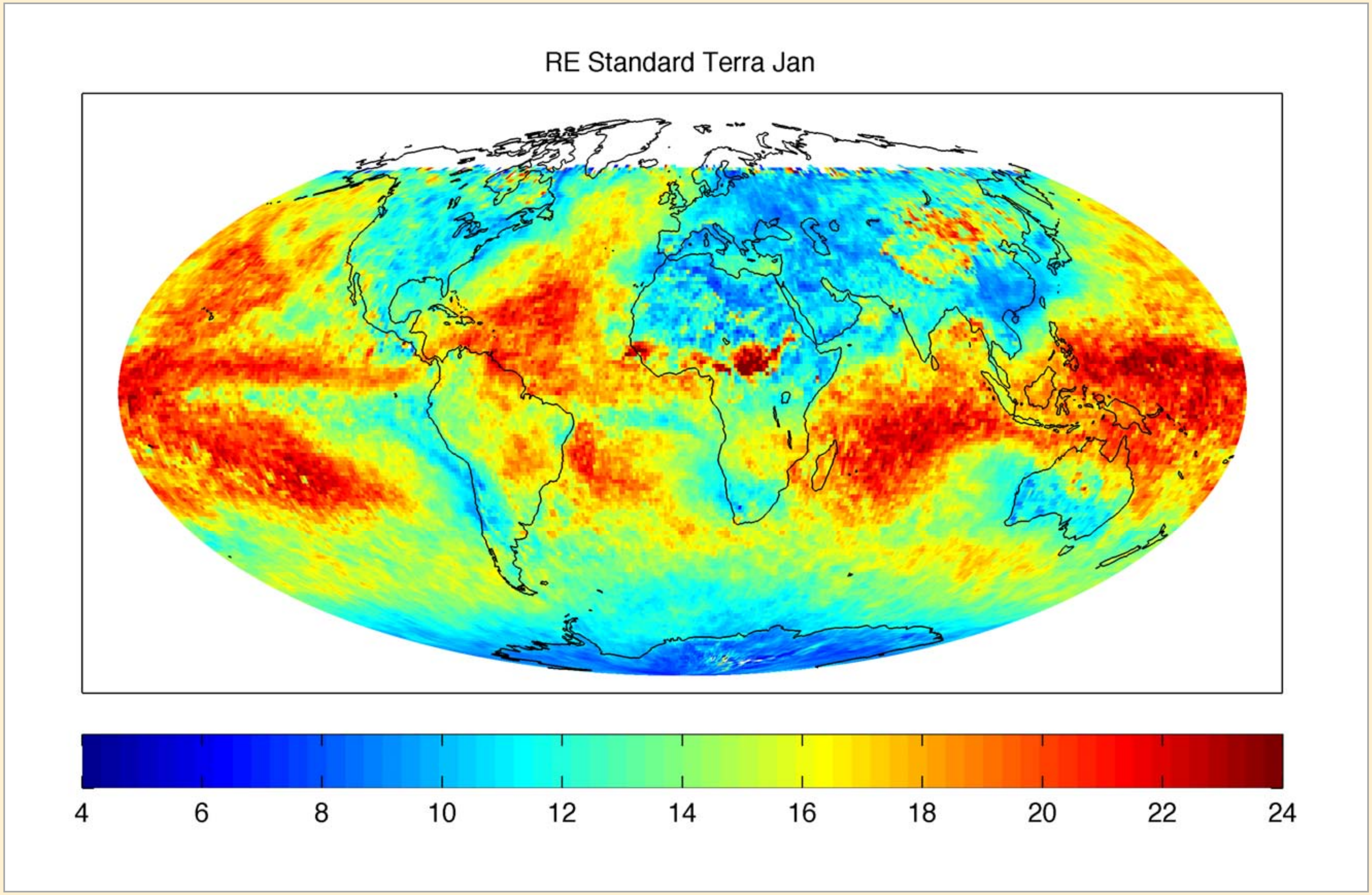






Monthly Mean Cloud Effective Radius: 2.1 vs. 3.7 μm

Water Clouds - Terra MODIS June 2005 (Brent Maddux et al.)



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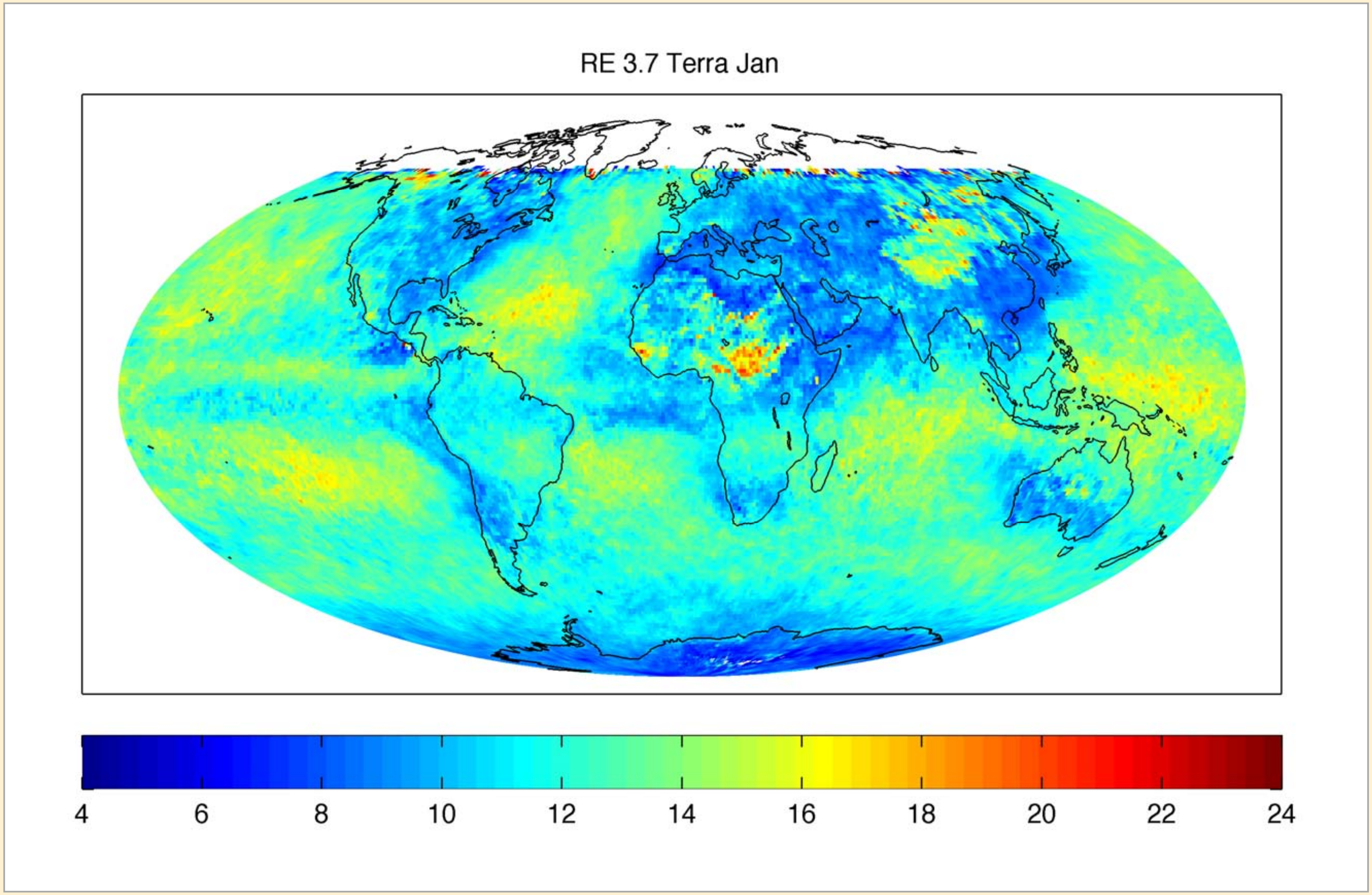
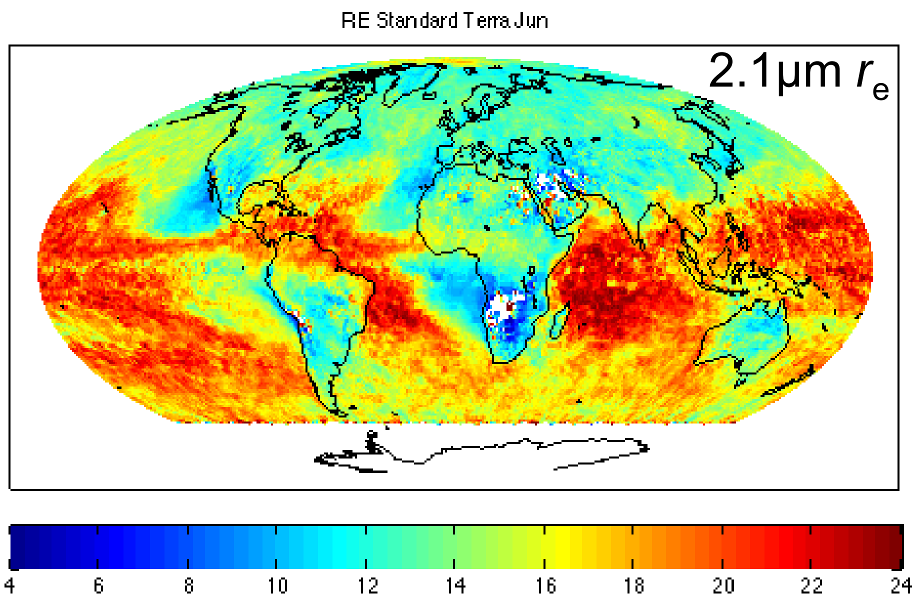
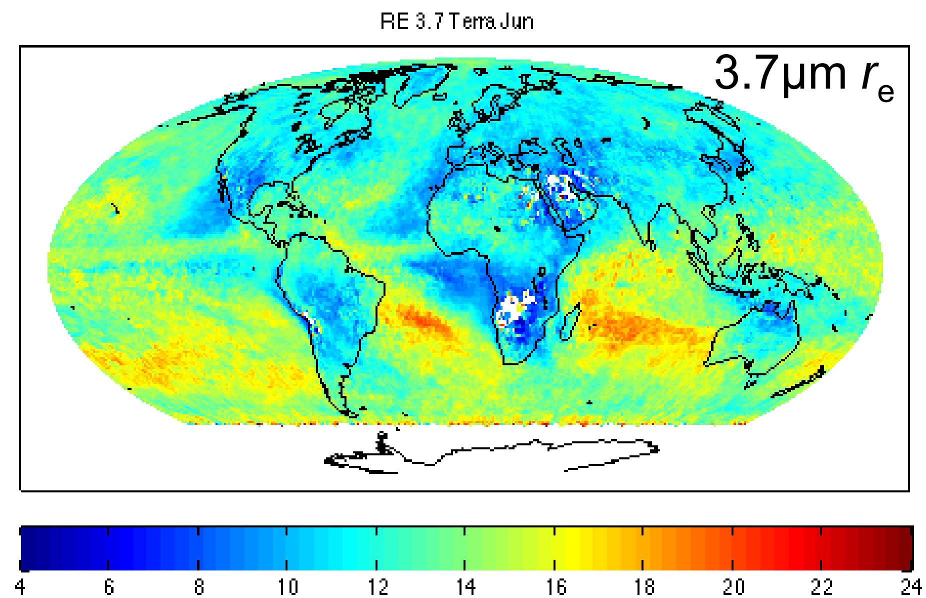
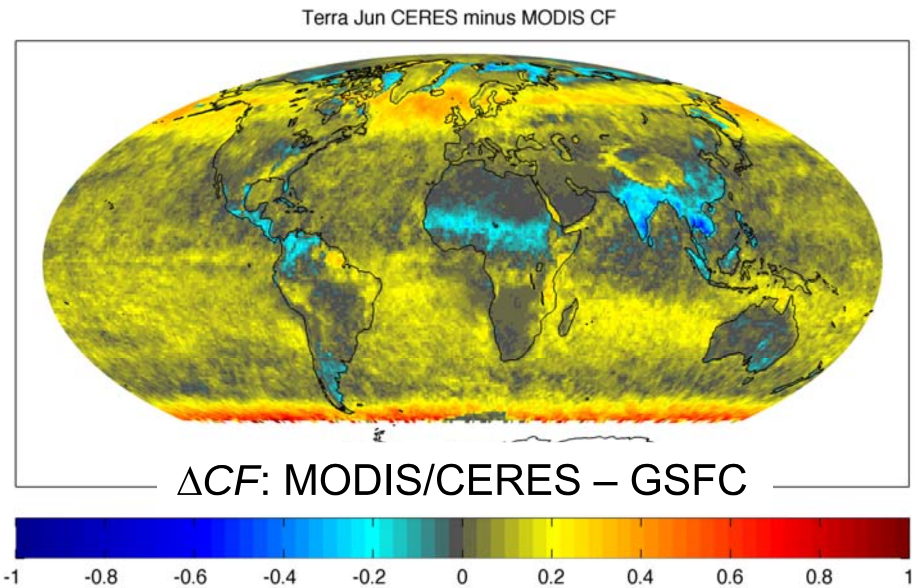


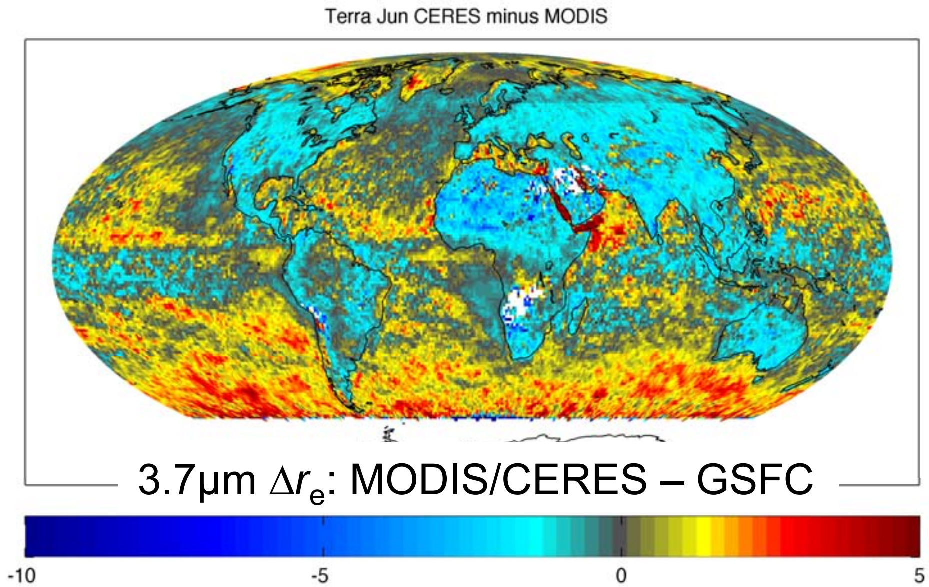
Monthly Mean Cloud Effective Radius: 2.1 vs. 3.7 µm

(Terra MODIS June 2005)



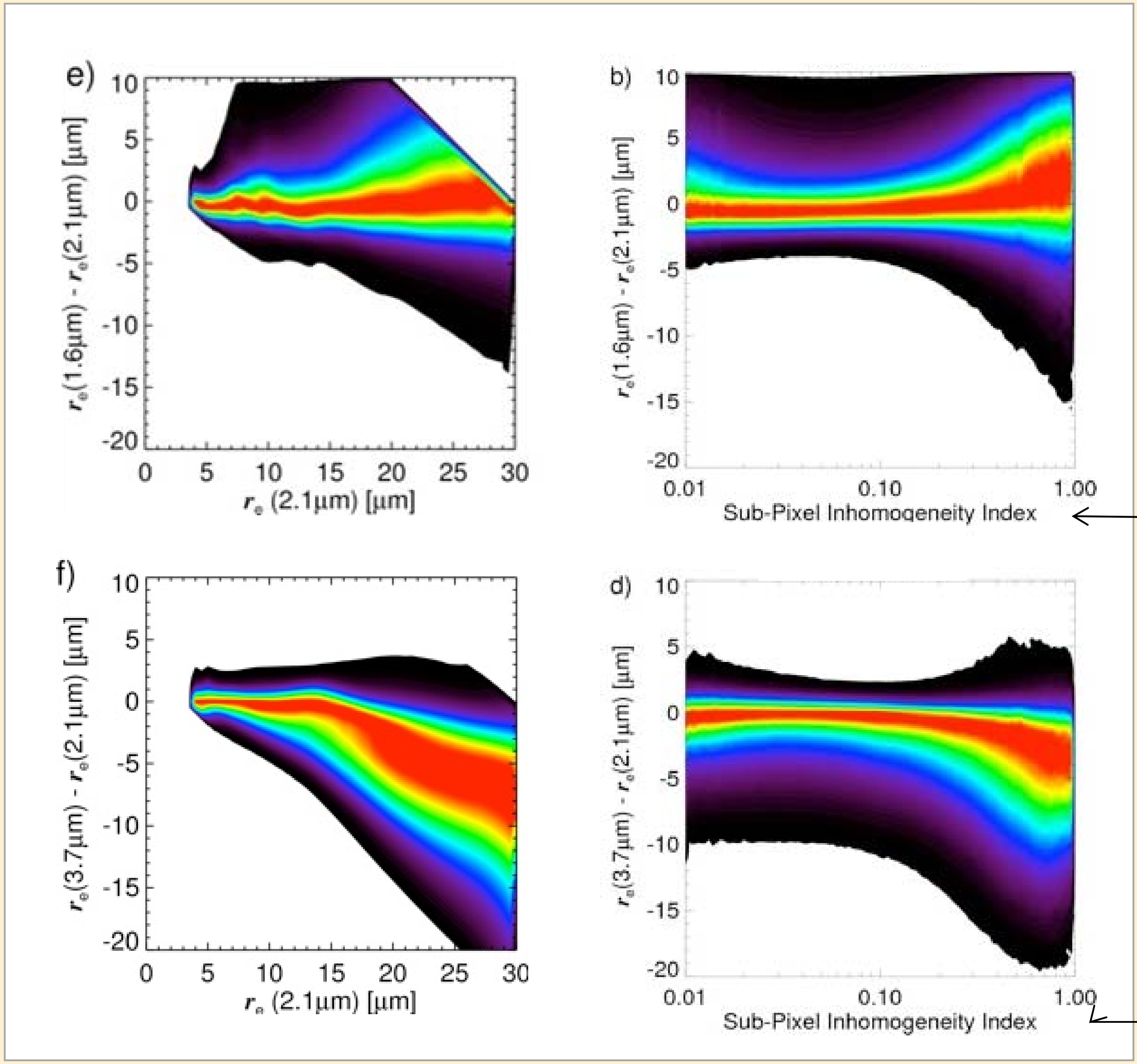






3.7–2.1 µm r_e Differences Correlated w/re(2.1) and Inhomogeneties

Global Ocean, ±60°, April 2005, Terra (Zhibo Zhang)



σ/µ for 0.86 µm 250m pixels

All Δr_e distributions (vertical sections) normalized

Summary of 2.1 μm vs. 3.7 μm r_e Results

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  - Don't directly compare MODIS standard retrieval (2.1 μm) with AVHRR or MODIS/CERES 3.7 μm derived data sets.
  - Differences between these data sets are due to choice of bands uses, not algorithmic.
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