Towards the Retrieval of Cirrus Particle Size and Optical Depth with AIRS

by

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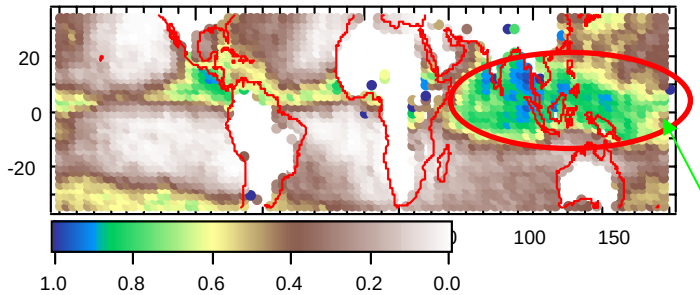
Cloud pictures courtesy of australiansevereweather.com

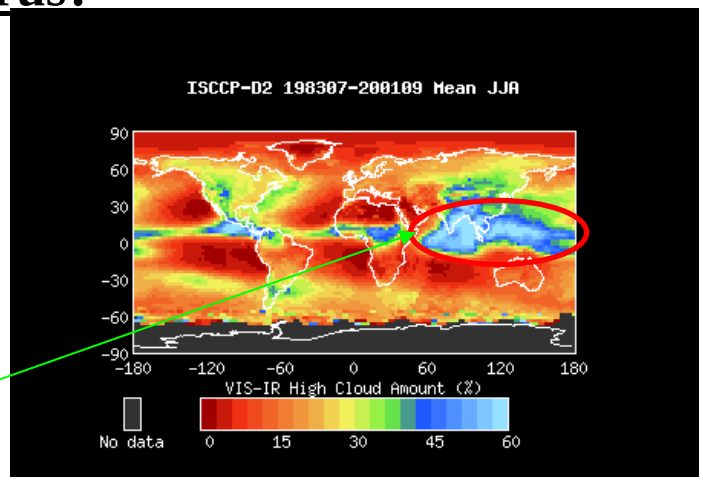
Outline

- Cirrus frequency from AIRS: how does it compare to other climatologies?
- Multilayered clouds
- Mixed phase clouds: AIRS versus MODIS
- Retrieving thin cirrus D_e and τ with AIRS radiances
- Preliminary results

Where is the cirrus?

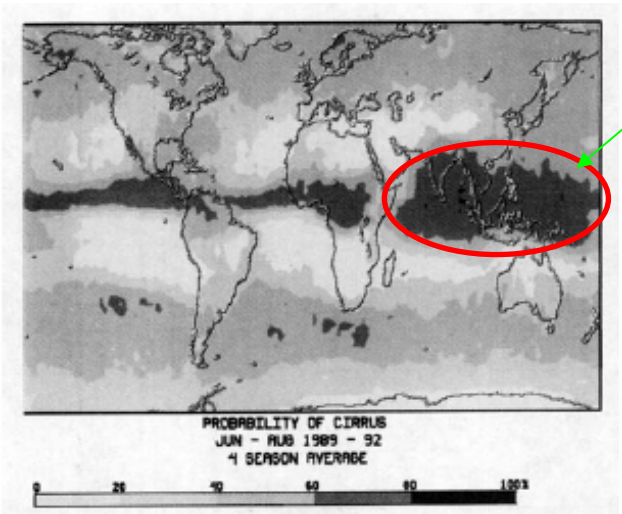


AIRS June/July 2005

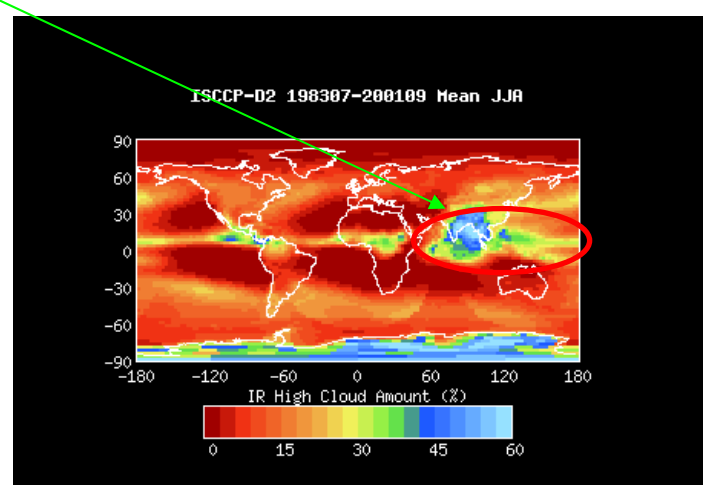


ISCCP IR/VIS only JJA (1983-2001)

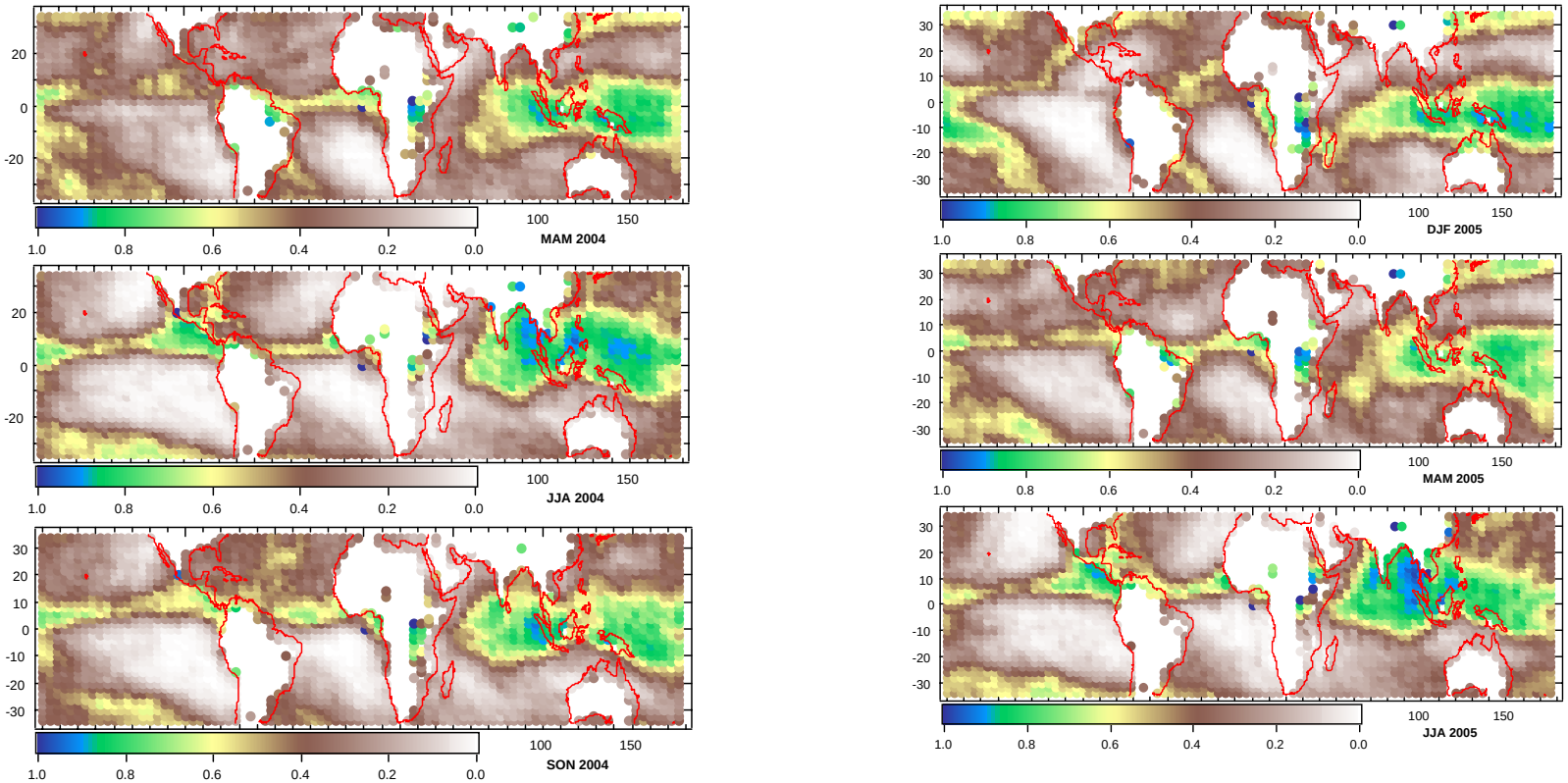
Significant differences exist between different platforms!



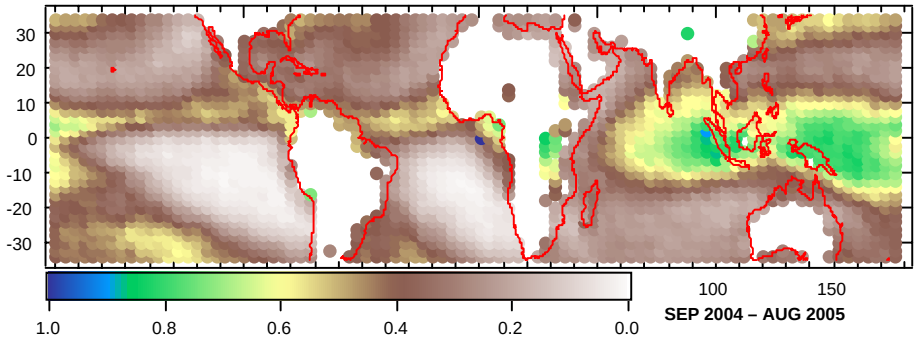
HIRS 4-year JJA



ISCCP IR only JJA (1983-2001)



- Seasonal maps of Ci frequency from MAM 2004 until JJA 2005 using AIRS V4.0
- Cloud mask from *Kahn et al.* [2005] + a threshold for "missed" clouds, using $BT_{960} < 273$ K.
- A ***conservative*** cloud mask which misses many thin cirrus clouds with $\tau_{IR} < 0.1–0.15$.
- Despite the conservative thresholds, the frequency exceeds 80–90% over much of the tropics

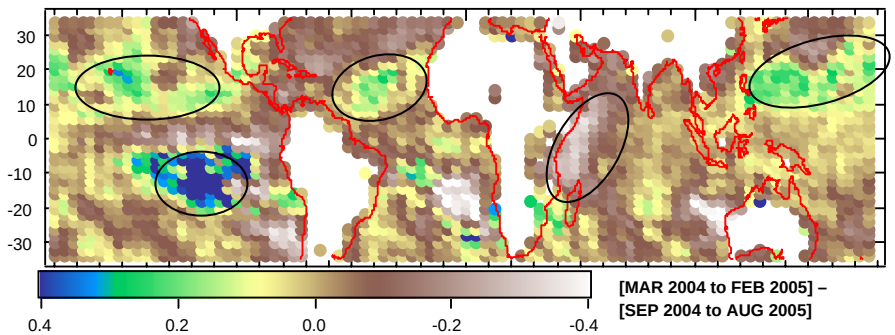


Top: Yearly average from Sep 2004 – Aug 2005

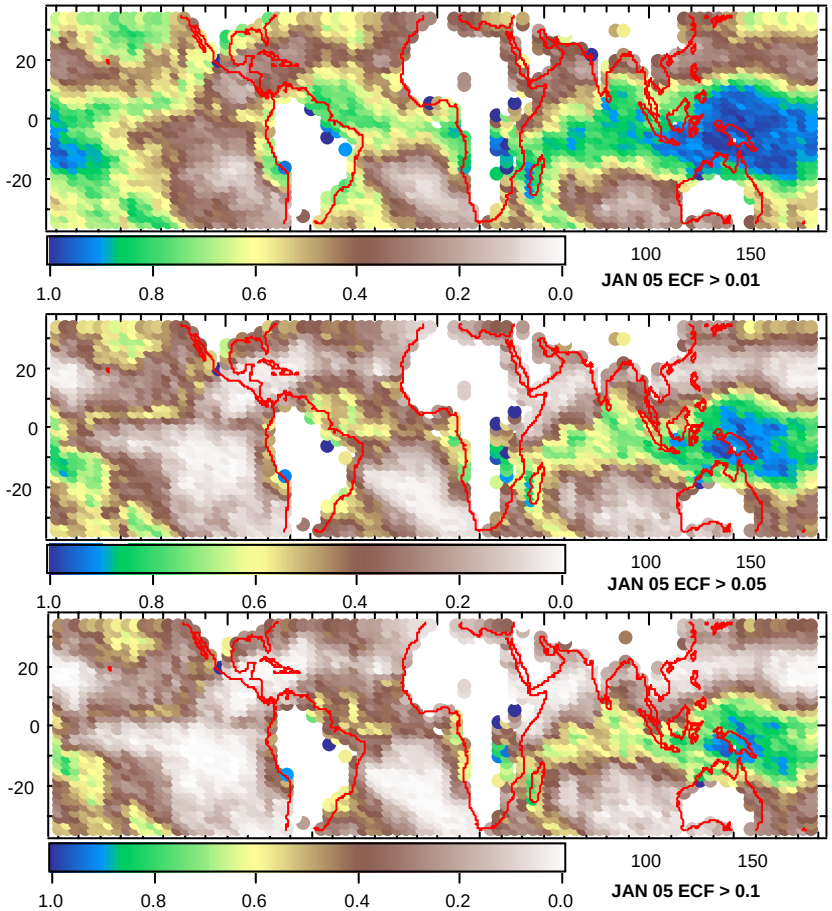
Note ragged features smooth greatly with a longer time average

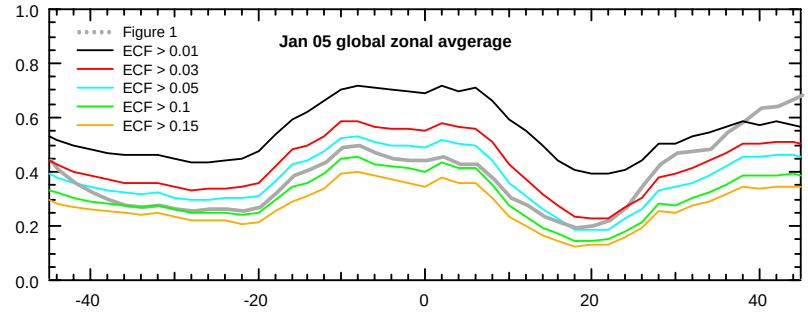
The maximum frequency decreases to the neighborhood of 80–85%.

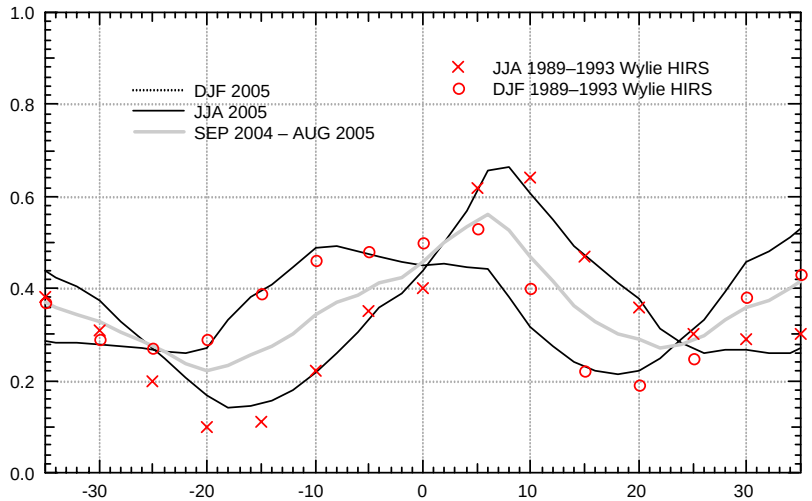
Bottom: % difference in annual frequency of cirrus between 03/2004 – 02/2005 & 09/2004 – 08/2005 Large Interannual variability is noted in particular regions of interest



How realistic are AIRS cloud fields?



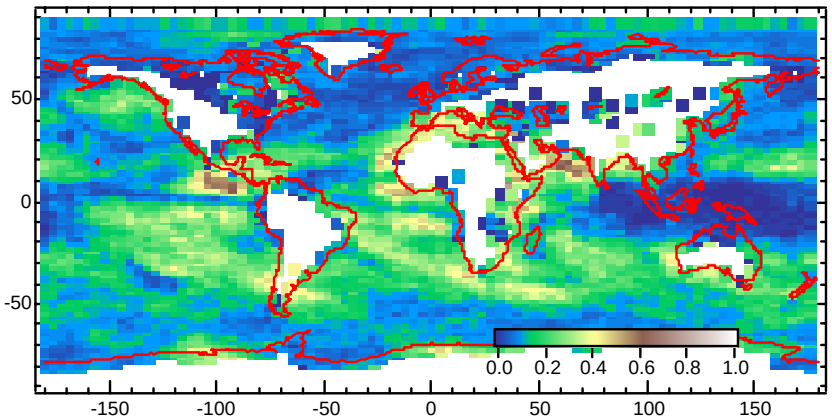




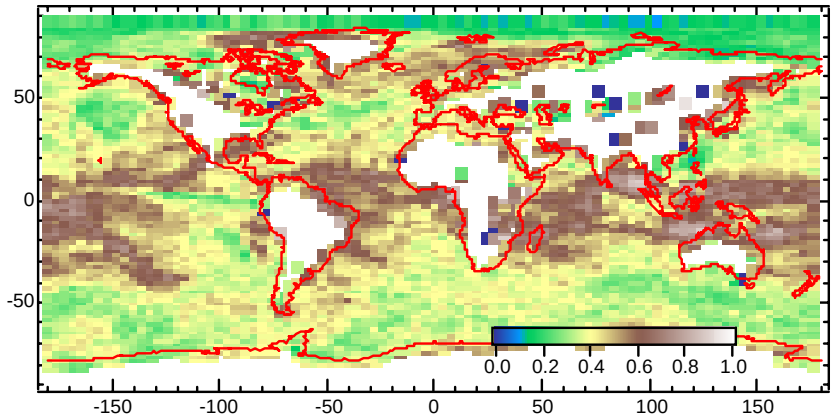
Bottom line: Using *f* as a "cloud mask" produces reasonable cloud fields compared to *Kahn et al.* (2005), JGR, and *Wylie et al.*, (1994) J. Climate

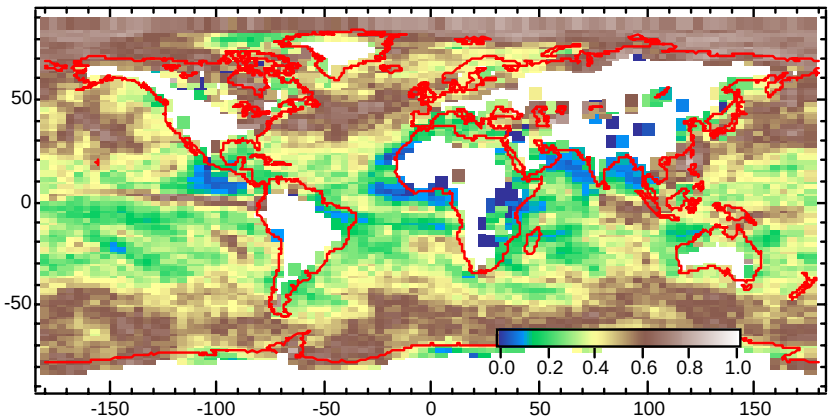
Multilayer Clouds: January 2005

Clear



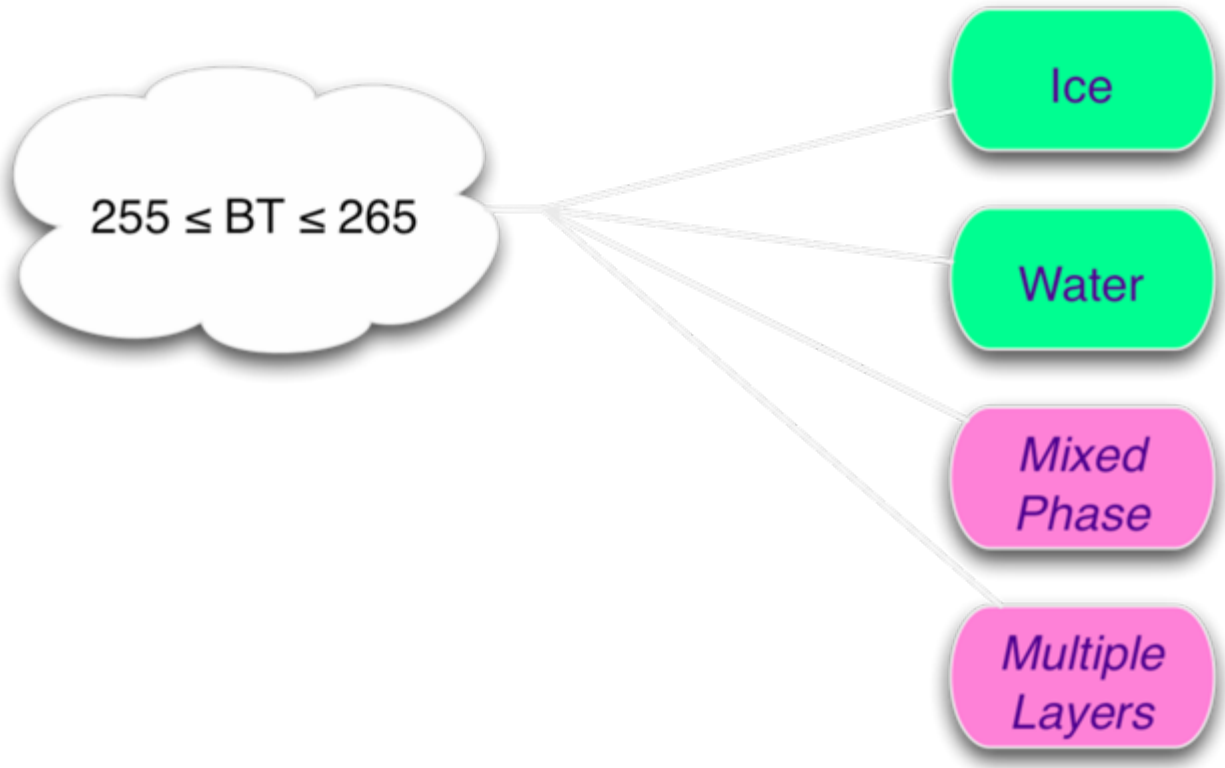
Single Layer





Multilayer

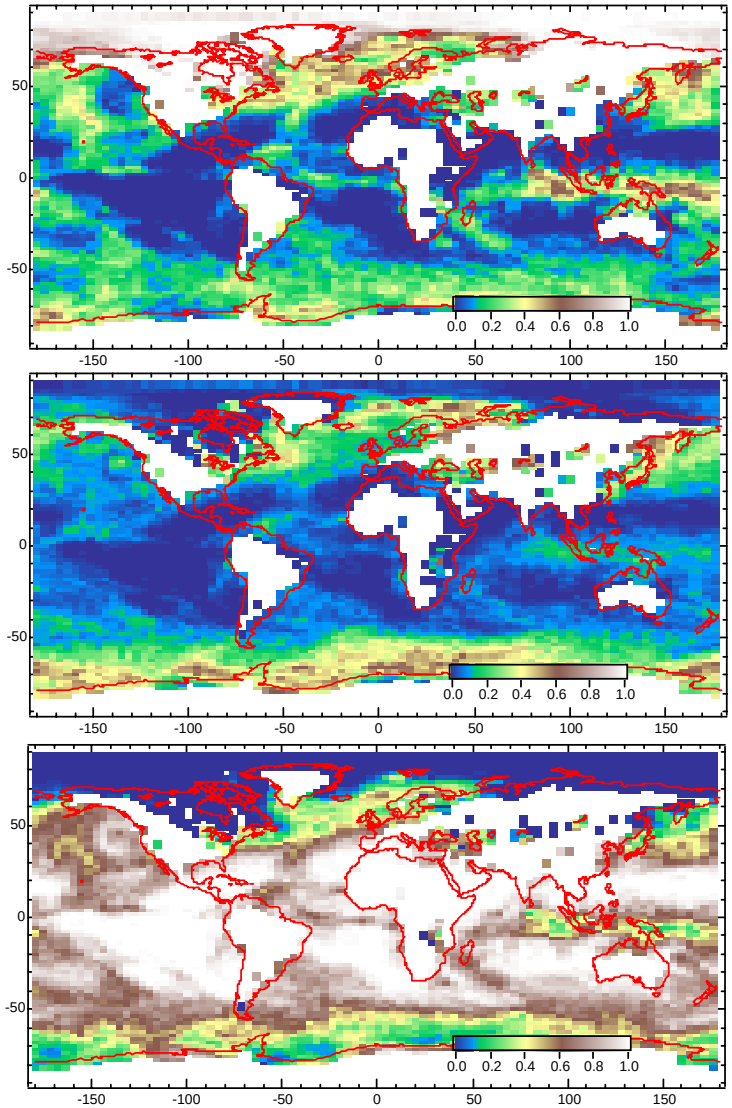
What about more complicated cloud configurations?



Nasiri and Kahn, 2006

January 2005 AIRS L2 Version 4.0

The "uncertain" clouds:
A ***majority*** in polar oceans!



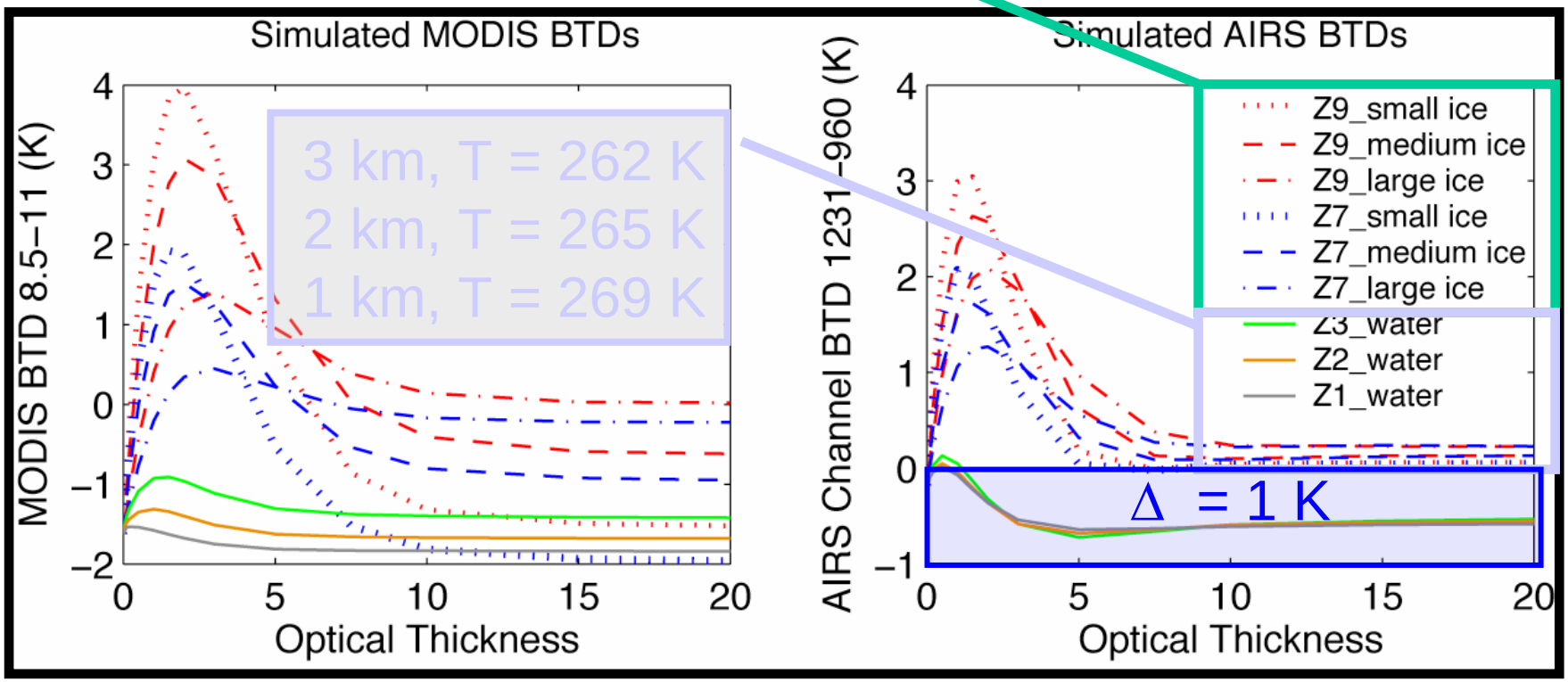
BT 960 cm $^{-1}$ < 255 K

255 K < BT 960 cm $^{-1}$ < 265 K

BT 960 cm $^{-1}$ > 265 K

Nasiri and Kahn, 2006

9 km, T = 226 K
7 km, T = 238 K



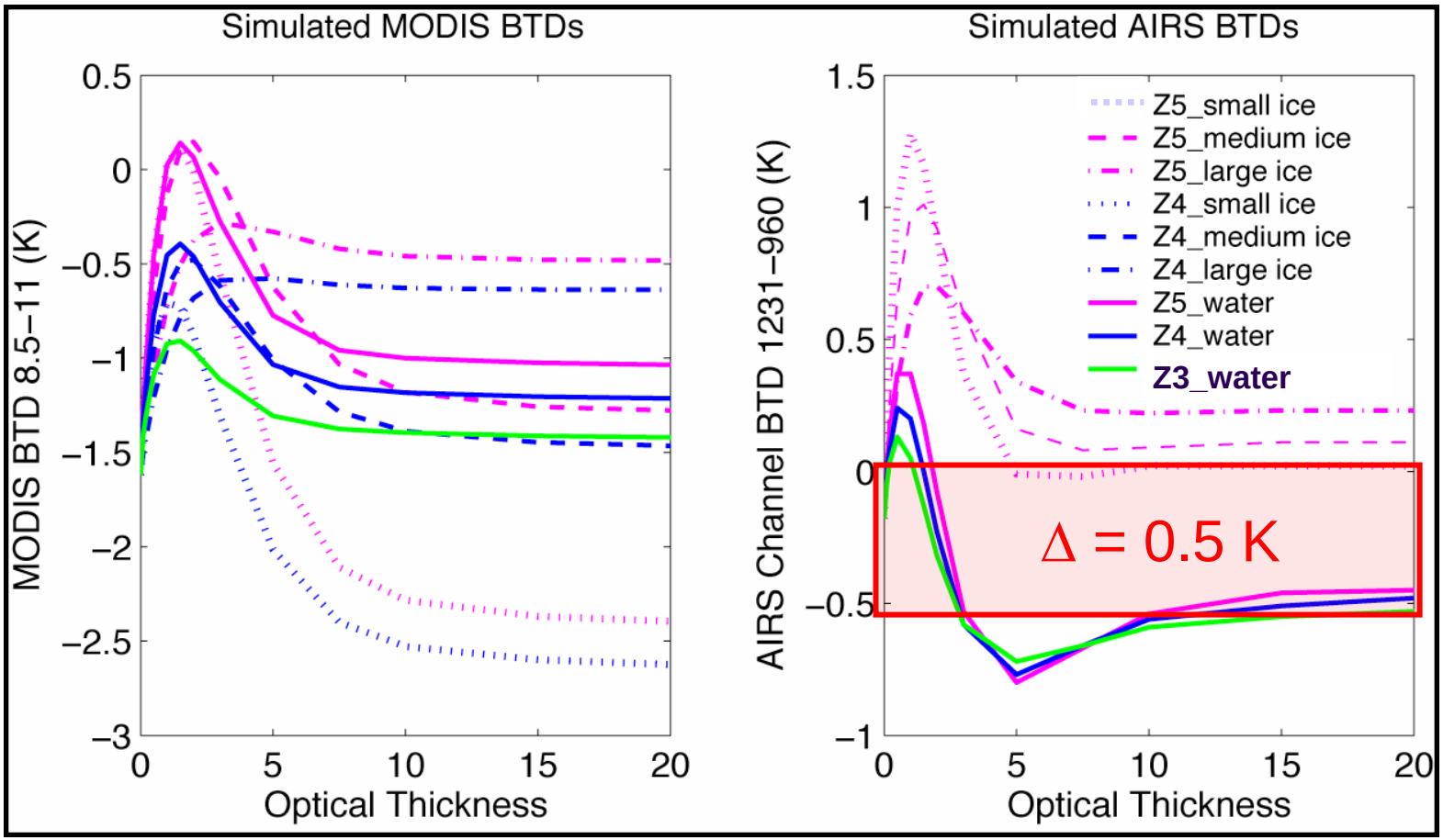
Optical thickness at 11 μm

MODIS sims from DISORT

AIRS sims from CHARTS

Nasiri and Kahn, 2006

What about the harder cases from 3–5 km?



5 km, T = 256 K 4 km, T = 262 K 3 km, T = 265 K

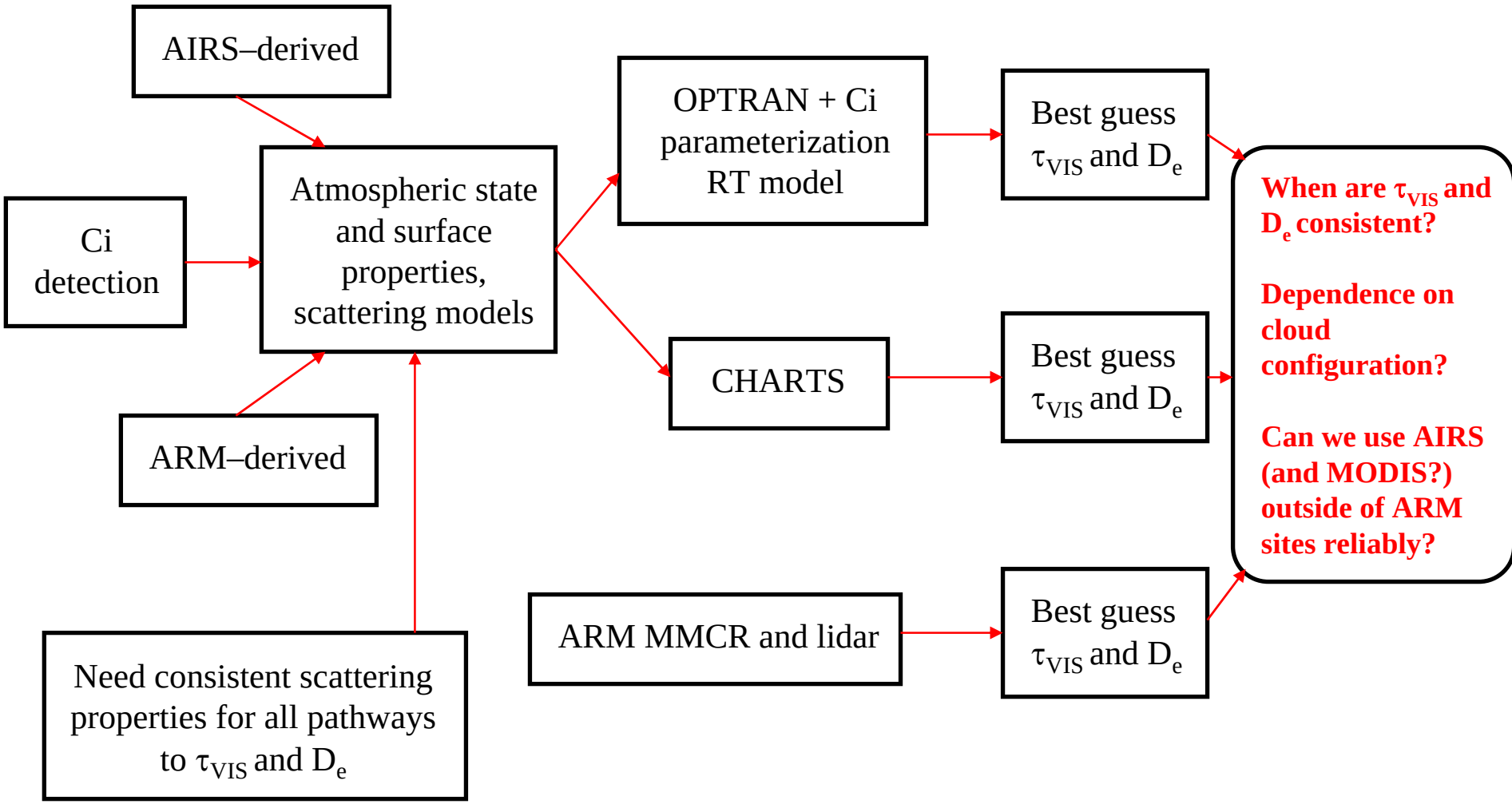
Nasiri and Kahn, 2006

Retrieving cirrus properties

- (Faster) RT model (OPTRAN) + parameterized thin Ci [*Yue et al.* 2006]
  - Calculate τ_{VIS} and D_e from AIRS
- (Slower) RT model + multiple scattering (CHARTS)
  - complicated atmospheric configurations [e.g., *Kahn et al.*, 2003, GRL]
- AIRS provides: cloud detection [e.g., *Kahn et al.*, 2005, JGR], Z_{CLD}, T_{CLD}, *f* (up to 2 layers), T(z), RH(z), etc.
- ARM sites provide accurate cloud location, independent validation of τ_{VIS} and D_e, T(z) and RH(z), etc.

Bottom line: Use CHARTS to validate parameterized OPTRAN RT model w.r.t. Ci characterization over ARM sites, then use AIRS data alone to expand beyond ARM sites

***Answer*: AIRS cloud products are consistent with other measurements**



The "fast" RT approach: OPTRAN + ci parameterization

- Combine OPTRAN clear-sky radiances with a thin cirrus parameterization
- Cirrus represented by series of D_e and habit distributions
- Fit AIRS radiance to best τ, and D_e and habit distributions: **the Ci "retrieval"**

$$I_\nu = I_0\left(1-\varepsilon_\nu\right)+\varepsilon_\nu B_\nu\left(T_c\right)$$

$$\varepsilon_\nu \approx \left(1-\varpi_\nu\right)\tau_{IR}/\mu$$

$$\tau_{IR} \approx \frac{< Q_{ext,IR} >}{2}\tau$$

Yue et al., 2006

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From AIRS L2 retrieval

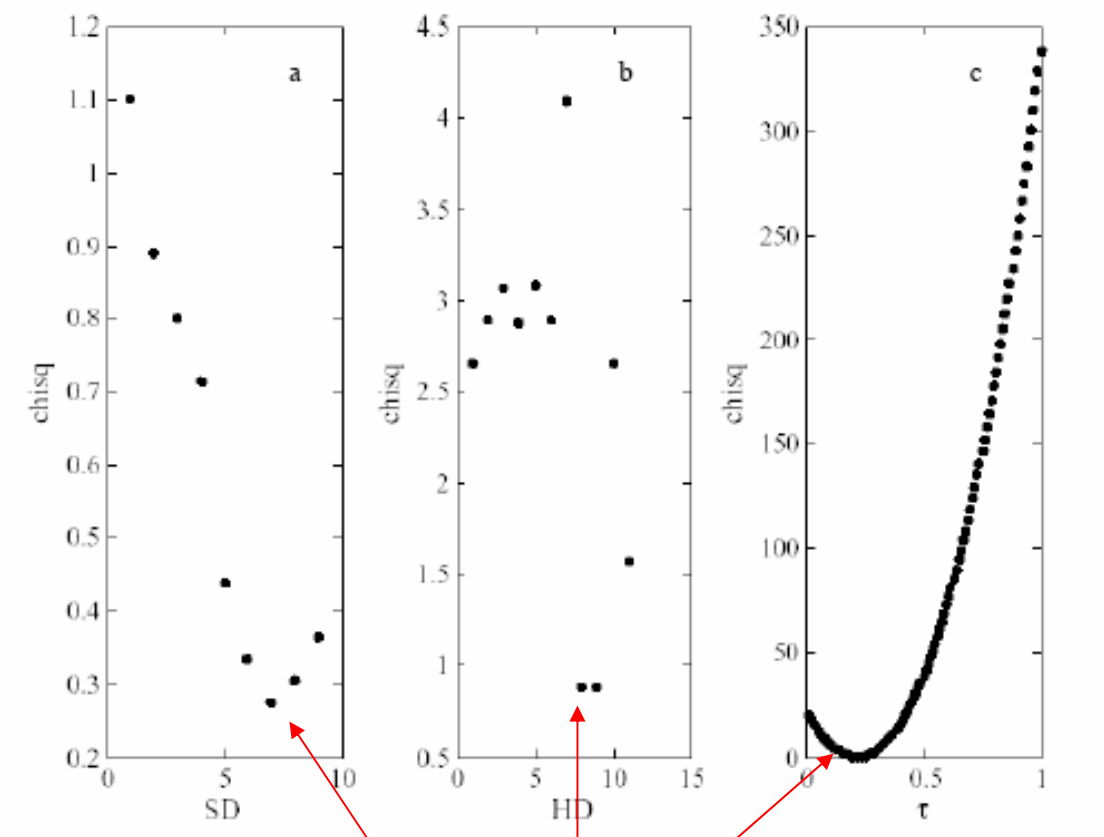
$$\varepsilon_\nu \approx \left(1-\varpi_\nu\right)\tau_{IR}/\mu$$

$$\tau_{IR} \approx \frac{< Q_{ext,IR} >}{2}\tau$$

Size and habit models impact here

Yue et al., 2006

The "fast" RT approach: OPTRAN + ci parameterization

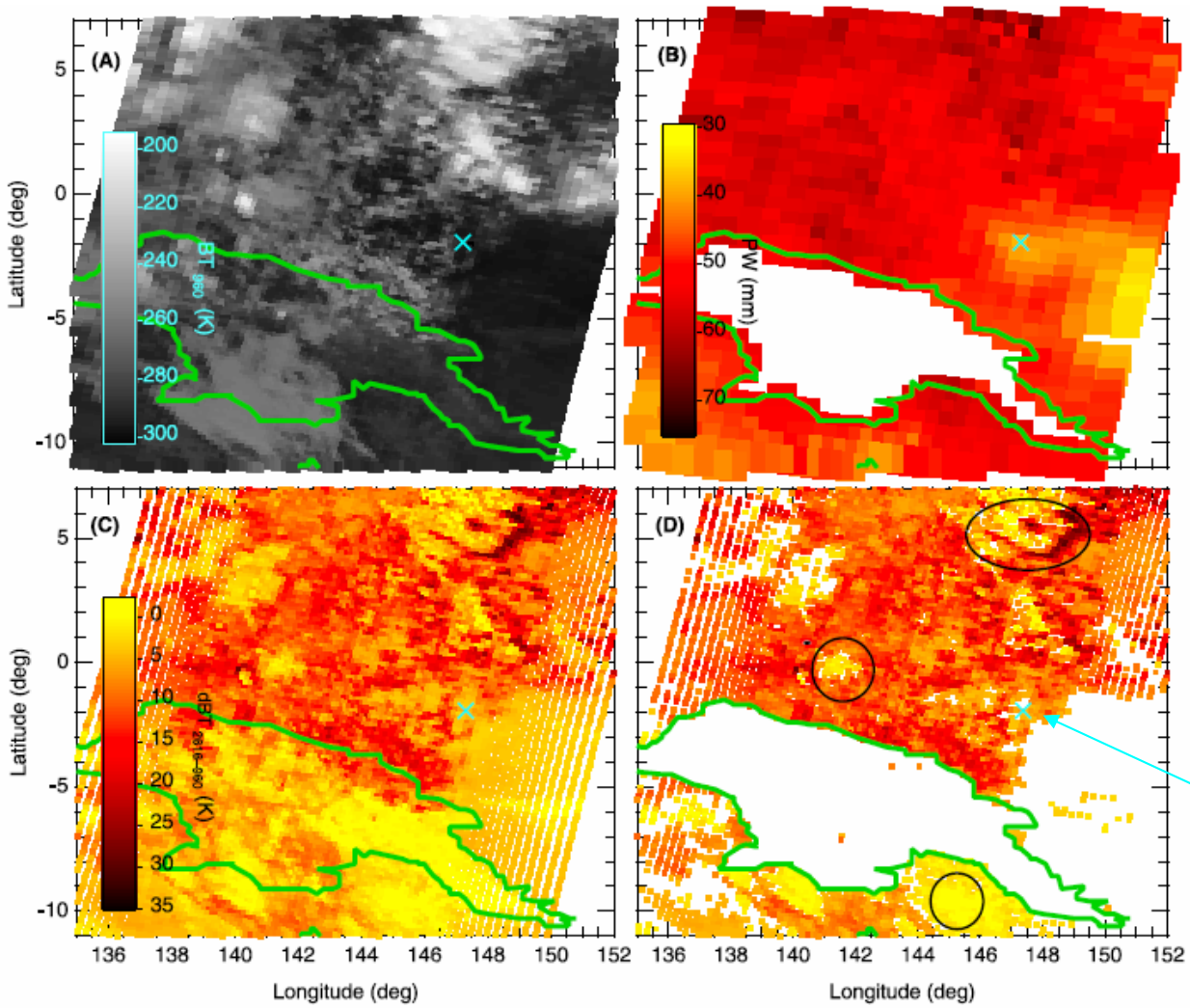


- 9 size distributions
- 11 habit distributions
- 100 τ_{VIS} from 0–1.0

Yue et al., 2006

An illustrative example on June 20, 2003, at Manus Island

$BT_{960\ cm^{-1}}$



$BT_{2616\ cm^{-1}} - BT_{960\ cm^{-1}}$

Total column precipitable water vapor

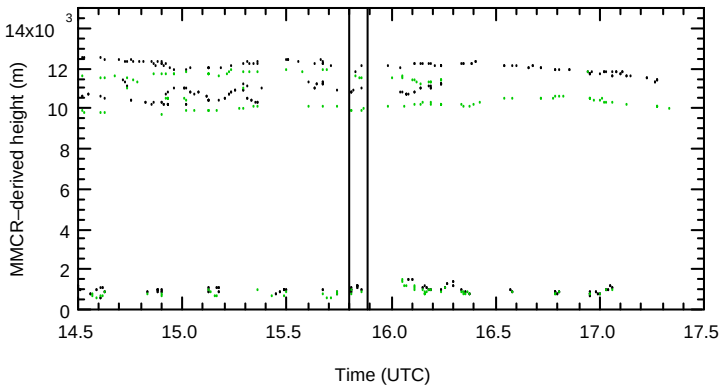
"cloud mask"

Manus Island Arm site (blue cross)

Kahn et al., 2005, J. Geophys. Res.

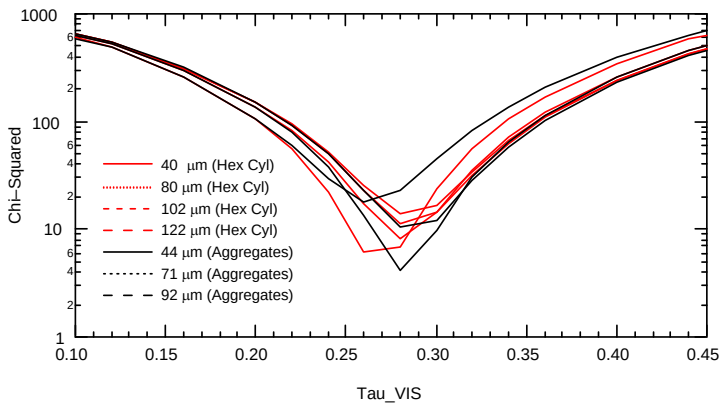
An illustrative example on June 20, 2003, at Manus Island

ARM cloud height from radar



	Param		
	RT Model	CHARTS	MMCR
τ_{VIS}	0.26	0.28	0.13
D_e (μm)	91.5	71.4	106

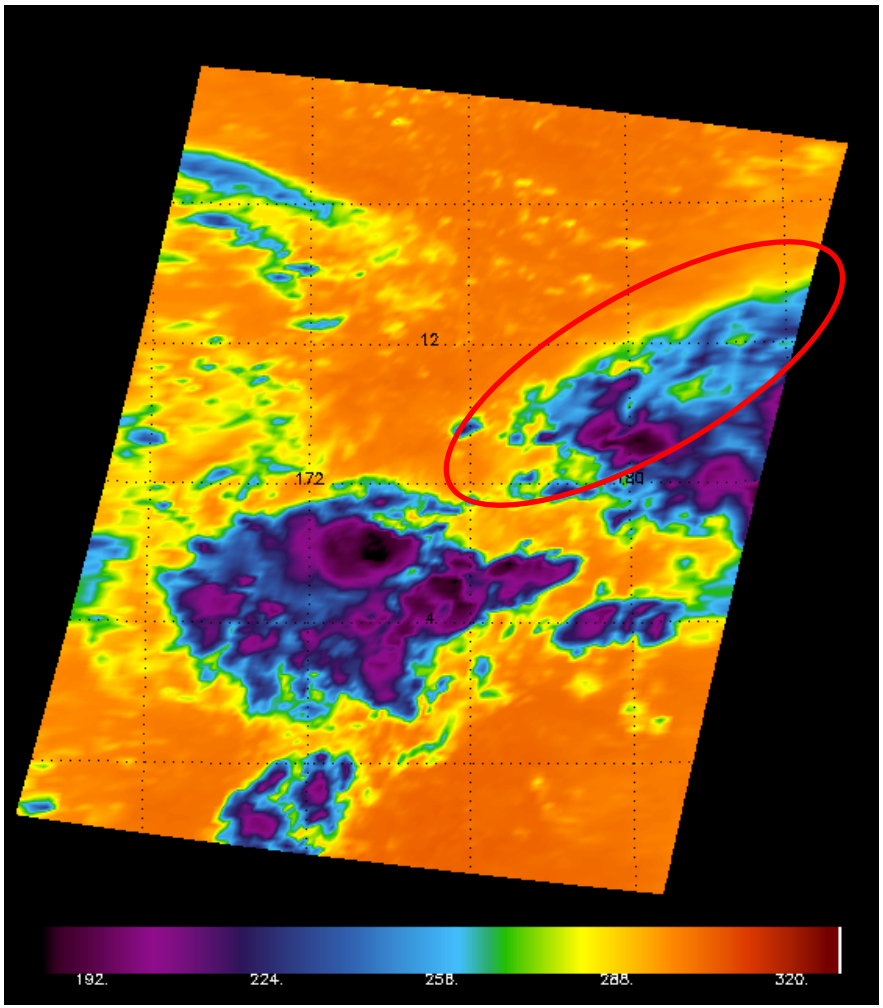
χ^2 model–obs fit



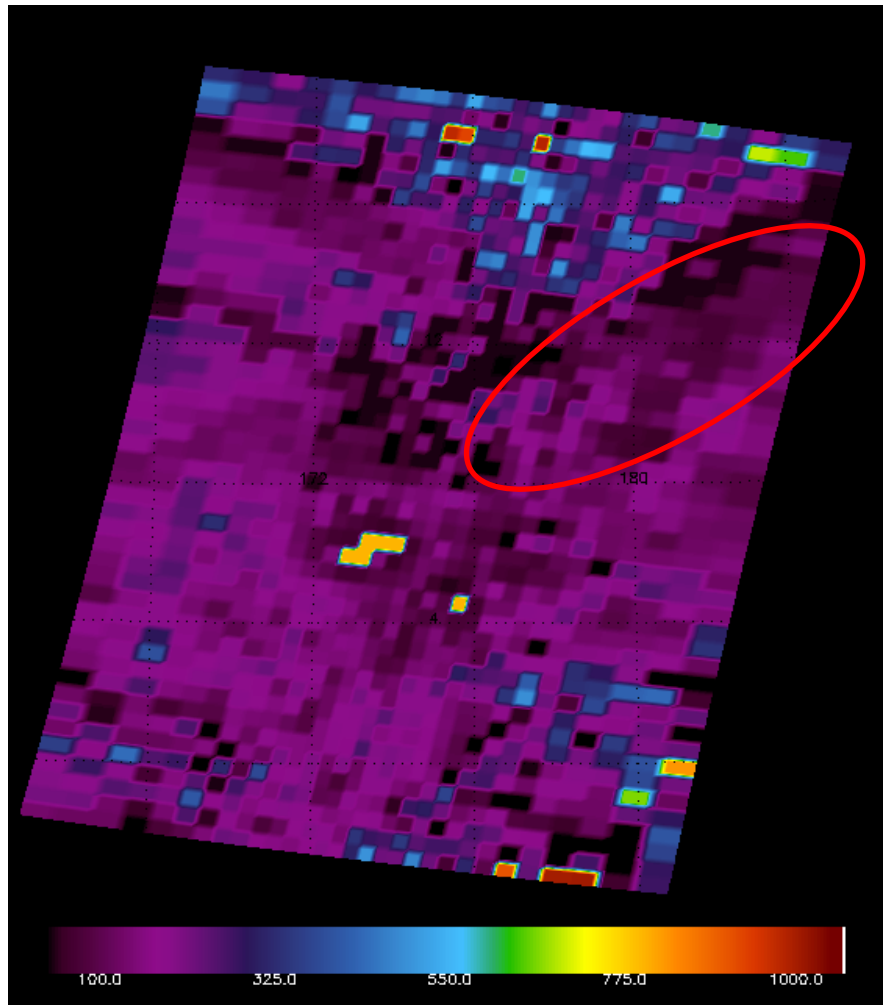
CHARTS and parameterized RTM retrievals have larger τ_{VIS} and smaller D_e than MMCR: indicative of missed small particles by MMCR?

Tempting to say… but need more cases, and add in MPL!

An illustrative granule on July 1st, 2003

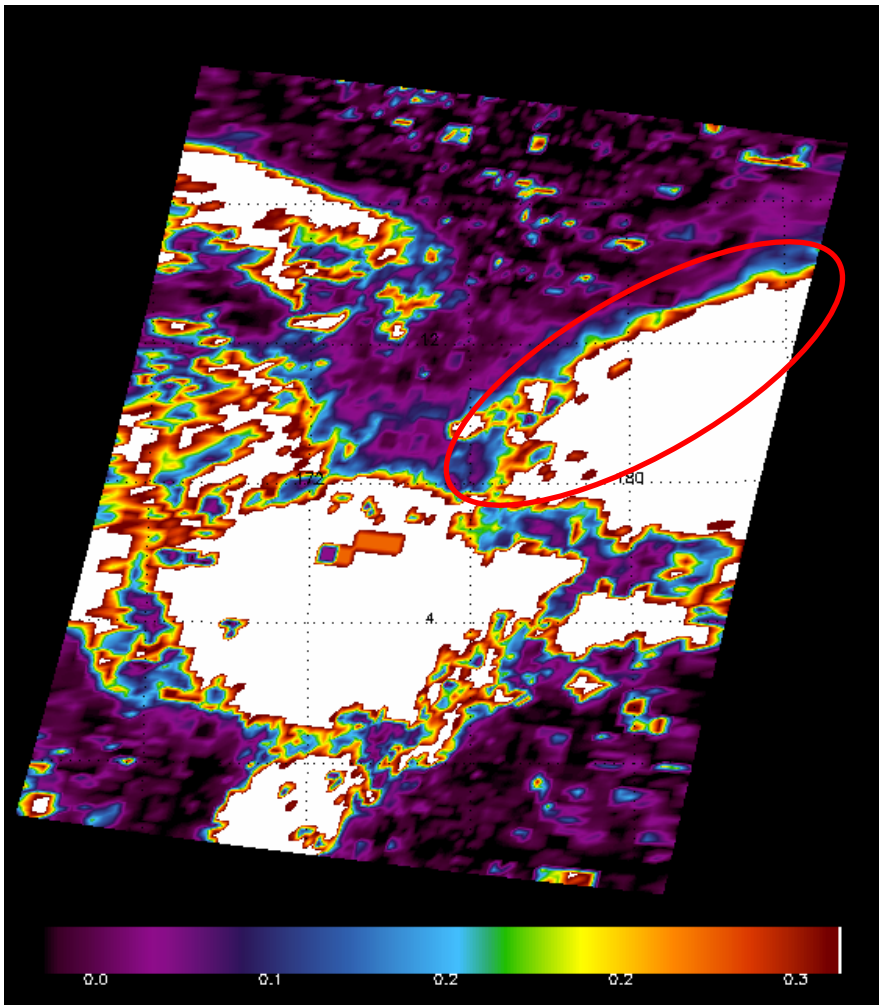


BT_{960} (K)

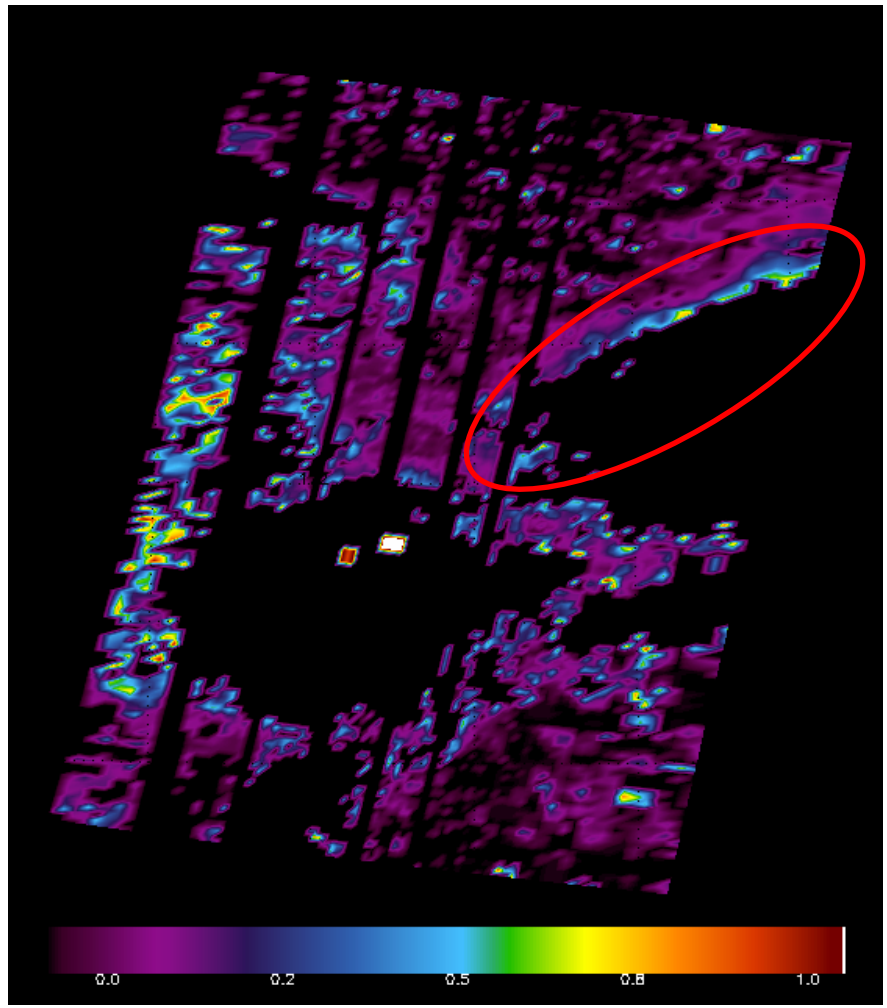


Upper CTP (hPa)

An illustrative granule on July 1st, 2003

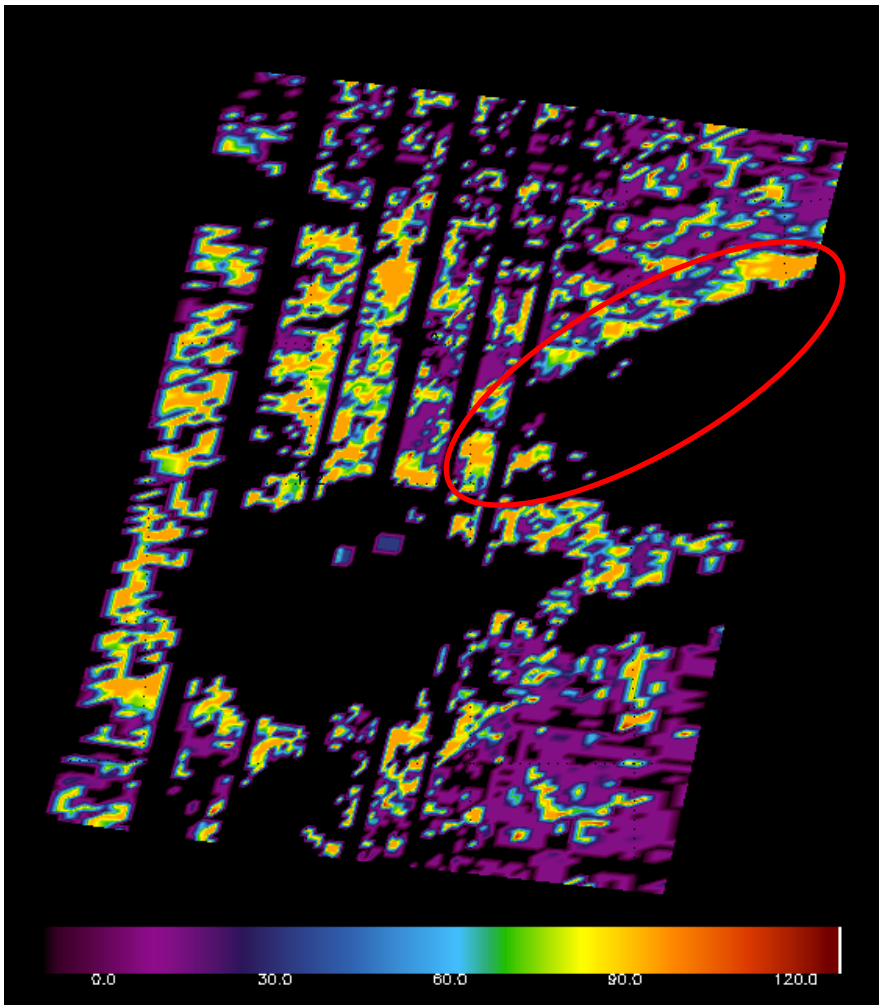


ECF (Upper)

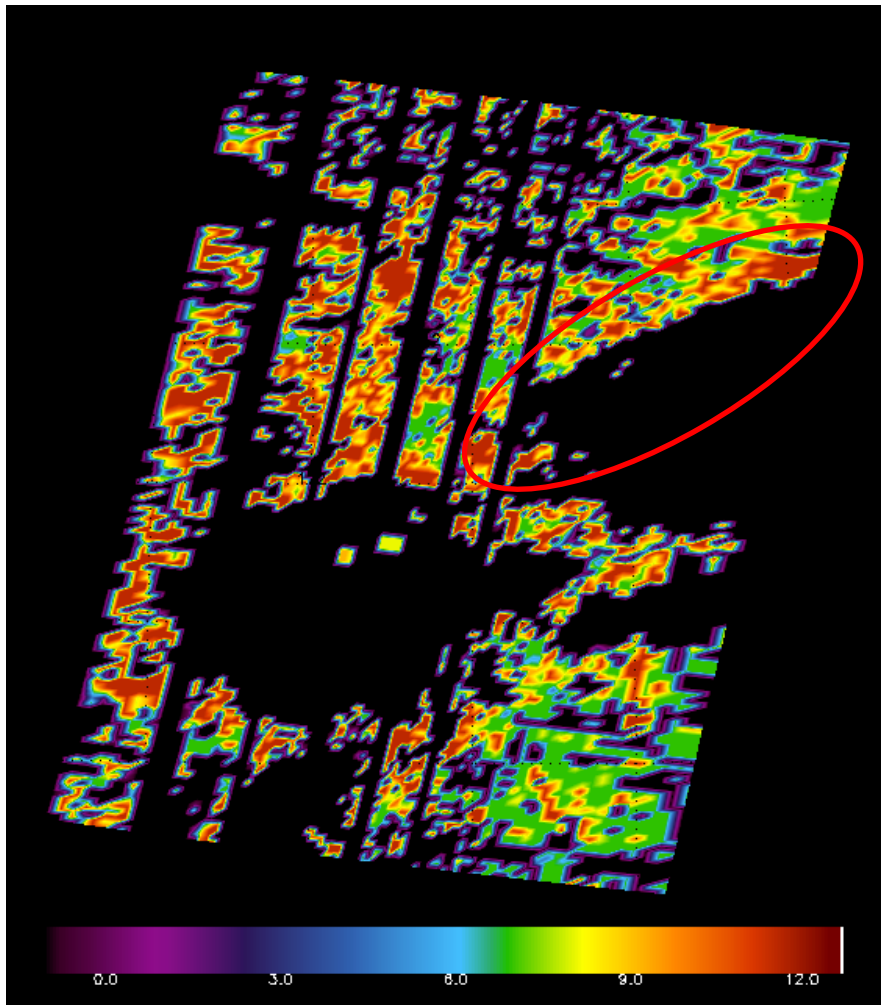


τ_{VIS}

An illustrative granule on July 1st, 2003

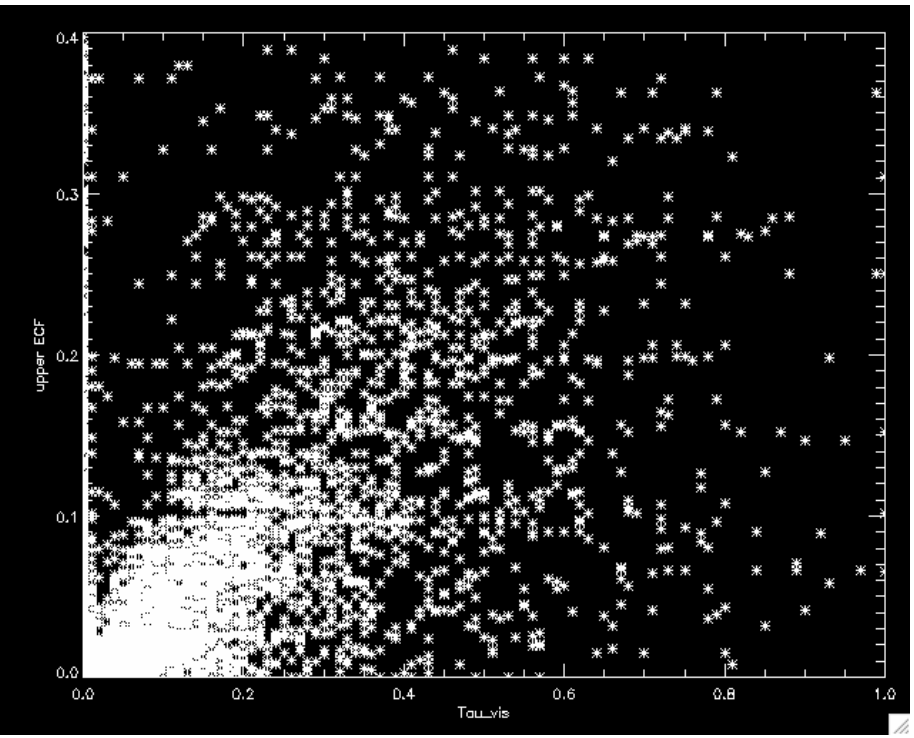


D_e (microns)

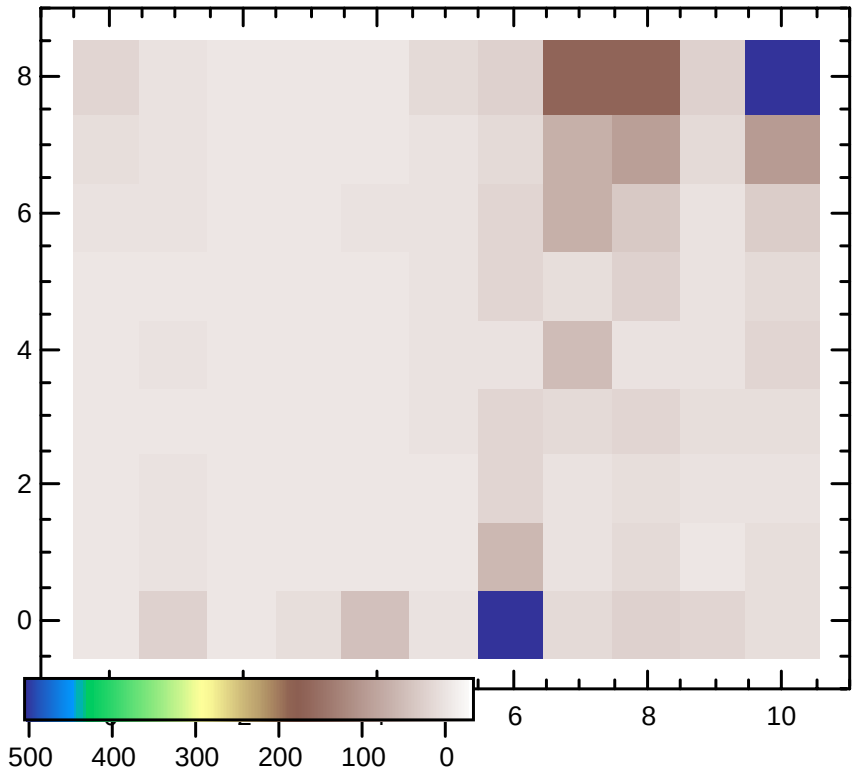


Habit Distribution

An illustrative granule on July 1st, 2003



ECF (Upper) versus τ_{VIS}



Frequency of size dist and habit dist

Summary and Conclusions

- AIRS maps out cirrus realistically
  - Working on pushing limits of thin cirrus detection
- AIRS may be useful for more complicated cloud configurations
  - Cloud phase
  - Multilayered clouds
- Fast RT approach to retrieve thin cirrus D_e and τ with AIRS radiances
  - Future modifications with δ-4 stream…thicker ci?
- Need to work on efficiency
- Further comparisons to ARM site-derived and MODIS-derived D_e and τ