Cross–comparison of AIRS Cloud Products with ARM and A-train Measurements

by

Brian Kahn[1], Amy Braverman[1], Annmarie Eldering[1], Eric Fetzer[1], Evan Fishbein[1], Michael Garay[1,2], Jonathan Jiang[1], Sung-Yung Lee[1], and Shaima Nasiri[3]

[1]Jet Propulsion Laboratory, Pasadena, CA, USA
[2]Department of Atmospheric and Oceanic Sciences, UCLA, Los Angeles, CA, USA
[3]Department of Atmospheric Sciences, Texas A&M University, College Station, TX, USA

Cloud pictures courtesy of australiansevereweather.com

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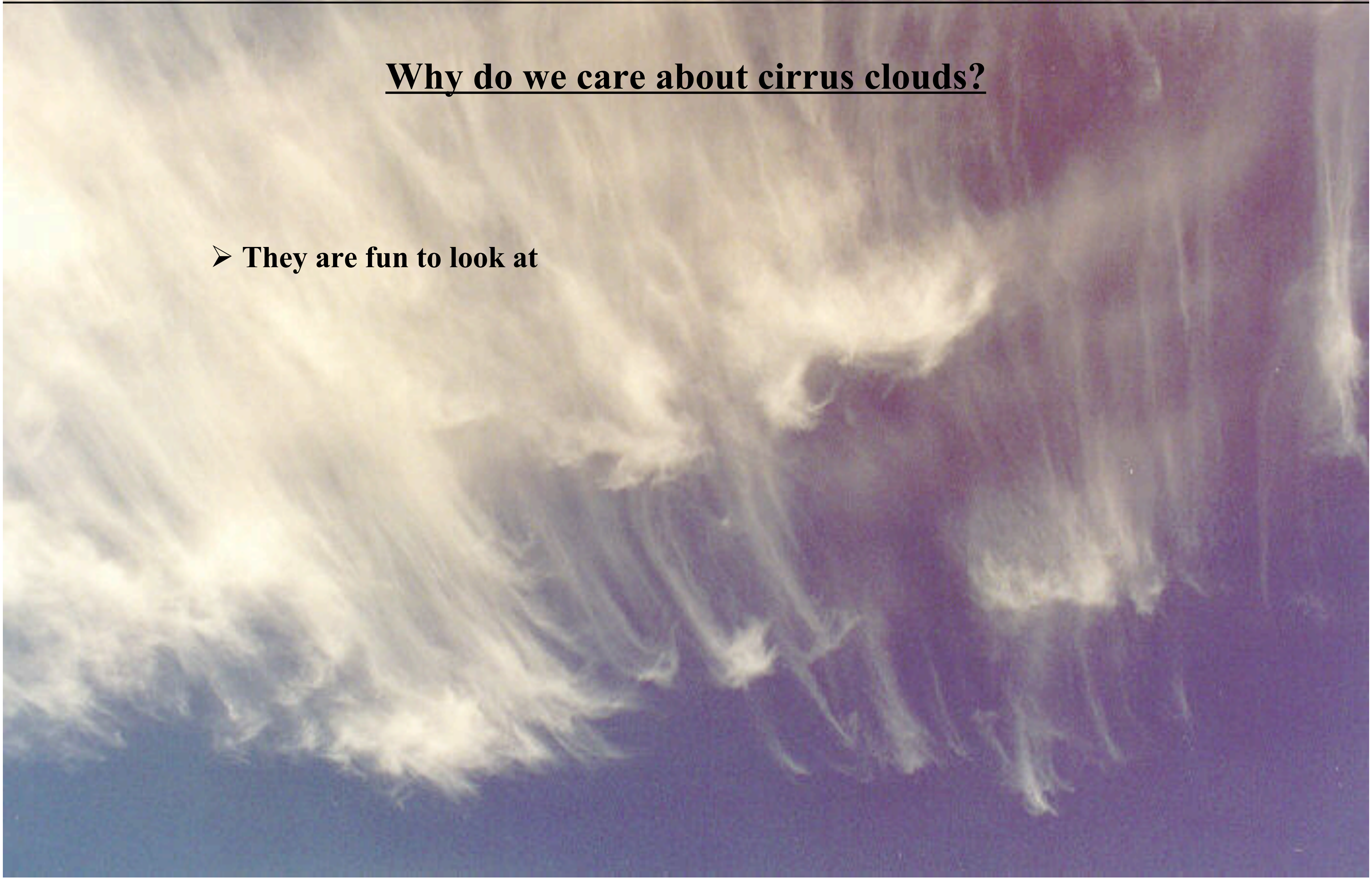
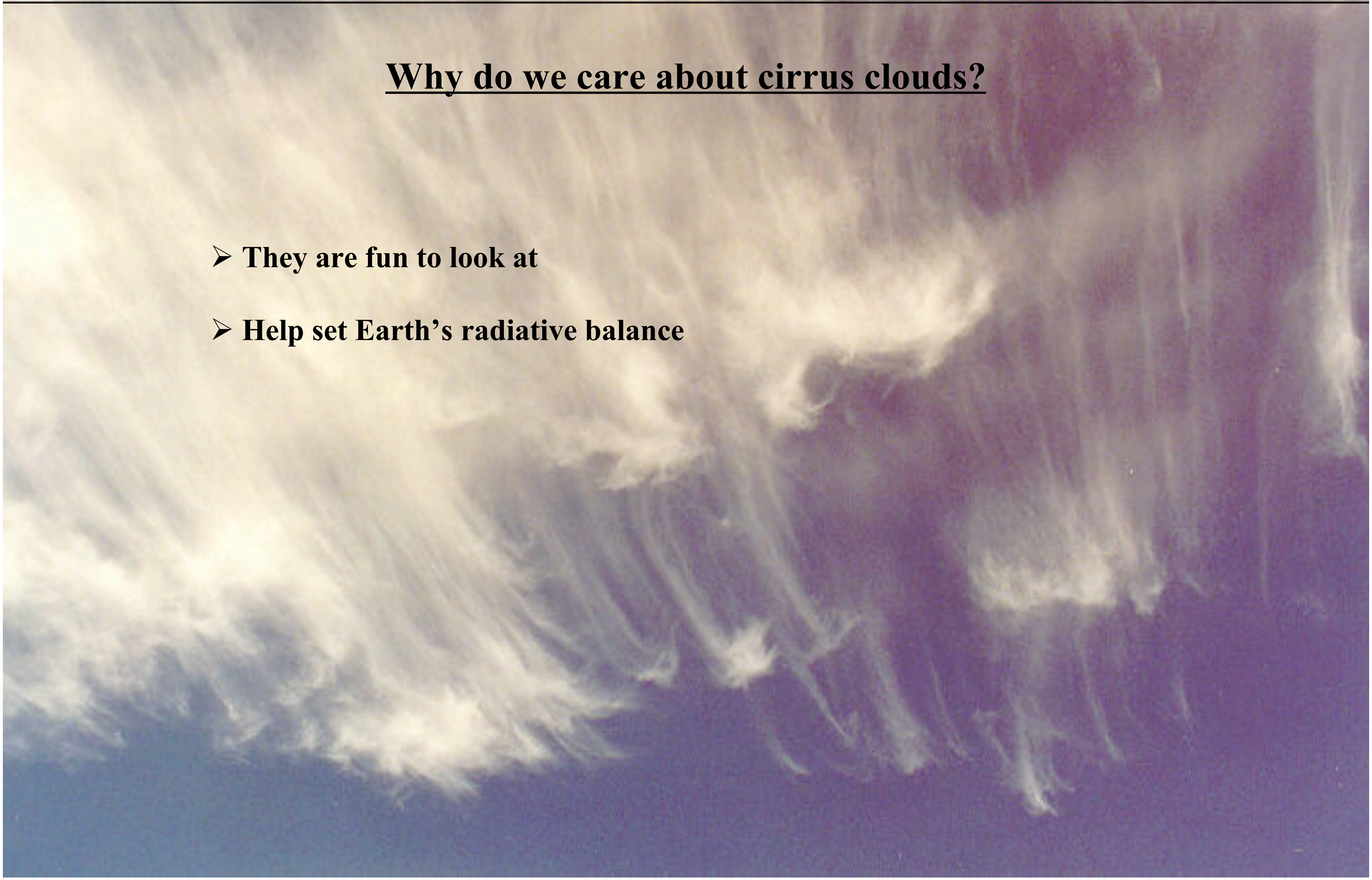
- They are fun to look at





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- **Feedbacks between radiation, dynamics, and thermodynamics**
- **Indirect effects**
- **Responses to anthropogenic climate change?**

Outline

- **How valid are the AIRS V4 cloud fields?**

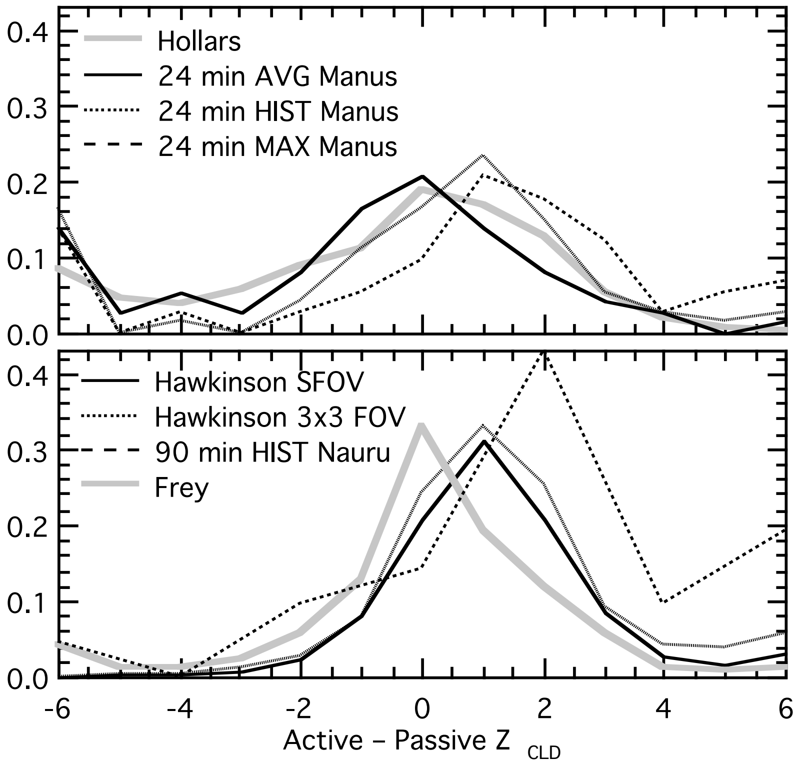
- **Focus on upper level CTP**
  - **ARM TWP mm-wave cloud radar (Manus Island) and micropulse lidar (Nauru Island)**
  - **AIRS is sensitive (statistically significant) to thin (and thick) cirrus**

- **AIRS CTP and Microwave Limb Sounder (MLS) IWC comparisons**
  - **PDFs of AIRS and MODIS agree well…**
  - **…but statistics conditional on MLS level, IWC threshold, AIRS ECF, etc.**

- **AIRS and MODIS: a "holistic" view**
  - **Use CTP, ECF and T_s to explore consistency in retrievals**
  - **Good agreement for high and opaque clouds**
  - **Some issues within multilayer clouds and cloud edges**

- **Where to go from here?**

Checking the cloud top height between AIRS and Atmospheric Radiation Measurement (ARM) program observations



Frequency histogram of the agreement between an active and passive-derived Z_{CLD} obtained from several independent data sources. We compare ARM–AIRS to:

Top: ground-based MMCR with GMS-5 (*Hollars et al.*, 2004)

Bottom: aircraft lidar and the MODIS Airborne Simulator Z_{CLD} (*Frey et al.*, 1999), ground-based lidar+radar and GOES Z_{CLD} (*Hawkinson et al.*, 2005), and ground-based lidar and AIRS Z_{CLD}.

Kahn et al., 2006a

	Location/Time	Time (min)	Height Method	$0. \le f < .05$	$.05 \le f < .15$	$.15 \le f < .5$	$.5 \le f < .85$	$.85 \le f < 1.0$
Radar at night	Manus/Night	–	–	*N*=13	*N*=9	*N*=21	*N*=16	*N*=16
		54	AVG	7.2 ± 7.0	2.1 ± 3.4	**0.4 ± 3.7**	***–0.1 ± 1.5***	***0.7 ± 1.8***
		126	AVG	7.1 ± 6.5	**1.8 ± 3.2**	**0.5 ± 3.6**	***–0.3 ± 1.2***	***0.7 ± 2.0***
		186	AVG	7.0 ± 6.5	**1.9 ± 3.0**	**0.4 ± 3.6**	***–0.4 ± 1.3***	***0.6 ± 2.0***
		54	HIST	7.1 ± 7.3	1.1 ± 5.1	***–0.9 ± 3.4***	***–0.5 ± 1.3***	***–0.1 ± 1.7***
		126	HIST	4.9 ± 7.4	–0.5 ± 4.5	***–0.9 ± 3.4***	***–1.2 ± 1.0***	***–0.3 ± 2.0***
		186	HIST	4.7 ± 7.5	–0.4 ± 4.1	***–1.0 ± 3.3***	***–1.2 ± 1.0***	***–0.2 ± 2.0***
		54	MAX	5.3 ± 8.4	0.6 ± 4.9	**–2.2 ± 4.0**	***–1.4 ± 1.3***	***–0.8 ± 1.9***
Radar at day	Manus/Day	–	–	*N*=21	*N*=12	*N*=16	*N*=12	*N*=16
		54	AVG	7.6 ± 5.6	6.3 ± 5.8	**1.2 ± 4.2**	***0.2 ± 2.3***	***1.1 ± 1.6***
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		126	HIST	3.7 ± 9.5	–1.0 ± 8.3	**–0.7 ± 3.8**	***–1.1 ± 2.1***	***0.4 ± 1.6***
		186	HIST	1.5 ± 7.8	–1.5 ± 8.5	**–0.8 ± 3.8**	***–1.1 ± 2.1***	***0.4 ± 1.5***
		54	MAX	4.8 ± 8.3	3.1 ± 8.1	***–0.7 ± 3.8***	***–1.5 ± 1.7***	***–0.2 ± 1.4***
Lidar at night	Nauru/Night	–	–	*N*=32	*N*=20	–	–	–
		54	AVG	8.2 ± 6.1	***2.1 ± 3.9***	–	–	–
		126	AVG	7.1 ± 6.1	***1.9 ± 3.2***	–	–	–
		186	AVG	6.3 ± 5.4	***1.9 ± 3.0***	–	–	–
		54	HIST	7.4 ± 7.3	***0.3 ± 4.1***	–	–	–
		126	HIST	5.3 ± 7.8	***–0.7 ± 3.7***	–	–	–
		186	HIST	3.0 ± 7.3	***–1.1 ± 3.1***	–	–	–
		54	MAX	7.0 ± 7.5	***–0.5 ± 4.5***	–	–	–

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Location/Time	Time (min)	Height Method	0. ≤ *f* < .05	.05 ≤ *f* < .15	.15 ≤ *f* < .5	.5 ≤ *f* < .85	.85 ≤ *f* < 1.0
Manus/Night	–	–	*N*=13	*N*=9	*N*=21	*N*=16	*N*=16
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Three time averages

Kahn et al., 2006a

Three ARM Z_{CLD} averages

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Five ECF bins

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# of samples

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	54	MAX	7.0 ± 7.5	***–0.5 ± 4.5***	_	_	_

AIRS–ARM ± 1-σ (km)

Bold: significant @ 5%
Italic: significant @ 1%

Kahn et al., 2006a

Location/Time	Time (min)	Height Method	0. ≤ *f* < .05	.05 ≤ *f* < .15	.15 ≤ *f* < .5	.5 ≤ *f* < .85	.85 ≤ *f* < 1.0
Manus/Night	–	–	*N*=13	*N*=9	*N*=21	*N*=16	*N*=16
	54	AVG	7.2 ± 7.0	2.1 ± 3.4	**0.4 ± 3.7**	***–0.1 ± 1.5***	***0.7 ± 1.8***
	126	AVG	7.1 ± 6.5	**1.8 ± 3.2**	**0.5 ± 3.6**	***–0.3 ± 1.2***	***0.7 ± 2.0***
	186	AVG	7.0 ± 6.5	**1.9 ± 3.0**	**0.4 ± 3.6**	***–0.4 ± 1.3***	***0.6 ± 2.0***
	54	HIST	7.1 ± 7.3	1.1 ± 5.1	***–0.9 ± 3.4***	***–0.5 ± 1.3***	***–0.1 ± 1.7***
	126	HIST	4.9 ± 7.4	–0.5 ± 4.5	***–0.9 ± 3.4***	***–1.2 ± 1.0***	***–0.3 ± 2.0***
	186	HIST	4.7 ± 7.5	–0.4 ± 4.1	***–1.0 ± 3.3***	***–1.2 ± 1.0***	***–0.2 ± 2.0***
	54	MAX	5.3 ± 8.4	0.6 ± 4.9	**–2.2 ± 4.0**	***–1.4 ± 1.3***	***–0.8 ± 1.9***
Manus/Day	_	_	*N*=21	*N*=12	*N*=16	*N*=12	*N*=16
	54	AVG	7.6 ± 5.6	6.3 ± 5.8	**1.2 ± 4.2**	***0.2 ± 2.3***	***1.1 ± 1.6***
	126	AVG	7.8 ± 5.6	4.5 ± 4.9	**1.3 ± 3.9**	***0.5 ± 2.3***	***1.3 ± 1.6***
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	54	HIST	6.4 ± 8.8	5.4 ± 6.1	***–0.4 ± 3.7***	***–0.1 ± 2.7***	***0.5 ± 1.6***
	126	HIST	3.7 ± 9.5	–1.0 ± 8.3	**–0.7 ± 3.8**	***–1.1 ± 2.1***	***0.4 ± 1.6***
	186	HIST	1.5 ± 7.8	–1.5 ± 8.5	**–0.8 ± 3.8**	***–1.1 ± 2.1***	***0.4 ± 1.5***
	54	MAX	4.8 ± 8.3	3.1 ± 8.1	***–0.7 ± 3.8***	***–1.5 ± 1.7***	***–0.2 ± 1.4***
Nauru/Night	_	_	*N*=32	*N*=20	_	_	_
	54	AVG	8.2 ± 6.1	***2.1 ± 3.9***	_	_	_
	126	AVG	7.1 ± 6.1	***1.9 ± 3.2***	_	_	_
	186	AVG	6.3 ± 5.4	***1.9 ± 3.0***	_	_	_
	54	HIST	7.4 ± 7.3	***0.3 ± 4.1***	_	_	_
	126	HIST	5.3 ± 7.8	***–0.7 ± 3.7***	_	_	_
	186	HIST	3.0 ± 7.3	***–1.1 ± 3.1***	_	_	_
	54	MAX	7.0 ± 7.5	***–0.5 ± 4.5***	_	_	_

Some day/night variation – slightly worse during day

Kahn et al., 2006a

Location/Time	Time (min)	Height Method	0. ≤ *f* < .05	.05 ≤ *f* < .15	.15 ≤ *f* < .5	.5 ≤ *f* < .85	.85 ≤ *f* < 1.0
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	126	AVG	7.1 ± 6.5	**1.8 ± 3.2**	**0.5 ± 3.6**	***–0.3 ± 1.2***	***0.7 ± 2.0***
	186	AVG	7.0 ± 6.5	**1.9 ± 3.0**	**0.4 ± 3.6**	***–0.4 ± 1.3***	***0.6 ± 2.0***
	54	HIST	7.1 ± 7.3	1.1 ± 5.1	***–0.9 ± 3.4***	***–0.5 ± 1.3***	***–0.1 ± 1.7***
	126	HIST	4.9 ± 7.4	–0.5 ± 4.5	***–0.9 ± 3.4***	***–1.2 ± 1.0***	***–0.3 ± 2.0***
	186	HIST	4.7 ± 7.5	–0.4 ± 4.1	***–1.0 ± 3.3***	***–1.2 ± 1.0***	***–0.2 ± 2.0***
	54	MAX	5.3 ± 8.4	0.6 ± 4.9	**–2.2 ± 4.0**	***–1.4 ± 1.3***	***–0.8 ± 1.9***
Manus/Day	–	–	*N*=21	*N*=12	*N*=16	*N*=12	*N*=16
	54	AVG	7.6 ± 5.6	6.3 ± 5.8	**1.2 ± 4.2**	***0.2 ± 2.3***	***1.1 ± 1.6***
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	54	AVG	8.2 ± 6.1	***2.1 ± 3.9***	–	–	–
	126	AVG	7.1 ± 6.1	***1.9 ± 3.2***	–	–	–
	186	AVG	6.3 ± 5.4	***1.9 ± 3.0***	–	–	–
	54	HIST	7.4 ± 7.3	***0.3 ± 4.1***	–	–	–
	126	HIST	5.3 ± 7.8	***–0.7 ± 3.7***	–	–	–
	186	HIST	3.0 ± 7.3	***–1.1 ± 3.1***	–	–	–
	54	MAX	7.0 ± 7.5	***–0.5 ± 4.5***	–	–	–

Variation w.r.t. method of ARM Z definition

Kahn et al., 2006a

Location/Time	Time (min)	Height Method	0. ≤ *f* < .05	.05 ≤ *f* < .15	.15 ≤ *f* < .5	.5 ≤ *f* < .85	.85 ≤ *f* < 1.0
Manus/Night	–	–	*N*=13	*N*=9	*N*=21	*N*=16	*N*=16
	54	AVG	7.2 ± 7.0	2.1 ± 3.4	**0.4 ± 3.7**	***–0.1 ± 1.5***	***0.7 ± 1.8***
	126	AVG	7.1 ± 6.5	**1.8 ± 3.2**	**0.5 ± 3.6**	***–0.3 ± 1.2***	***0.7 ± 2.0***
	186	AVG	7.0 ± 6.5	**1.9 ± 3.0**	**0.4 ± 3.6**	***–0.4 ± 1.3***	***0.6 ± 2.0***
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	54	HIST	7.4 ± 7.3	***0.3 ± 4.1***	_	_	_
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	54	MAX	7.0 ± 7.5	***–0.5 ± 4.5***	_	_	_

Agreement strong function of *f*

Kahn et al., 2006a

Location/Time	Time (min)	Height Method	$0. \le f < .05$	$.05 \le f < .15$	$.15 \le f < .5$	$.5 \le f < .85$	$.85 \le f < 1.0$
Manus/Night	–	–	*N*=13	*N*=9	*N*=21	*N*=16	*N*=16
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	126	HIST	4.9 ± 7.4	–0.5 ± 4.5	***–0.9 ± 3.4***	***–1.2 ± 1.0***	***–0.3 ± 2.0***
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	54	AVG	8.2 ± 6.1	***2.1 ± 3.9***	_	_	_
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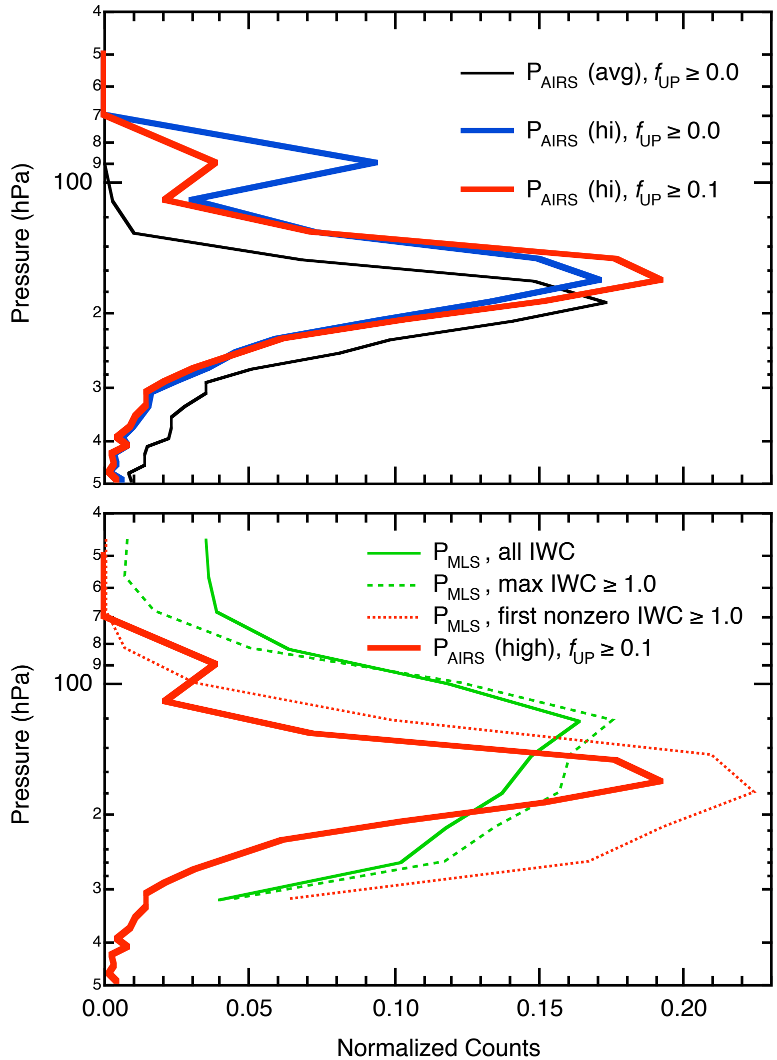
	126	HIST	5.3 ± 7.8	***–0.7 ± 3.7***	_	_	_
	186	HIST	3.0 ± 7.3	***–1.1 ± 3.1***	_	_	_
	54	MAX	7.0 ± 7.5	***–0.5 ± 4.5***	_	_	_

Agreement much improved for thin ci using lidar over radar

Kahn et al., 2006a

What about AIRS and MLS?

- MLS is a passive microwave limb sounder
- Reports IWC at 11 altitudes from 46 to 316 hPa
- "Pixel" size roughly 165 × 7 × 3 km (along-track, cross-track, and vertical)
- Use nonzero IWC as a proxy to CTP
  - Highest altitude of occurrence of IWC > 0 defined to be CTP
  - Lowest values of IWC "similar" to clear sky
- Define AIRS CTP two ways:
  - "High": lowest CTP from 3 nearest along-track
  - "Avg": average CTP from 3 nearest along-track
- Different "views" of similar clouds



- Frequency of **<u>coincident</u>** AIRS and MLS P_{CLD}. The AIRS values in 20 hPa bins, and MLS reported at the MLS standard pressure levels.

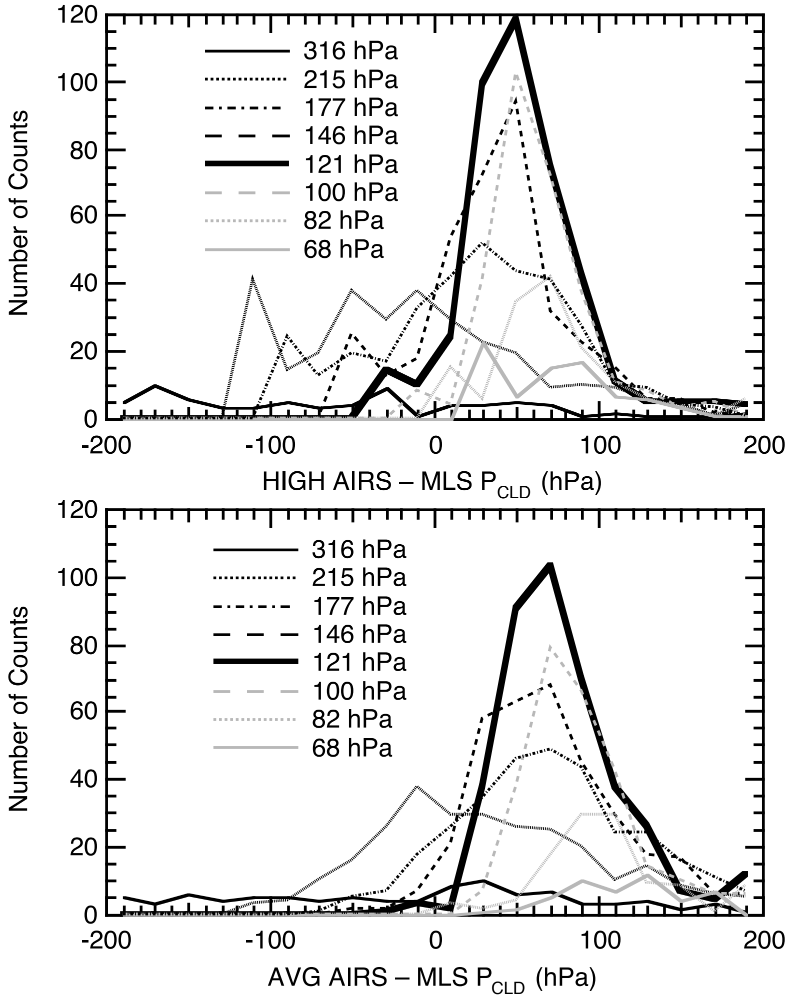
- When we use all AIRS and MLS clouds, PDFs vary substantially

- When we exclude MLS *max* IWC < 1.0 mg m^{-3}, the agreement is similar

- When we exclude MLS first IWC < 1.0 mg m^{-3}, the agreement is *much improved*

Used ~20 days in January 2005 ± 30 deg latitude

Kahn et al., 2006a



Difference between AIRS and MLS P_{CLD} per MLS pressure level: AIRS “hi” approach at top, “avg” approach at bottom

Some MLS pressure levels agree much more poorly than others

For lowest MLS pressure levels, AIRS and MLS cloud distributions ***statistically different***

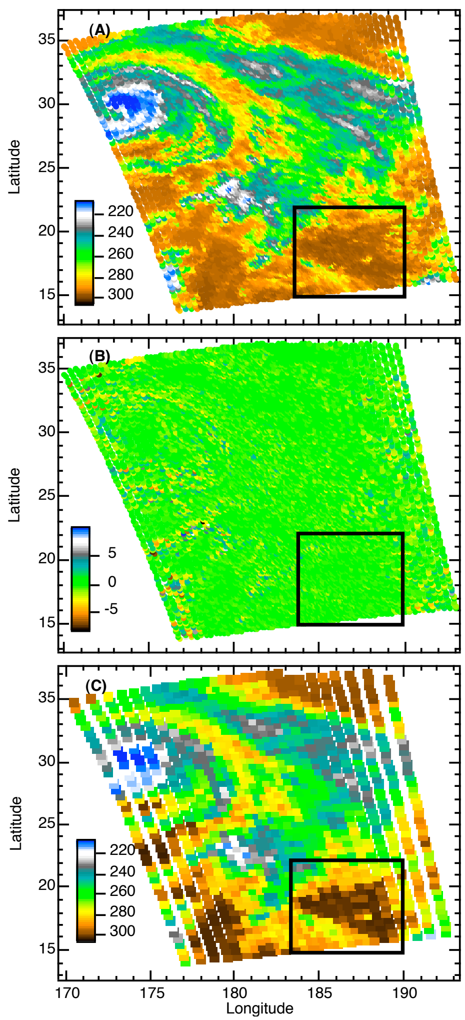
Lesson: the cloud morphology might look good after averaging, but individual match-ups can have large disagreement

Kahn et al., 2006a

Coincident AIRS and MODIS Cloud Products

- ***Many*** cloud products from AIRS and MODIS: focus on operational ECF and CTP
- AIRS reports up to two cloud layers of CTP and ECF, MODIS only one
- MODIS reports ~ 5 km, while AIRS ~ 15 km for ECF, ~45 km for CTP
- Need to collocate AIRS and MODIS: not trivial
- How do we compare similar quantities from different instruments?

Consistency between AIRS and MODIS cloud products ?



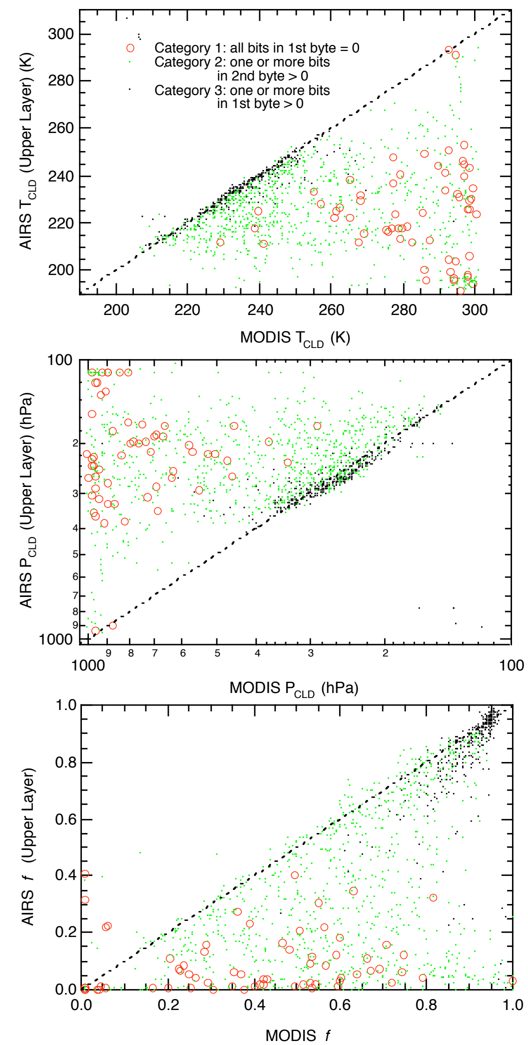
Left: September 6th, 2002, Granule 11, North-Central subtropical Pacific Ocean

Right: Agreement between AIRS and MODIS T_{CLD}, P_{CLD}, and *f* as a function of AIRS retrieval type.

Bottom line:

When clouds are thin and broken: ***bad agreement***.

When clouds are high and thick: ***good agreement***.

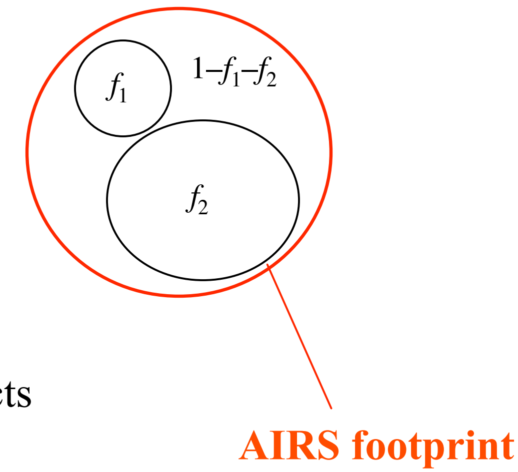


Kahn et al., 2006b

Should we think of cloud products in terms of “a whole” ?

$$BT_{AIRS} = f_1 \cdot T_1 + f_2 \cdot T_2 + (1 - f_1 - f_2) \cdot T_{sfc}$$

$$BT_{MODIS} = f_{cld} \cdot T_{cld} + (1 - f_{cld}) \cdot T_{sfc}$$



- “Re-build” BT from MODIS and AIRS cloud and surface products

- Replace Planck function by T of emitting layer or surface

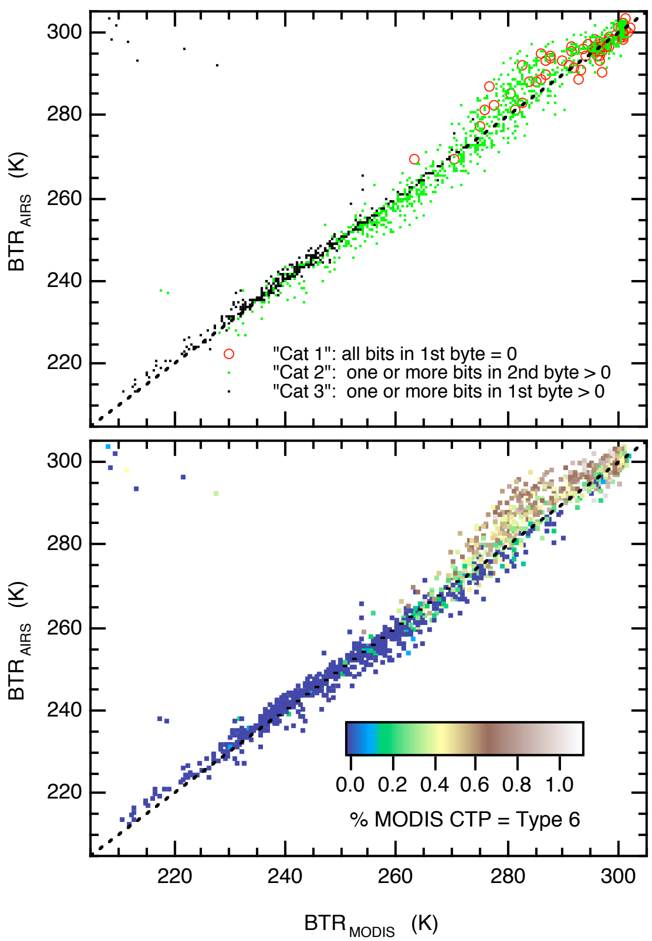
- *First-order* means of comparison: does not guarantee that T or *f* agree individually , but
  shows if the “sum of the whole” agrees or not

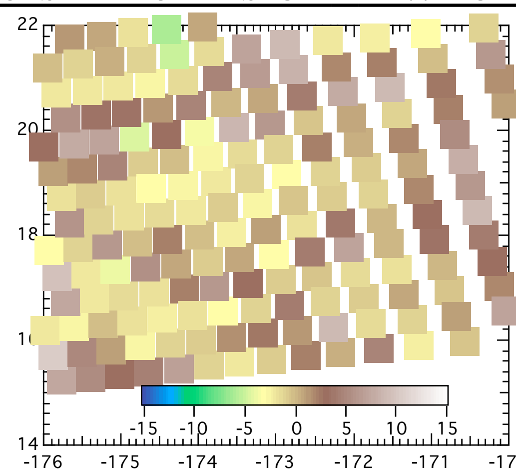
- All products averaged to AMSU scale (~ 45 km)

Bottom line: A way to look at “consistency” of cloud products between AIRS and MODIS

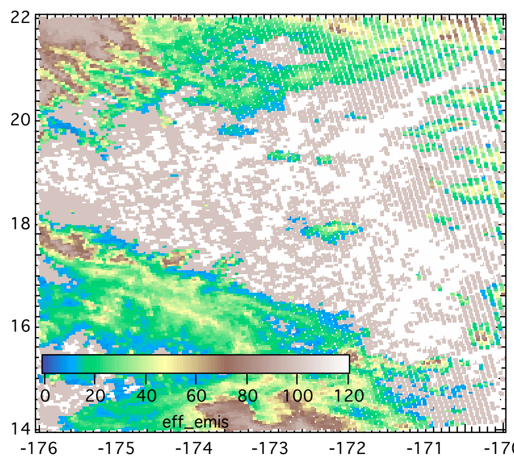
Kahn et al., 2006b

Should we think of cloud products in terms of "a whole" ?





AIRS–MODIS BT_R

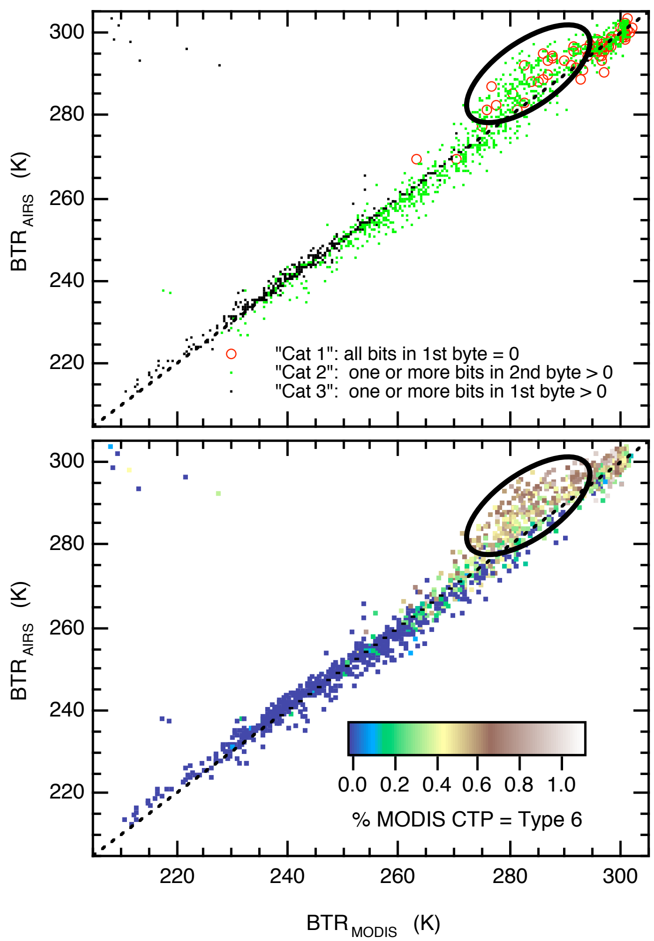


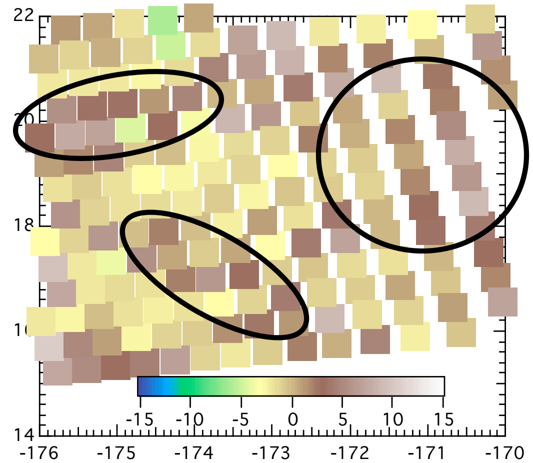
MODIS Effective Emissivity

Bottom line: BT_R is consistent, except near Ci edges – many possible reasons for disagreement

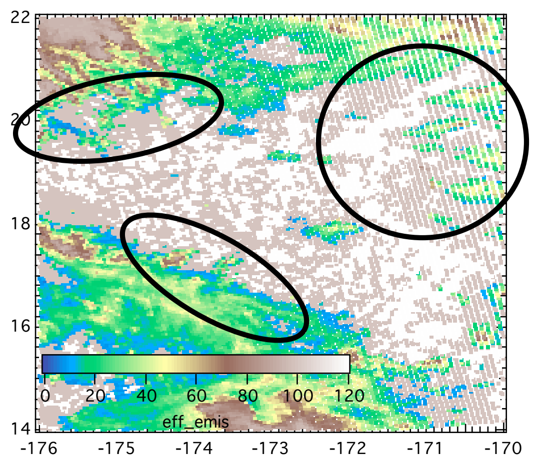
Kahn et al., 2006b

Should we think of cloud products in terms of "a whole" ?





AIRS–MODIS BT_R



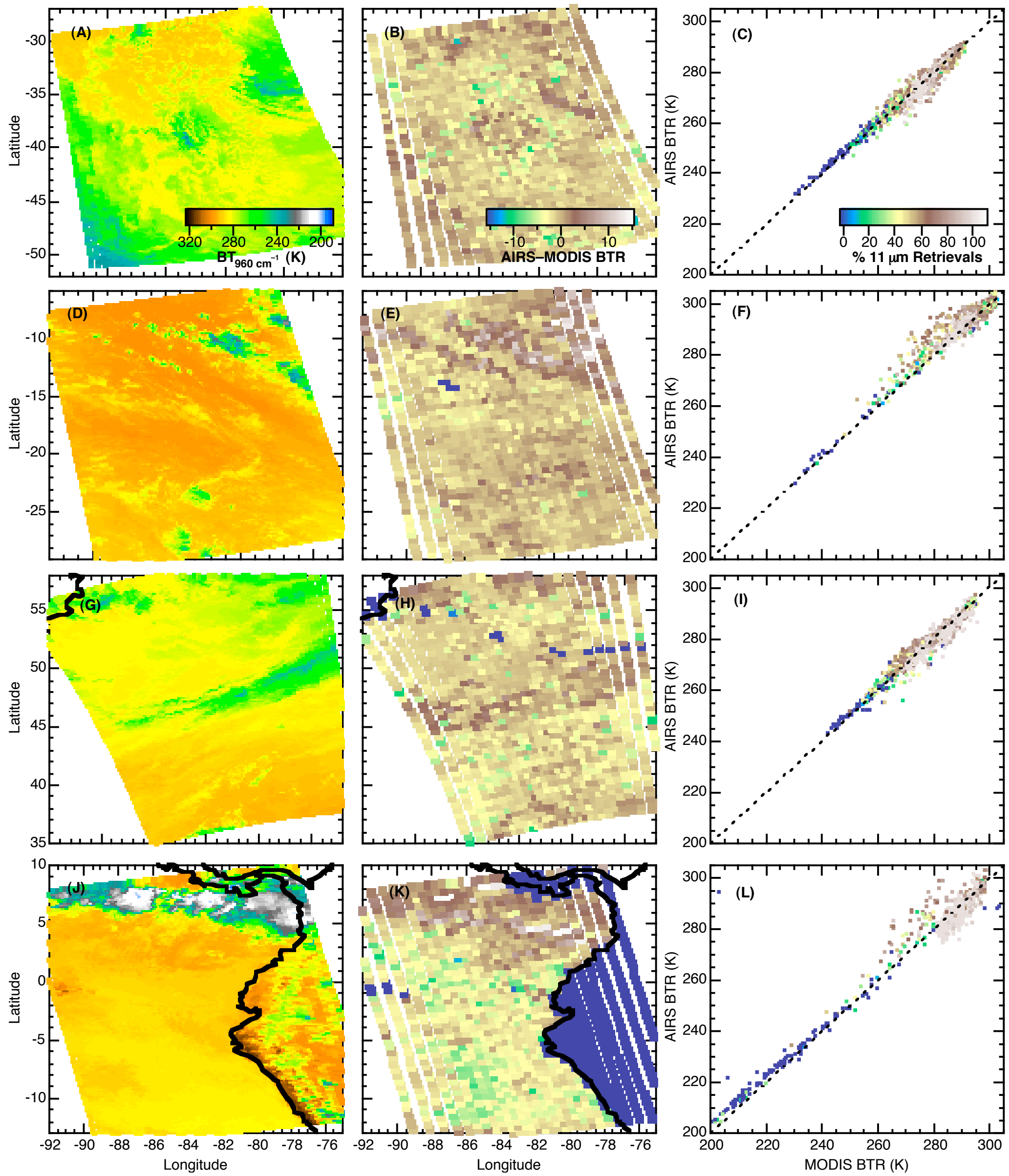
MODIS Effective Emissivity

Bottom line: BT_R is consistent, except near Ci edges – many possible reasons for disagreement

Kahn et al., 2006b

Why are there differences?

- MODIS and AIRS look at different clouds: collocation not perfect
- "Misplaced" MODIS cirrus as low cloud
  - MODIS cloud mask misses Ci w/ $\tau < 0.2$–0.3
- Multilayered clouds: errors in inferred cloud properties [*Baum and Wielicki* 1994]
- Method of averaging MODIS to AIRS footprint
  - Lessons learned from AIRS/ARM comparisons
- Nonlinearity in BT
  - Misfits of MODIS and AIRS radiances, use of different channels
- Systematic errors in retrieval algorithms?
- 3-D IR effects [*Liou and Ou* 1979; *Harshvardhan and Weinman* 1982; *Cornet et al*. 2005]
  - BT differences in plane-parallel and cubic clouds ~ 2–5 K or more at TOA
  - **Look at background picture: Ci is not plane-parallel**



Midlatitude SH

Subtropical/tropical SH

Midlatitude NH

Equatorial East Pacific

Summary and Conclusions

- AIRS upper level CTP agrees well with ARM CTH, even for thin cirrus
    - Lidar comparisons imply AIRS CTP locates thin cirrus better than MMCR
    - Implications for studies of thin ci – AIRS has excellent coverage

- AIRS and MLS cloud placement similar when thin, tenuous cases discarded
    - However, height-dependence on agreement

- Holistic view of AIRS and MODIS more consistent than individual comparisons
    - Disagreement in reconstructed BT associated with cloud edges, multilayer clouds
    - Other possible reasons too
    - Useful diagnostic tool

- Confidence in AIRS Version 4.0 clouds, despite large pixel size (~45 km CTP, ~15 km ECF)

- Useful for quantitative analyses, such as cirrus mapping and frequency, and τ and D_e retrievals

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

by

Brian Kahn[1], Annmarie Eldering[1], Kuo Nan Liou[2], Omar Mussa[2], Shaima Nasiri[3], and Qing Yue[2]

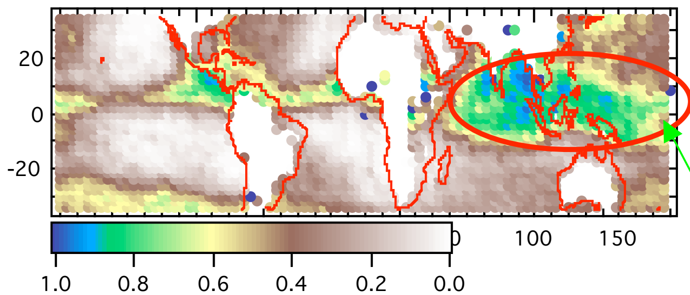
[1]Jet Propulsion Laboratory, Pasadena, CA, USA
[2]Department of Atmospheric and Oceanic Sciences, UCLA, Los Angeles, CA, USA
[3]Department of Atmospheric Sciences, Texas A&M University, College Station, TX, USA

Cloud pictures courtesy of australiansevereweather.com

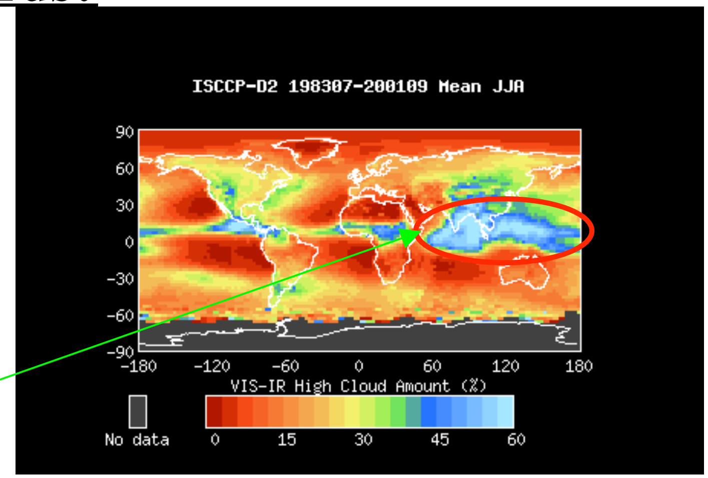
<u>Outline</u>

- **Cirrus frequency from AIRS: how does it compare to other climatologies?**
- **Multilayered clouds in V4.0**
- **Mixed phase clouds: simulations of AIRS versus MODIS**
- **Retrieving thin cirrus D_e and τ with AIRS radiances**
    - **An example footprint at the Manus Island ARM site**
    - **An example granule in the Tropical Pacific**

Where is the cirrus?

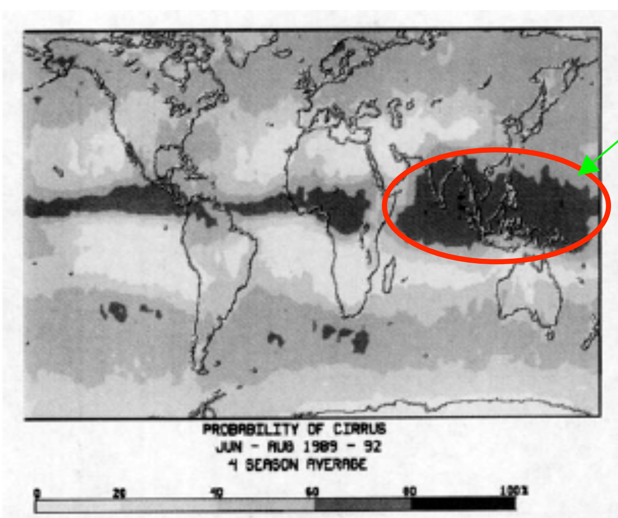


AIRS June/July 2005

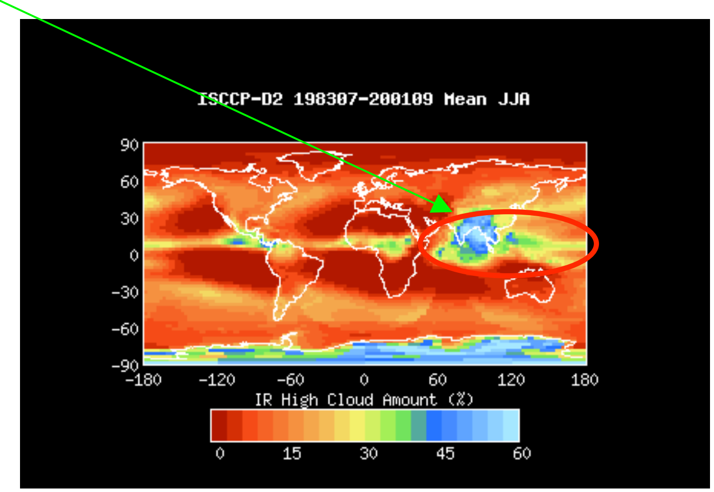


ISCCP IR/VIS only JJA (1983-2001)

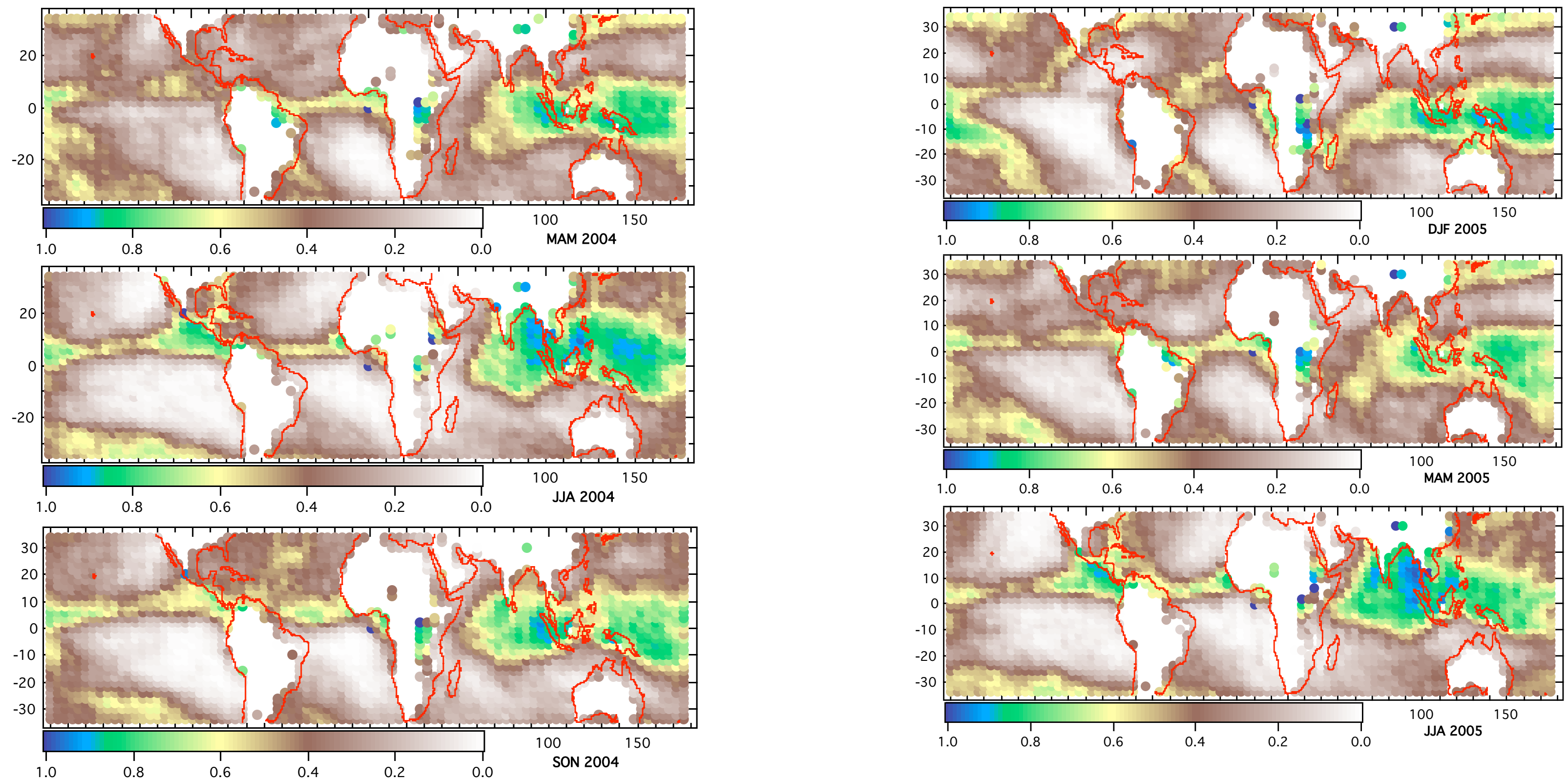
Significant differences exist between different platforms!



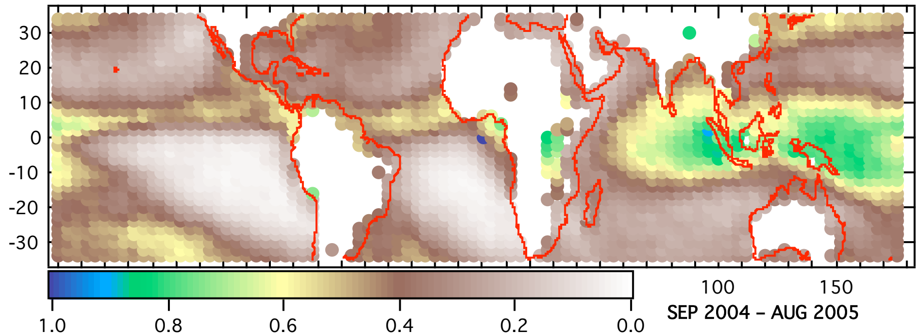
HIRS 4-year JJA



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



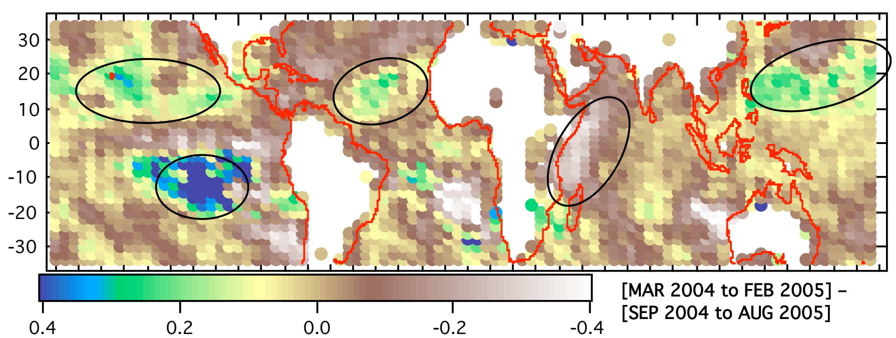
Top: Yearly average from Sep 2004 – Aug 2005

Note ragged features smooth greatly with a longer time average

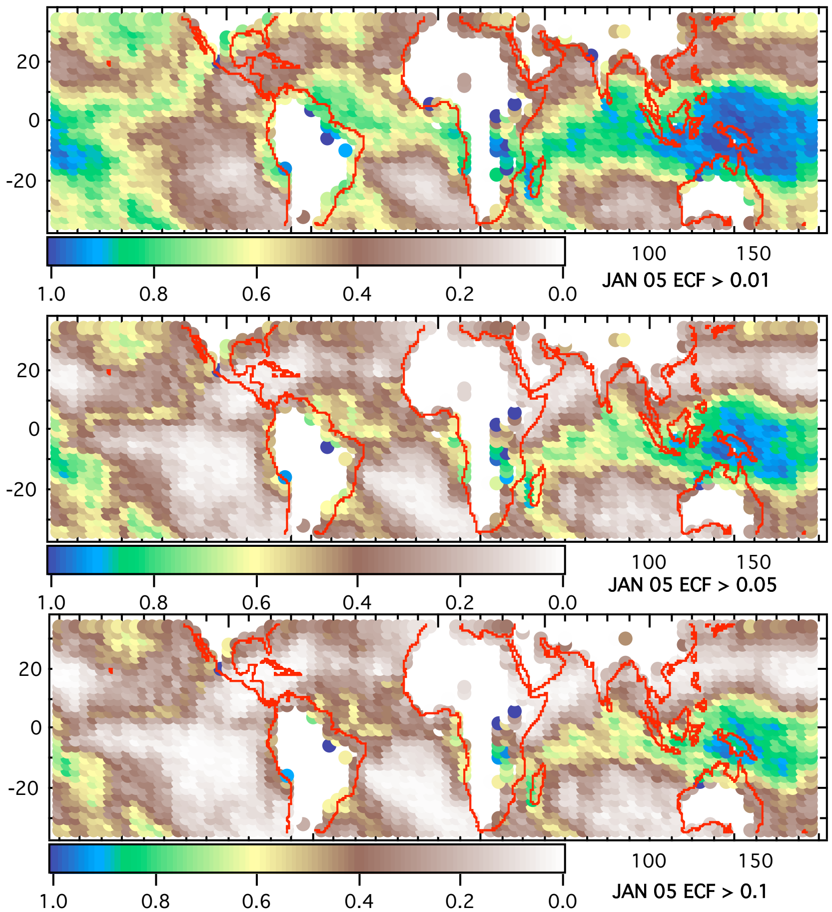
The maximum frequency decreases to the neighborhood of 80–85%.

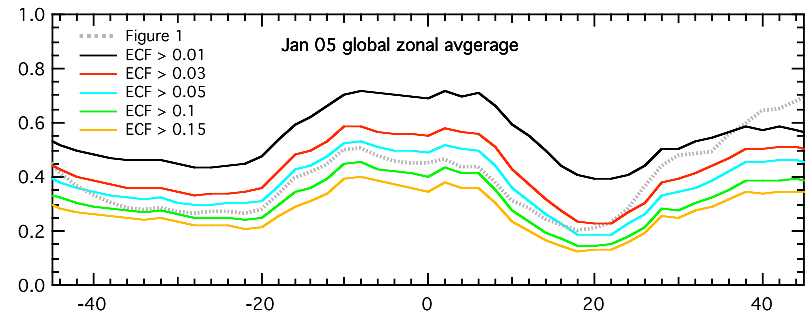
Bottom: % difference in annual frequency of cirrus between 03/2004 – 02/2005 & 09/2004 – 08/2005 Large

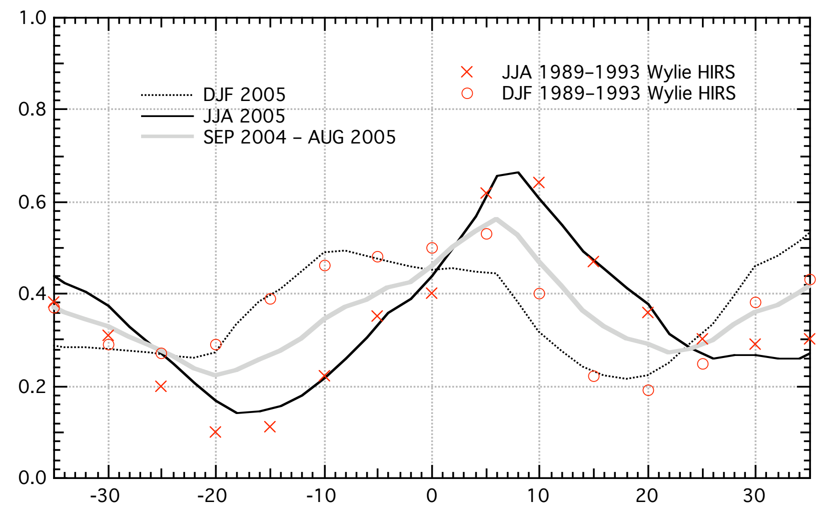
Interannual variability is noted in particular regions of interest



How realistic are AIRS cloud fields?



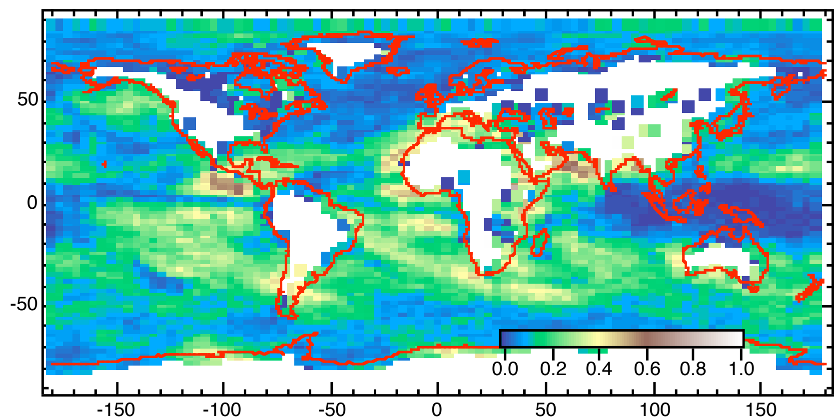




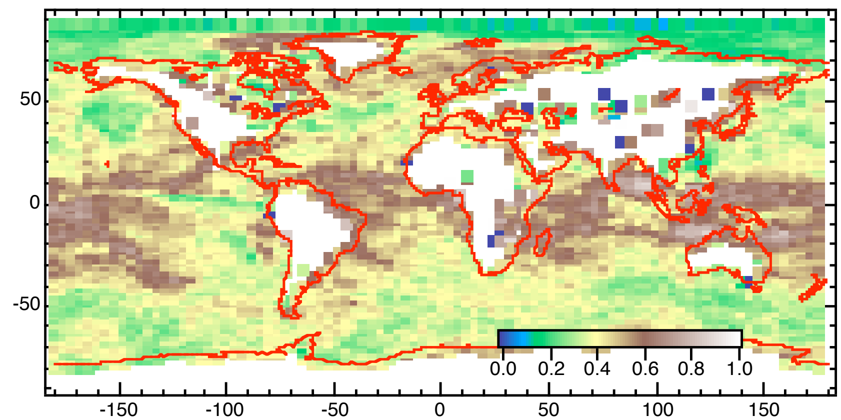
Bottom line: **Using *f* as a "cloud mask" produces reasonable cloud fields compared to *Kahn et al.* (2005), JGR, and *Wylie et al.*, (1994) J. Climate**

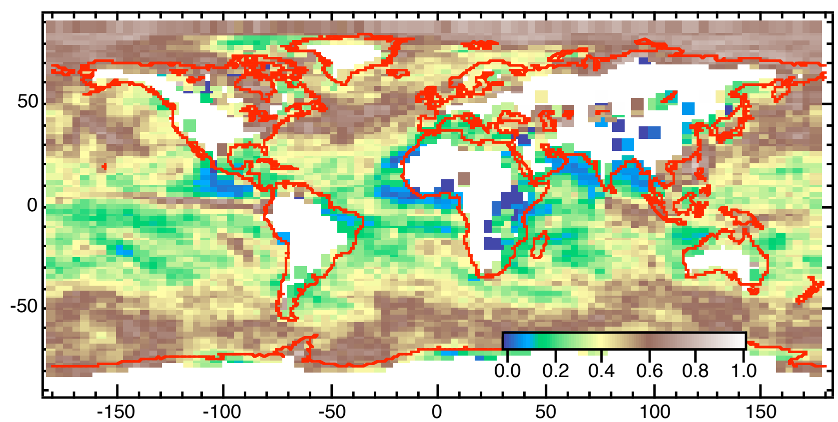
Multilayer Clouds: January 2005

Clear



Single Layer

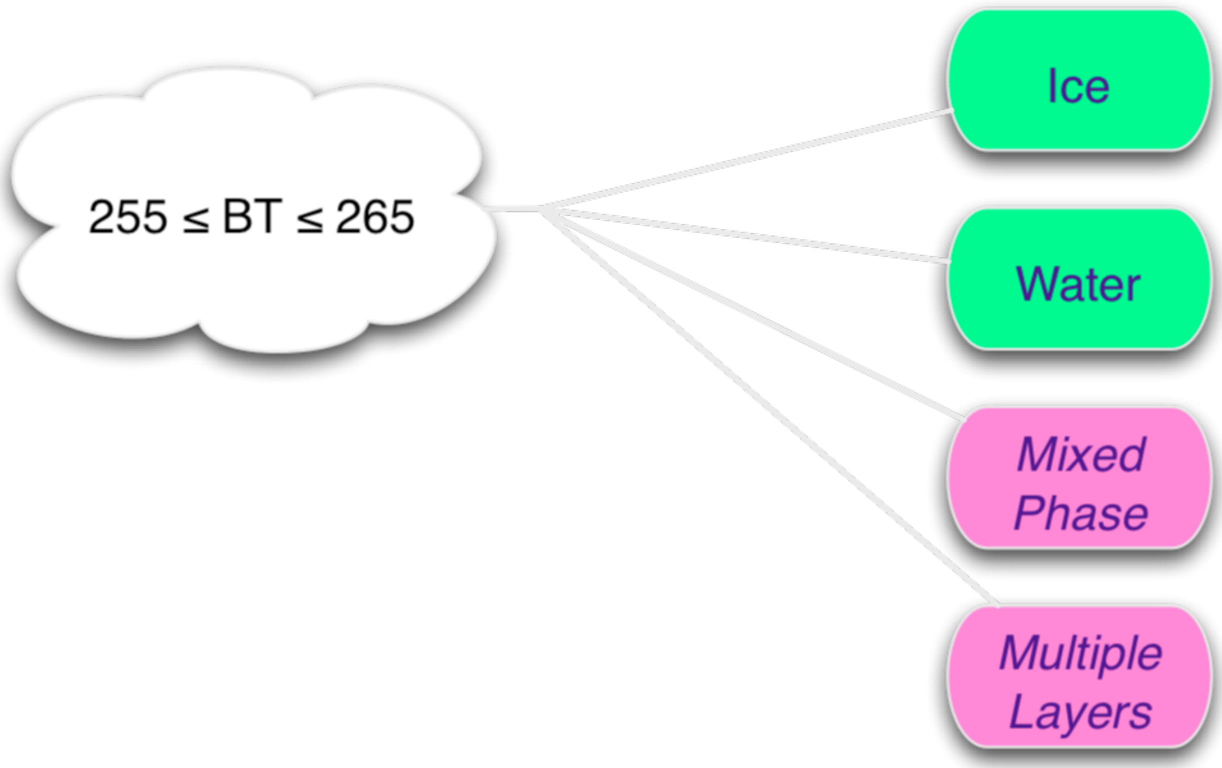




Multilayer

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

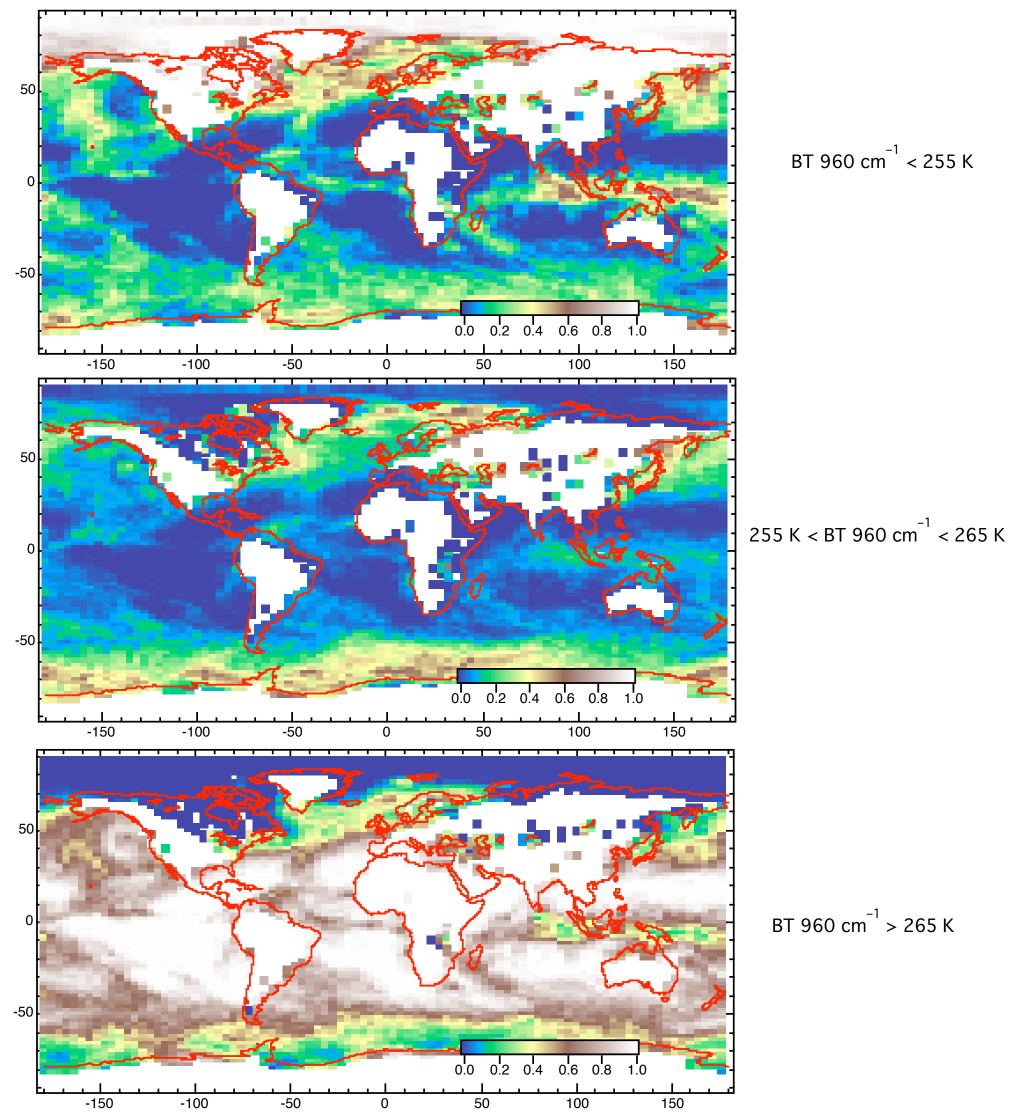
What about more complicated cloud configurations?



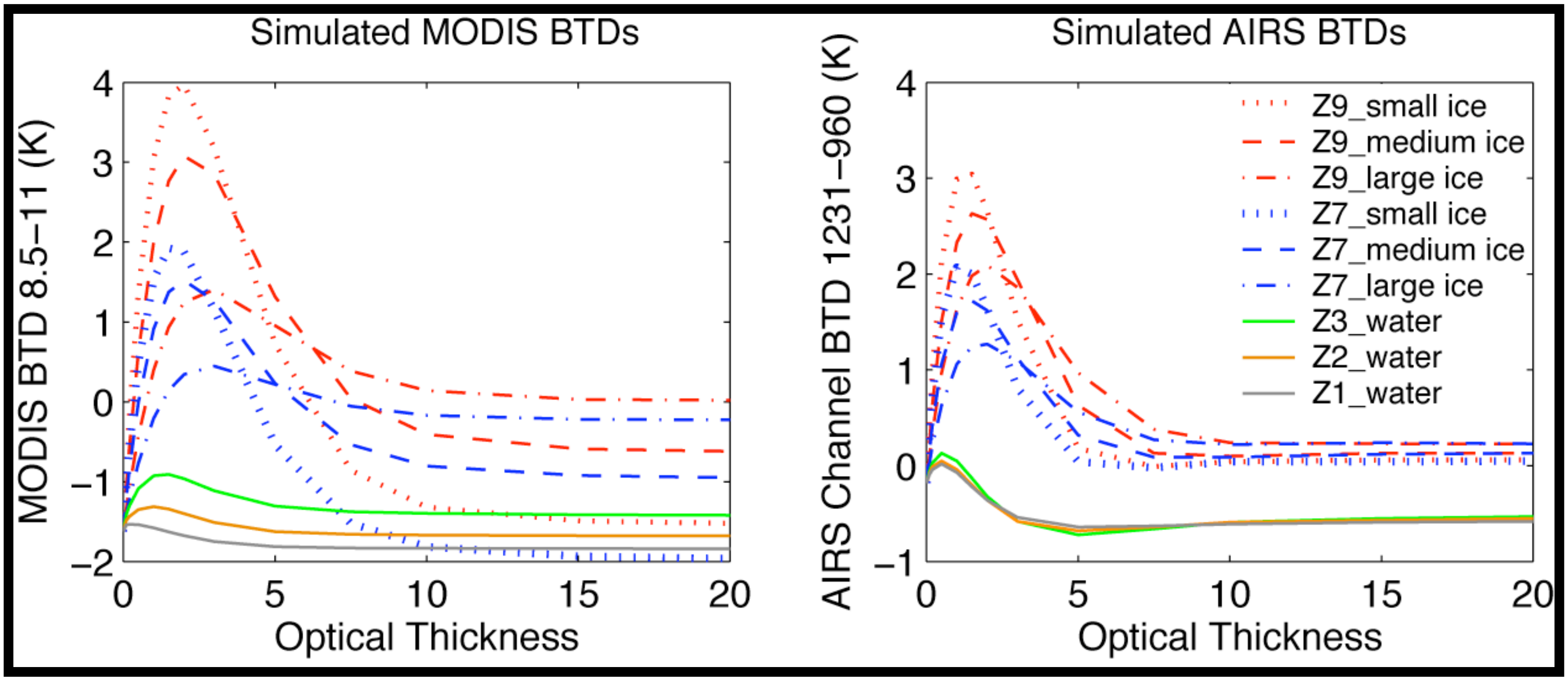
Nasiri and Kahn, 2006

January 2005 AIRS L2 Version 4.0

The "uncertain" clouds:
A large ***minority*** in
polar oceans!



Nasiri and Kahn, 2006

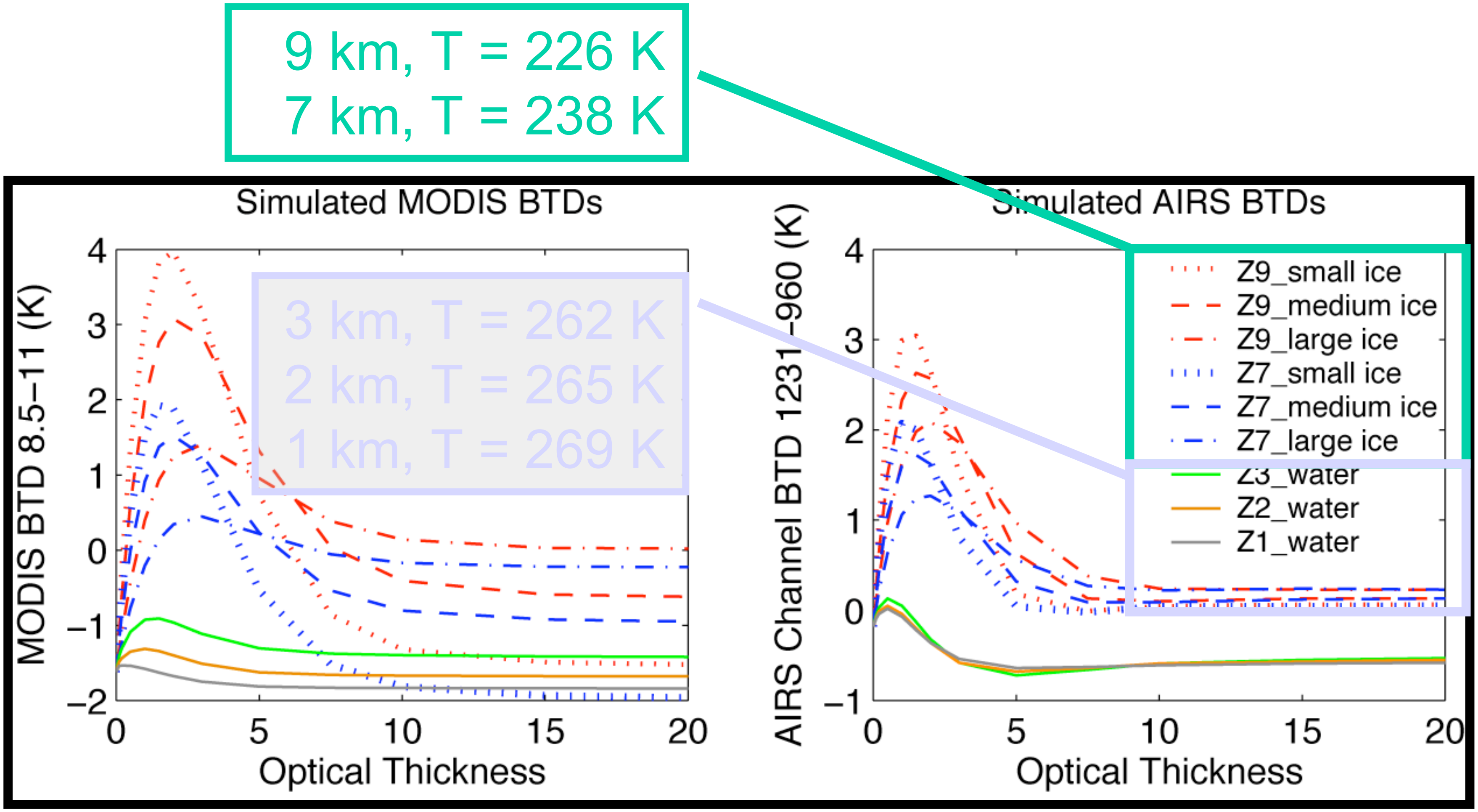


Optical thickness at 11 µm

MODIS sims from DISORT

AIRS sims from CHARTS

Nasiri and Kahn, 2006



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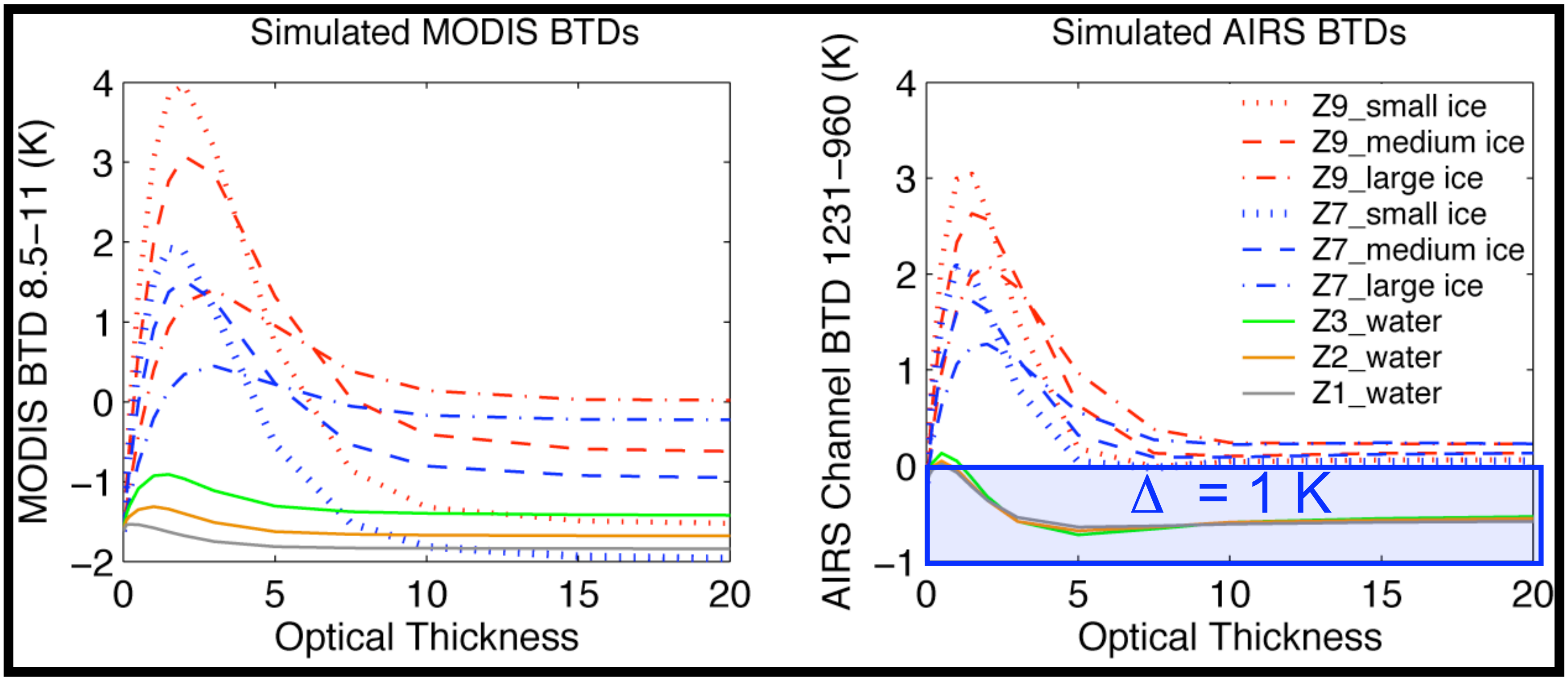

Optical thickness at 11 µm

MODIS sims from DISORT

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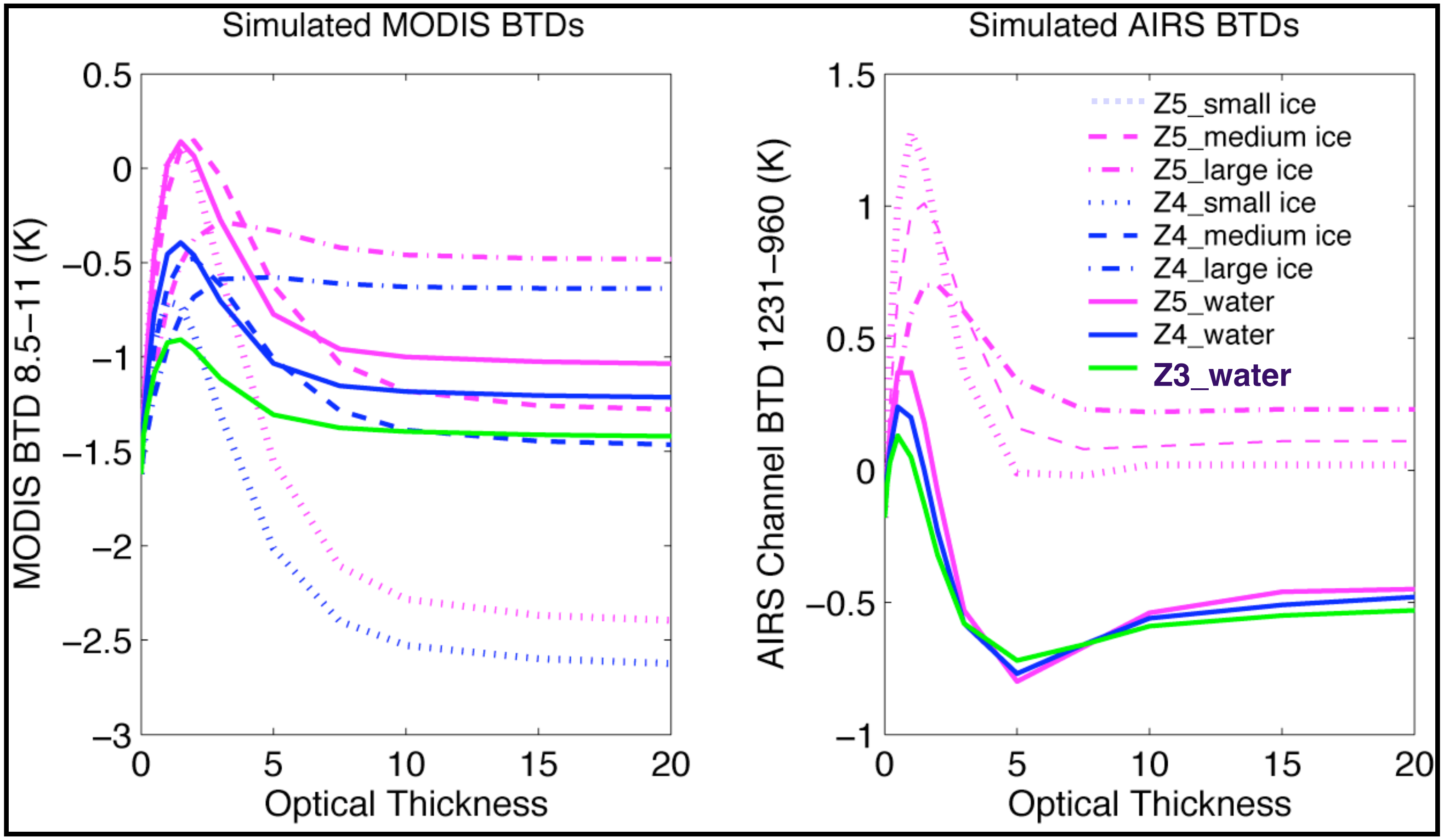
Nasiri and Kahn, 2006

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

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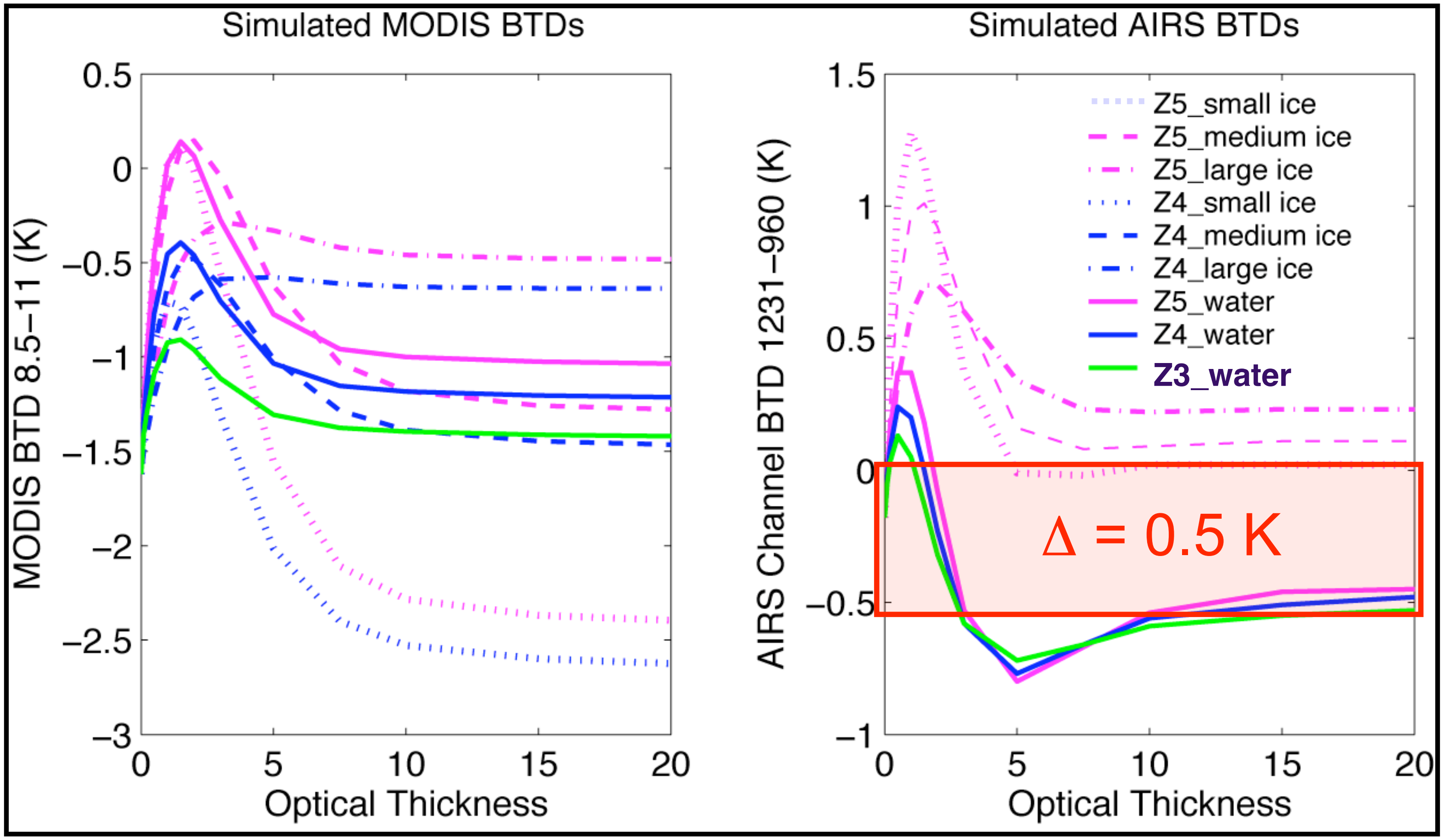


5 km, T = 256 K   4 km, T = 262 K   3 km, T = 265 K

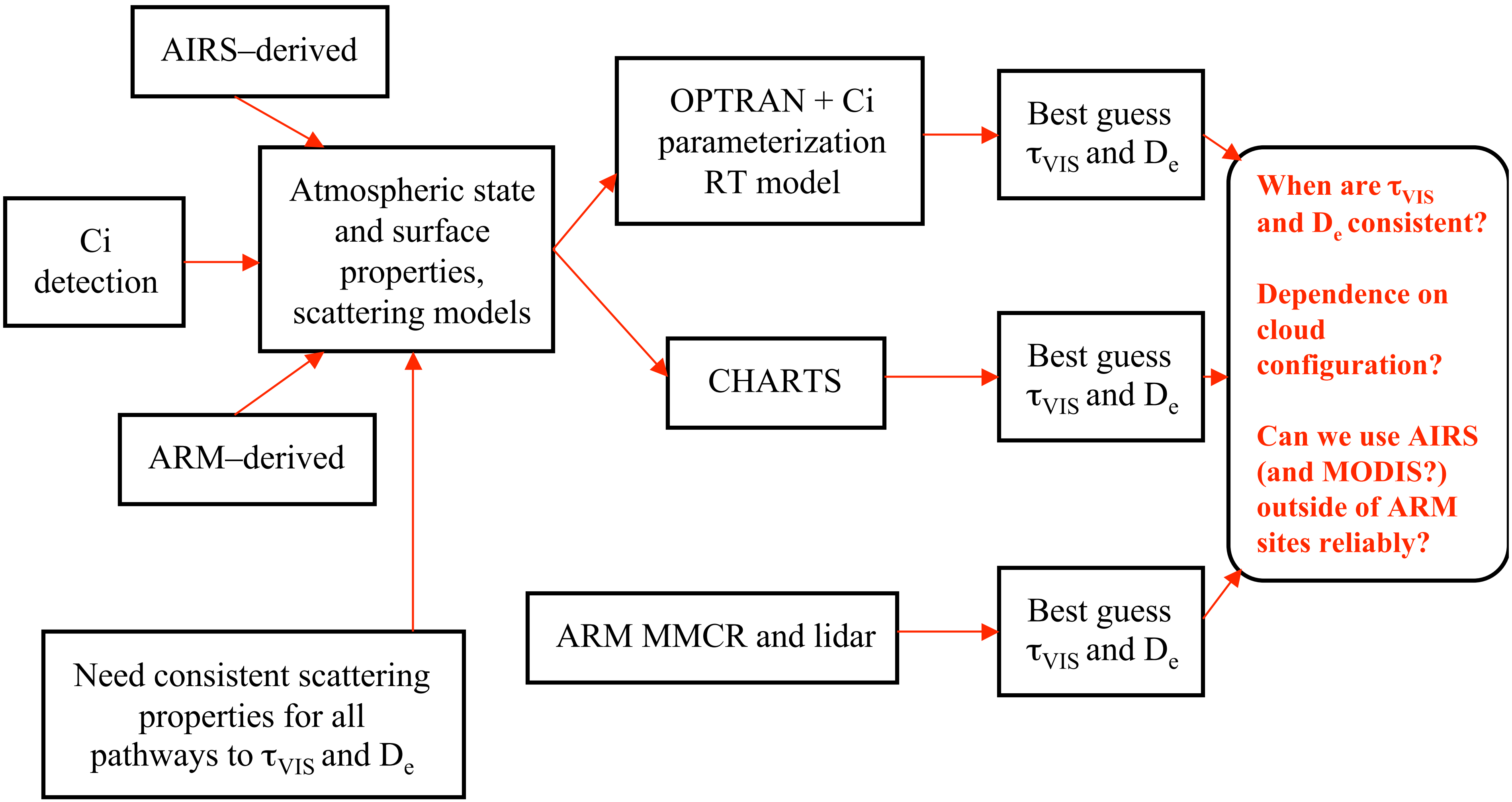
Nasiri and Kahn, 2006

Retrieving cirrus properties

- (Faster) RT model (OPTRAN) + parameterized thin Ci [*Yue et al*., 2006, JAS, *submitted*]
  - Calculate τ_{VIS} and D_e from AIRS (no scattering… yet)
- (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"**

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

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

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

Yue et al., 2006

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From AIRS L2 retrieval

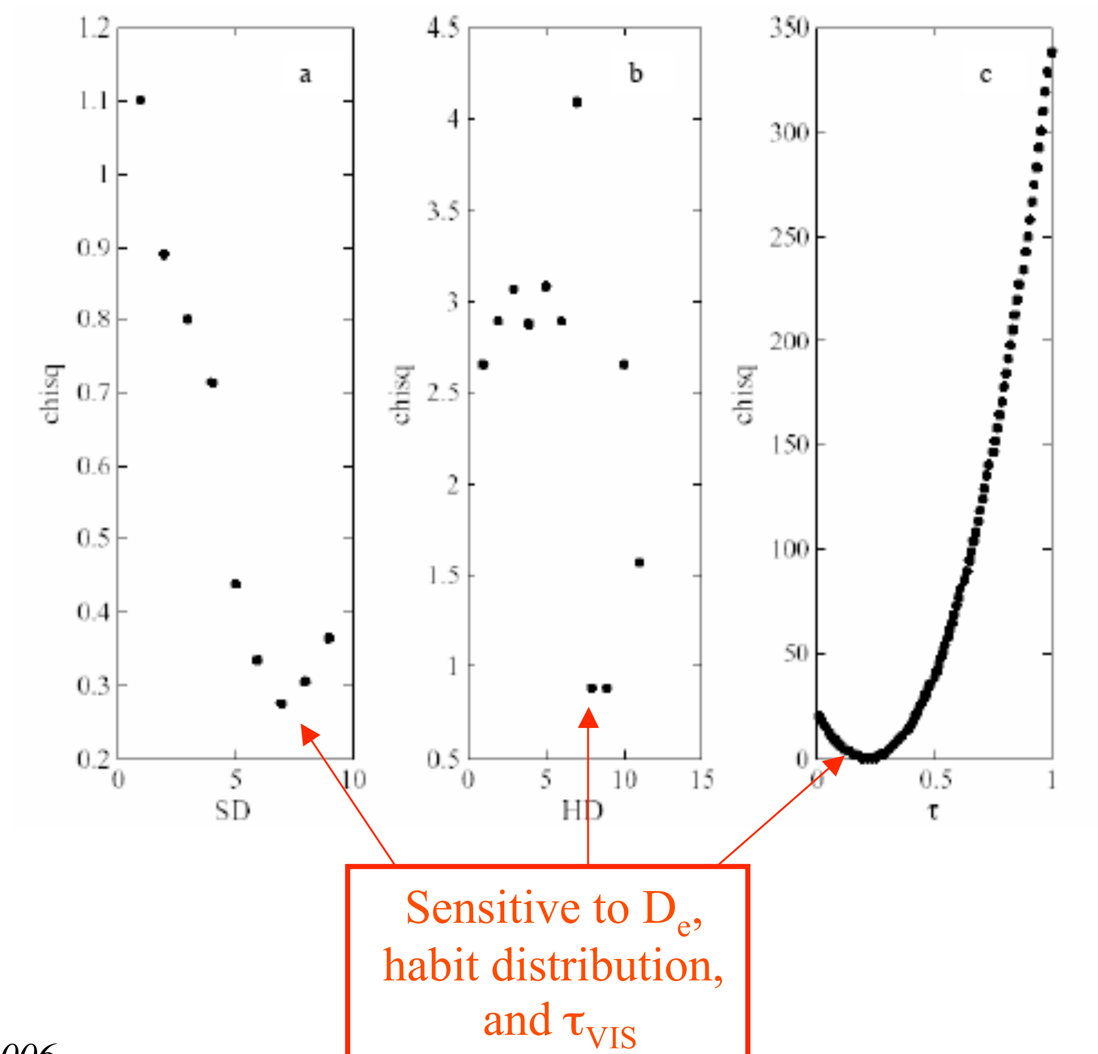
$$\varepsilon_\nu \approx \left(1-\varpi_\nu\right)\tau_{IR}/\mu$$

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

Size and habit models impact here

Yue et al., 2006

The "fast" RT approach: OPTRAN + ci parameterization



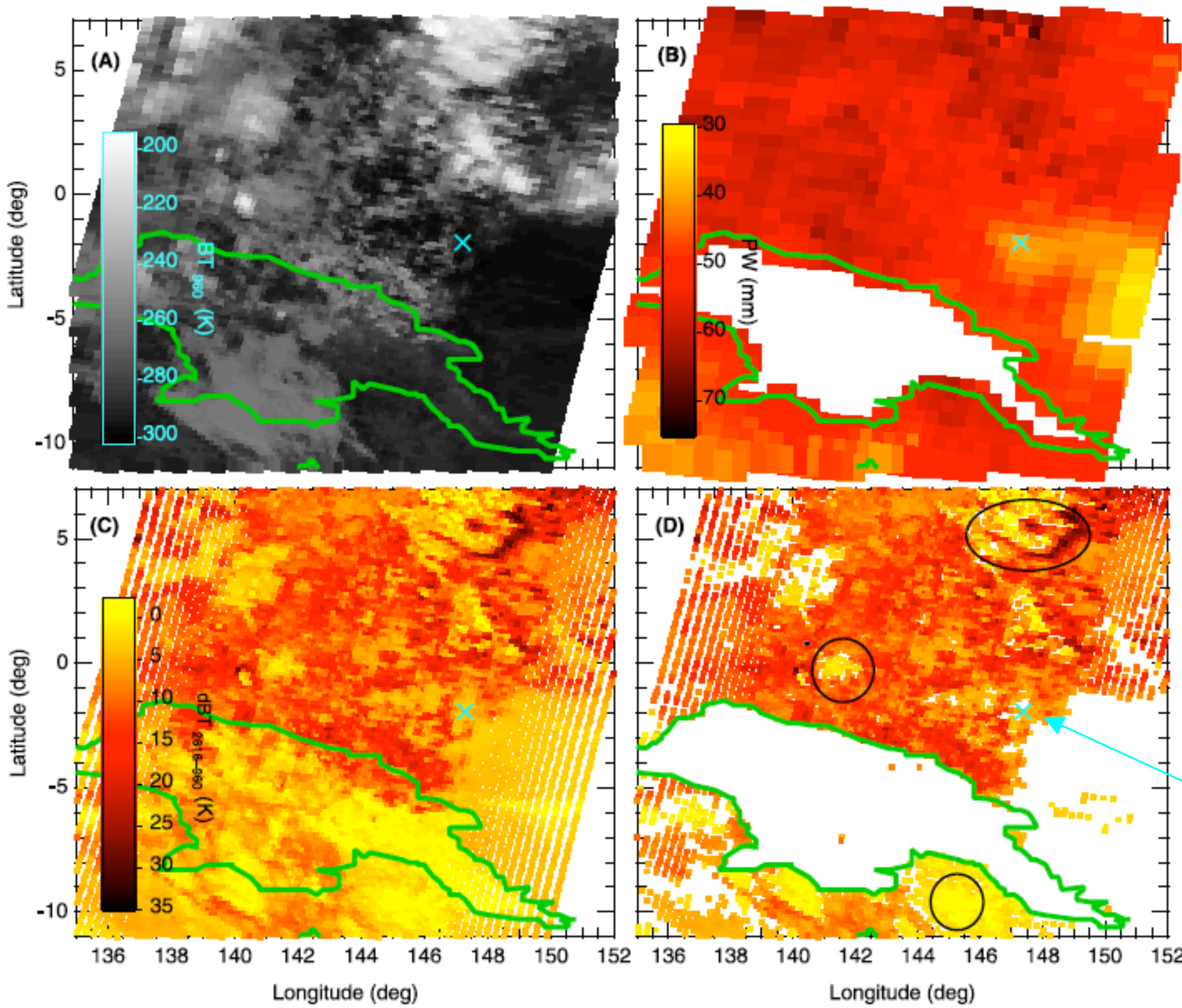
- 9 size distributions
- 11 habit distributions
- 100 τ_{VIS} from 0–1.0

Yue et al., 2006

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

BT $_{960\ cm^{-1}}$

Total column precipitable water vapor



BT $_{2616\ cm^{-1}}$ – BT $_{960\ cm^{-1}}$

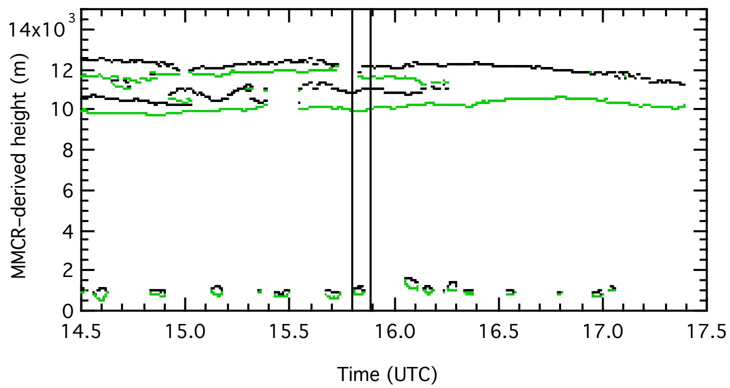
“cloud mask”

Manus Island Arm site (blue cross)

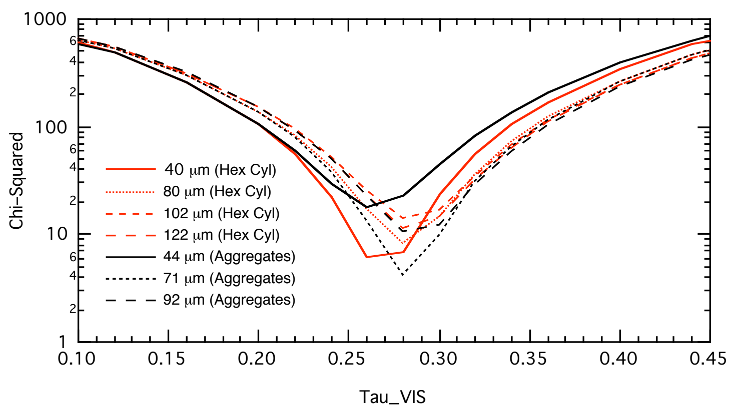
Kahn et al., 2005, J. Geophys. Res.

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

ARM cloud height from radar



χ^2 model–obs fit

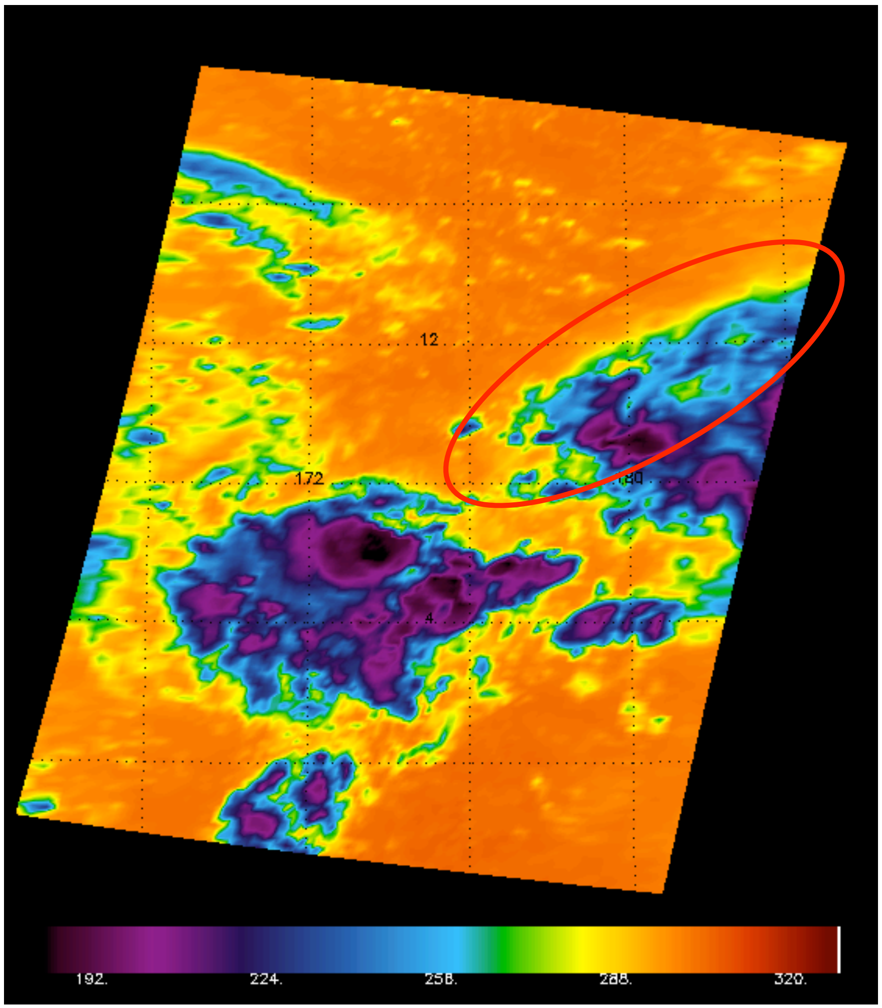


	Param RT Model	CHARTS	MMCR
τ_{VIS}	0.26	0.28	0.13
D_e (μm)	91.5	71.4	106

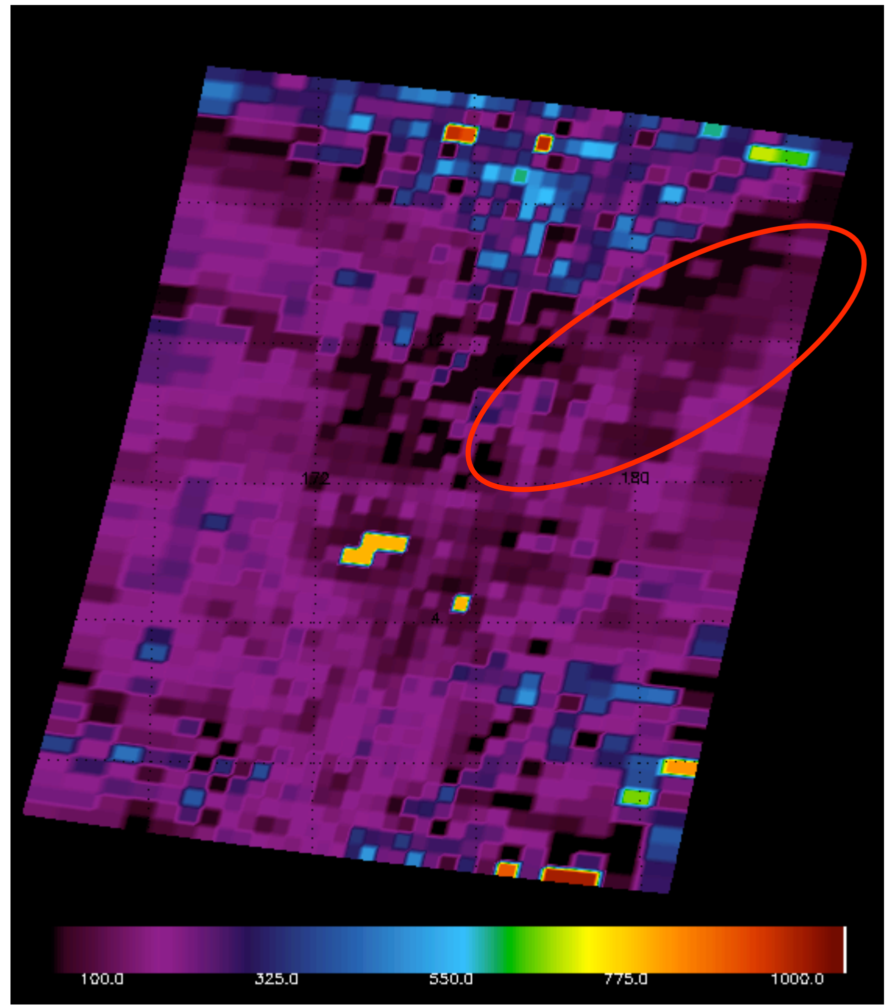
CHARTS and parameterized RTM retrievals have larger τ_{VIS} and smaller D_e than MMCR: indicative of missed small particles by MMCR?

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

An illustrative granule on July 1st, 2003



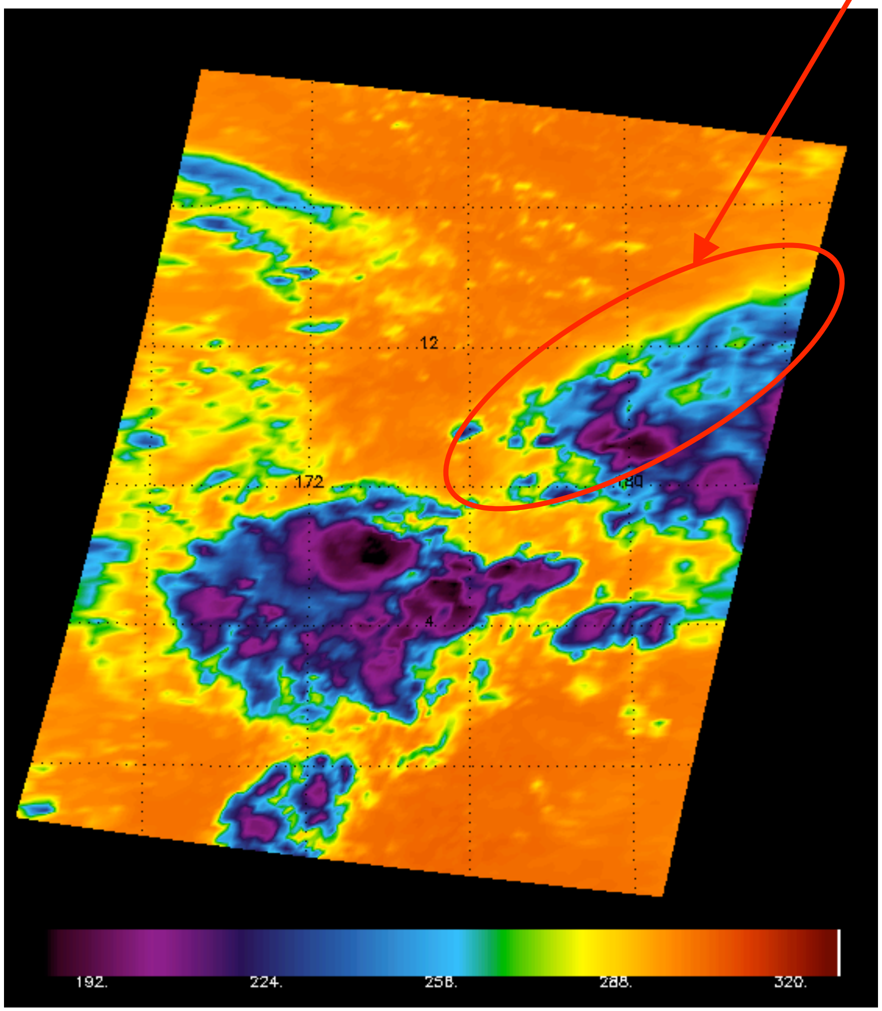
BT_{960} (K)



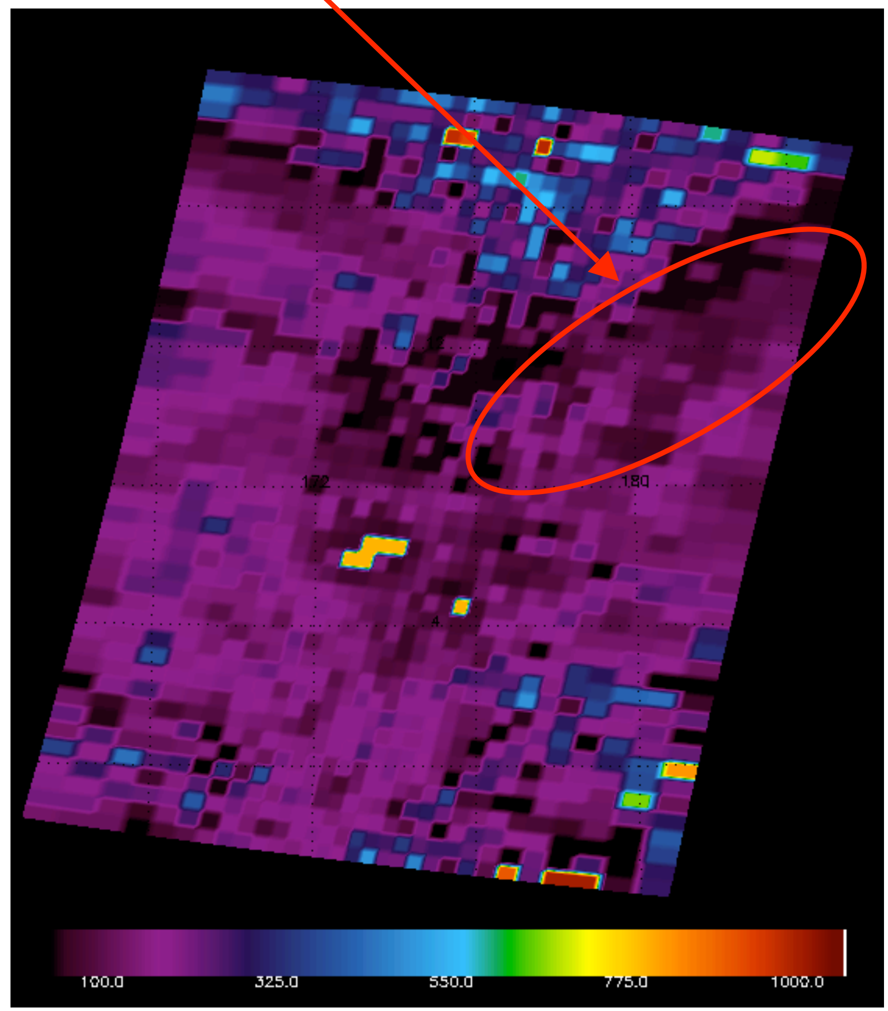
Upper CTP (hPa)

Cloud top increases away from convective towers
Is this the elusive "upper peak" in the AIRS-MLS comparisons?

An illustrative granule on July 1st, 2003



BT_{960} (K)



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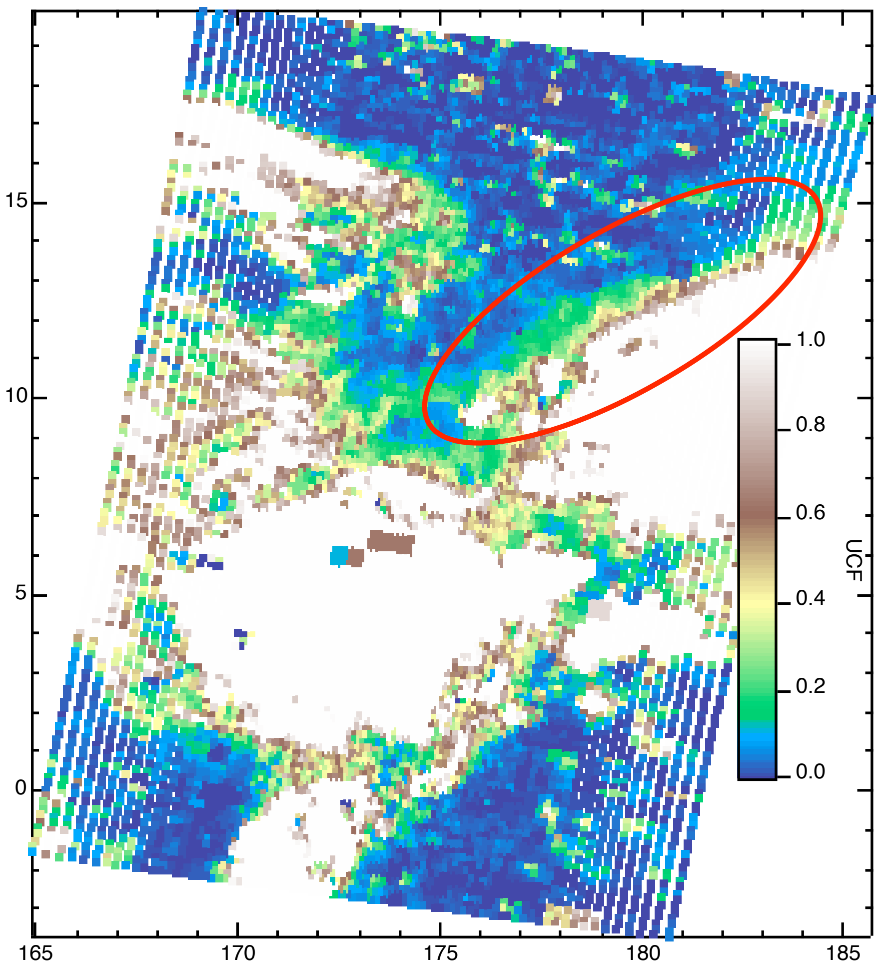
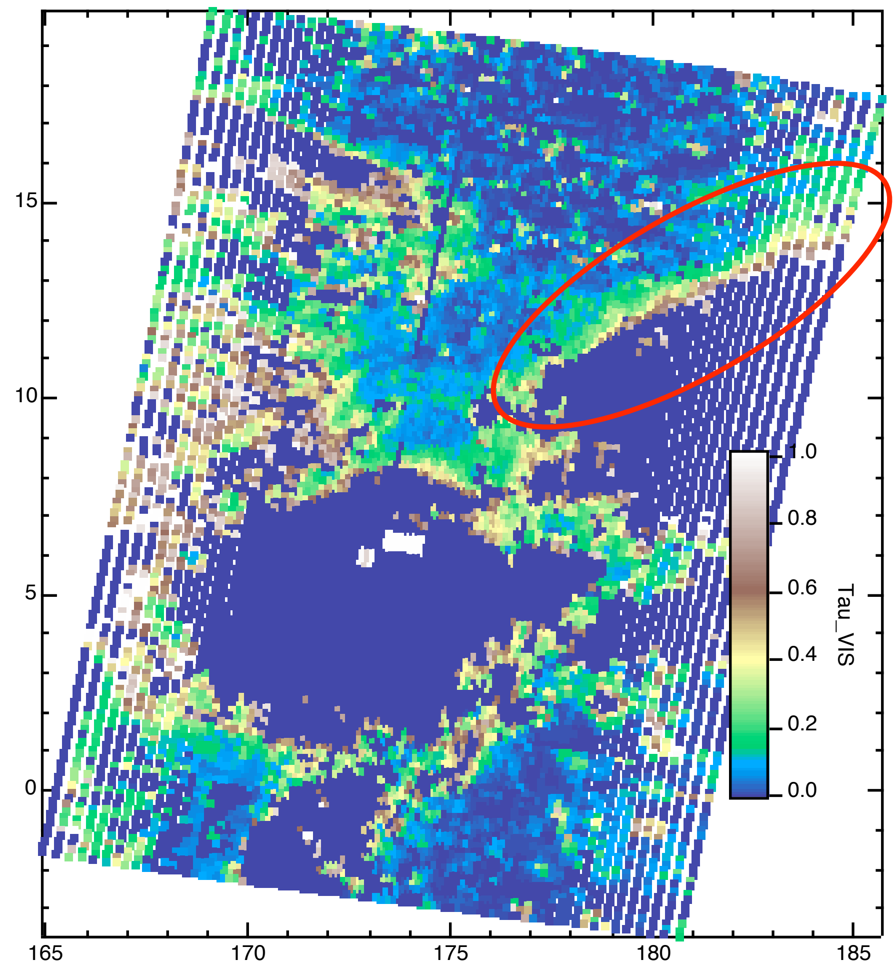
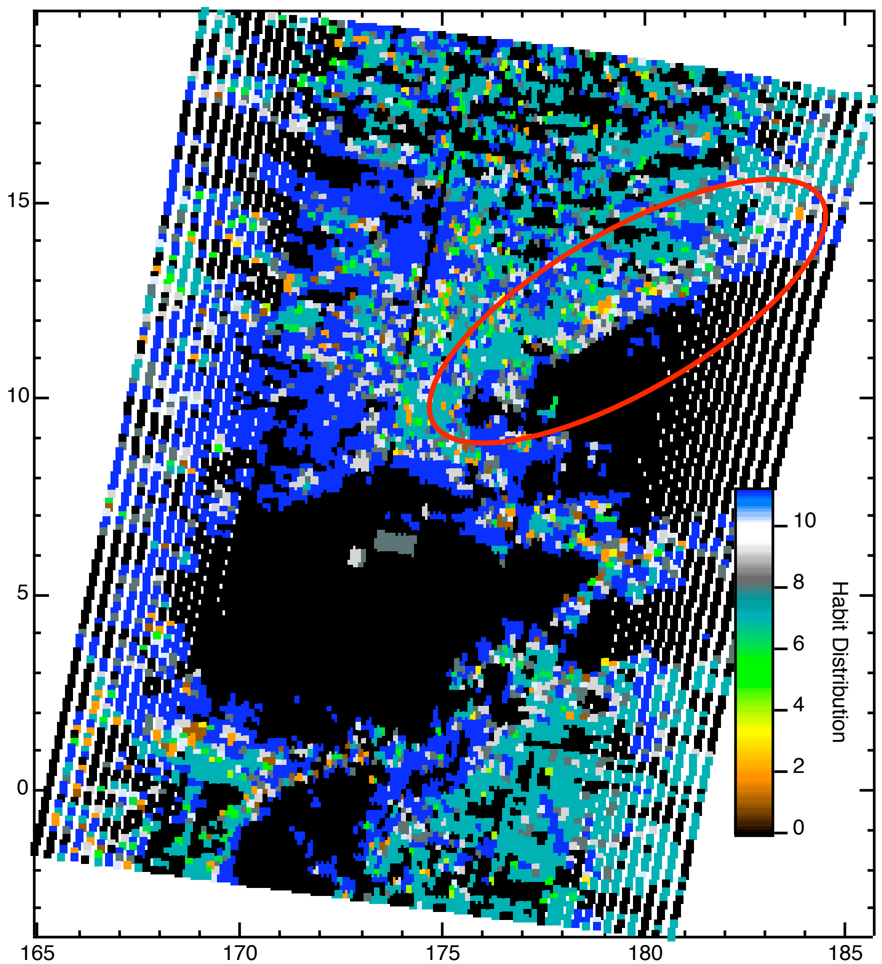


ECF (Upper)

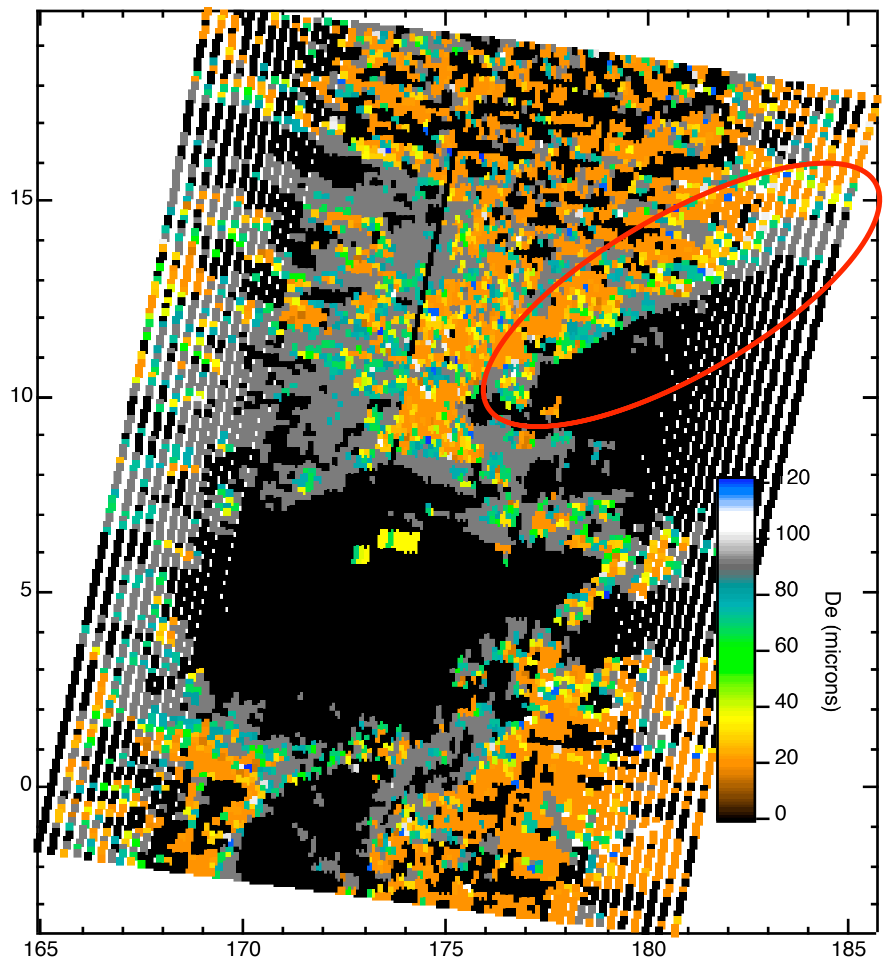


τ_{VIS}

An illustrative granule on July 1st, 2003

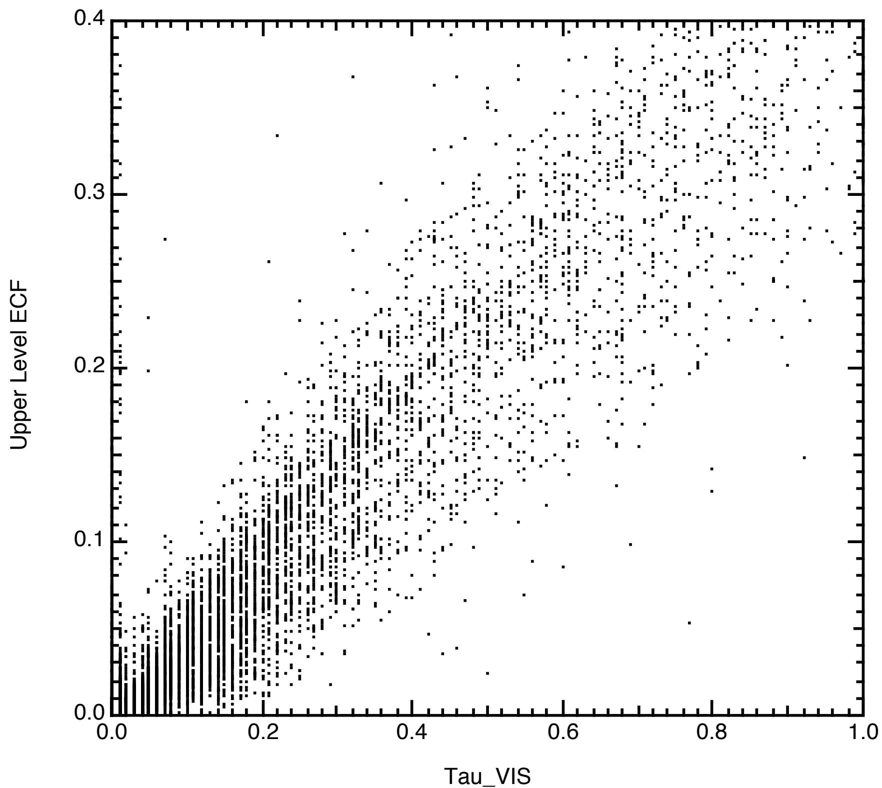


D_e (microns)

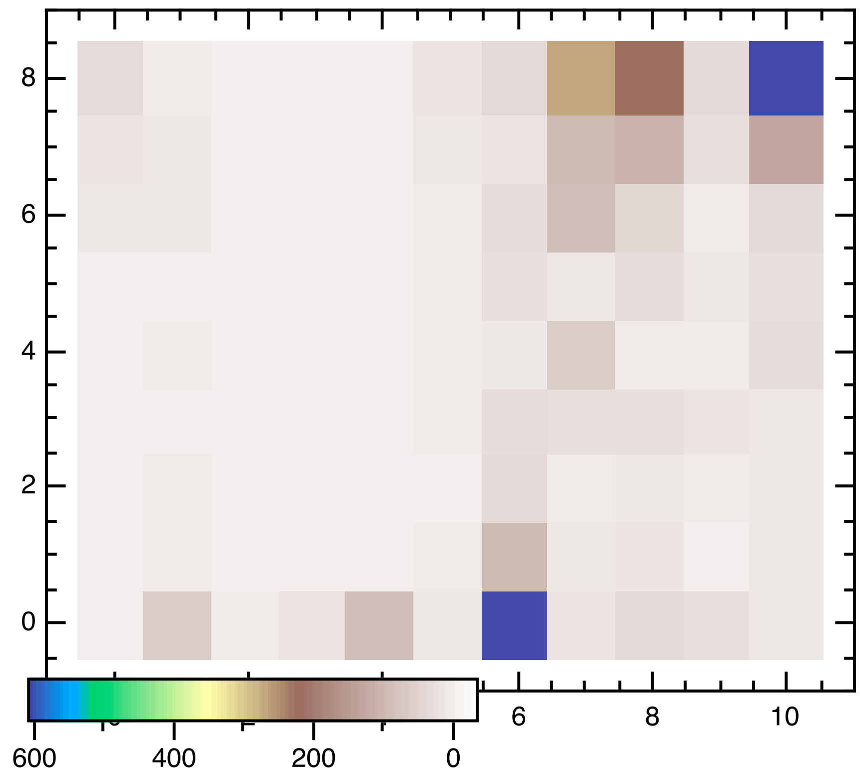


Habit Distribution

An illustrative granule on July 1st, 2003



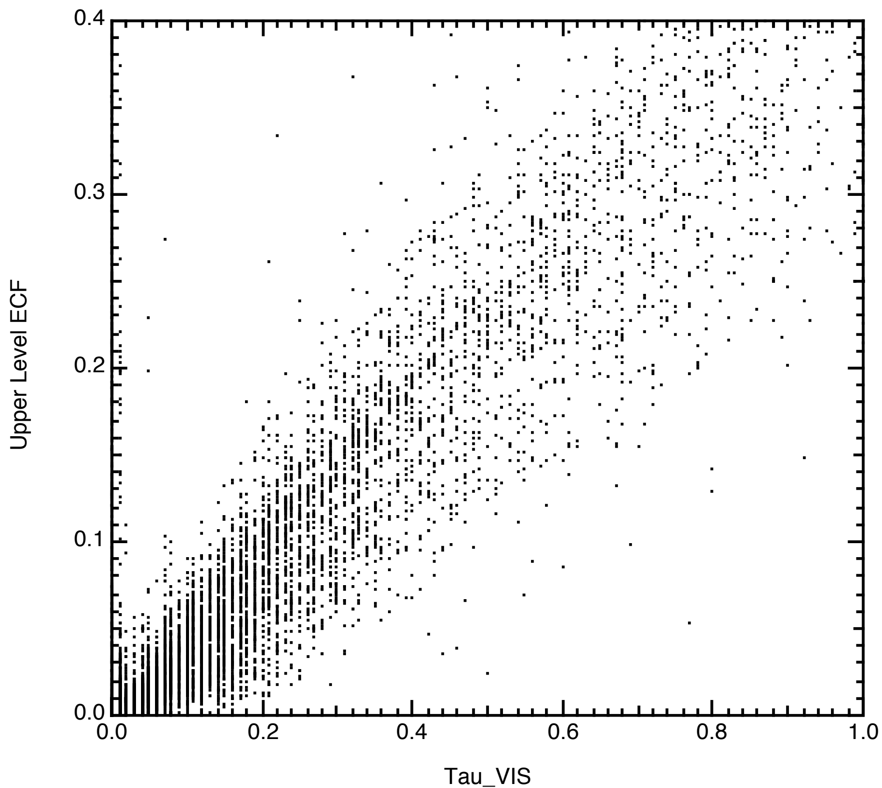
ECF (Upper) versus τ_{VIS}



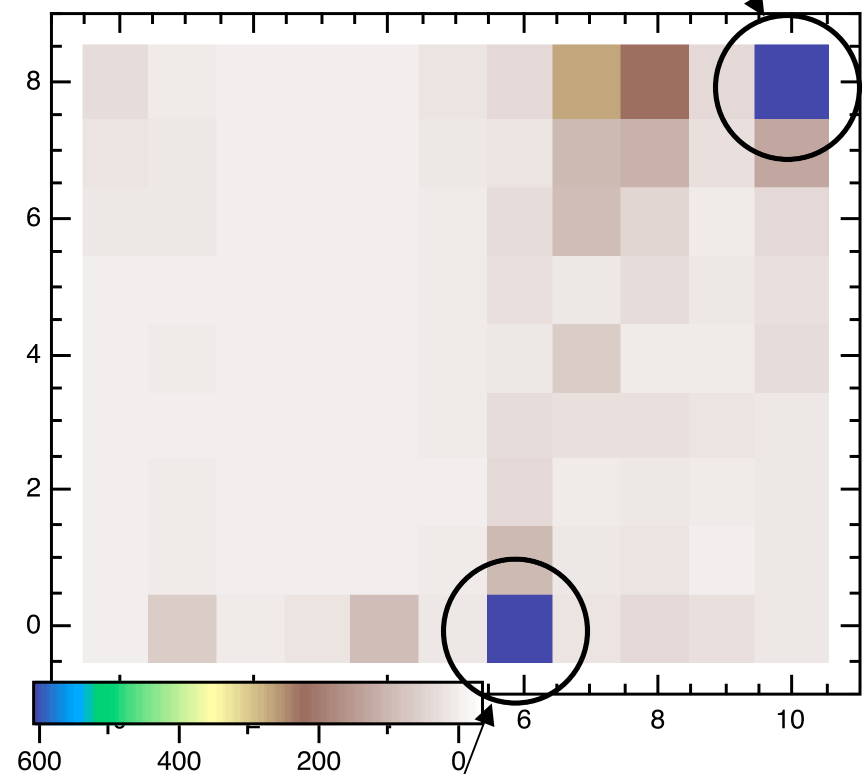
Frequency of size dist and habit dist

Slightly thicker Ci: 100% SC: *Baum et al*. [2005]

An illustrative granule on July 1st, 2003



ECF (Upper) versus τ_{VIS}



Frequency of size dist and habit dist

Thinnest Ci: 33.7% SC, 24.7% BR, 41.6% A: *McFarquhar et al*. [1999]

Summary and Conclusions

- AIRS maps out cirrus realistically
  - Limits of thin cirrus detection have not been reached

- AIRS may be useful for more complicated cloud configurations
  - Cloud phase – tradeoff between sensitivity and footprint size when compared to MODIS
  - Multilayered clouds – V4.0 clouds have coherent patterns

- Fast RT approach to retrieve thin cirrus D_e and τ with AIRS radiances
  - Future modifications with 4-stream approximation…thicker Ci

- Efficiency of calculation work in progress

- Further comparisons to ARM site-derived and MODIS-derived D_e and τ are necessary