IWP, r_e, τ

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Background

- IR (e.g. TOVS, AIRS, IASI)
- IR/VIS (e.g. MODIS,PATMOS-x, ISCCP, and ATSR)
- MV (E.g AMSU-b & MHS)
- Active (E.g CloudSat & Calipso)

Articles

- Choice of ice crystal model (SRBS)
- PDFs of retrievals
- Cloud vertical heterogeneity

Where we are at now ([Eliasson et al., 2010])

- Spatial distribution IWP
- Spatial distribution IWP
- Regional statistics IWP

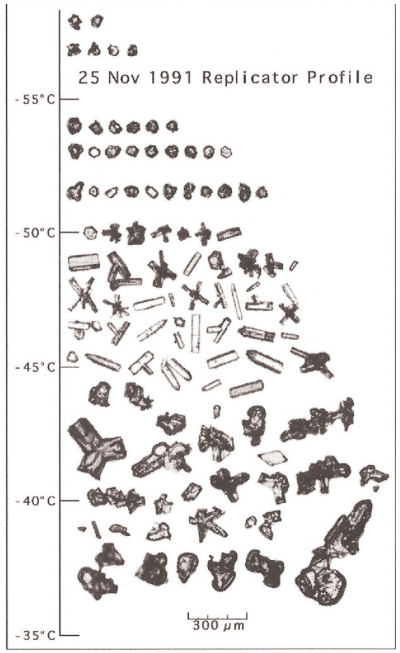
Data team results

- Comparisons: E_m, τ_v, r_e, WP
- ATSR

Conclusion

Understanding Cirrus microphysics is important

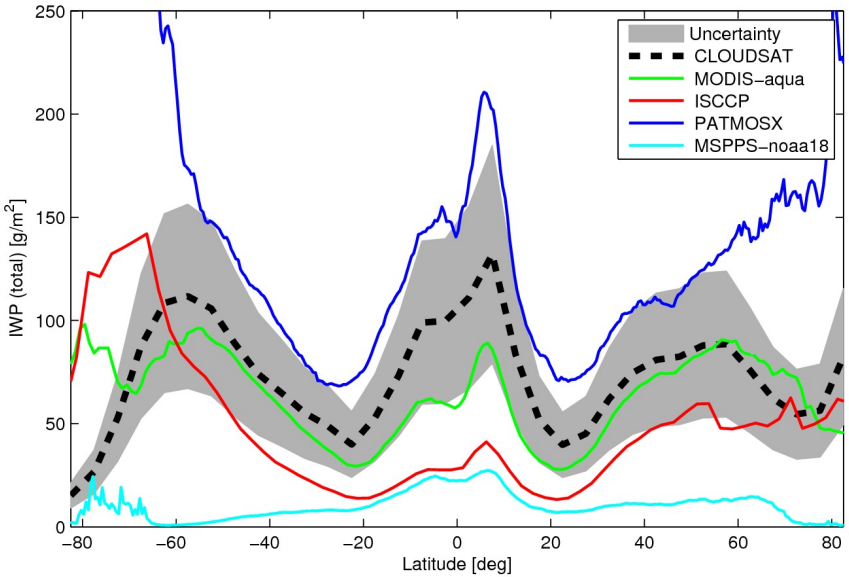
- Impacts:
  - Hydrological cycle
  - Radiative forcing
  - Tropospheric $\Leftrightarrow$ Stratosphere exchange
- Difficult due to:
  - Particle habit hard to determine
  - Clouds are vertically inhomogeneous
  - Uncertainties in CTH

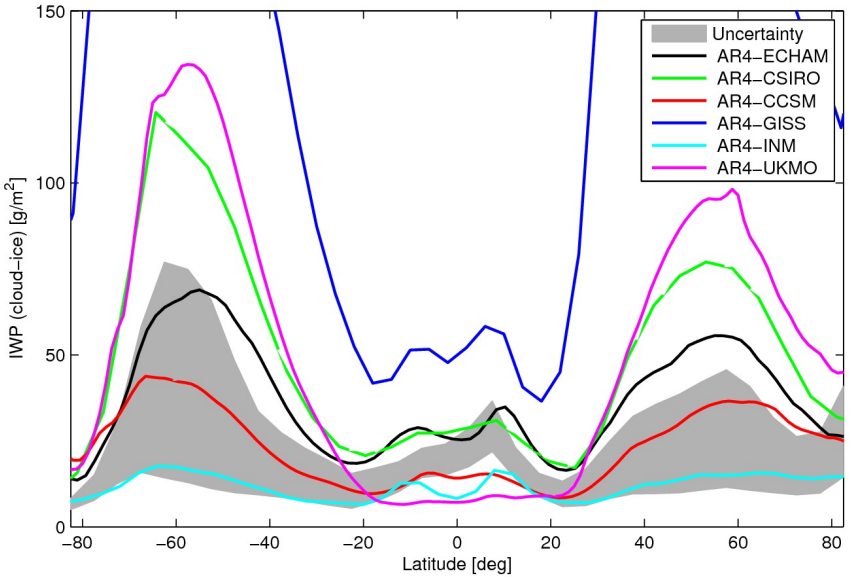


Heymsfield and Miloshevic [2002]

- r_e and τ_c are the two most fundamental microphysical and radiative parameters for ice clouds. [e.g., Zhang et al., in press]
- Realistic shape $\rightarrow$ difference of 10/ 25 Wm^{-2} in SW / LW [Kristjánsson et al., 2000]

Dataset differences

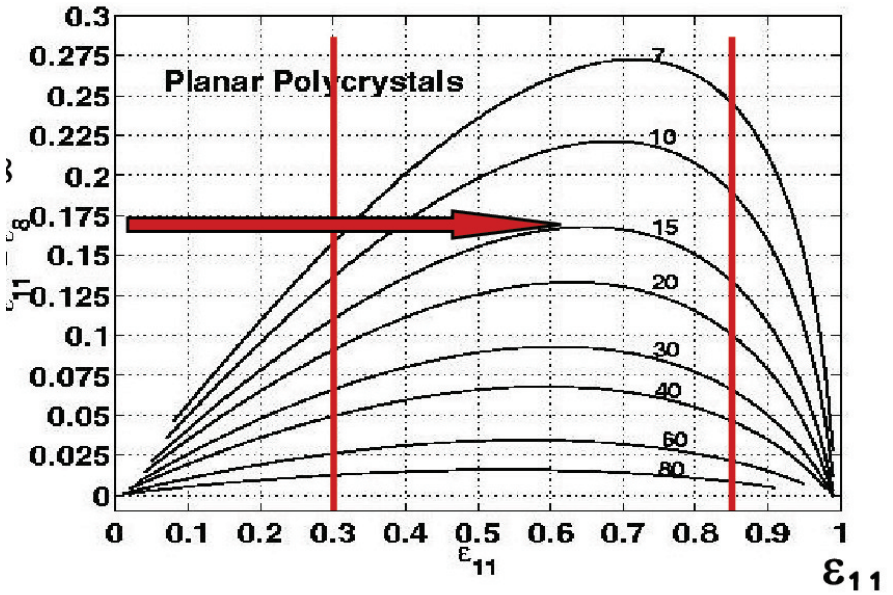




- Large differences between:
  obs. $\Leftrightarrow$ obs. & mod. $\Leftrightarrow$ mod. & mod. $\Leftrightarrow$ obs.
  [e.g. Waliser et al., 2009, Li et al., 2005, John and Soden, 2006, Eliasson et al., 2010].
- Not possible to validate GCMs in AR4 archive in terms of IWP.
- Need to combine information from datasets.
- i.e. with caution as retrievals are based on different instruments and techniques.

Passive IR only channels

- Calculated from differences in channel emissivities.
- For semi-transparent cirrus only.
- Optical thickness $\tau = -2ln(1-\epsilon)$ is independent of microphysical assumptions.
- Can also use IR Split Window (IRSpW) method.



$$D_e = 2r_e^{VP} = 2\frac{\int \frac{3V}{4\pi} n(r)dr}{\int \frac{P}{\pi} n(r)dr} = \frac{3}{2}\frac{IWC}{\rho_i P}$$

for $0.3 < \varepsilon_{11\mu m} < 0.85$
$0.7 < \tau_{VIS} < 3.8$

sensitivity up to $D_e \leq 80\mu m$

C. Stubenbauch GEWEX presentation 2008

Passive IR & VIS channels

- The Solar Reflectance Bi- Spectral (SRBS) method uses reflection measurements to retrieve τ_c and r_e simultaneously.

- Cloud reflectance, R(VIS), is a strong function of τ_c, R(SWIR/NIR) is sensitive to r_e.
- Retrieve ice cloud properties during daytime.
- Not too thick.
- Very sensitive to ice crystal shape.

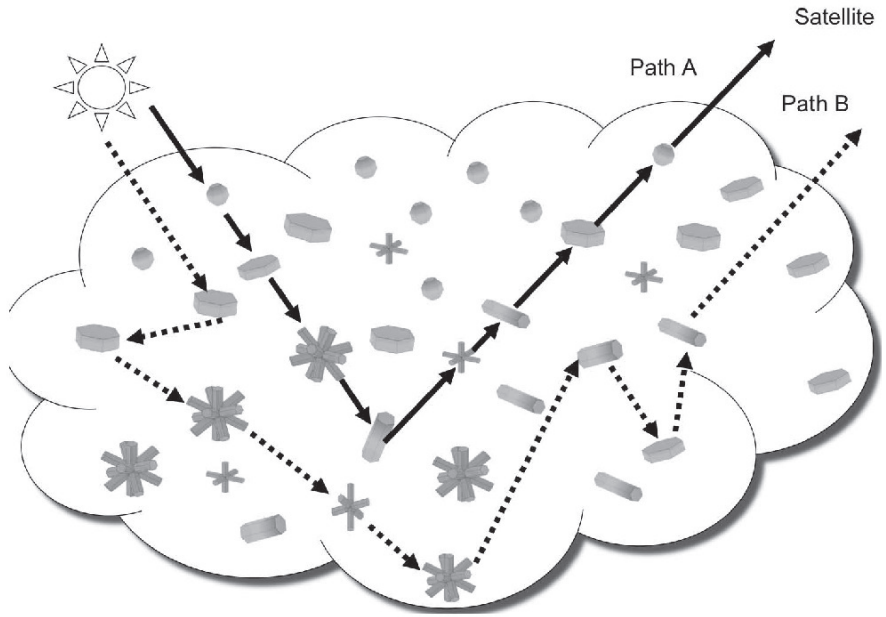
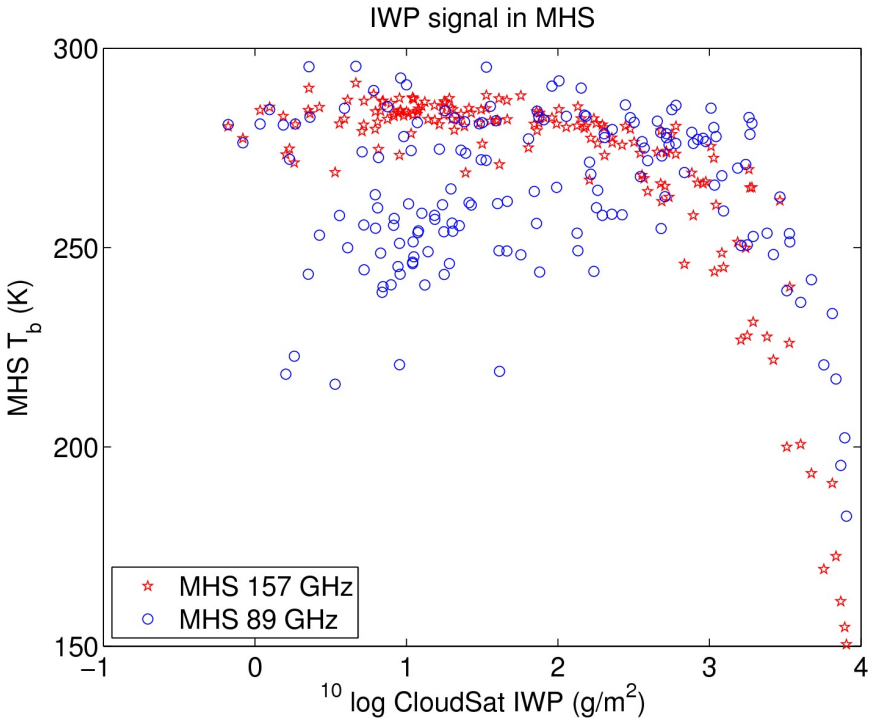


Fig. 8. Schematic illustration of two possible paths of photons within ice cloud. Note that back scattering event occurs only once in "Path A", but several times in "Path B".

[Zhang et al., 2009]

Passive Microwave channels

- IWP and r_e are retrieved from scattering measurements @ 89 and 157 GHz. [Zhao and Weng, 2002]
  - No sensitivity to clouds with IWP $< 100 \frac{\mathrm{g}}{\mathrm{m}^2}$ for passive MV channels (figure).
  - IWP information from Microwave can complement IWP from the other techniques?



Gerrit Holl

Active sensors

Provides information on the vertical structure of clouds.

CloudSat:

- 94 GHz, Cloud Profiling Radar.
- Can penetrate deep clouds.
- Good CBH.
- High vertical resolution,
- Small footprint

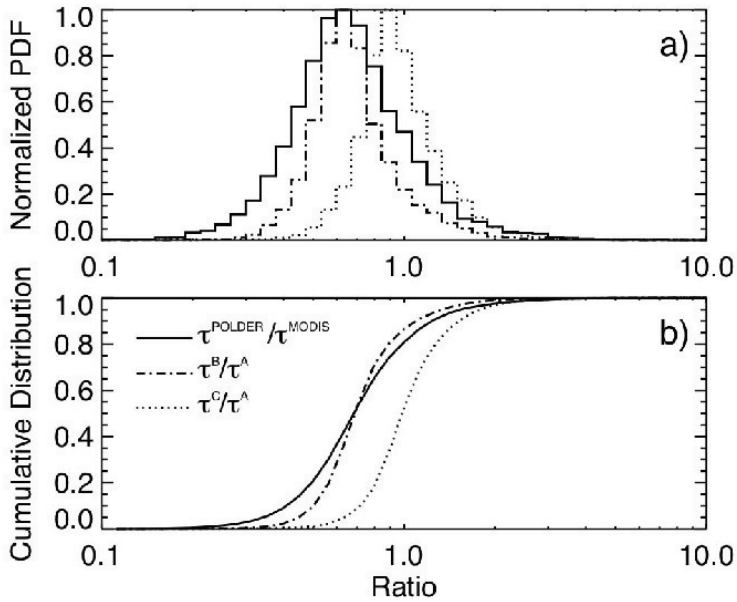
Calipso:

- Green Visible LIDAR
- Can detect very thin clouds.
- Great for CTH.
- Very high vertical resolution.
- Very small footprint

τ_V from MODIS and POLDER [Zhang et al., 2009]

- SRBS retrievals
- $\tau^P << \tau^M$
- Main differences:
  1. Retrieval resolution
  2. POLDER uses assumed r_e, MODIS uses retrieved r_e.
  3. Differences in ice particle model. IHM vs. Baum05

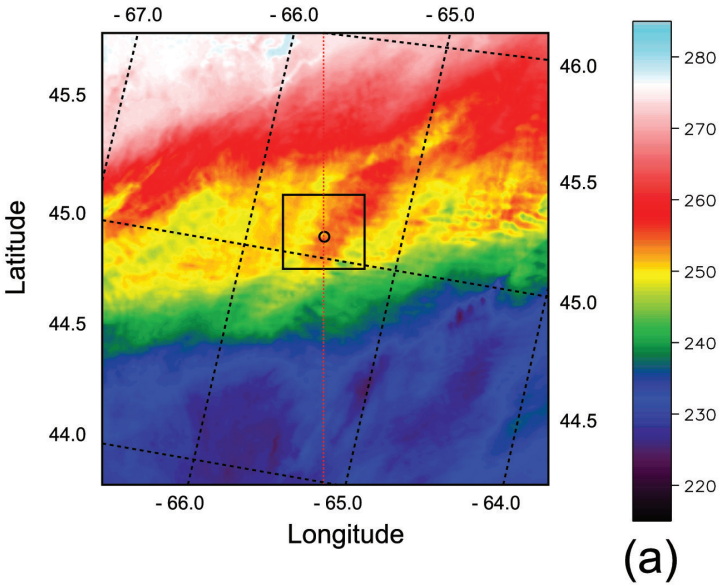
Experiment	Radiance source	Radiance resolution	Bulk scattering model
A	MODIS	$6\times6\,\mathrm{km}^2$	Baum05 ($r_e = 30\mu m$)
B	POLDER	$6\times6\,\mathrm{km}^2$	IHM ($r_e = 30\,\mu m$)
C	POLDER	$6\times6\,\mathrm{km}^2$	Baum05 ($r_e = 30\,\mu m$)

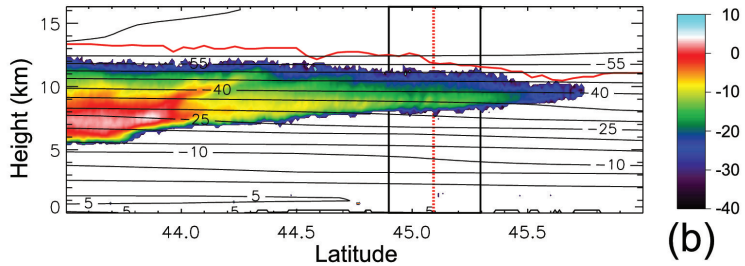


- τ-bias greatly reduced when the same model is used in both retrievals.
- $\tau^P(\mathrm{IHM}) < \tau^P(\mathrm{Baum05})$ from the same observation.

PDFs of retrievals [Posselt et al., 2008]

- All retrievals have an associated PDF, based on uncertainties in the observations, a priori and models
- Case study IRSpW:

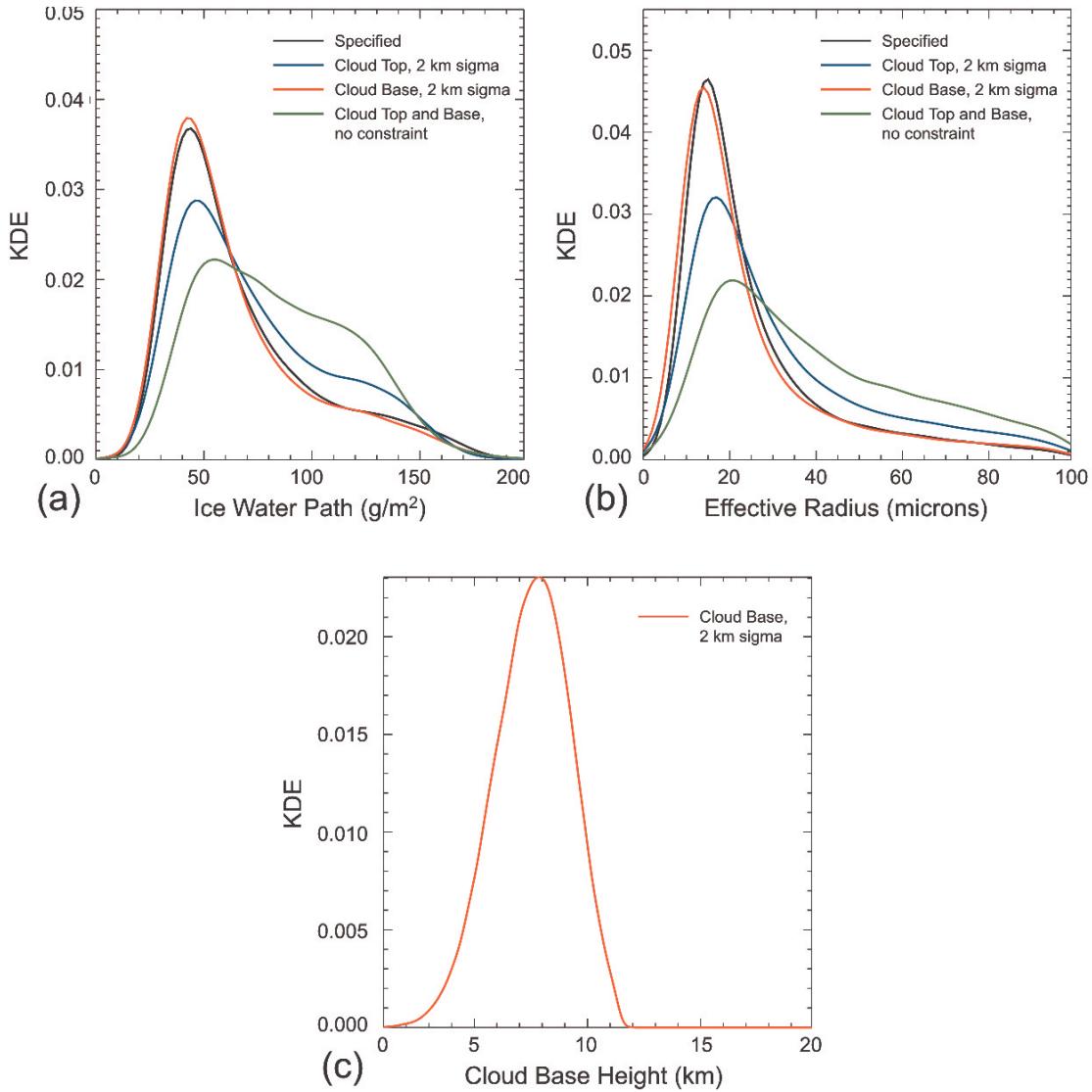




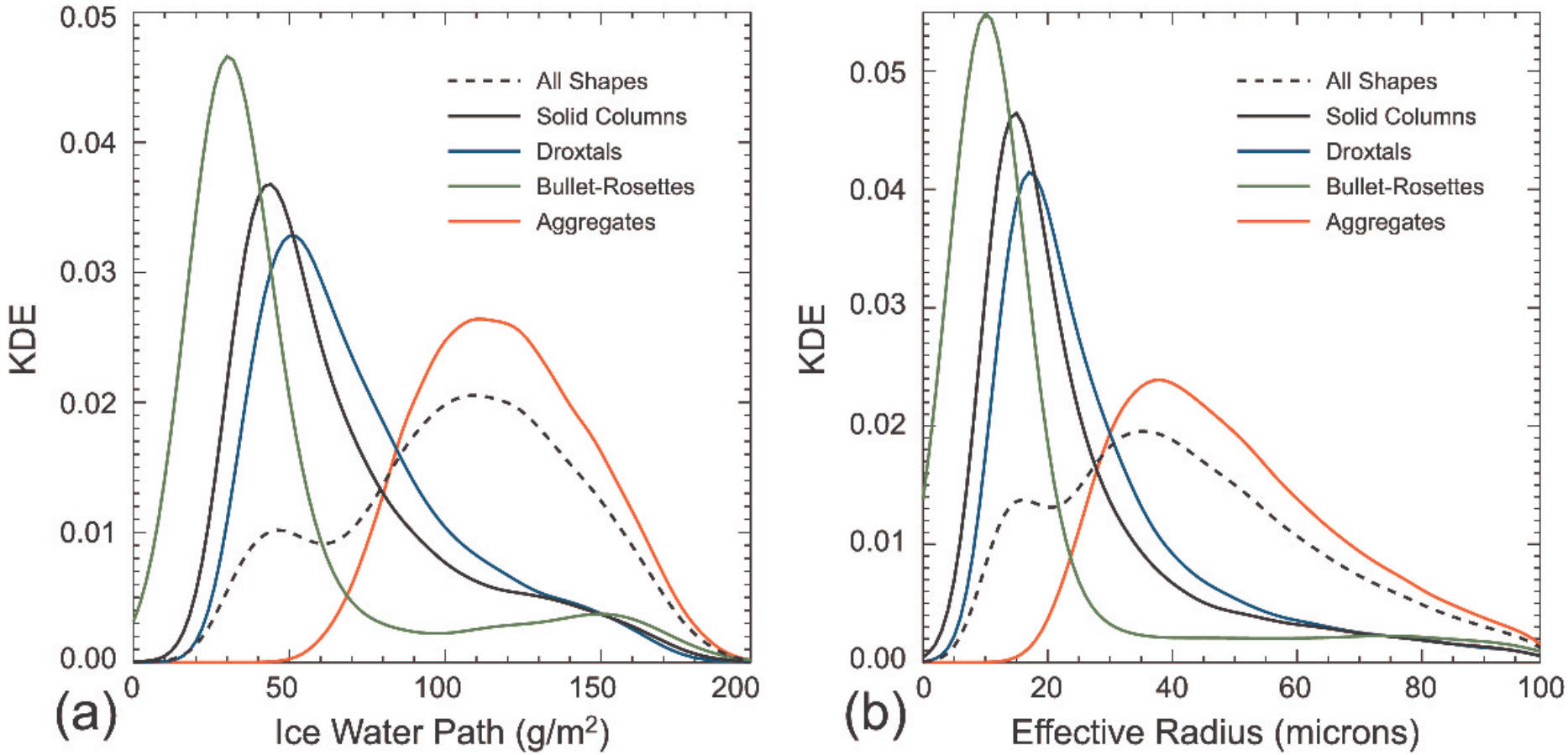
Assumed particle habit [Posselt et al., 2008]

The PDF retrievals assuming solid columns:

- Specified CBH & CTH
- CTH may vary with $2\mathrm{km}\,\sigma$
- CBH may vary with $2\mathrm{km}\,\sigma$
- Vary without constraint
- The PDF of the CBH retrieval with 2km σ



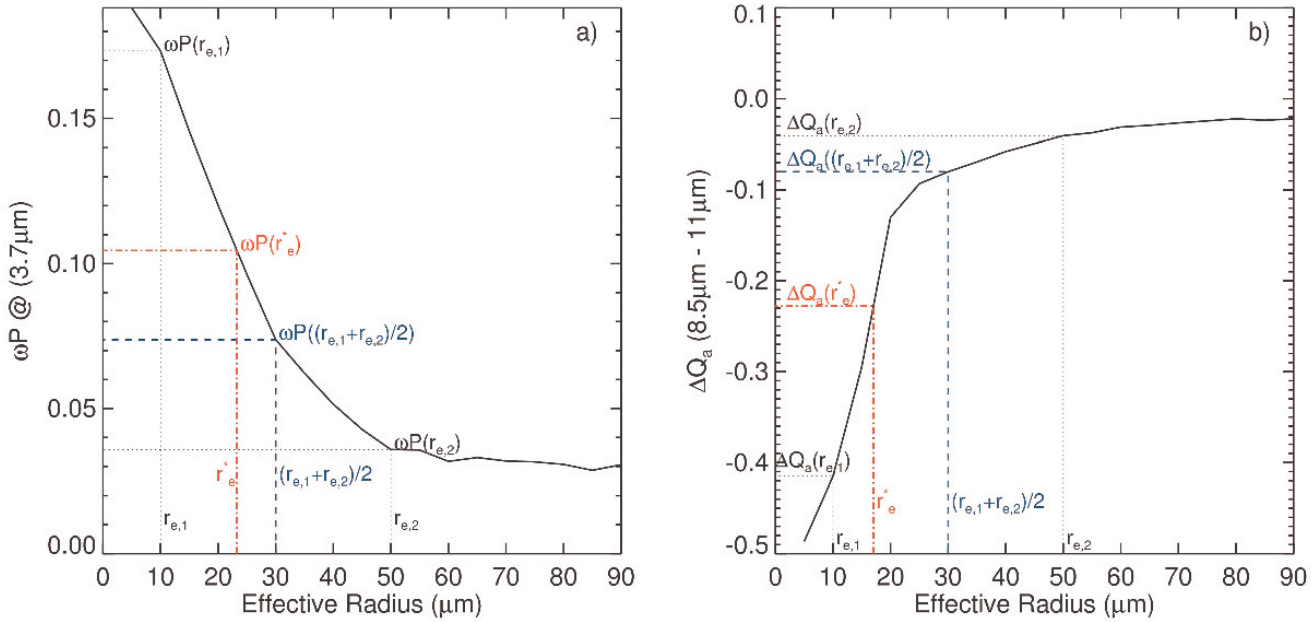
Assumed cloud base and top [Posselt et al., 2008]



- Variations in crystal shape generally drive the accuracy of retrieved products

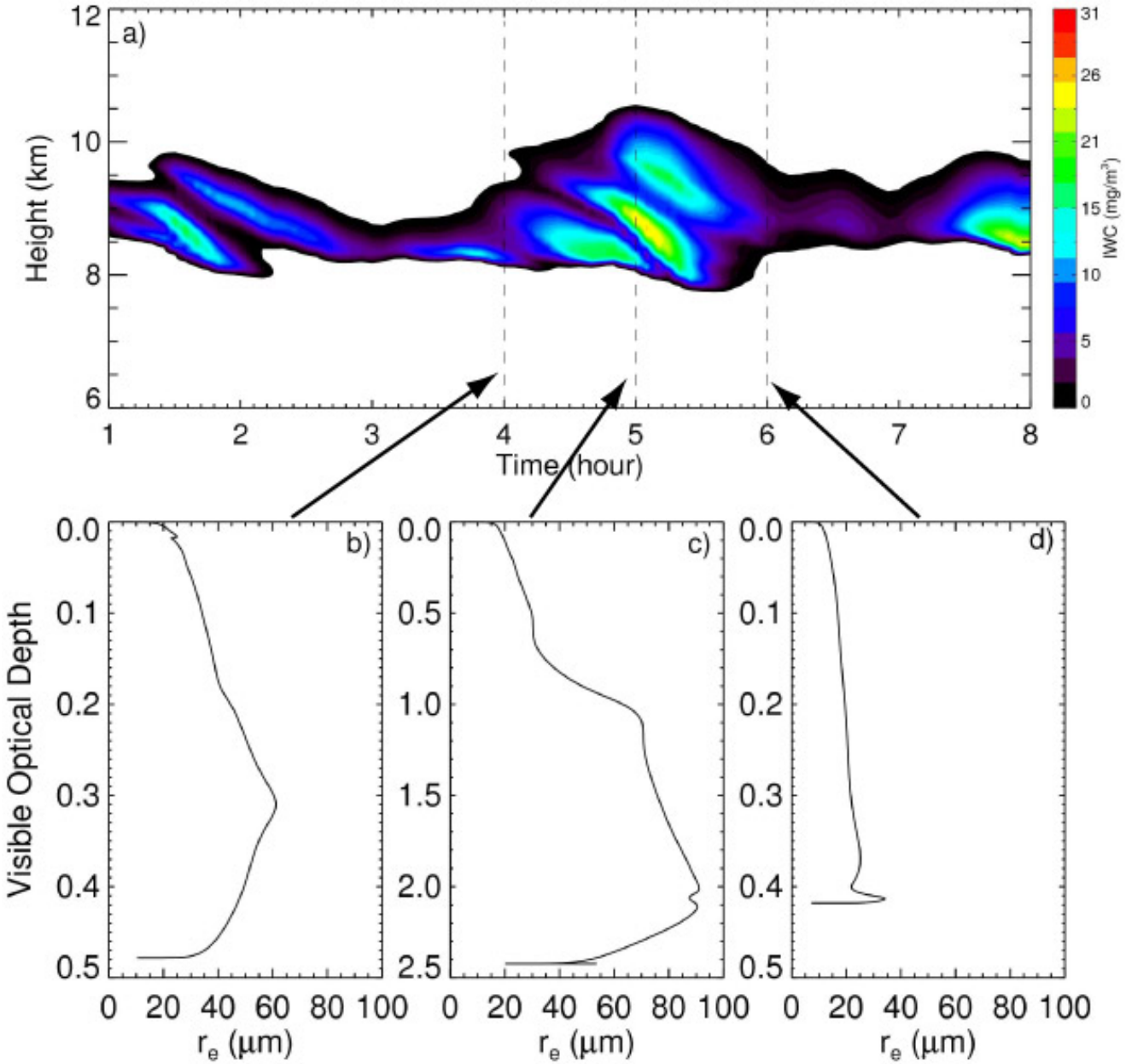
Cloud vertical inhomogeneity [Zhang et al., in press]

Case study: 2 clouds with r_{e1} and r_{e2} ($\tau_c < 1$)



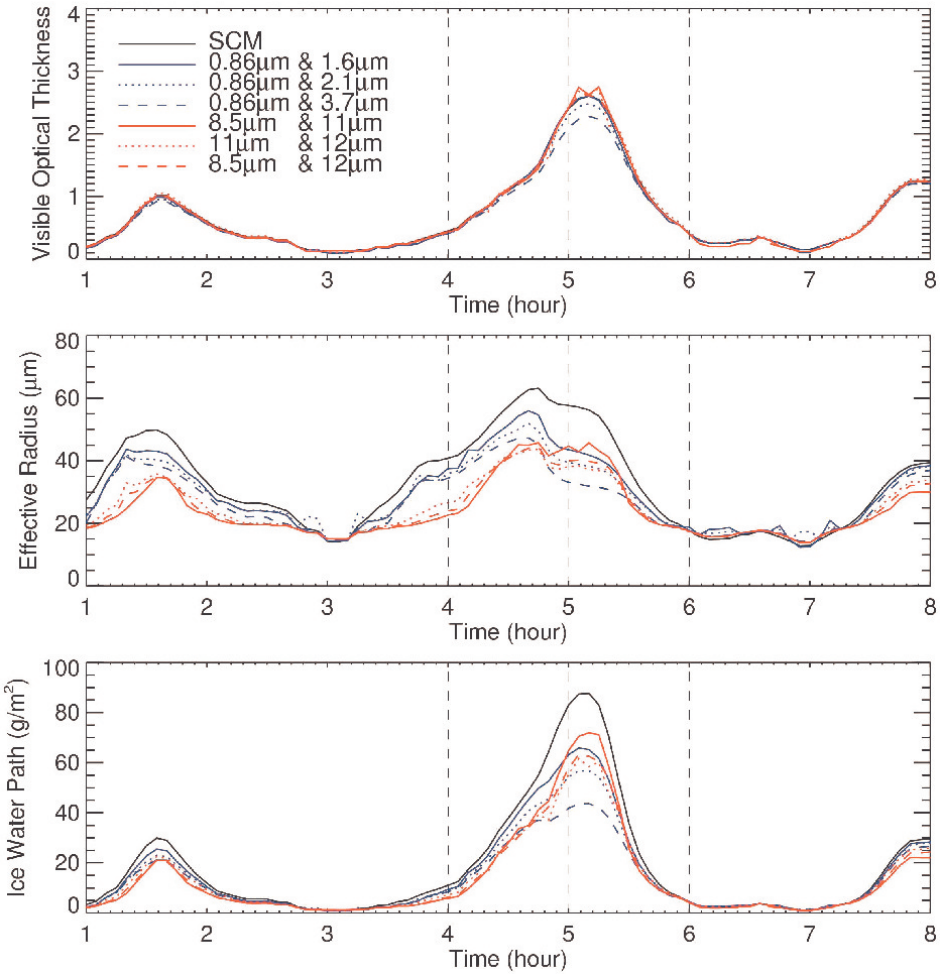
- Figure shows $r_e < (r_{e1} + r_{e2})/2$.
- Due to non-linearity dependence on r_e.
- For a given thin cloud the resultant r_e and IWP may be quite different depending on the technique.

A modeled cloud [Zhang et al., in press] I



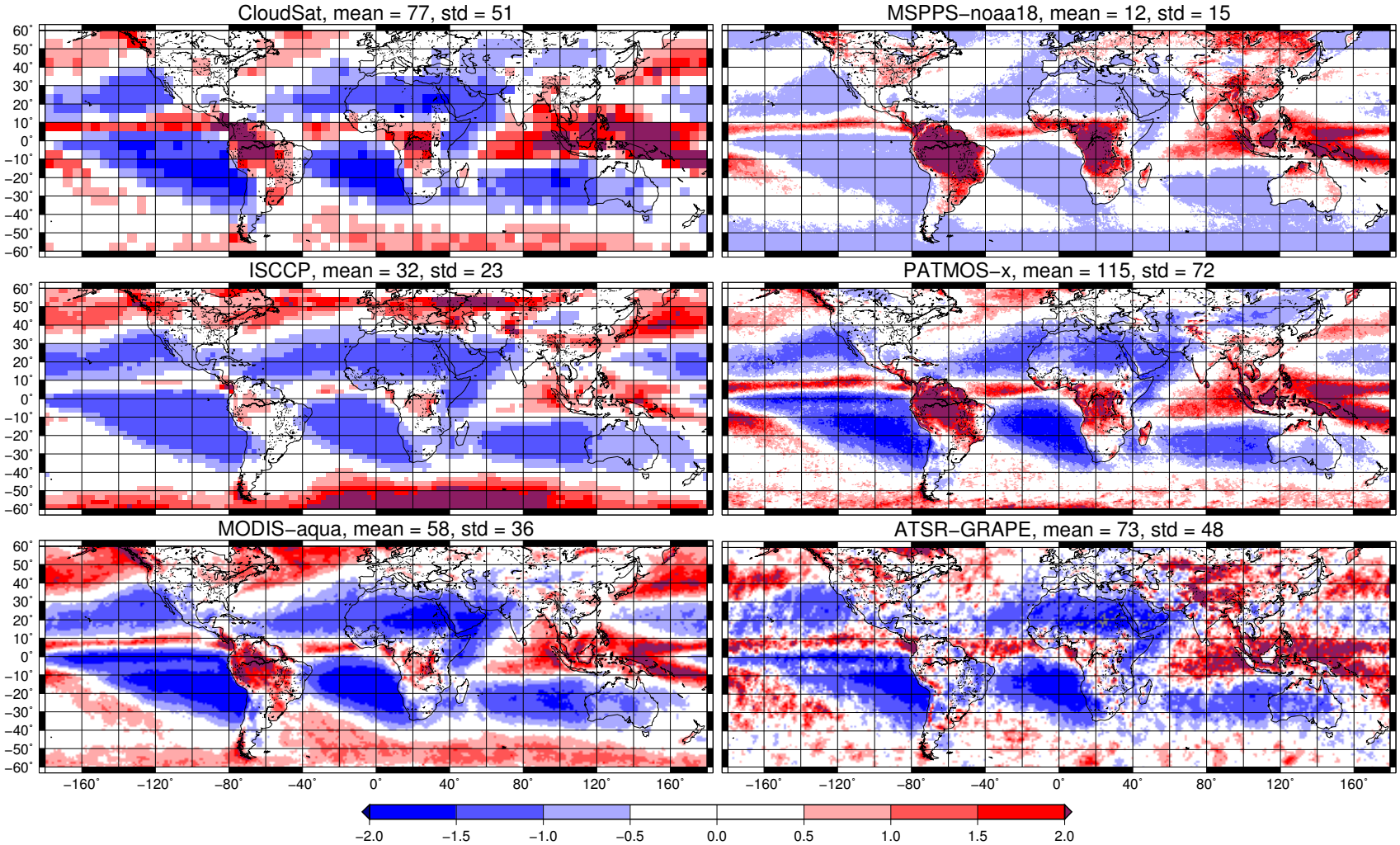
A modeled cloud [Zhang et al., in press] II

- Methods are in agreement in terms of τ_c.
- Both underestimate IWP when $r_e(0) < r_e(\tau)$.
- Good agreement for IWP and r_e, but up to 50% differences depending on channels and V-homogeneity.
- SRBS is more sensitive to top and IRSpW to smaller particles.
- The difference between SRBS and IRSpW retrievals is very large if large particles were at the top of the cloud (not shown).

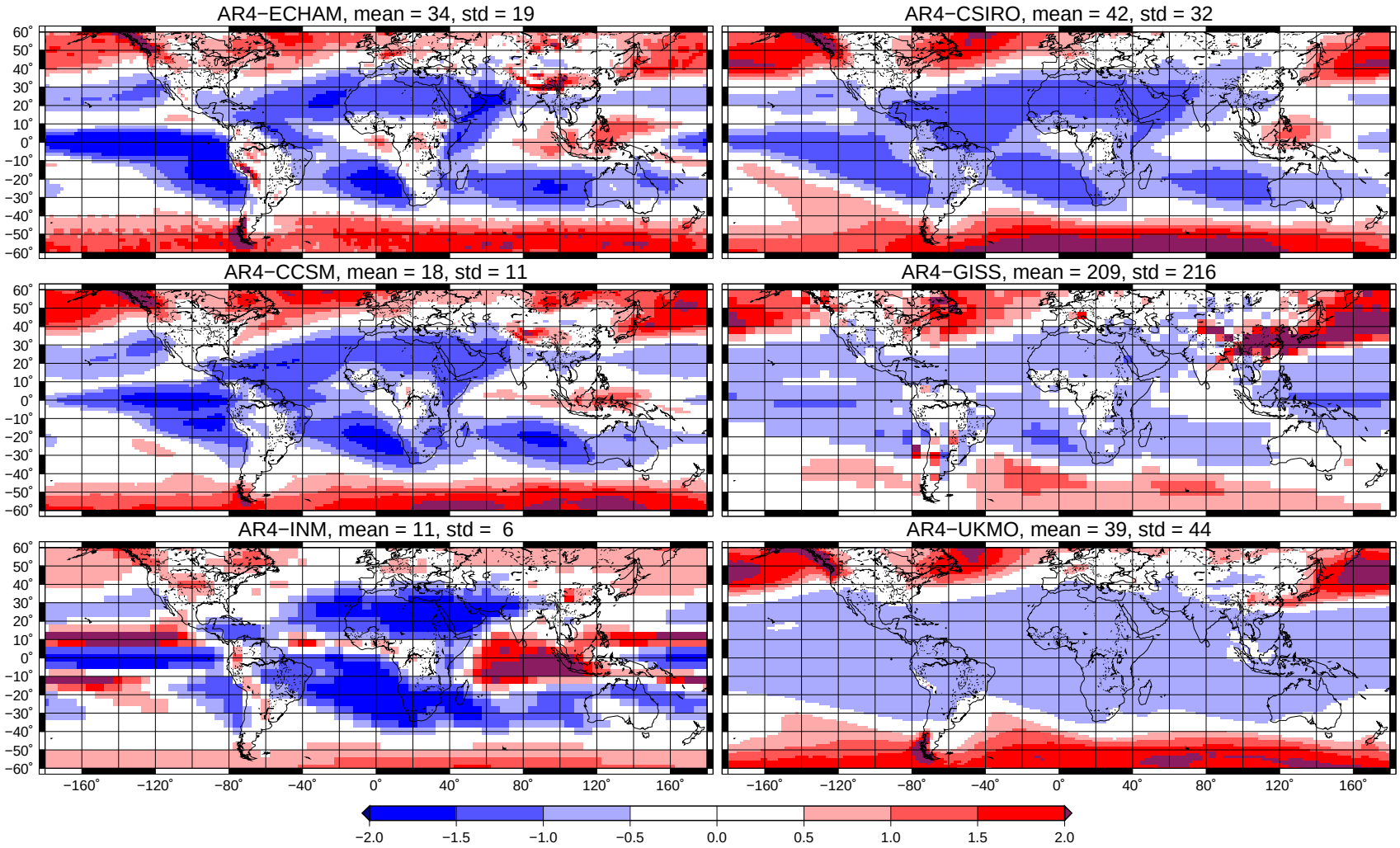


IWP satellite observations

Normalized due to large offsets between satellite data sets. $X = \frac{\mathrm{IWP} - \overline{\mathrm{IWP}}}{\sigma_{\mathrm{IWP}}}$

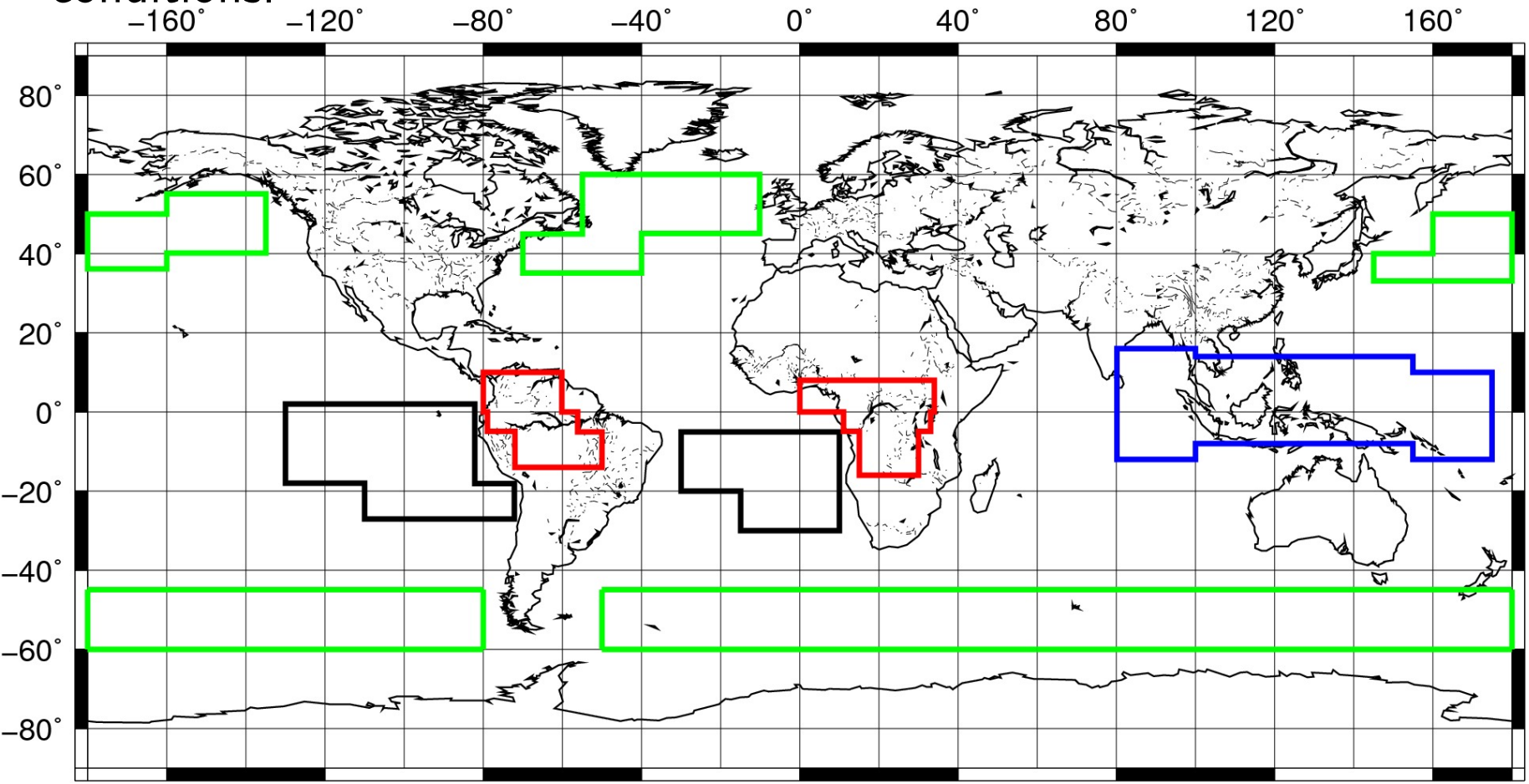


IWP model observations



Map of regions

Regional statistics in large regions of quasi-homogeneous atmospheric conditions.



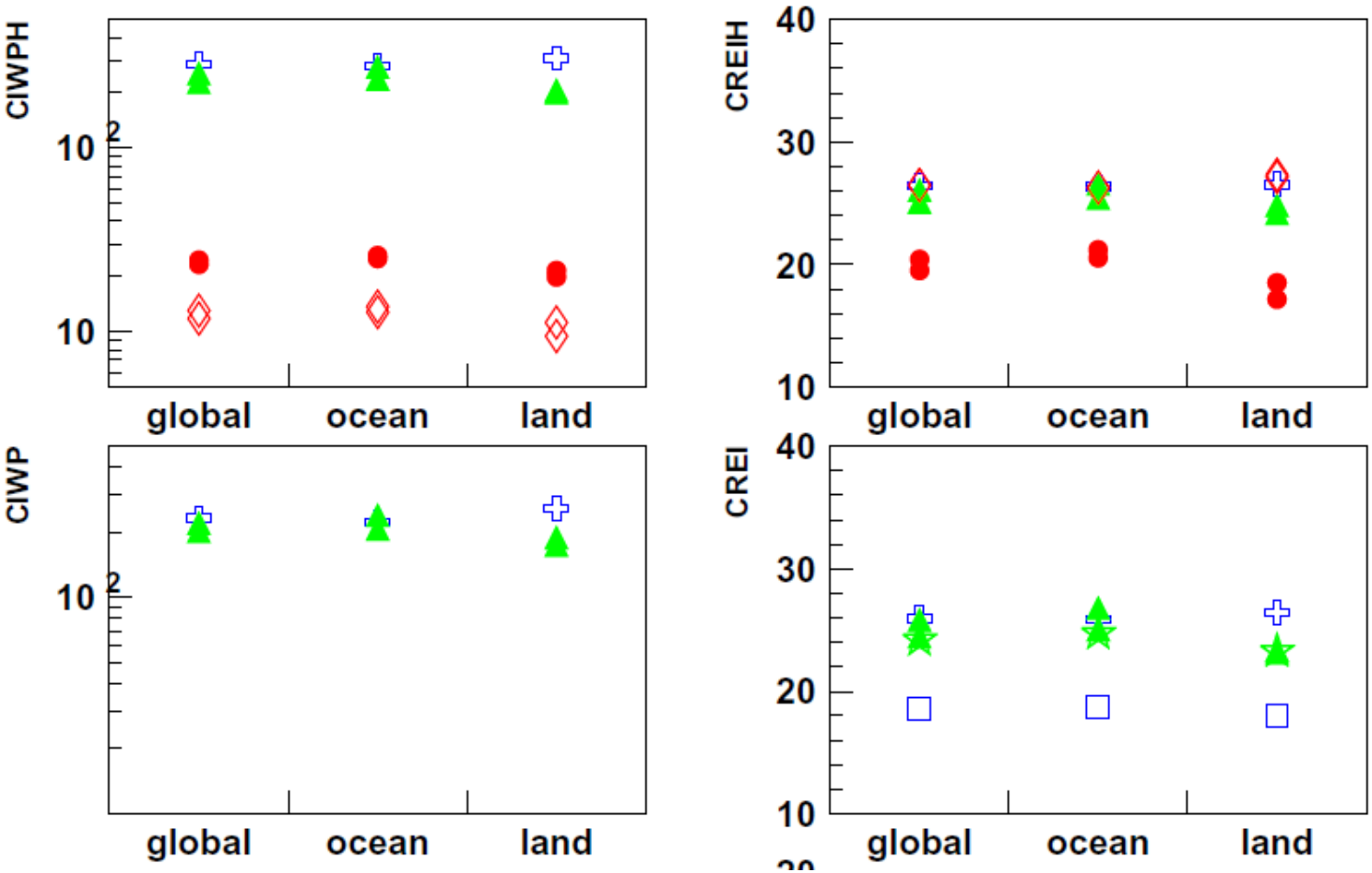
Regional Statistics

Values in parenthesis refers to % of the area weighted mean value ($\pm 60°$)

Data set	ocean_sub	trop_cont	warm_pool	westerlies	total
CloudSat	4.7 (6)	161.3 (209)	175.8 (227)	106.8 (138)	77.3
ISCCP	2.2 (7)	41.8 (140)	45.9 (154)	57.0 (191)	29.8
PATMOS-x	16.0 (15)	183.3 (173)	197.4 (187)	164.1 (155)	105.7
MODIS-aqua	4.4 (8)	95.3 (163)	104.7 (179)	91.9 (157)	58.5
MSPPS-noaa18	0.5 (4)	59.9 (488)	31.4 (256)	4.8 (39)	12.3

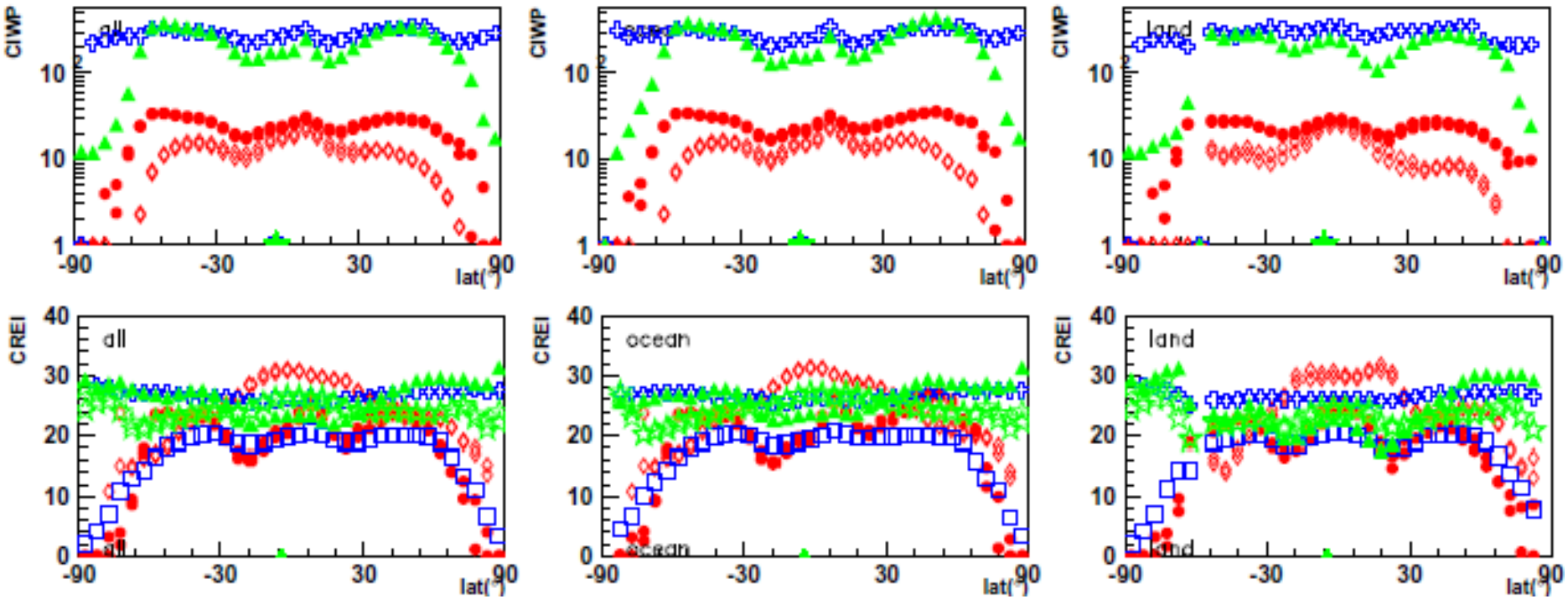
- Observations show higher IWP values in the tropical convective regions, (factor 2).
- The largest averages are found over tropical continental convection regions. MSPPS (MV) has a factor 5 higher values here than it's global mean value.
- ISCCP (IR/VIS) has high values in the westerly regions.

Global: Cloud WP and Cloud Particle r_e



Zonal: Cloud WP and Cloud Particle r_e

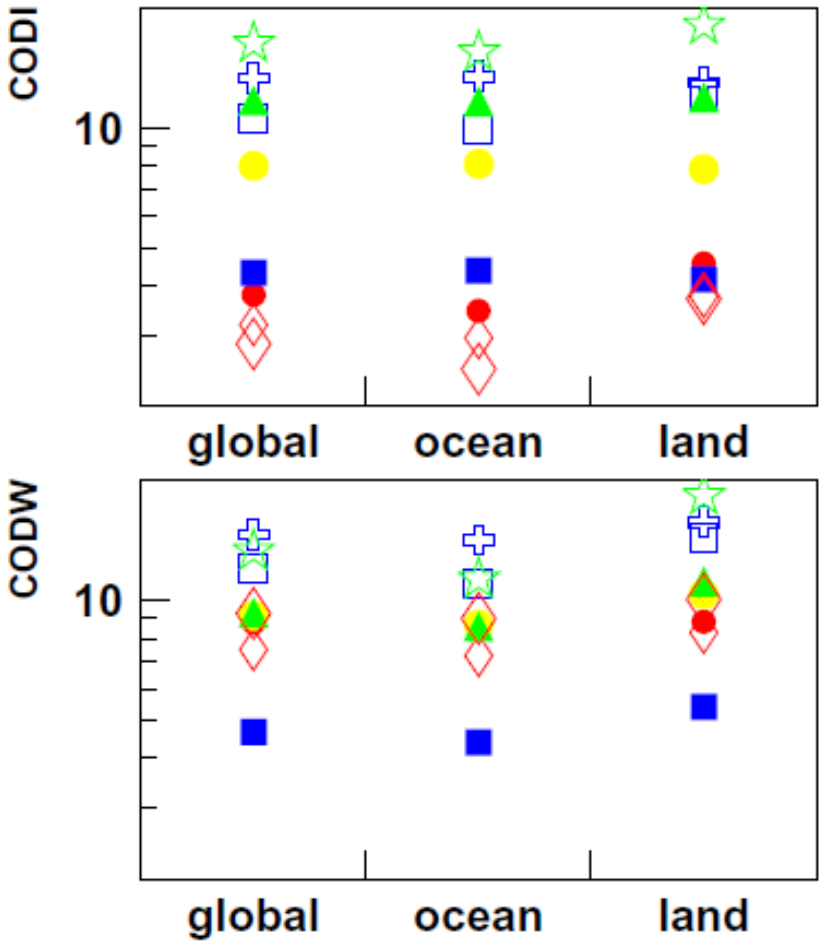
All: Ocean: Land:



● *AIRS-LMD* ▲ *MODIS-CE* ■ *ISCCP* ✚ *ATSR*

◊ *TOVS* ☆ *MODIS-ST* □ *PATMOSX*

Global: Cloud Optical Depth (τ_v)

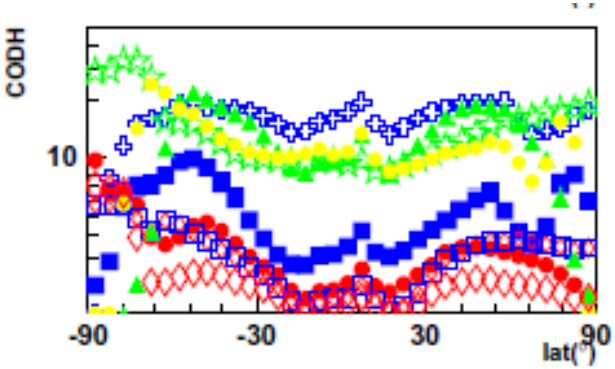


Are these τ really based on the radiative mean or are they the mean of the τ's?

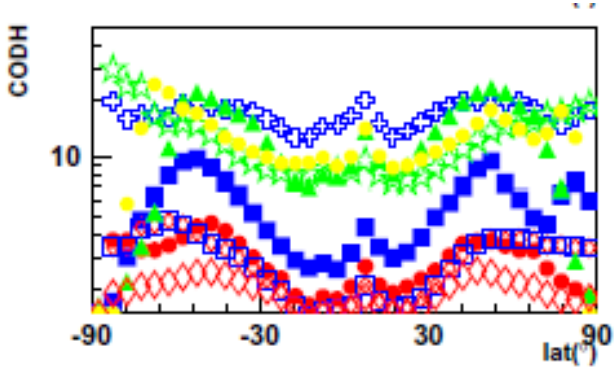
AIRS-LMD MODIS-CE ISCCP ATSR
TOVS MODIS-ST PATMOSX

Zonal: Cloud Optical Depth (τ_v)

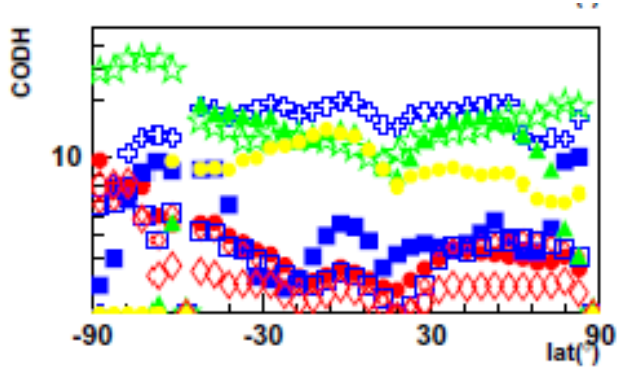
All:



Ocean:



Land:



ATSR-2 IWP (Andy Sayer)

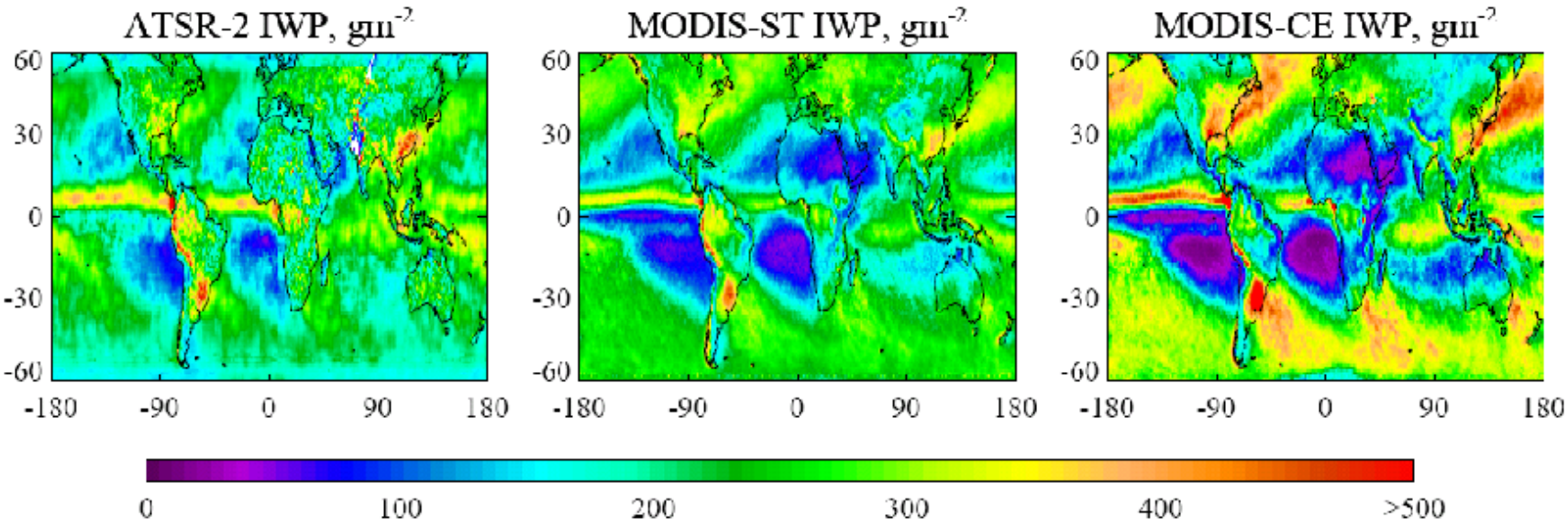
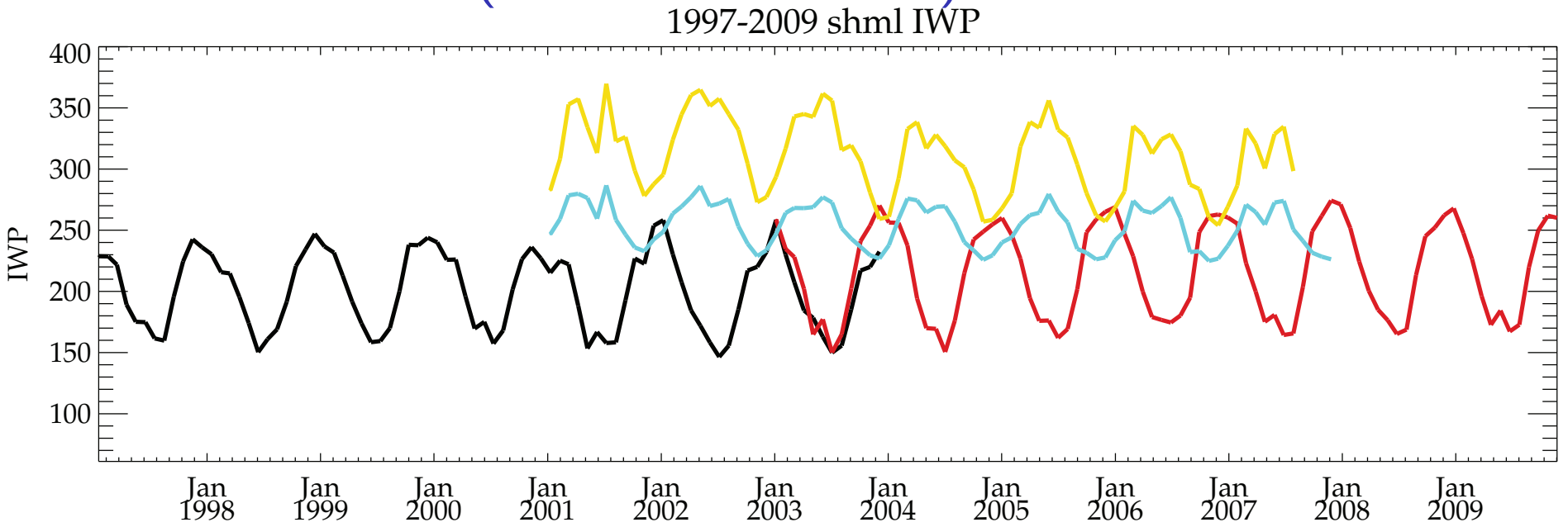


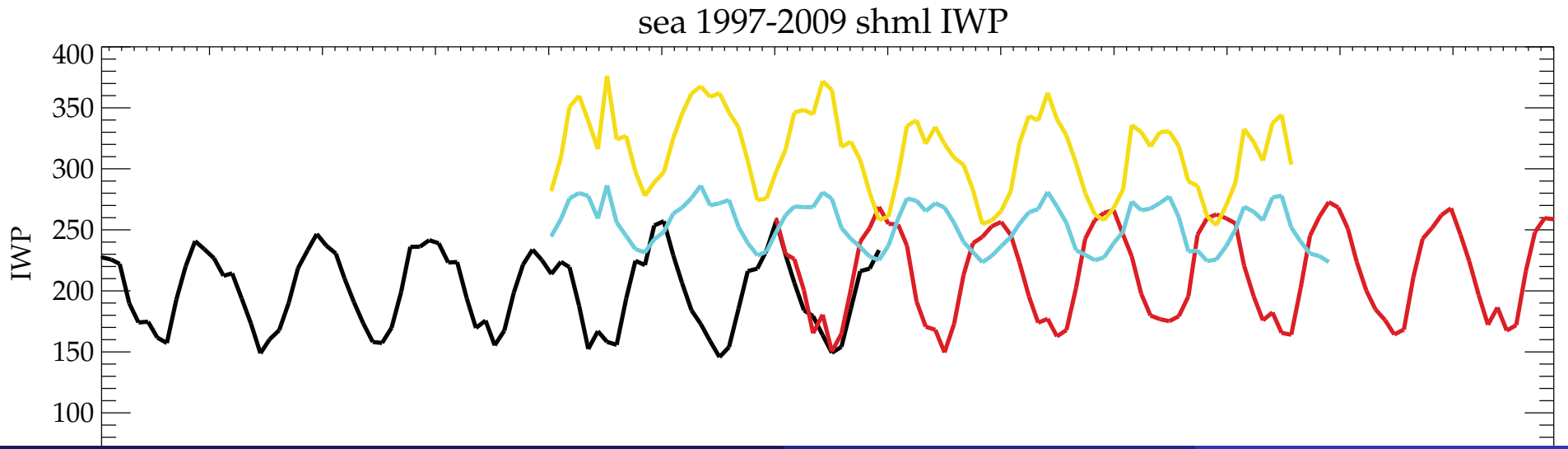
Figure 17: As Figure 16, except for ice clouds.

ATSR detects less IWP in the mid latitudes

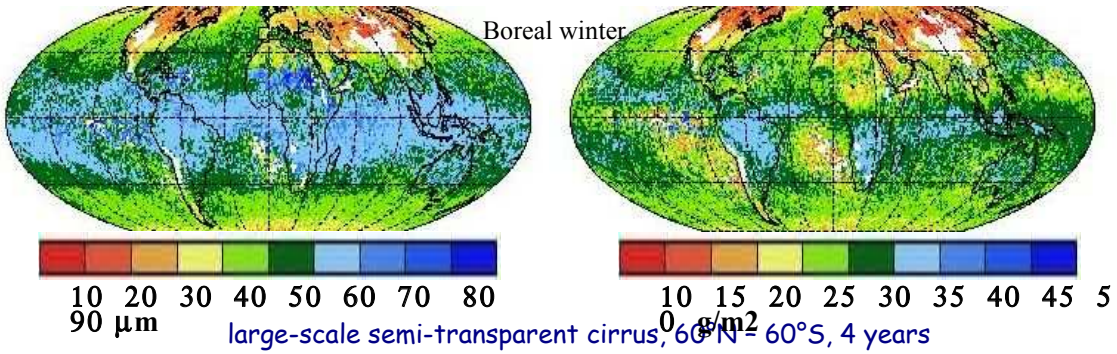
- Sampling
- Different optical properties

ATSR vs MODIS (Caroline Poulsen)





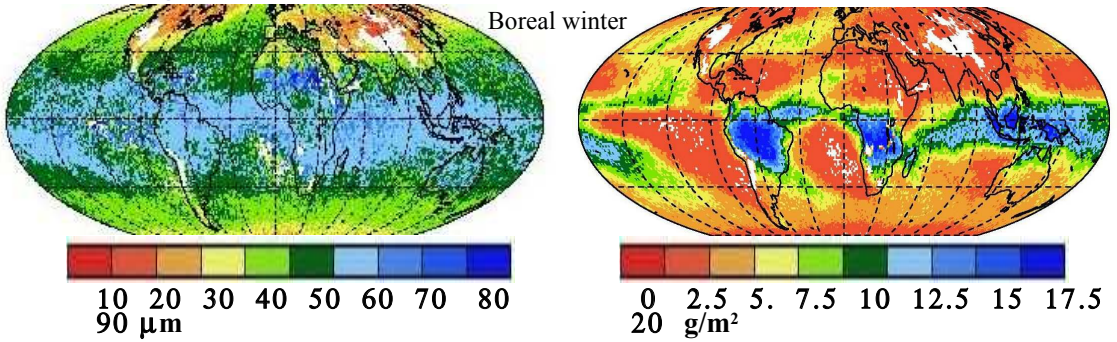
IWP product



large-scale semi-transparent cirrus, 60°N - 60°S, 4 years

$\langle D_e \rangle$ = 52µm $\langle IWP \rangle$ = 30 gm^{-2}

large-scale semi-transparent cirrus (1 < τ < 3.8), 60°N – 60°S, 1987-1991 (NOAA10)



Conclusion

- Long satellite data sets.
- Caution when comparing and/or combining data from different retrieval approaches.
- Advantage rather than disadvantage.
- The reasons:
  - Lack of reliable collocated in-situ measurements.
  - More complicated than liquid clouds.
- Satellite simulators (e.g. CloudSat simulator) to make model to observation comparisons possible.
- IWP Data sets based on different techniques inherently give different data, it should be the responsibility of the data teams to make sure that what they provide is well-defined for inter-comparability.

Thanks

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