On cirrus cloud fields measured by the Atmospheric Infrared Sounder

by

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Outline of Talk

- Trends in clouds measured by AIRS: Are they reasonable?
  - Single and multilayered cloud trends
- Retrievals of thin cirrus D_e and τ: Single-layered cloud only
  - Relationships between ECF, D_e, τ, and T_{CLD}
- MODIS vs. AIRS retrievals

Quick Summary of AIRS Cloud Products

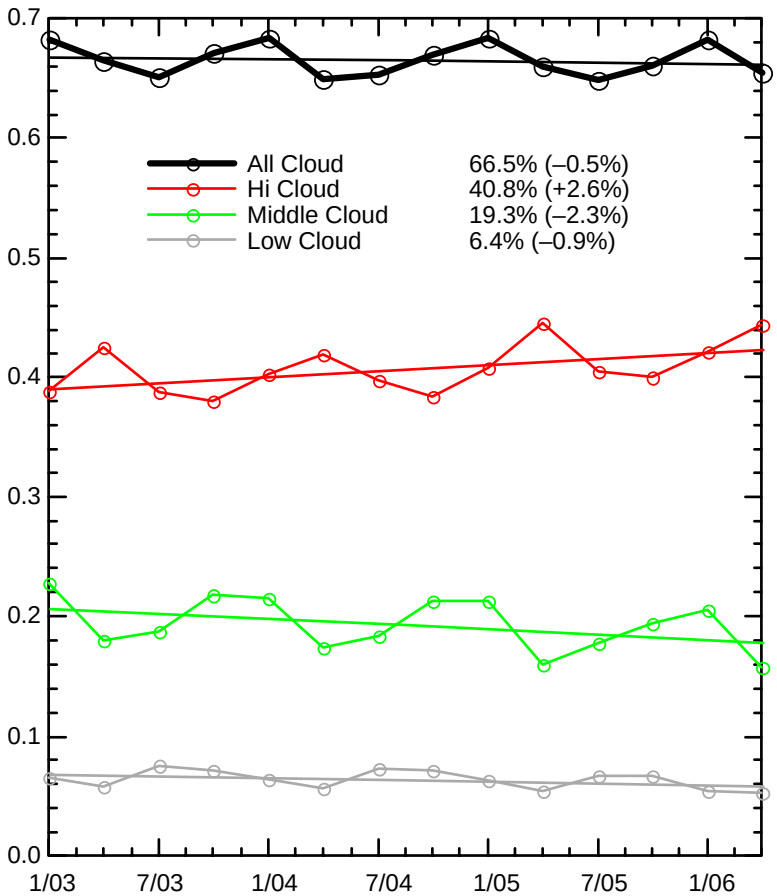
- Clouds retrieved as part of cloud-clearing methodology [*Susskind et al.* 2003]

- Entire AIRS record reprocessed to V4
  - Special validation issue in *J. Geophys. Res.* (and other papers) devoted to validating V4 products

- Up to 2 layers of clouds retrieved
  - Effective cloud fraction on AIRS FOV (~15 km)
  - Cloud top pressure on AMSU FOV (~45 km)

- A fast model to retrieve thin Ci D_e and τ has been developed [*Yue et al.* 2006]
  - Clear-sky (OPTRAN) + thin Ci parameterization
  - Requires atmospheric and surface properties for input

Trends in V4 AIRS Cloud Products?



Global cloudiness trends from January 2003 to April 2006.

Shown are total cloudiness, high cloud (< 400 hPa), middle cloud (440–680 hPa), and low cloud (> 680 hPa), following the ISCCP convention [*Rossow and Schiffer* 1999].

All-sky (cloud and clear sky) total to 1.0.

Only effective cloud fractions ≥ 0.05 are included.

Trends in V4 AIRS Cloud Products?

NH (20N–90N)
Tropics (20S–20N)
SH (90S–20S)

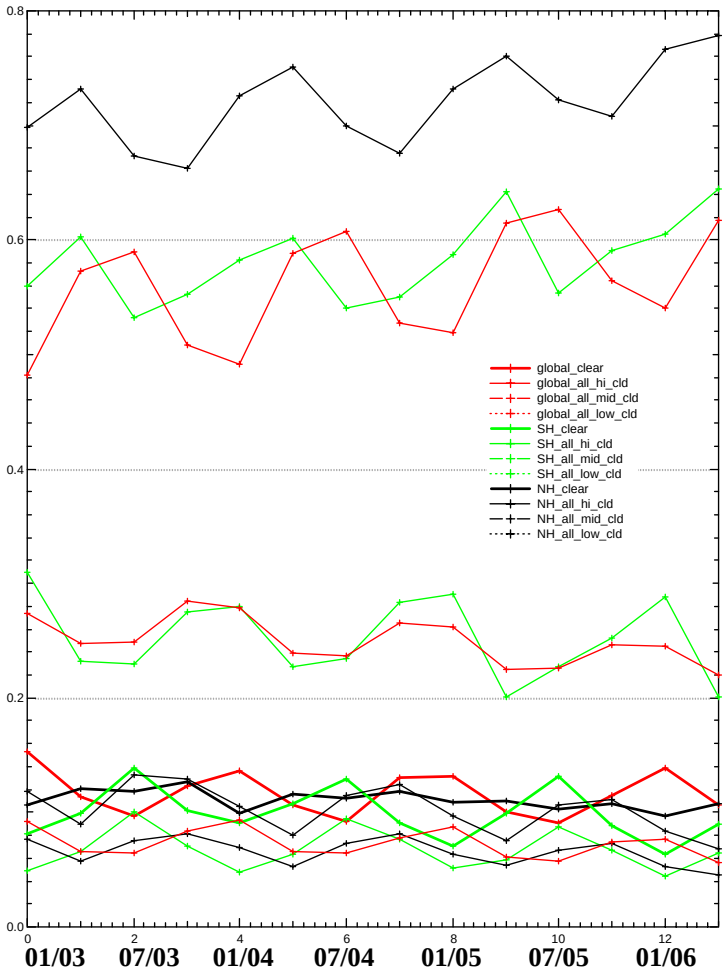
All effective cloud fractions are included

High cloud (solid)

Middle cloud (dashed)

Clear Sky (solid)

Low cloud (dotted)

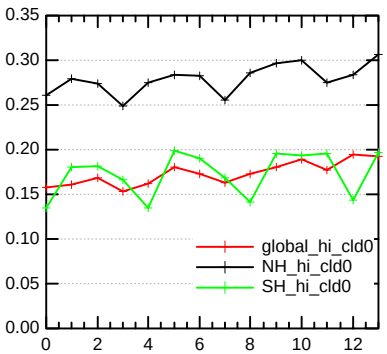


Trends in V4 AIRS Cloud Products?

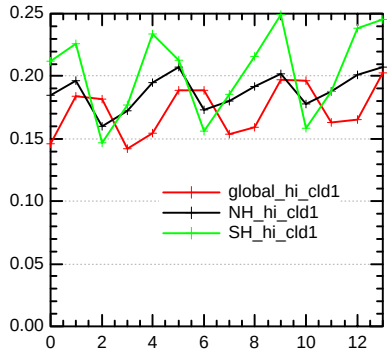
NH (20N–90N)
Tropics (20S–20N)
SH (90S–20S)

All effective cloud fractions are included

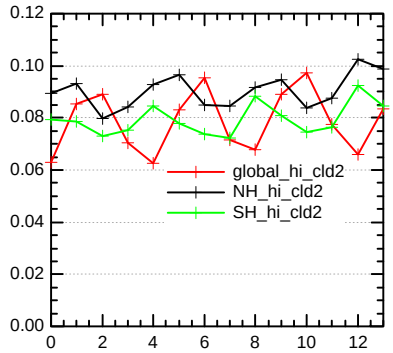
0.0 < ECF < 0.05

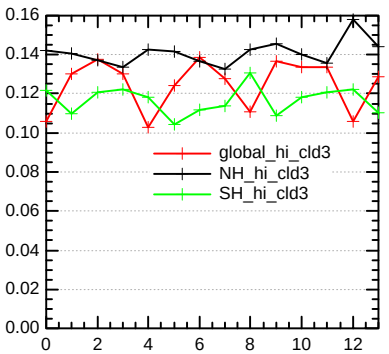


0.05 < ECF < 0.25

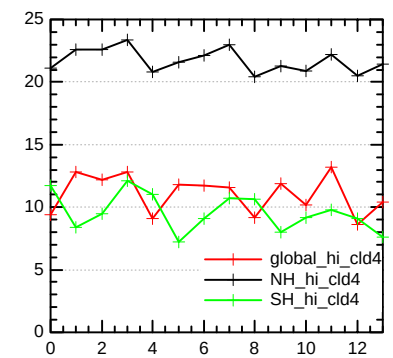


0.25 < ECF < 0.5





0.5 < ECF < 0.95



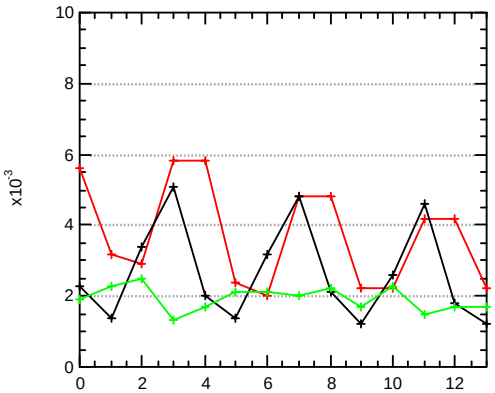
ECF > 0.95

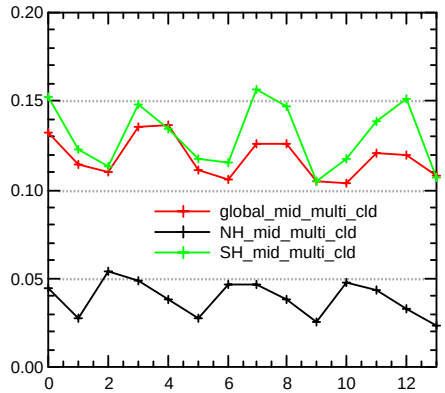
Trends in V4 AIRS Cloud Products?

NH (20N–90N)
Tropics (20S–20N)
SH (90S–20S)

Multilayered Clouds

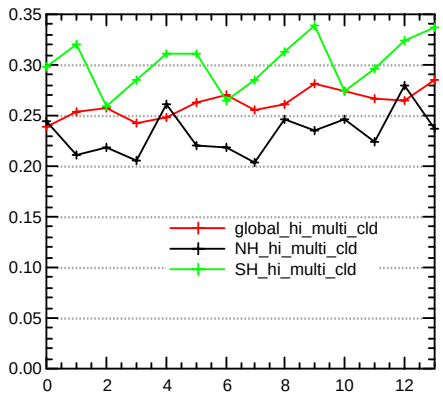
"Low" Multilayer

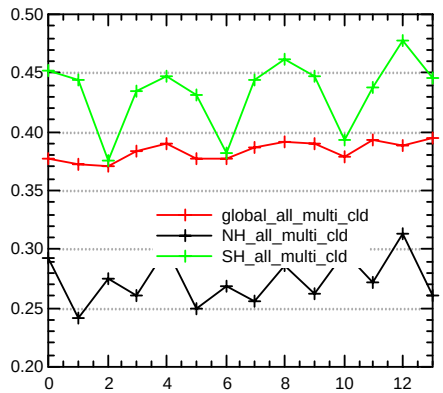




"Middle" Multilayer

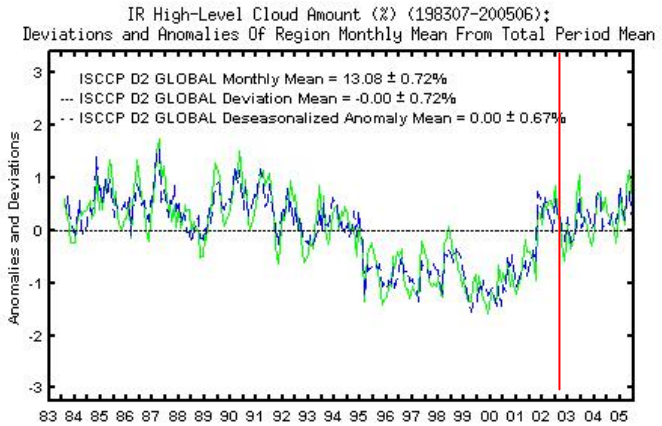
"High" Multilayer



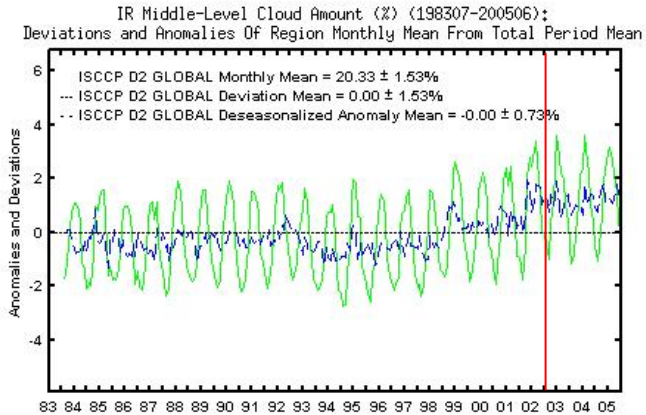


All Multilayer

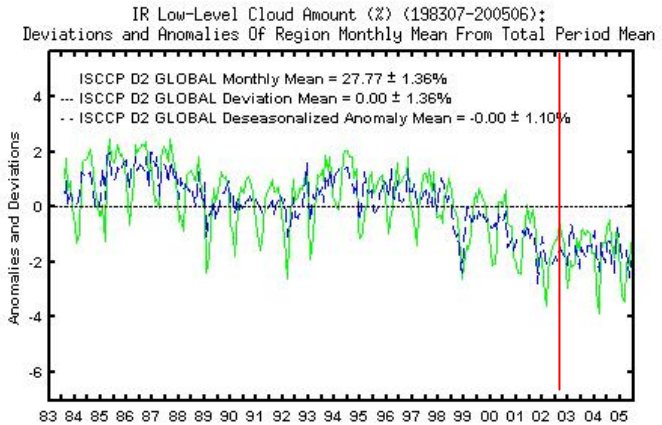
Recent ISCCP Trends Similar to AIRS?



More Ci



More middle cloud



Less low cloud

OPTRAN + thin cirrus parameterization

- Combine OPTRAN clear-sky radiances with a thin cirrus parameterization
  - See *Yue et al.* [2006]
  - Probably most applicable for thin Ci with ECF ≤ 0.3–0.4
  - 30–40% of AIRS FOVs in tropical oceans single-layered thin Ci!

- Cirrus represented by series of D_e and habit distributions
  - Can substitute "parameterized" size/habit distributions

- Fit AIRS radiance to best τ and D_e: **the Ci "retrieval"**

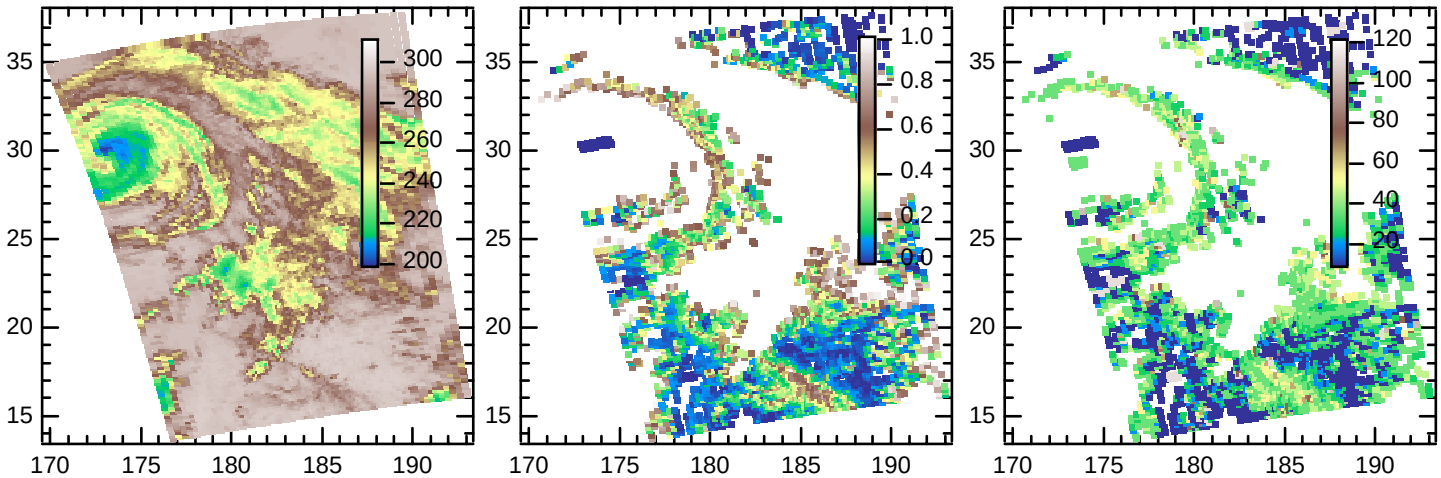
$$I_\nu = I_0\left(1-\varepsilon_\nu\right)+\varepsilon_\nu B_\nu\left(T_c\right)$$

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

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

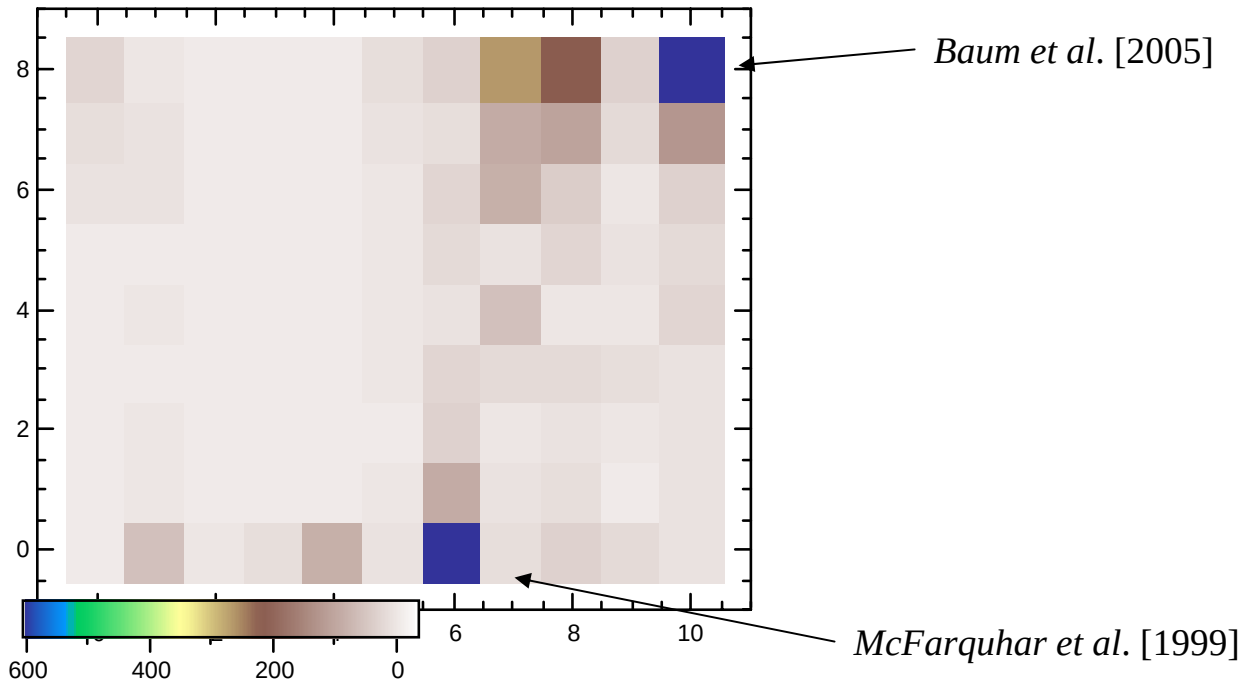
Yue et al. [2006]

An Illustrative Granule



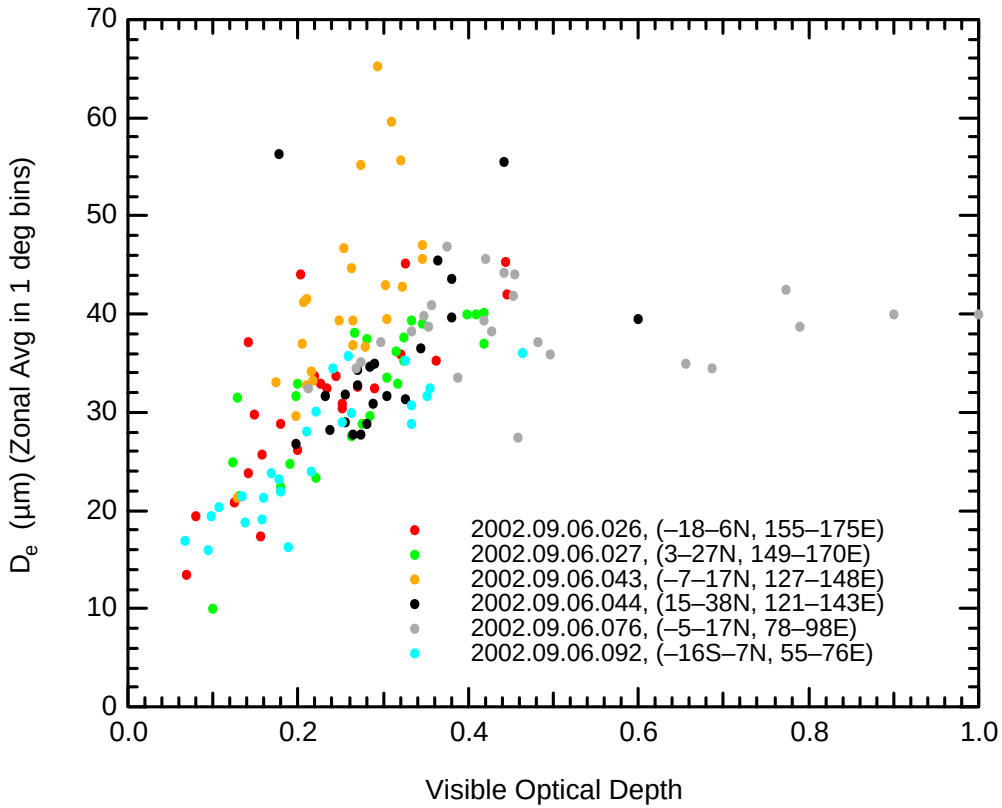
An illustrative granule demonstrating the retrieval of τ_{VIS} and D_e from AIRS radiances: this scene is in the central subtropical Pacific on 0105 UTC on September 6, 2002. Brightness temperature at 960 cm^{-1} (BT_{960}) in K (left), τ_{VIS} (center), and D_e (μm) (right).

Parameterized vs. Observed Size/Habit Dist?



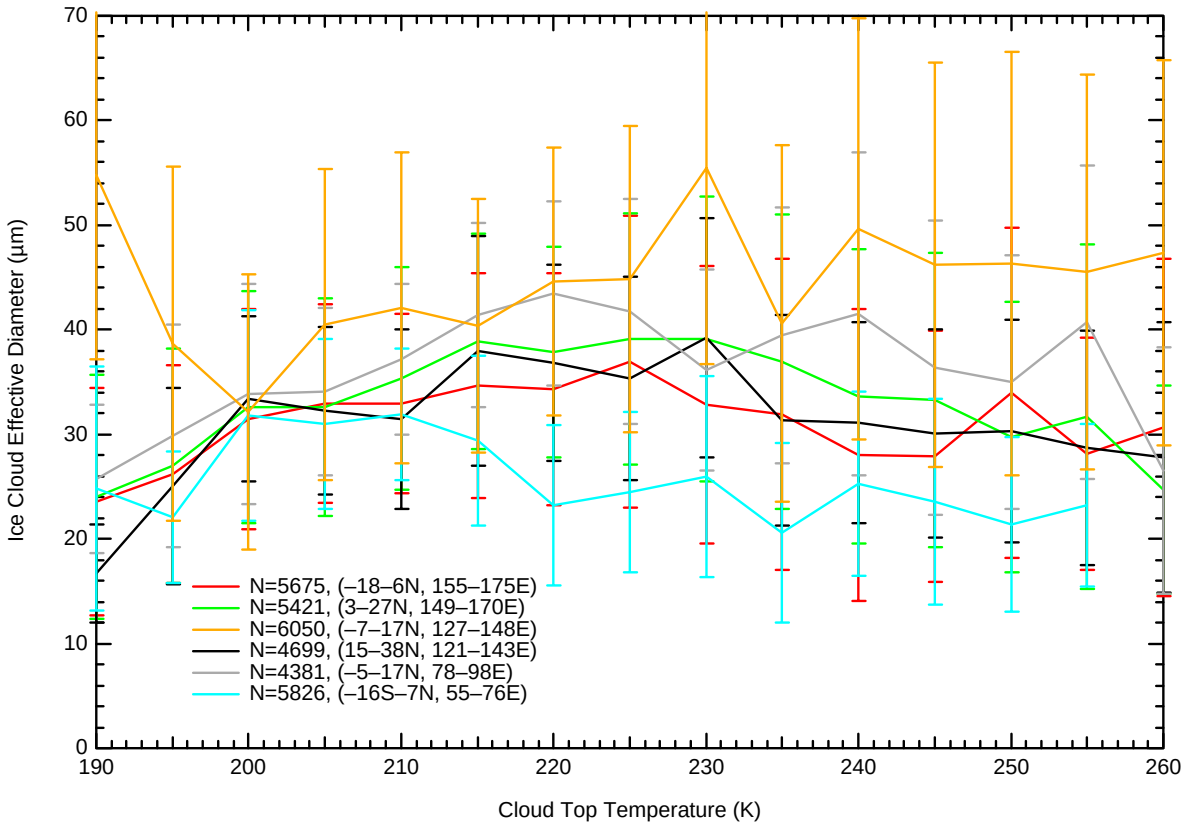
- Frequency of 9 observed size/habit combinations: two preferred clusters
- **Food for thought**: Justification for use of parameterized size/habit distributions?

τ–D_e Relationships for 6 Granules



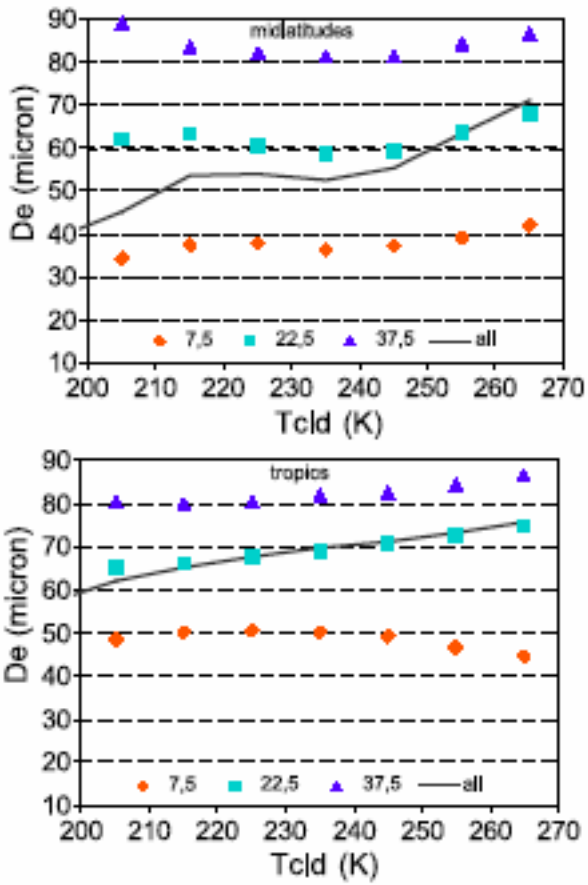
- Increasing τ and D_e for $0.0 < \tau < 0.3–0.4$
- Some granule-to-granule differences

T_{CLD}–D_e Relationships for 6 Granules



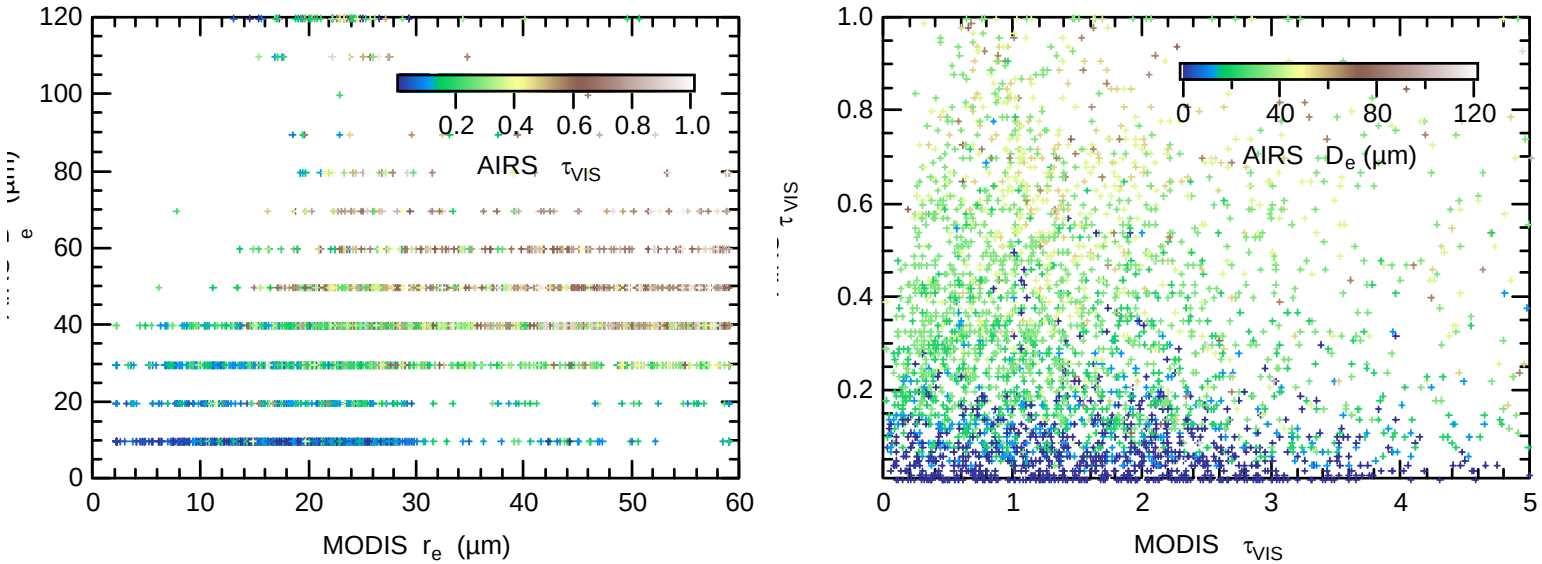
- Increasing D_e and T_{CLD} when T_{CLD} < 215–230 K
- Granule-to-granule differences

T_{CLD}–D_e Relationships from TOVS



- Figure from *Stubenrauch et al.* [2004], *Atm. Res.*
  - TOVS Path-B + ECMWF re-analysis
- Generally increasing D_e with T_{CLD}
- Not necessarily true of thinnest cloud in tropics!
  - Same pattern seen with AIRS retrievals
- Larger D_e retrieved compared to AIRS

AIRS and MODIS Differences



- AIRS vs. MODIS effective particle size (D_e vs. r_e; left) and τ (right) (*Baum et al.* [2005] models)
- The color scales indicate the AIRS τ (left) and D_e (right), respectively.
- Some agreement for D_e, but none for τ
  - Virtually no correlation in D_e when observed size/habit distributions used
- Patterns also observed for many other granules

Summary and Results

- **Global cloud trends in AIRS**
  - Trends in high, middle, and low clouds
  - Increase for high, decrease for middle and low
  - Recent ISCCP show increase for high and middle (slight), decrease for low
  - Uncertain sign in AIRS trend of total global cloudiness: must use caution on “quality control”
  - Large inter-hemispheric differences in multilayer cloudiness, middle, and high clouds

Summary and Results

- **AIRS D_e and τ retrievals**
  - Strong preferences for combinations of size and habit distributions
    - Clusters related to τ
  - Some correlation of MODIS r_e and AIRS D_e for parameterized size/habit distributions
  - Poor/no correlation of AIRS and MODIS τ for single-layer clouds
  - D_e–T_{CLD} relationship similar to TOVS retrievals for thin cirrus
- Cirrus retrievals combination of operational products + RT modeling (and approximations)
  - **Must evaluate all inputs/assumptions/algorithms carefully!**