SYNERGETIC ANALYSIS OF HIGH-LEVEL CLOUDS USING AIRS, CALIPSO, AND CLOUDSAT DATA

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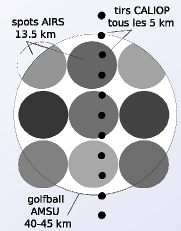
Outline

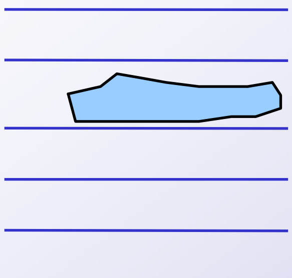
- Cloud observations from space:
  - passive sounders (TOVS, ATOVS, AIRS, IASI (1,2,3), IASI-NG) vs active sounders (radar/lidar)
  - good coverage (see also GEWEX cloud assessment poster) vs peculiarities of the vertical structure

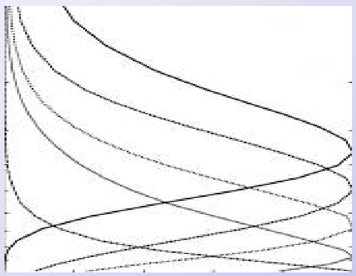
- A-Train synergy (AIRS-CALIPSO-CloudSat):
  - unique opportunity for global retrieval method validation
  - vertical structure of cloud types
  - evaluation of Ci height and microphysical properties
  - IWC and De profiles for different cloud types

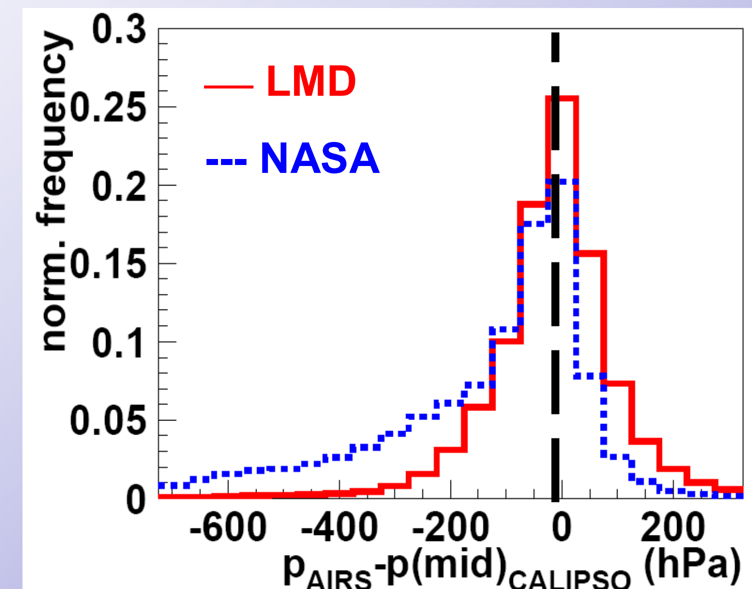
- Using AIRS for the analysis of the horizontal extent of cloud systems.

Prerequisites: AIRS retrieval / validation









- multi-spectral cloud detection
- $\varepsilon(p_k,\lambda_i)$ coherence: $$\varepsilon(p_k)=\sum_{i=1}^{N}\frac{R_m(\lambda_i)-R_{clr}(\lambda_i)}{R_{cld}(p_k,\lambda_i)-R_{clr}(\lambda_i)}$$
- AIRS-LMD: retrieval based on weighted χ^2 method as in TOVS-B
- Stubenrauch et al (1999,2006,2008,2010)
- Calculated Ci emissivities (8-12μm) 4A-DISORT + SSP of ice crystals Baran 2003) → LUT ε(λ,De,IWP) → → De, IWP (Rädel et al., 2003; Stubenrauch et al., 2004; Guignard et al., 2012)
- AIRS-LMD L3 (2003-2009) is available at http://ara.abct.lmd.polytechnique.fr
- AIRS-LMD L2 cloud data is distributed by ICARE: http://www.icare.univ-lille1.fr/

Level 2 data used in this work

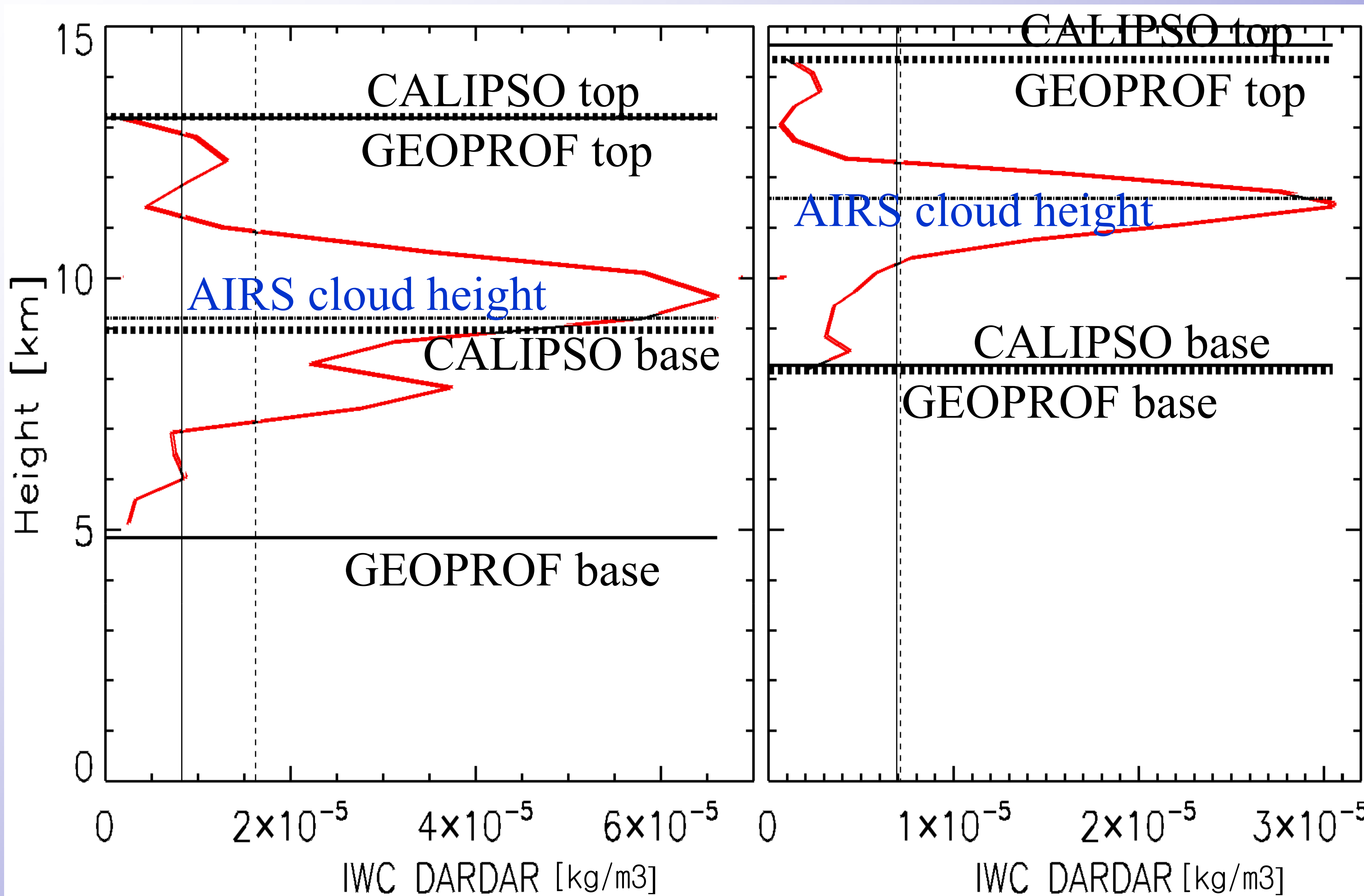
AIRS: cloud pressure, IR emissivity of uppermost cloud, Bulk microphysical properties of semi-transparent cirrus using spectral emissivity differences (A. Guignard, 2012 + poster today): De, IWP, aggregates/columns.

CALIPSO V3 5km: sub-visible cirrus, H, T, P, cloud type, and thermodynamical phase.

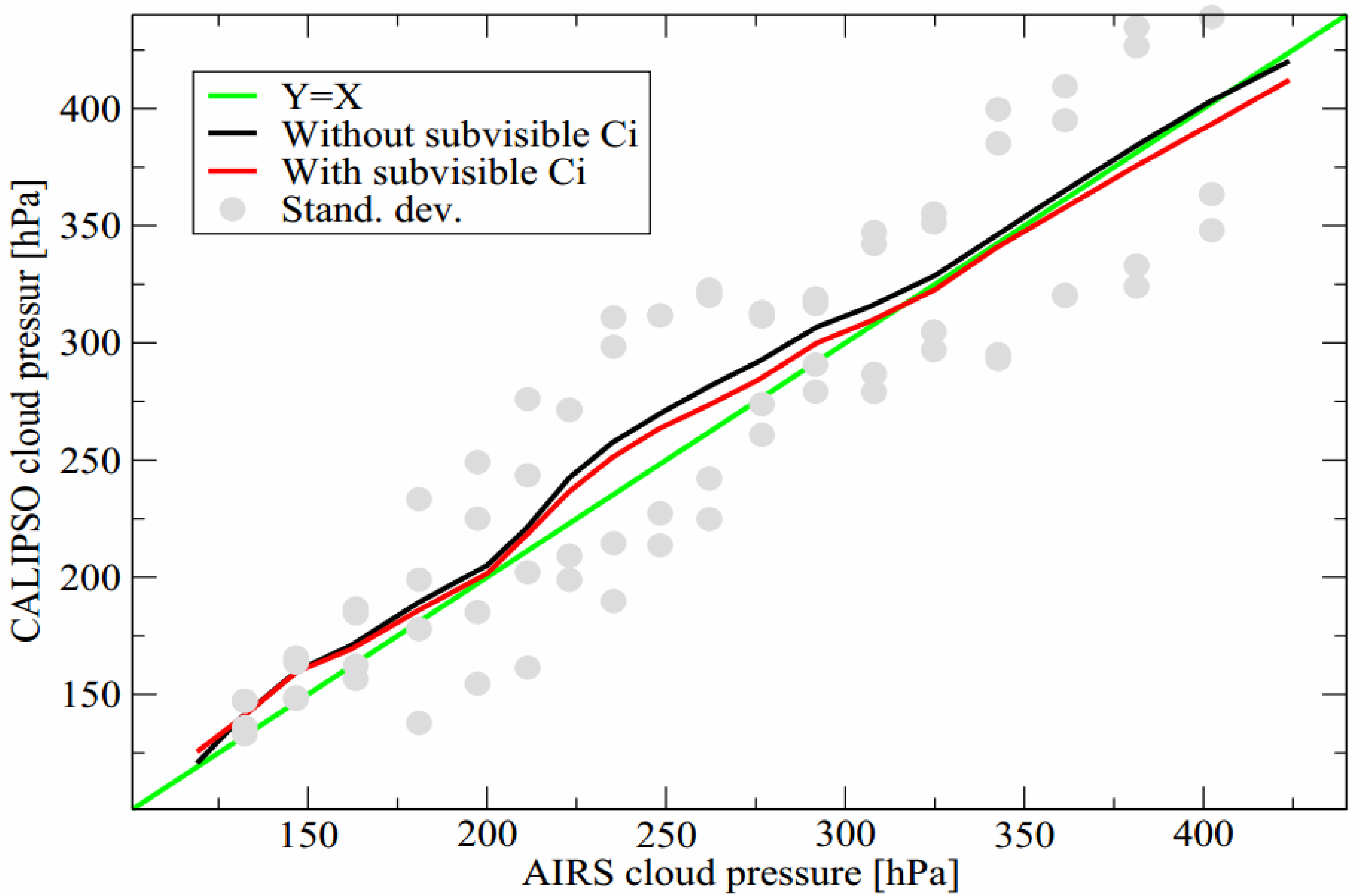
GEOPROF V4 (Mace et al. 2009): based on CloudSat cloud profiling radar and CALIPSO lidar measurements; retrieves cloud top, cloud base, number of cloud layers

DARDAR =liDAR+raDAR: (Delanoë and Hogan, 2010): Optimal estimation retrieval for ice clouds, profiles of thermodynamical phase, IWC, De.

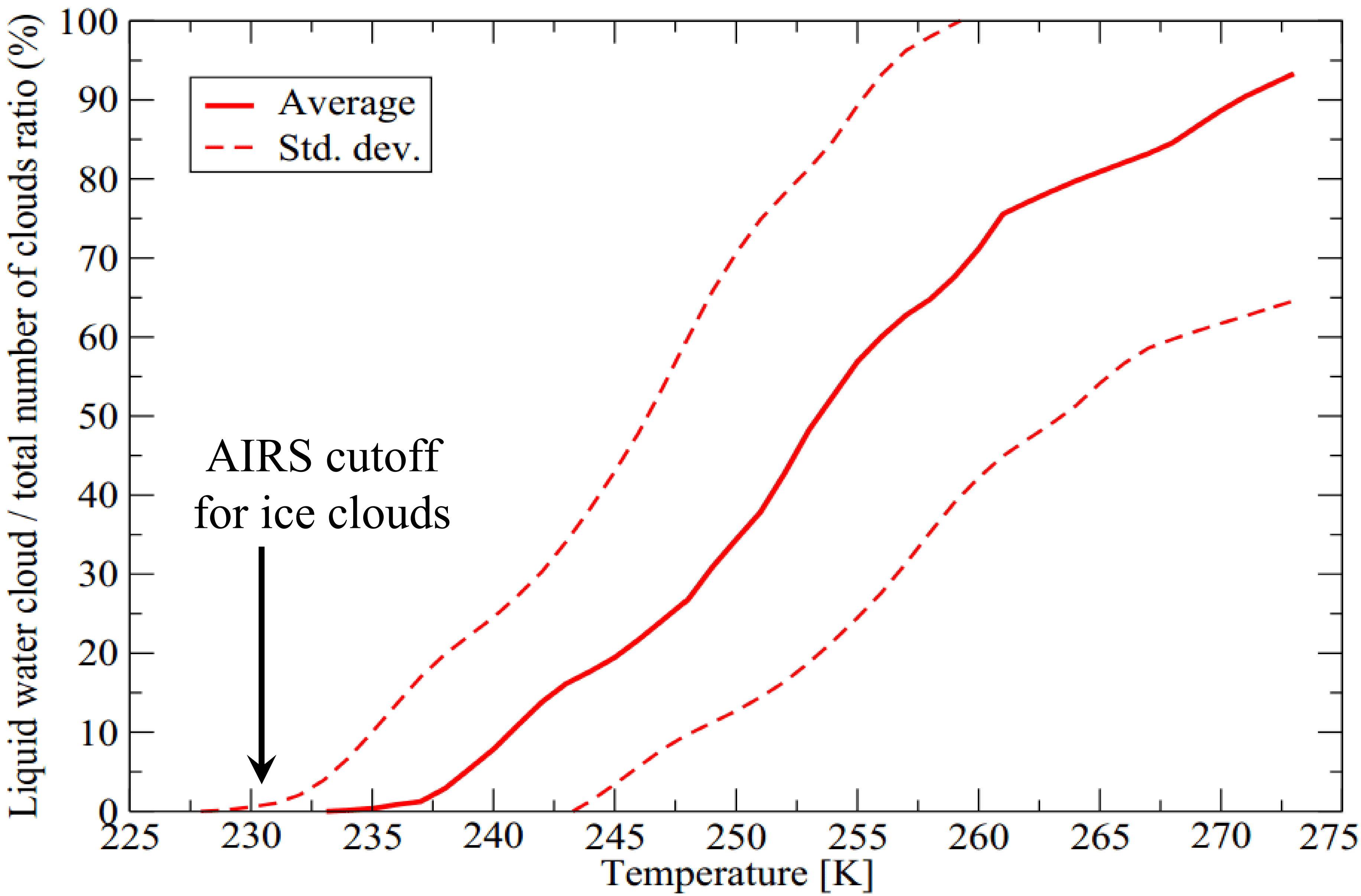
Example of co-located data



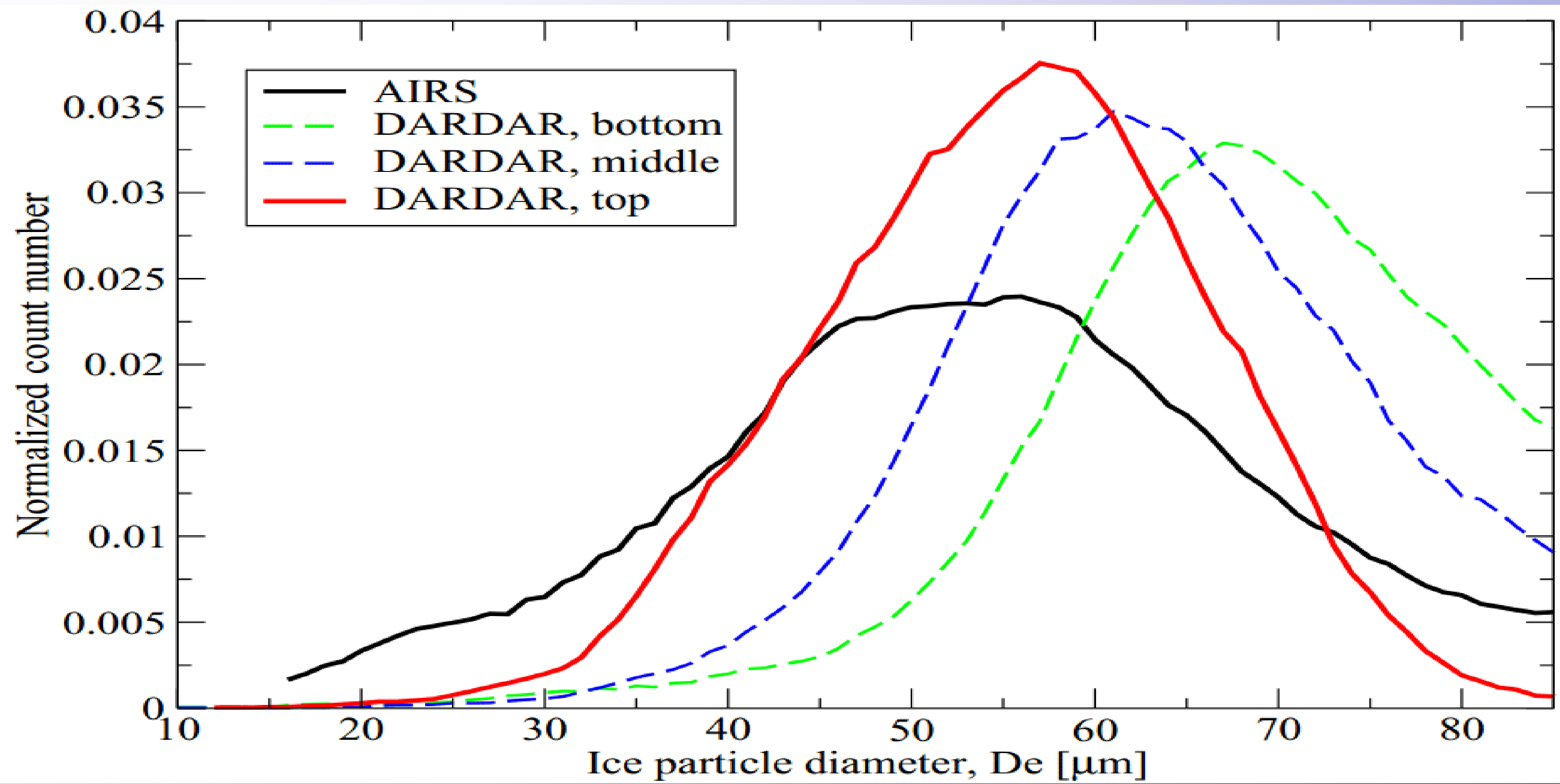
Sanity control: CALIPSO P vs AIRS P



Sanity control: CALIPSO cloud phase vs AIRS T

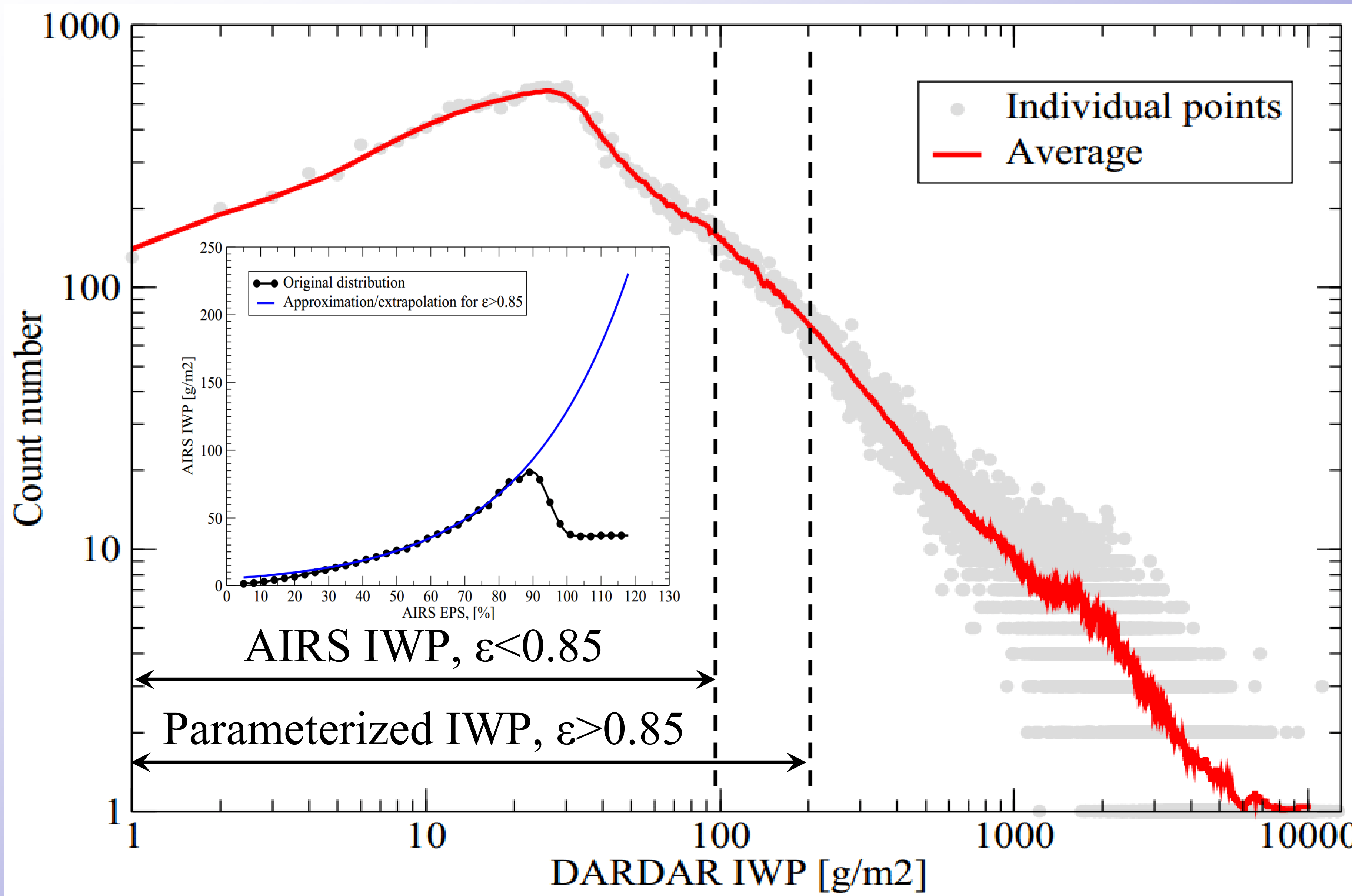


Ice particle size: DARDAR vs AIRS

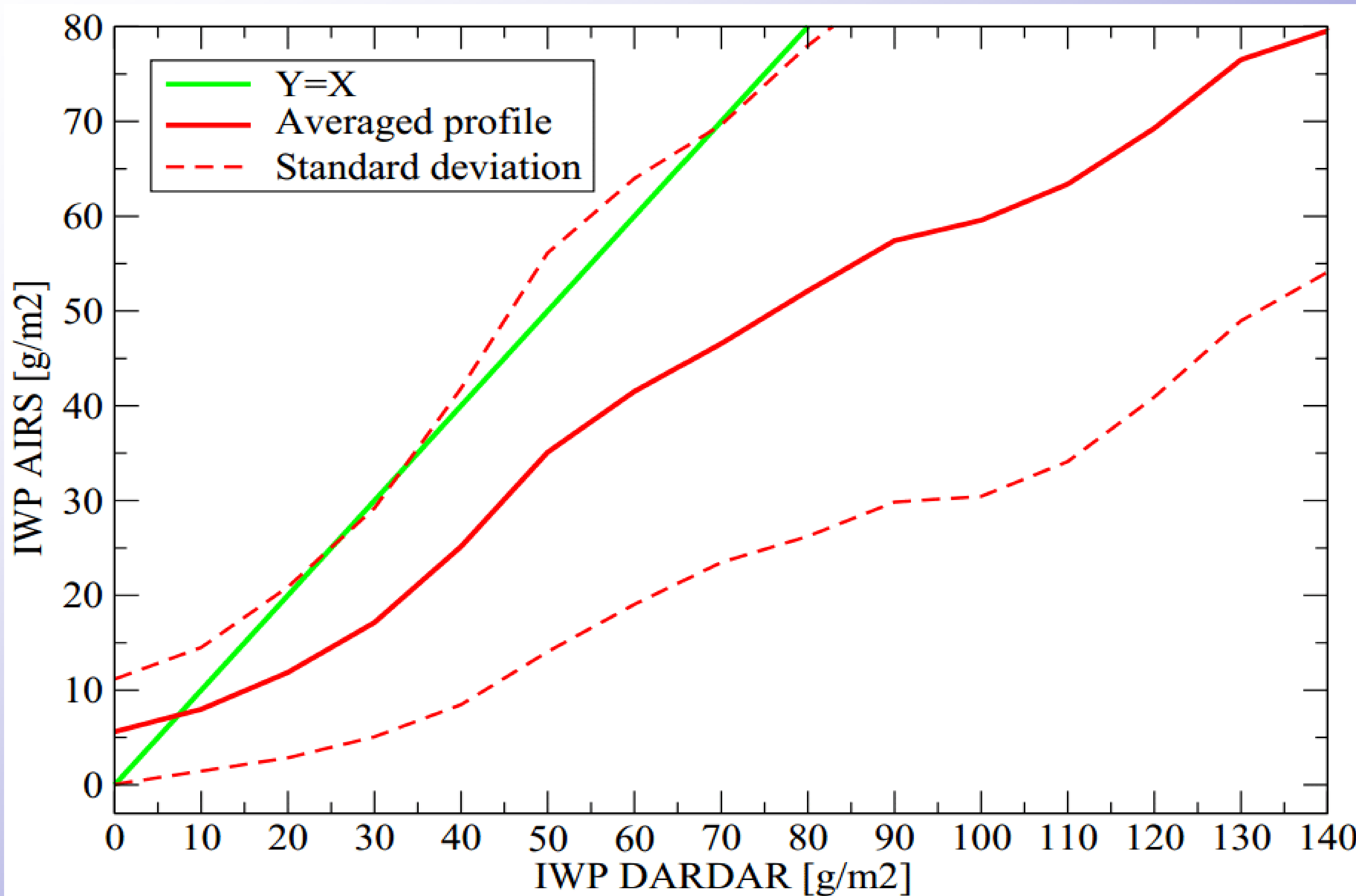


- AIRS De distributions are centered at ~55µm
- DARDAR De distributions are centered at ~62µm
- DARDAR De in the upper thirdth of the cloud is closer to AIRS De
- Radar is less sensitive to De < ~30µm and AIRS can't retrieve De > 90µm

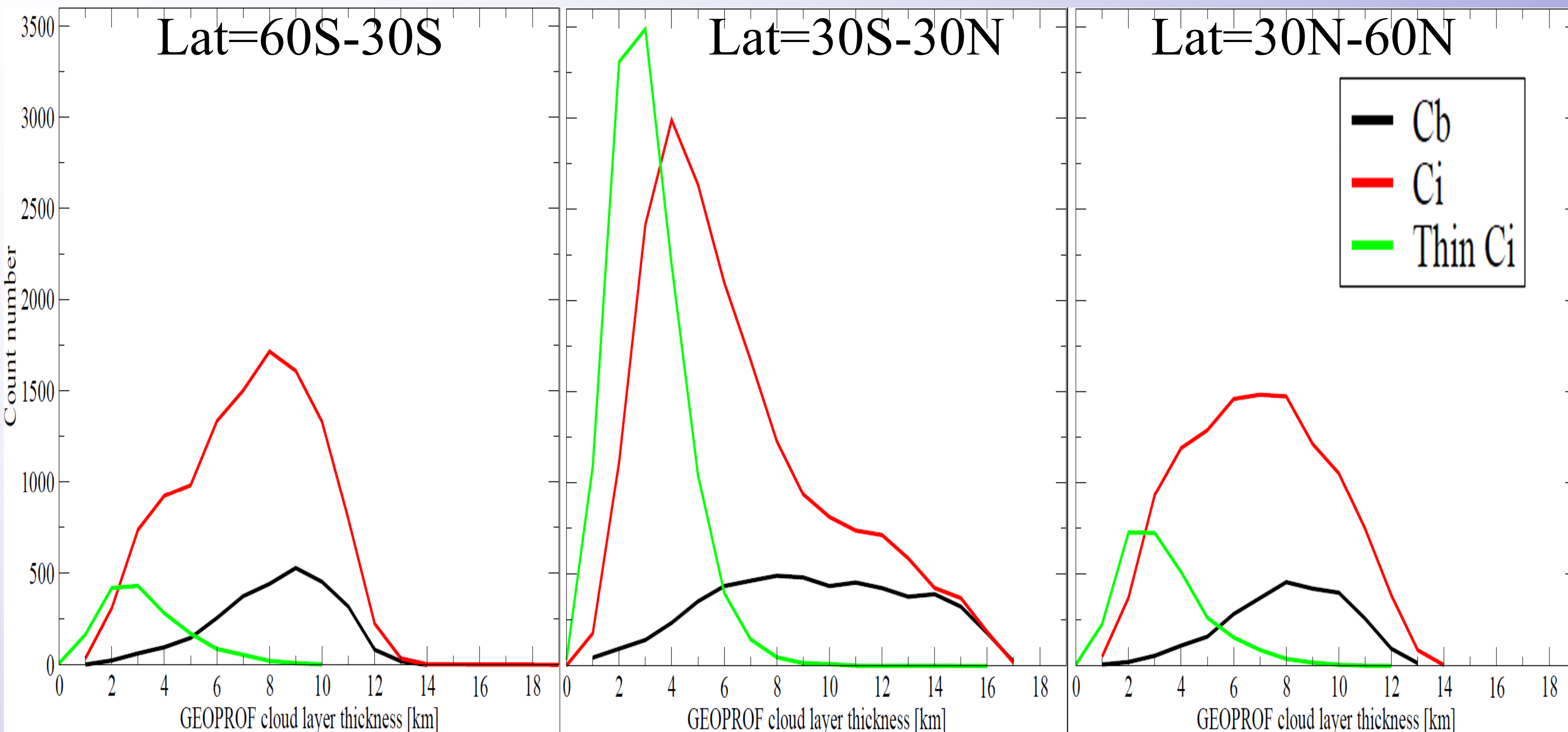
Accessible IWP domain



Ice water path AIRS vs DARDAR



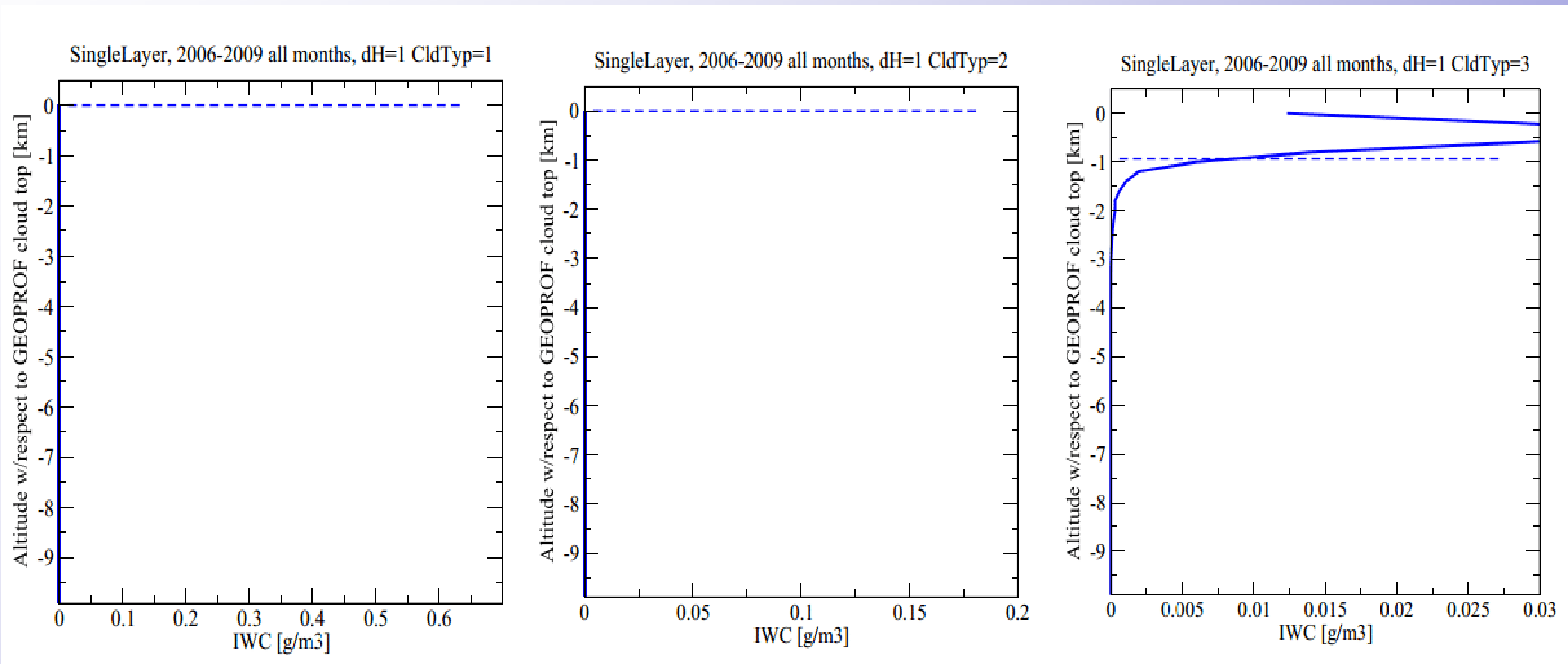
Cloud vertical extent distribution



- GEOPROF (Top-Base) values; AIRS cloud classification
- Cloud vertical extent increases from thin Ci to thicker clouds
- In general, the occurrence rate for thin Ci > 6 km is low.

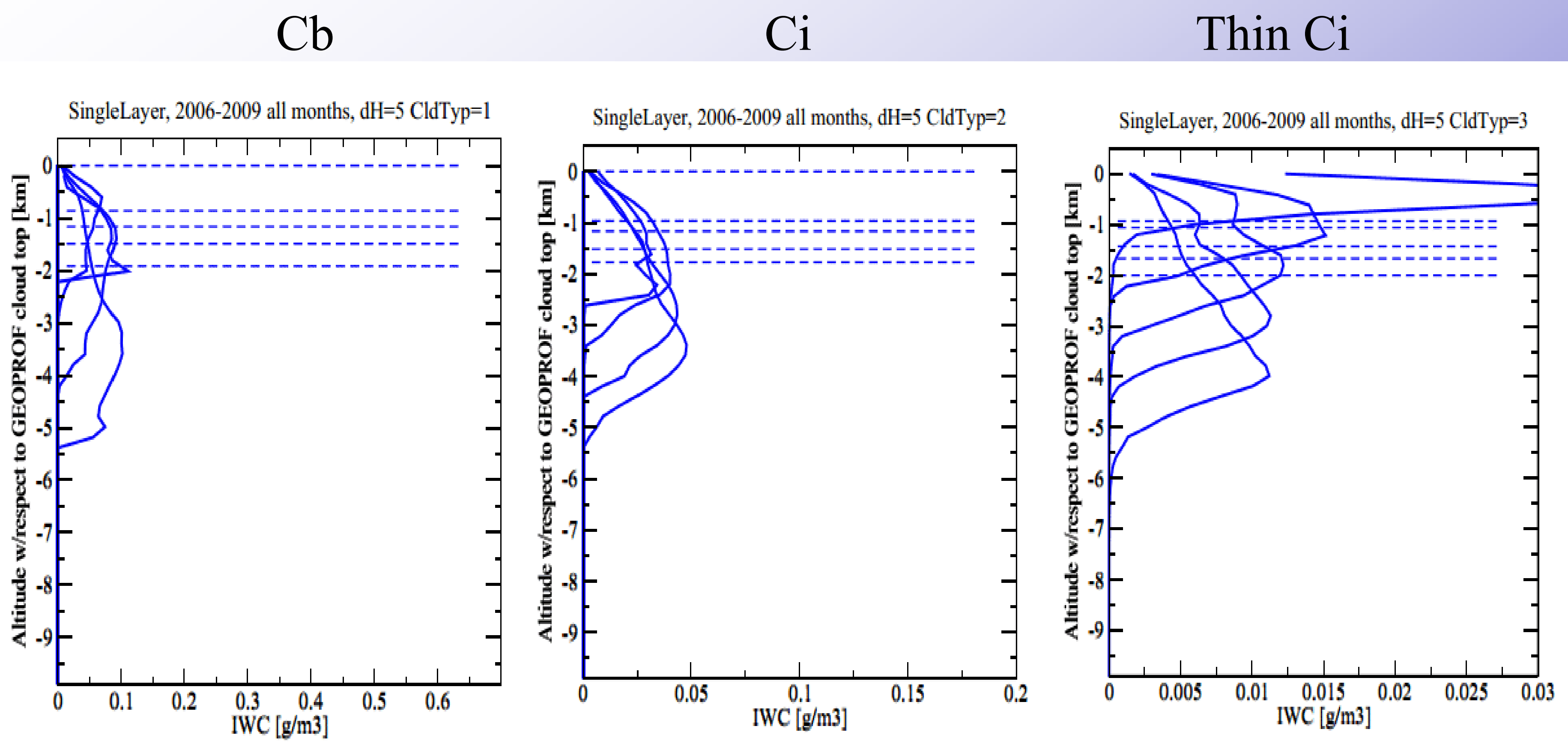
AIRS Clouds and DARDAR IWC profiles

Cb Ci Thin Ci



- The frames above are separated based on GEOPROF cloud geometrical thickness
- The IWC distributions were taken from the DARDAR data set
- The IWC profiles were aligned using the corresponding GEOPROF cloud top values
- Horizontal dashed lines correspond to average position of AIRS cloud

AIRS Clouds and DARDAR IWC profiles



- Position of AIRS cloud varies from 0 to 2-3 km below the top of GEOPROF cloud
- IWC profile for the (i+1)-th cloud is a continuation of the i-th cloud for the convective clouds and Ci
- For thin Ci, the shape can be approximated by a triangle down to 4-5 km cloud thickness
- Further studies in combination with humidity and dynamics are needed to build the IWC vertical profile parameterization for climate models.

Using AIRS data for the analysis of the horizontal extent of cloud systems

Cloud system analysis

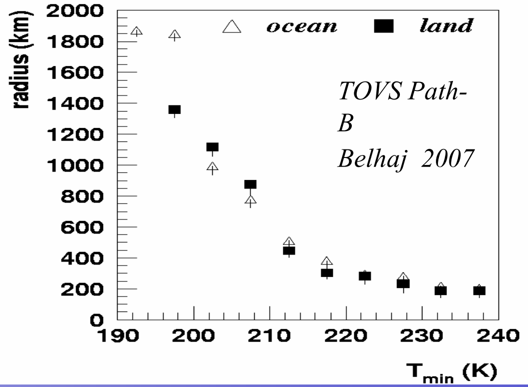
- General idea: explore horizontal extension of cloud systems and its relation to the thermodynamic and dynamic properties.

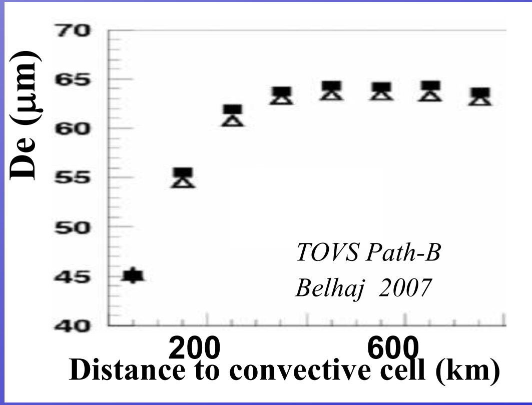
- Instantaneous «snapshot» of the atmospheric state is needed over the whole globe.

- Follow-up on TOVS analysis (1°×1° grid)

- Tropical systems:
 - anvil size increases continuously with decreasing T_{min} *(ISCCP, Machado & Rossow, 1993)*
 - anvil size also depends on dynamics (*Chen et al, JGR 1997*; *Belhaj et al. 2007)*

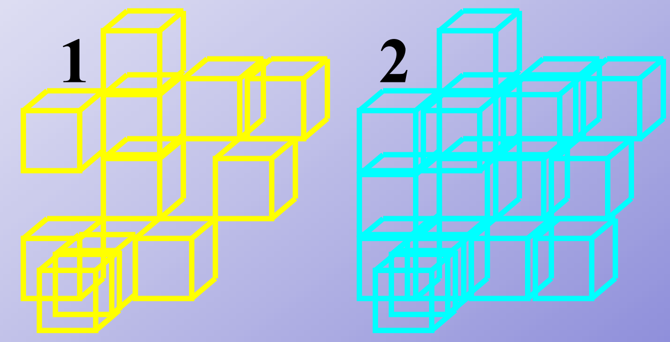
- De increases with distance from convective cell and during the life cycle of the system.



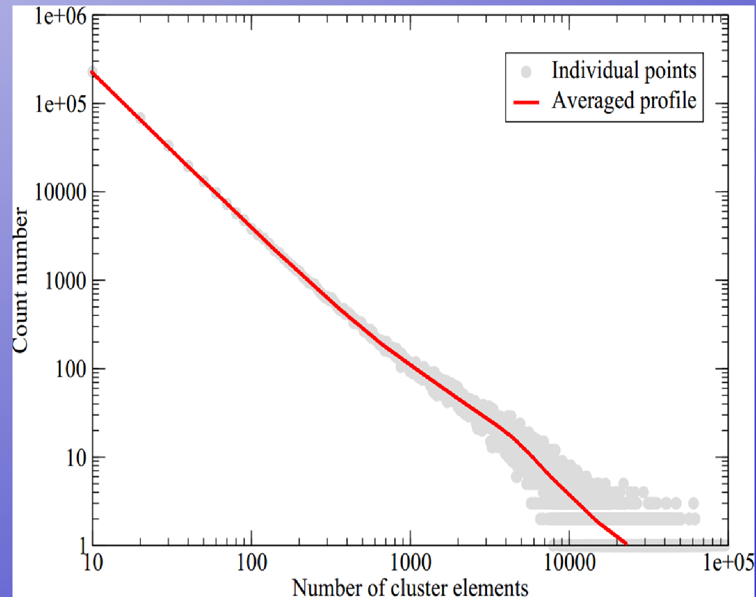


Using AIRS data for cloud system analysis

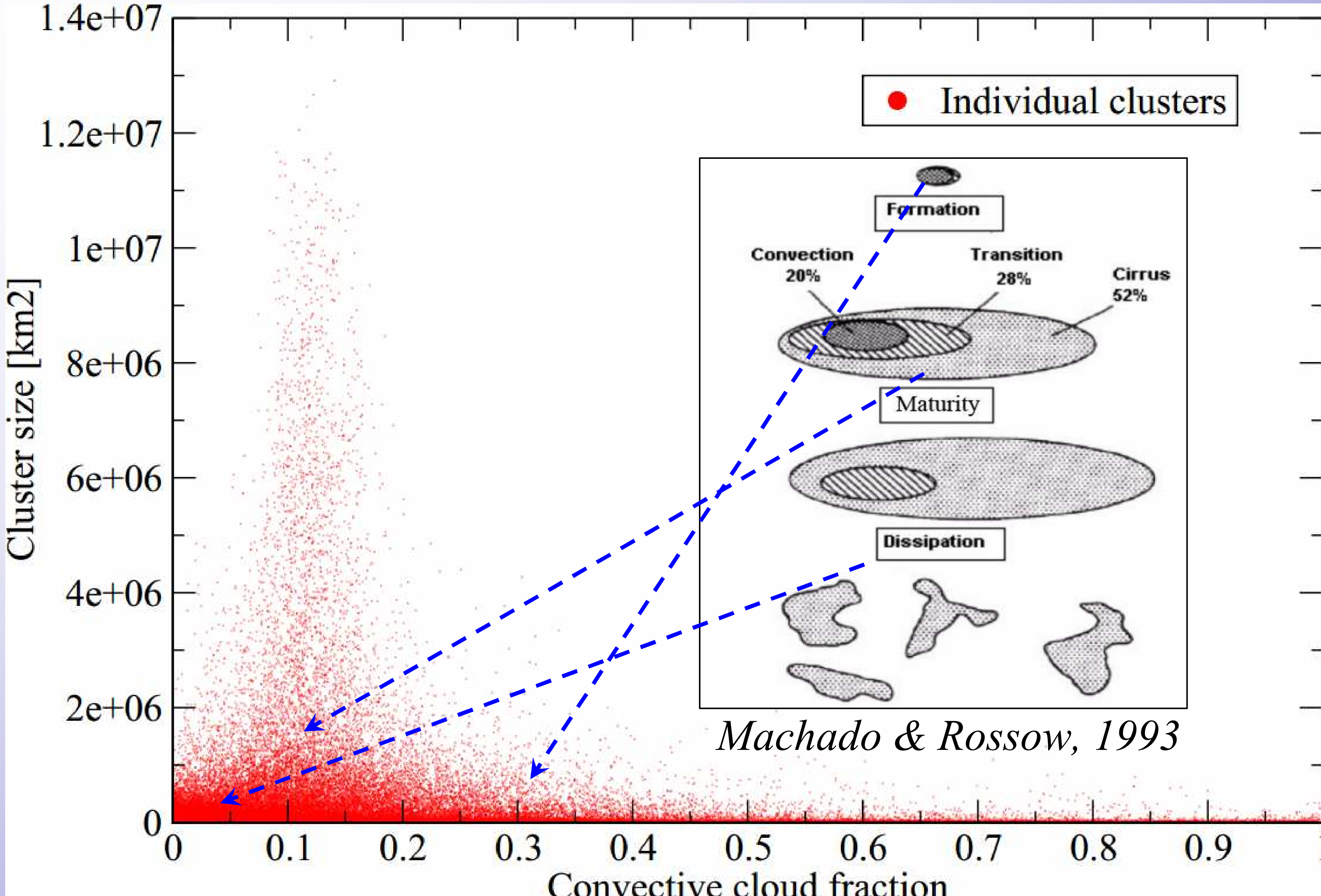
- The atmosphere above 440 hPa is gridded: 0.5°×0.5°×50hPa
- AIRS clouds fill the grid cells on a daily basis
- Filled neighboring grid cells form a "cluster"
- For each cluster, T_{aver}, T_{min}, N_{total}, N_{Cb}, N_{Ci}, and N_{thinCi} statistics are built and the horizontal and vertical extensions are estimated



- $N_{total\_1} \neq N_{total\_2}$
- $\Delta_{lat\_1} = \Delta_{lat\_2}$
- $\Delta_{lon\_1} = \Delta_{lon\_2}$

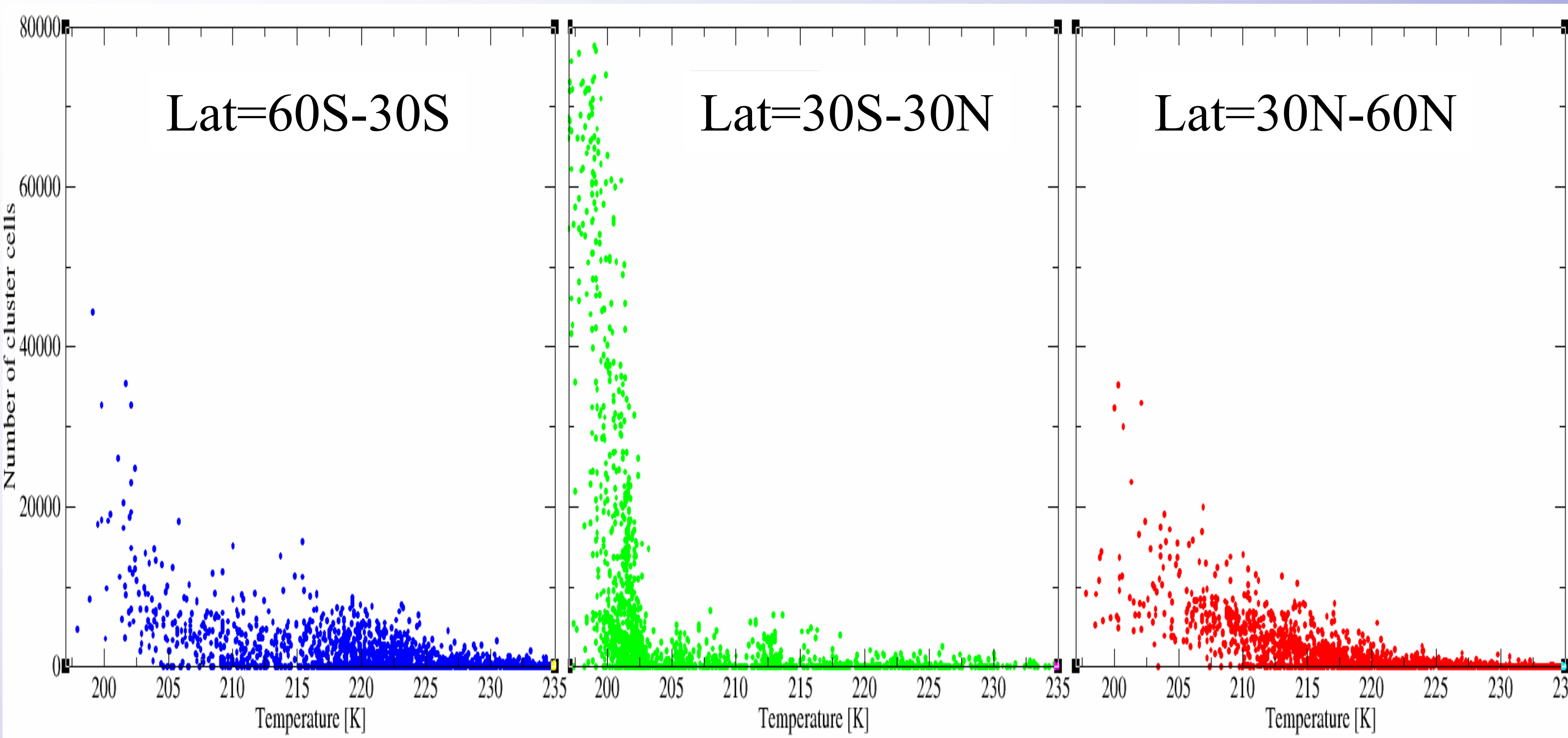


Cb fraction and the formation mechanism



Machado & Rossow, 1993

Cluster sizes vs T_{min}



- Only mature clouds (Cb fraction 0.08-0.3) were selected for this plot
- For the tropical case, the cluster size strongly depends on T_{min}.
- For midlatitude cases, the dependence is weaker

Conclusions

- IR sounders are sensitive to cirrus (also for multi-layered cloud systems, day & night) providing good spatial coverage
- available AIRS-LMD cloud data set covers at present 2003-2009
- A-Train constellation allowed validating AIRS retrievals for transfer to IASI.
- Retrieval of De and IWP seems to be coherent with CALIPSO/ CloudSat/DARDAR measurements.
- The IWC profile shape for Ci and Cb are close; for thin Ci it can be approximated as an isosceles triangle up to dH = 4km
- The probability of observing large cloud systems is higher for the systems with Cb fraction of ~12% probably corresponding to mature systems.
- Correlation between horizontal extent of cloud systems depends on minimal temperature within the cloud system.
- Next step: study link with thermodynamical and dynamical properties and include vertical extent.