Cloud properties
& bulk microphysical properties of semi-transparent cirrus from InfraRed Sounders
(TOVS, AIRS, IASI)

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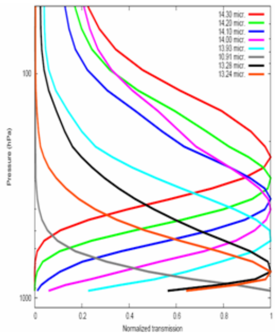
Sounders: TOVS, ATOVS, AIRS, IASI (1,2,3), IASI-NG

>1980 / 1995 NOAA, ≥2002 NASA, ≥2006 CNES-EUMETSAT



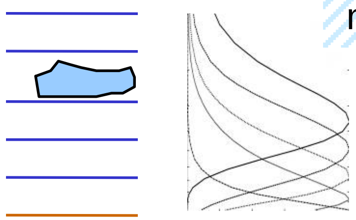
- long time series -> climate studies
- retrieval day & night
- increasing spectral resolution:
  - -> increasing vertical resolution (H_2O & T profiles)
  - -> decreasing noise (cirrus)

A-Train synergy (AIRS-CALIPSO-CloudSat):
- **unique opportunity for global retrieval method validation**
- **vertical structure of cloud types**

- **retrieval & evaluation**
- **cirrus occurrence, phys. & microphys. properties**
- **determination of ice supersaturation within atmospheric layers**
- **link between ISS and cirrus**

Cloud property retrieval : TOVS, AIRS, IASI

$R_m(\lambda_i)$ along CO_2 absorption band around 15 µm



multi-spectral cloud detection

cloud clearing & T, H_2O inversion

***3I*-TOVS** (Scott et al. 1999)

***NASA*-AIRS** (Susskind et al. 2003)

***NOAA*-IASI** (Gambacorta et al.)

atmospheric temperature & water vapor profiles, T_{surf}

-> thermodynamic state of atmosphere: select TIGR atmosphere *(proximity recognition)*

atm. spectral transmissivities from TIGR

+ spectral surface emissivities

$\varepsilon(p_k, \lambda_i)$ coherence

$$\varepsilon(p_k) = \sum_{i=1}^{N} \frac{R_m(\lambda_i) - R_{clr}(\lambda_i)}{R_{cld}(p_k, \lambda_i) - R_{clr}(\lambda_i)}$$

min of $\chi_w^2(p_k)$
on spectral cloud emissivites

no assumption on microphysics

ε_{cld}, p_{cld} *(Stubenrauch et al. 1999, 2006, 2008, 2010)*

'a posteriori' cloud detection

cirrus emissivities (8 - 12 µm)

Mitchell 1996, Baran 2003

4A-DISORT + SSP of ice crystals

hex. columns, aggregates

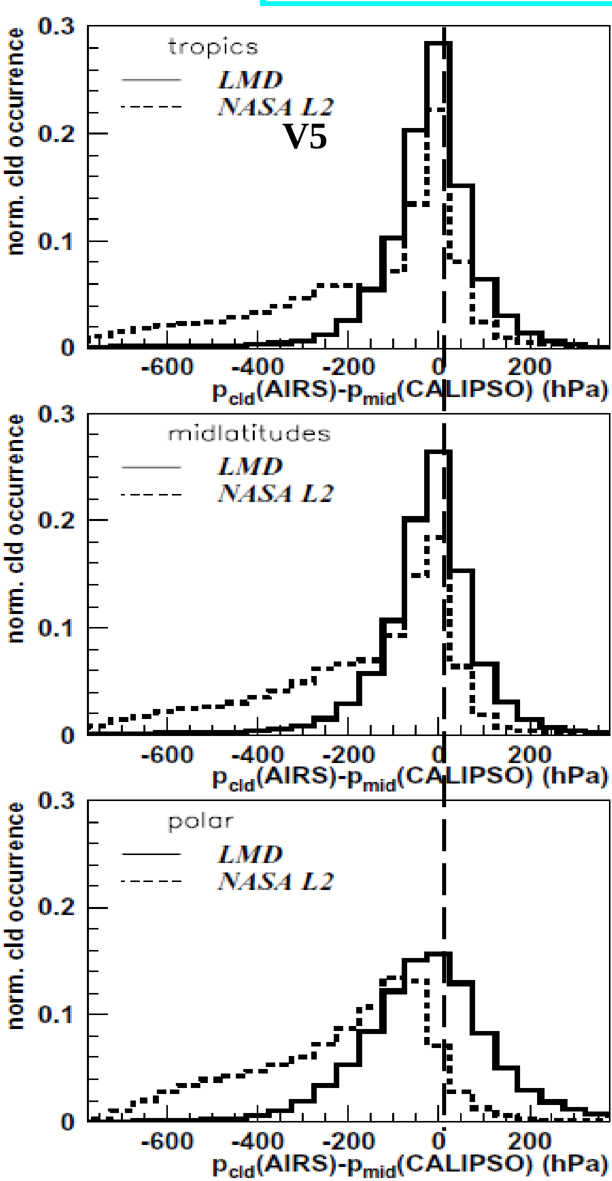
simulated $\varepsilon(\lambda, De, IWP)$

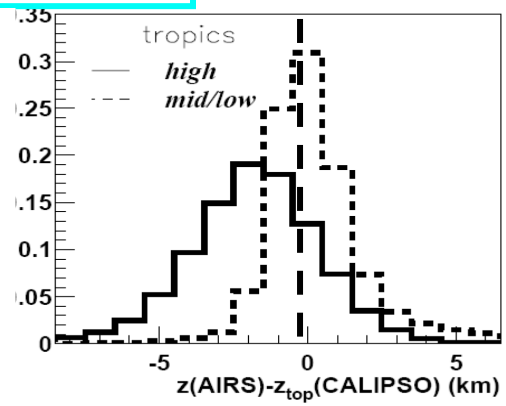
De, IWP *(CIRAMOSA, Rädel et al. 2003, Stubenrauch et al. 2004, Guignard et al. 2012)*

A-Train Synergy: *evaluation & vertical cloud structure*

Stubenrauch et al. ACP, 2008, 2010

Evaluation of cloud height

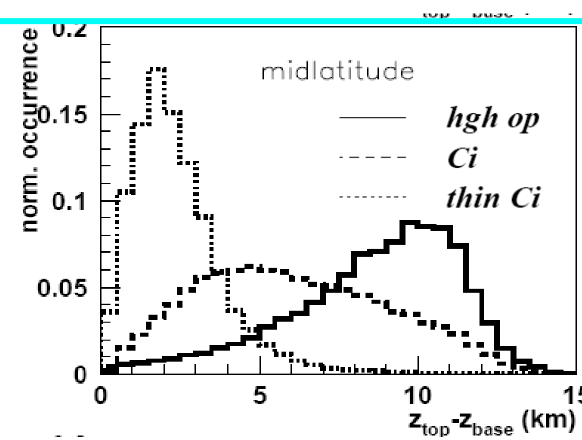




p_{cld}(AIRS) corresponds to:
midlevel of 'apparent' cloud (COD<3)

for clouds with diffusive tops:
z_{cld}(AIRS) on av. 1.5 km below cloud top

Cloud vertical extent for different cloud types



Δz (thin Ci) < Δz(Ci) < Δz(hgh op)

-> determine climatology of cloud vertical extent per cloud type

important input for determination of earth radiation budget

Occurrence of high-level clouds (p_{cld} < 440 hPa)

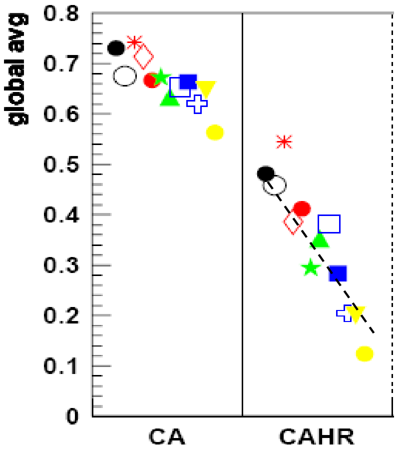
co-chairs: C. Stubenrauch, S. Kinne

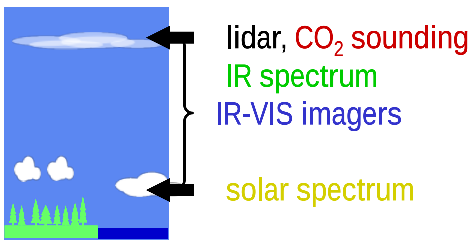
http://climserv.ipsl.polytechnique.fr/gewexca

comparison of 12 global cloud datasets

global gridded L3 data (1° x 1°) : monthly averages, variability, Probability Density Functions

Stubenrauch et al. WCRP, 2012





global CA 65-70% (+ 5% subvisible Ci)

40 – 50% of all clouds are high-level clouds

uncertainties & biases depend on cloud scene:

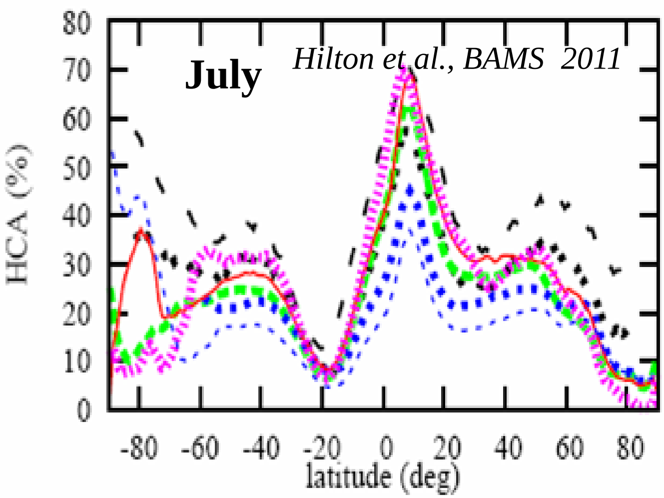
CAHR depends on instrument performance to identify thin Ci

active lidar > IR sounders > VIS-NIR-IR imagers > multi-angle VIS imagers

geographical distributions & seasonal cycles similar

vertical sounders :

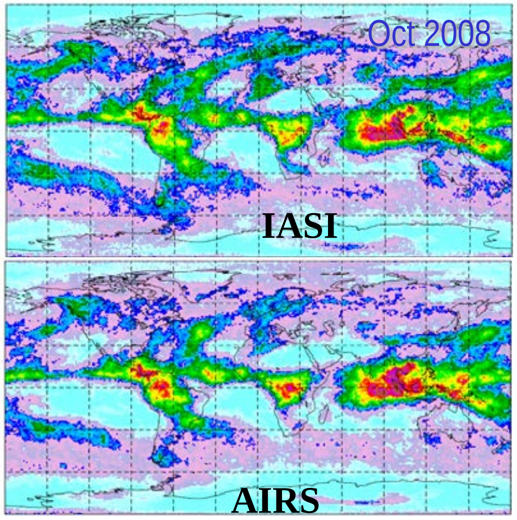
➢ ***sensitive to Ci properties*** *(also for multi-layered cloud systems; day & night)*



IASI cloud climatology

IASI-LMD
AIRS-LMD
TOVS-B

CALIPSO	incl subvis Ci excl subvis Ci
ISCCP	day day + night

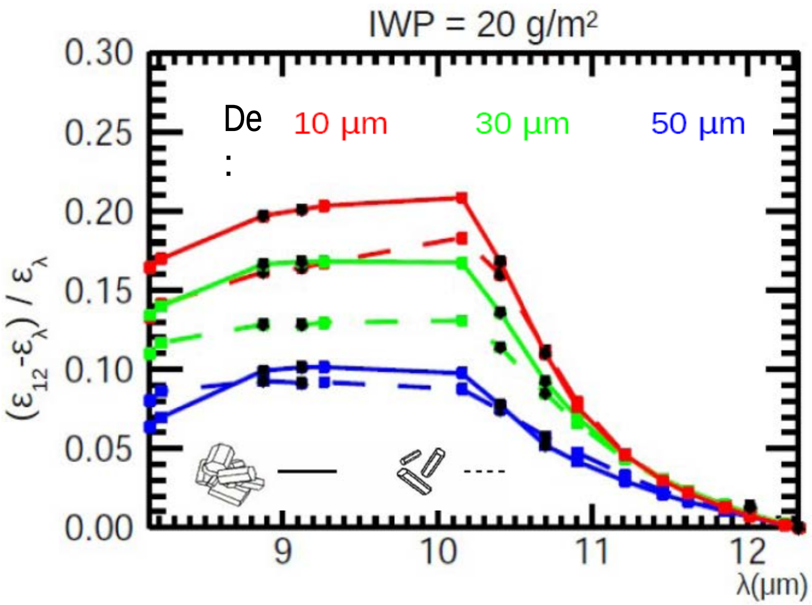


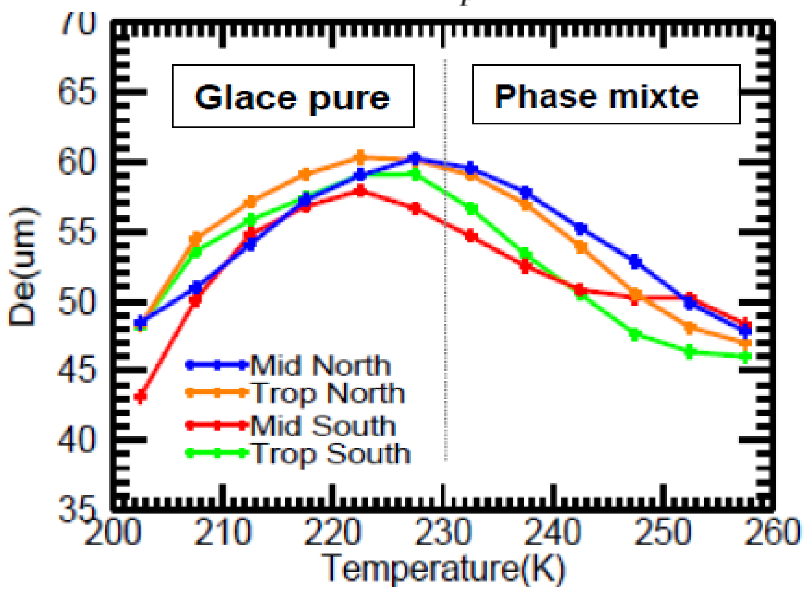
Microphysical properties of semi-transparent cirrus

PhD thesis Guignard 2012; Guignard et al. ACP 2012

Ci spectral ε difference increases with decreasing De

$$D_e = 2\frac{\int \frac{3V}{4p} n(r)\,dr}{\int \frac{P}{p} n(r)\,dr} = \frac{3}{2}\frac{IWC}{\rho_i P}$$





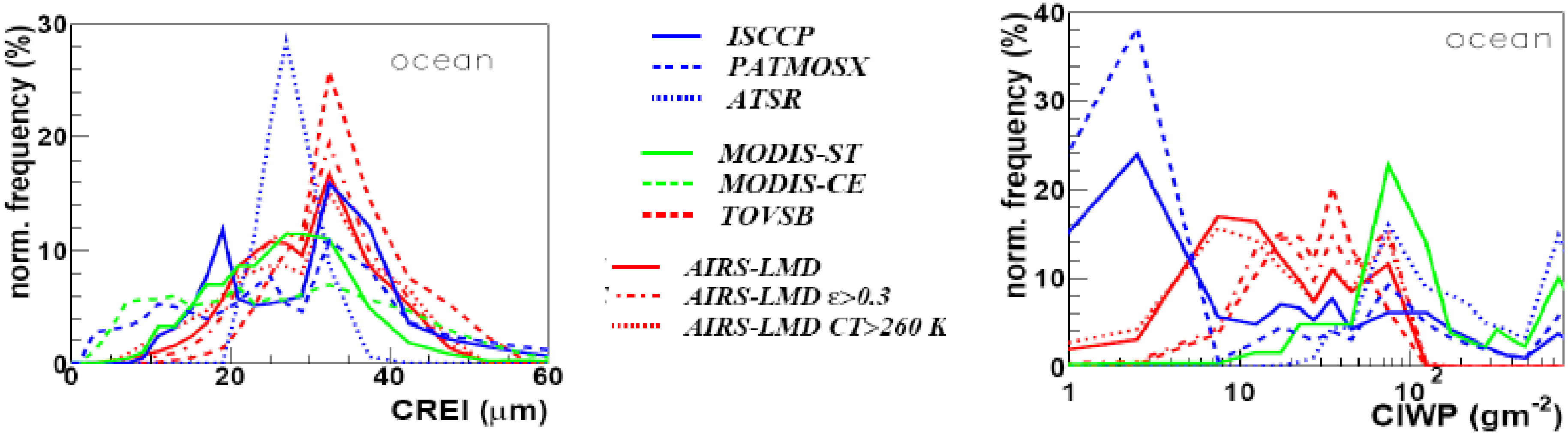
- **p_{cld} < 440 hPa, $0.20<\varepsilon_{cld}<0.85$; sensitivity: $D_e<90\mu m$, $IWP<120 gm^{-2}$**
- **6 AIRS channels -> crystal habit**
- **global biases due to assumptions < 5%**

- **De increases with T_{cld} up to 230 K;** Tcld > 230 K: liquid droplets influence retrieval

50% of semi-transparent high clouds are pure ice

eff. particle radius & ice water path distributions

Cloud Assessment



➢IR sounders, ISCCP: large peak at 32 μm, second peak of ISCCP at 18 μm: misidentified I-W?

➢peaks of MODIS-ST & ATSR-GRAPE at 27 μm linked to sub-sampling of optically thicker clouds & not to different channels (3.7 / 2.1 / 1.6 μm) -> only retrieved near cloud top

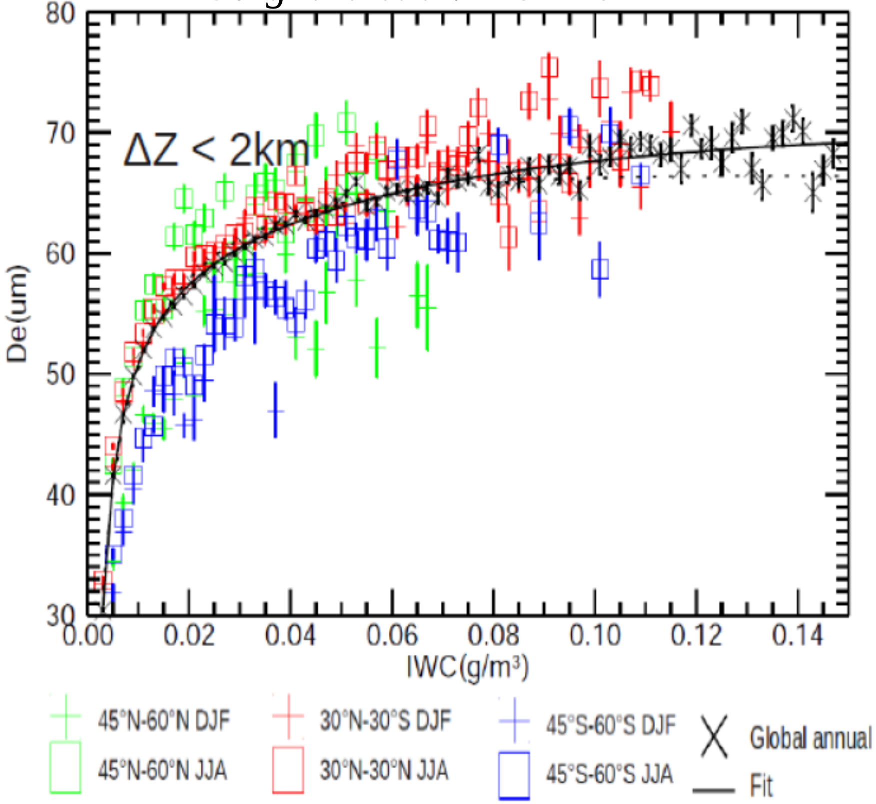
➢Distributions depend on sub-sampling & fraction of partly cloudy fields (Ci over low clds)

AIRS/TOVS compact distributions 5 - 100 gm^{-2}
MODIS-ST distribution starts at 10 gm^{-2}
ISCCP, PATMOSx additional large peak at 4 gm^{-2} (regions with low clouds, partly cloudy pixels?)

Parameterization of De as function of IWC

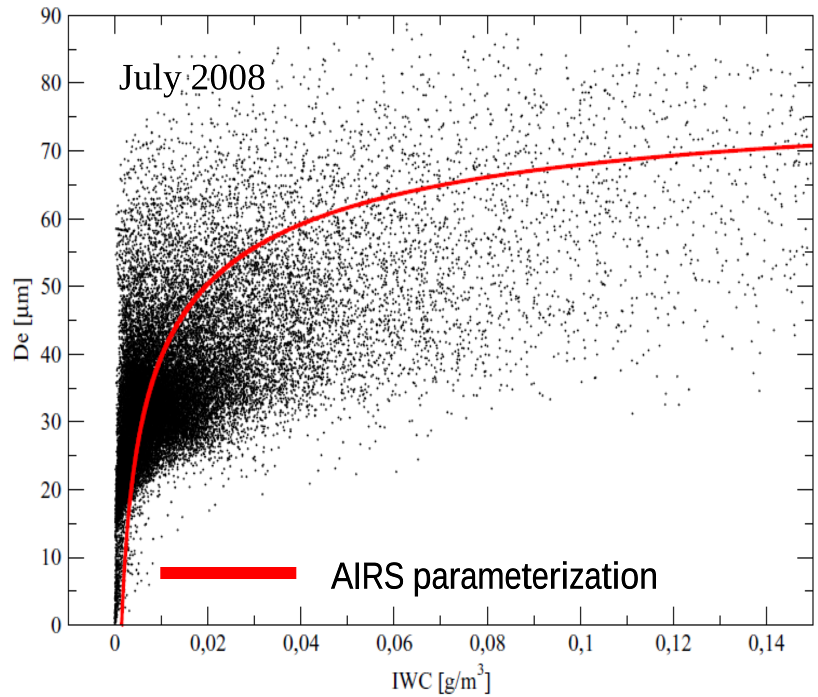
(A-Train Synergy)

Guignard et al. ACP 2012



Delanoë & Hogan, 2008, 2010

CloudSat-CALIPSO-DARDAR cloud data



p_{cld} < 440 hPa, $0.20<\varepsilon_{cld}<0.85$, T_{cld} < 230 K

- ➢**logarithmic increase of De with IWC** **(for small vert. extent)**
- ➢similar behaviour in tropics & NH midlatitudes, summer / winter
- ➢slightly differentslope in SH midlatitudes

➢preliminary comparison with De-IWC from DARDAR cloud data very encouraging!

How can we detect ice supersaturation (ISS)?

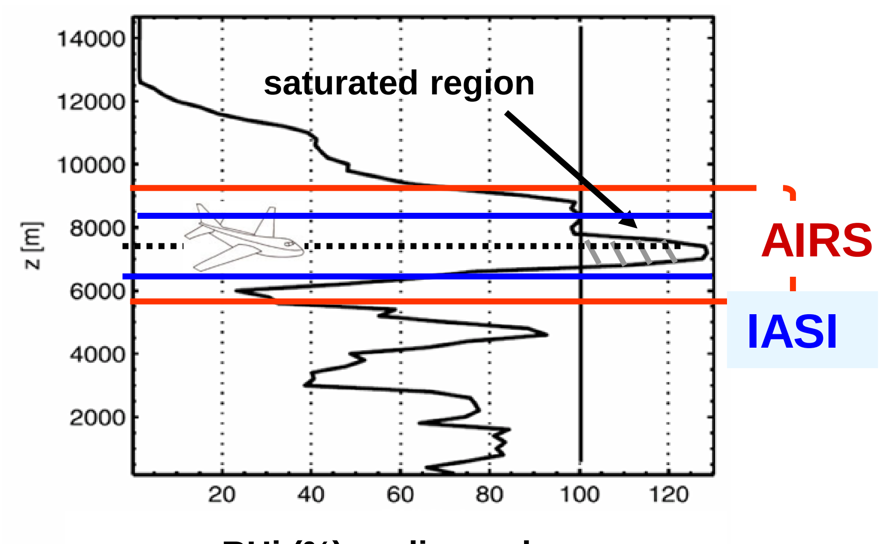
PhD thesis Lamquin 2009; Lamquin et al., ACP 2012

IR Sounders retrieve water vapour within atmospheric layers of km's

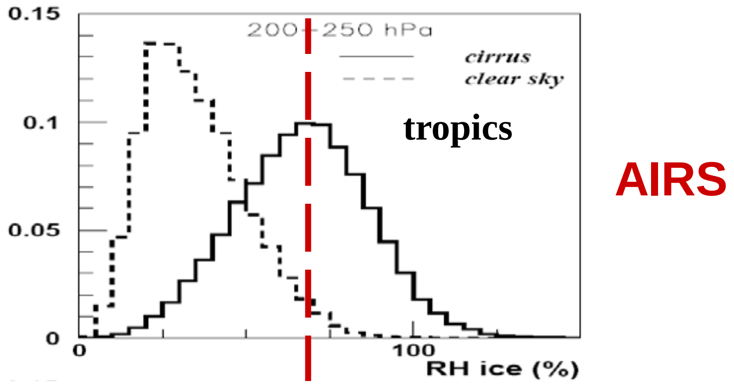
=> underestimation of RH_{ice} : AIRS peak for cirrus at 70% (instead of 100%)

improved spectral resolution : **IASI peak for cirrus at 80-85%**

ISS often occurs in vertical layers < 500 m



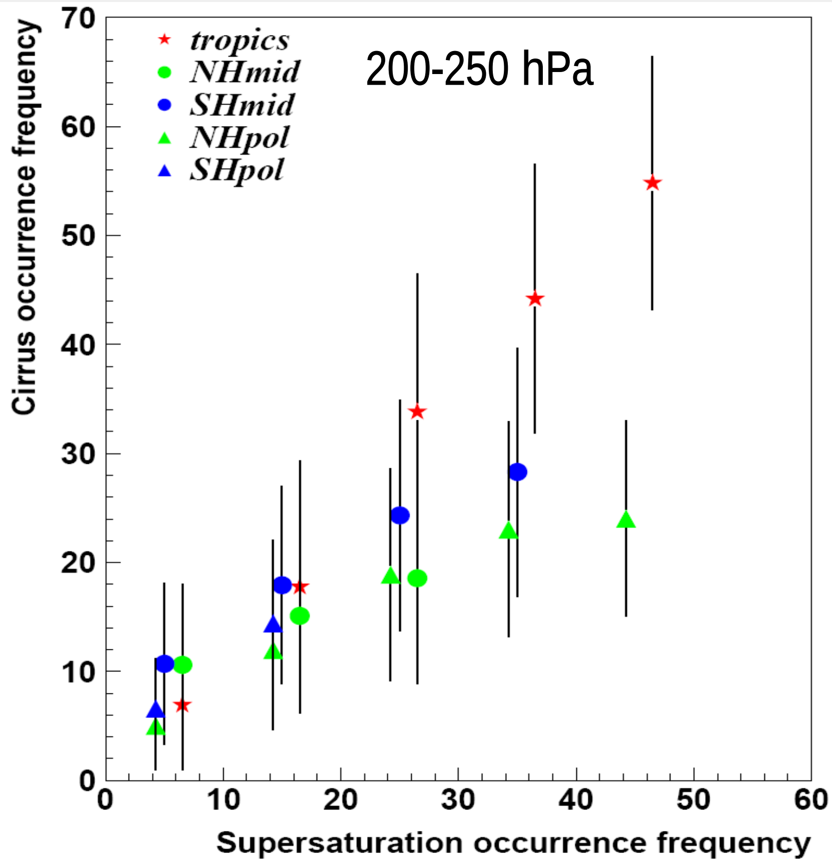
RHi (%), radiosondes



determine probability of ISS presence in layer by calibration with MOZAIC (commercial aircraft)

Influence of ISS occurrence on Cirrus occurrence

Ci occurrence from CALIPSO (including subvisible Ci)



from AIRS

extending results of *Gierens (2000)*
(using MOZAIC data in NH midlat)

- **Ci occurrence increases with ISS occurrence**
- **stronger increase in tropics than in midlatitudes**
  (different formation mecanism?)

Conclusions

- **IR sounders sensitive to cirrus** (also for multi-layered cloud systems, day & night)
- **p_{cld} corresponds to midlevel of apparent cloud depth**
  (slightly below height of max backscatter)
- **uncertainty estimation from χ^2 :** on av **40 hPa (4 K in T_{cld})**

  AIRS-LMD L3 cloud data (2003-2009) available at http://ara.abct.lmd.polytechnique.fr/
  AIRS-LMD L2 cloud data soon distributed by ICARE: http://www.icare.univ-lille1.fr/

- **40% of all clouds are high-level clouds**
  - 70% of all high-level clouds are semi-transparent clouds
  - 50% consist only of ice crystals (mostly aggregates)
- **Retrieval of De, IWP, ice crystal shape seems to be coherent:**
  - De increases logarithmically with IWC (IWP) -> parameterization for GCM's
  - first comparisons with colocated CLoudSat-CALIPSO DARDAR data promising!!!

- **A-Train constellation allowed to validate AIRS retrievals for transfer to IASI**

- **RH_{ice} determined over coarse atmospheric layers**
  - increase in spectral resolution -> increase of vertical resolution
  - RH_{ice} of Ci peaks at 70% for AIRS / 85% for IASI *(instead of 100% in-situ)*
- **Ice SuperSaturation can be detected after calibration with MOZAIC**
- **Ci occurrence increases with ISS occurrence**

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