

Cloud properties & bulk microphysical properties of semi-transparent cirrus from AIRS & IASI

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* until March 2012, now LATMOS

ABC(t) – ARA team

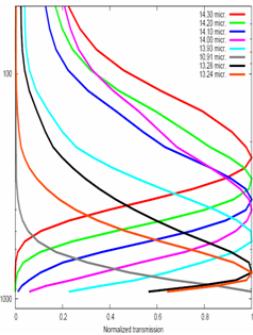
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and to A. Baran (MetOffice) for providing the data base of ice crystal single scattering properties*

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

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



- long time series → climate studies
- increasing spectral resolution:
 - increasing vertical resolution
- retrieval day & night
- RH_{ice} , aerosols & cirrus

A-Train synergy (AIRS-CALIPSO-CloudSat):

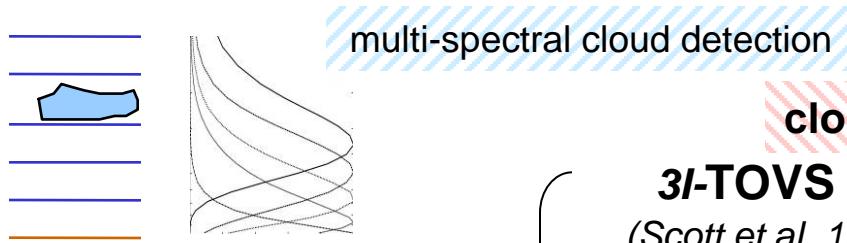
- unique opportunity for global retrieval method validation
- vertical structure of cloud types

Outline

- retrieval & evaluation; AIRS → IASI
- cirrus phys. & microphys. properties
- classification of IWC vertical profiles & effect on radiation
- detection of Ice SuperSaturation

Cloud property retrieval : TOVS, AIRS, IASI

$R_m(\lambda_i)$ along CO₂ absorption band around 15 μm



cloud clearing & T, H₂O 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 emissivities

no assumption on microphysics

$\varepsilon_{cld}, p_{cld}$ (Stubenrauch et al. 1999, 2006, 2008, 2010)

a posteriori cloud detection

cirrus emissivities (8 - 12 μm)

Mitchell 1996, Baran 2003

↓
 simulated $\varepsilon(\lambda, D_e, IWP)$

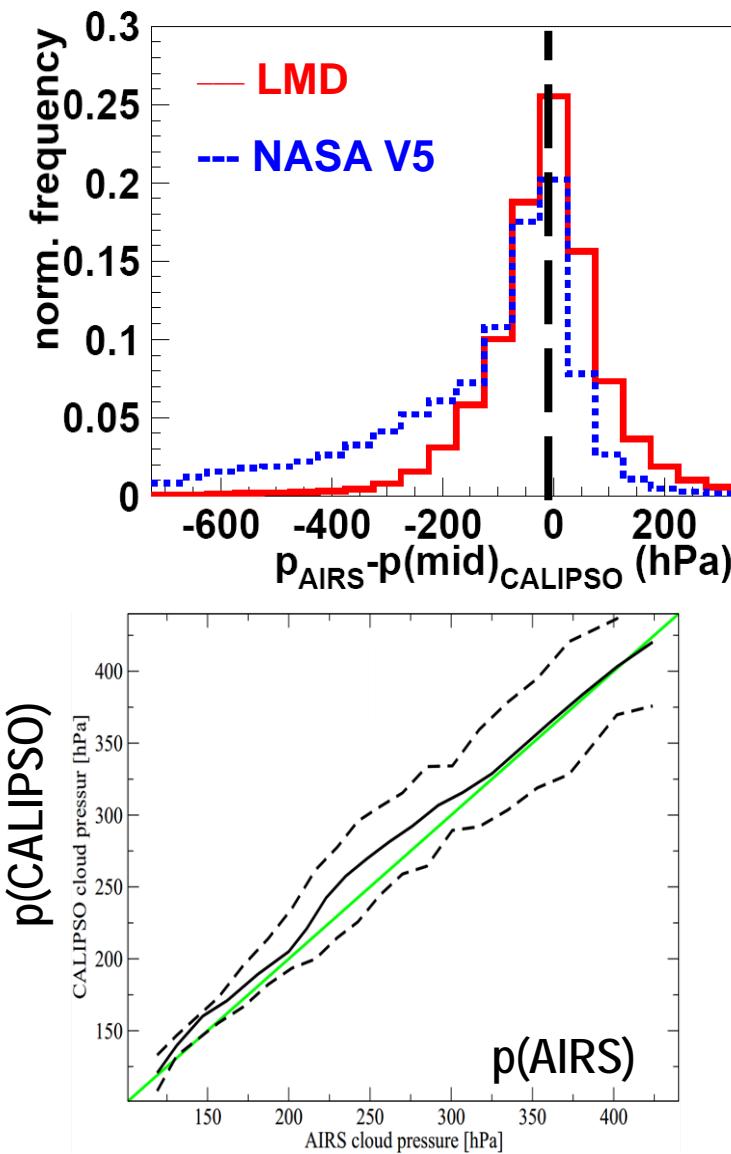
4A-DISORT + SSP of ice crystals
 hex. columns, aggregates

D_e, IWP

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

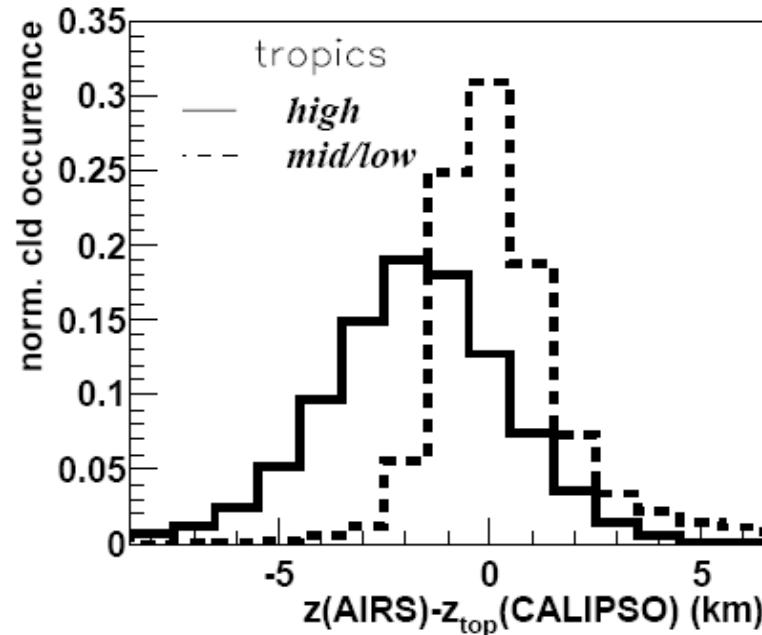
A-Train Synergy: evaluation of cloud height

Stubenrauch et al. ACP, 2008, 2010



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

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



Occurrence of high-level clouds



Cloud Assessment

12 global cloud datasets
global gridded L3 data ($1^\circ \times 1^\circ$)

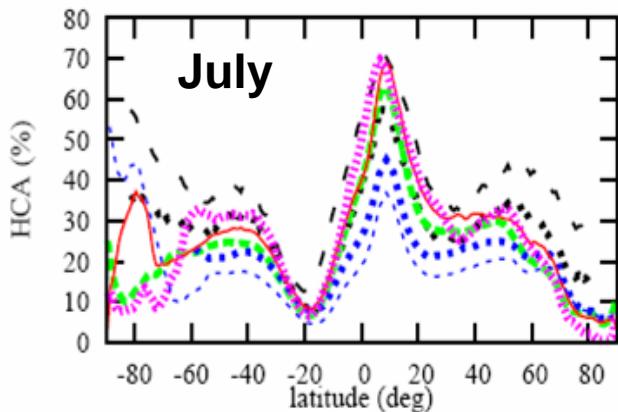
<http://climserv.ipsl.polytechnique.fr/gewexca>

Stubenrauch *et al.*, WCRP report 23/2012; Stubenrauch *et al.* BAMS 2013

➤ HCA depends on sensitivity to thin cirrus
(CALIPSO > IR sounders > ISCCP)

vertical sounders : sensitive to Ci properties
(also for multi-layered cloud systems; day & night)

- geographical & seasonal distributions similar
- 40-45% (50%) of all clouds are high (+ subvis)
- land – ocean : +10%

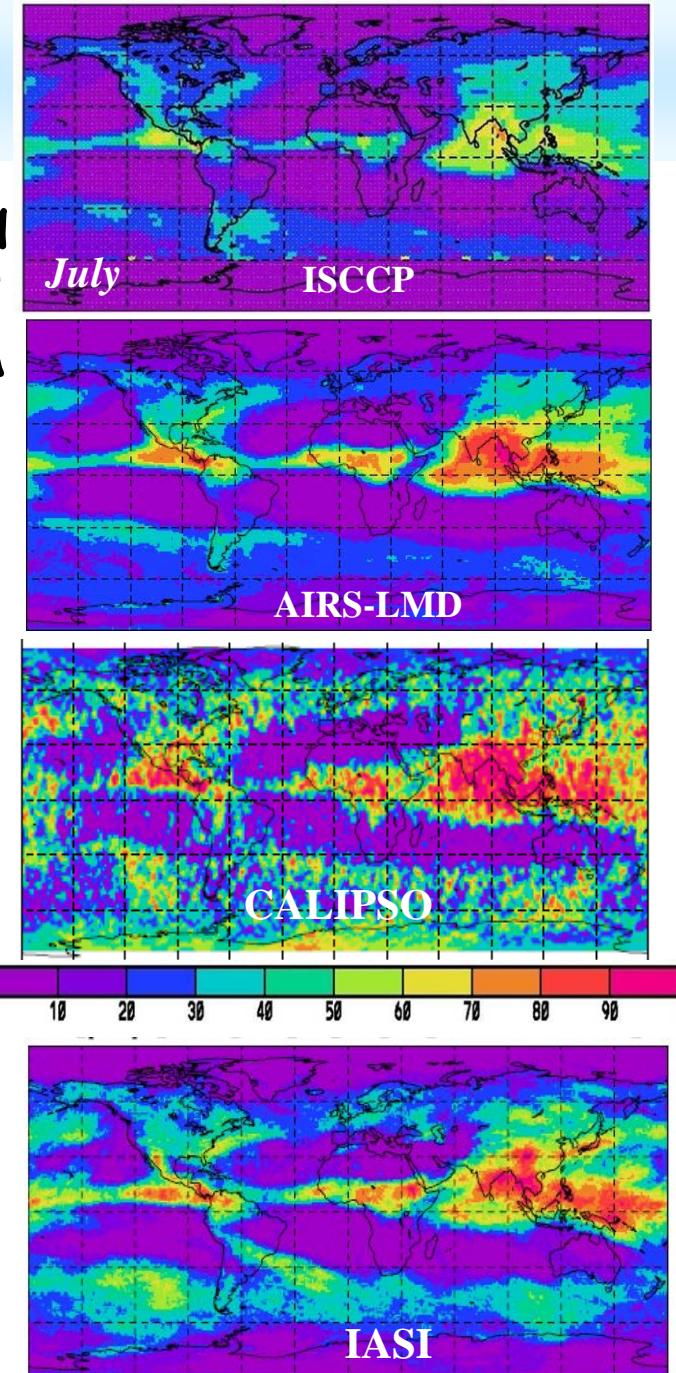


CALIPSO incl subvis Ci
excl subvis Ci

ISCCP day
day + night

TOVS-B
AIRS-LMD
IASI-LMD

Hilton *et al.*, BAMS 2012



Cloud property retrieval: AIRS → IASI

$p_{\text{cld}}/T_{\text{cld}}/\epsilon_{\text{cld}}$ retrieval

✓ **IASI data channel selection:**

CO₂ channels closest to AIRS in T_B
cloud detection & microphysics (7-12 μm, 7 μm)

✓ **auxiliary data:**

- spectral weights, spectral transmissivities of IASI channels: **TIGR**
- T/H₂O profiles, T_{surf}, microwave ice / snow flag: **IASI L2 from NOAA**
- p(tropopause) : **AIRS climatology**
- spectral surface emissivities (monthly climatologies):

30N-30S : IASI (*V. Capelle et al.*); **else MODIS** (interpolation of channels necessary)

LUT simulation of Ci emissivities as fct of (D_e, IWP)

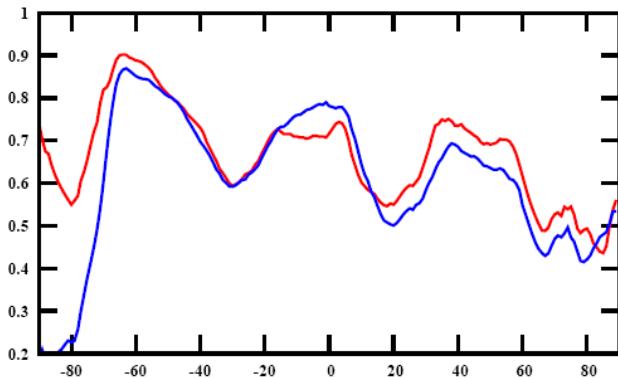
✓ **intergration of SSP's into 4A-OP**

pristine / aggregated ice columns (Baran); integrated over bimodal size distribution (Mitchell)

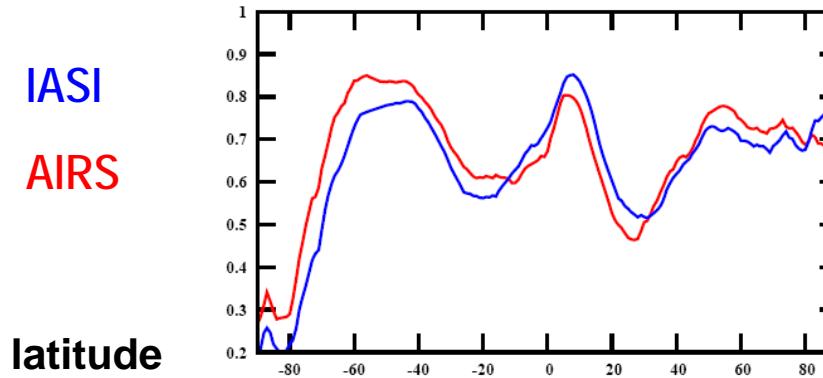
✓ **interpolation of LUTs**

IASI – AIRS comparison: *tot cloud amount*

January 2009



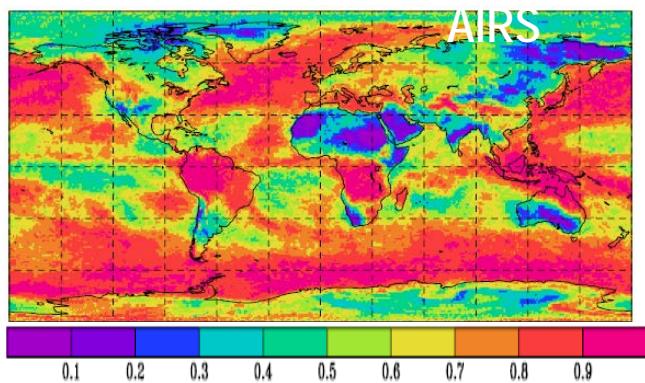
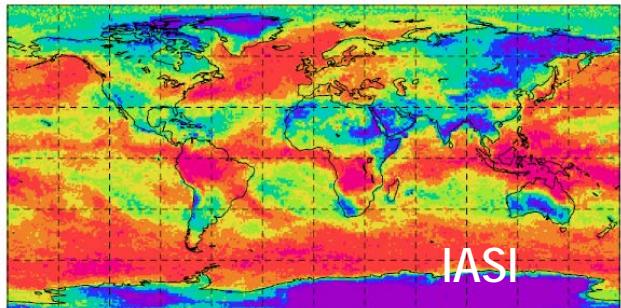
July 2009



IASI

AIRS

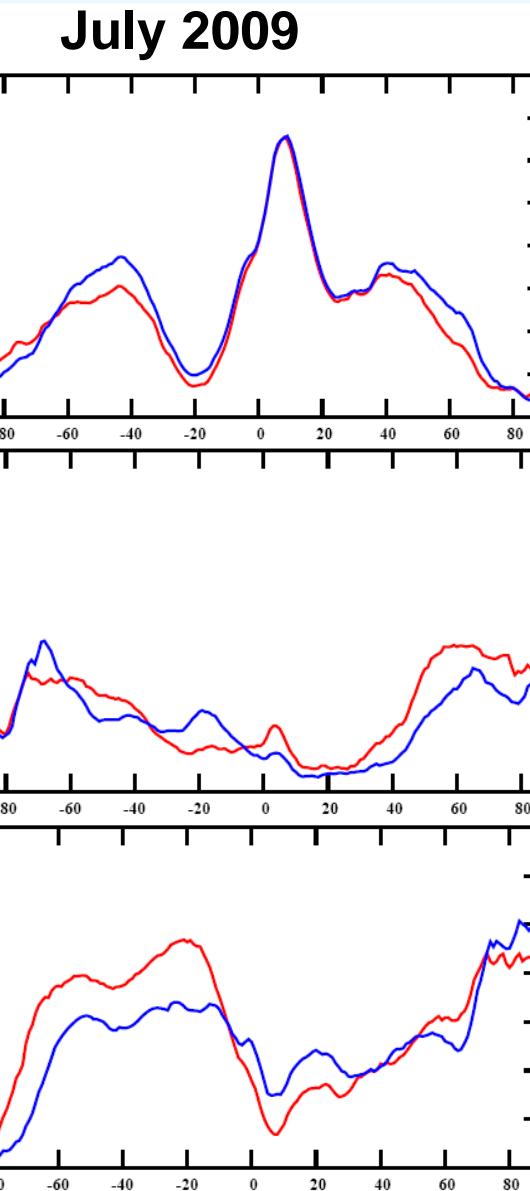
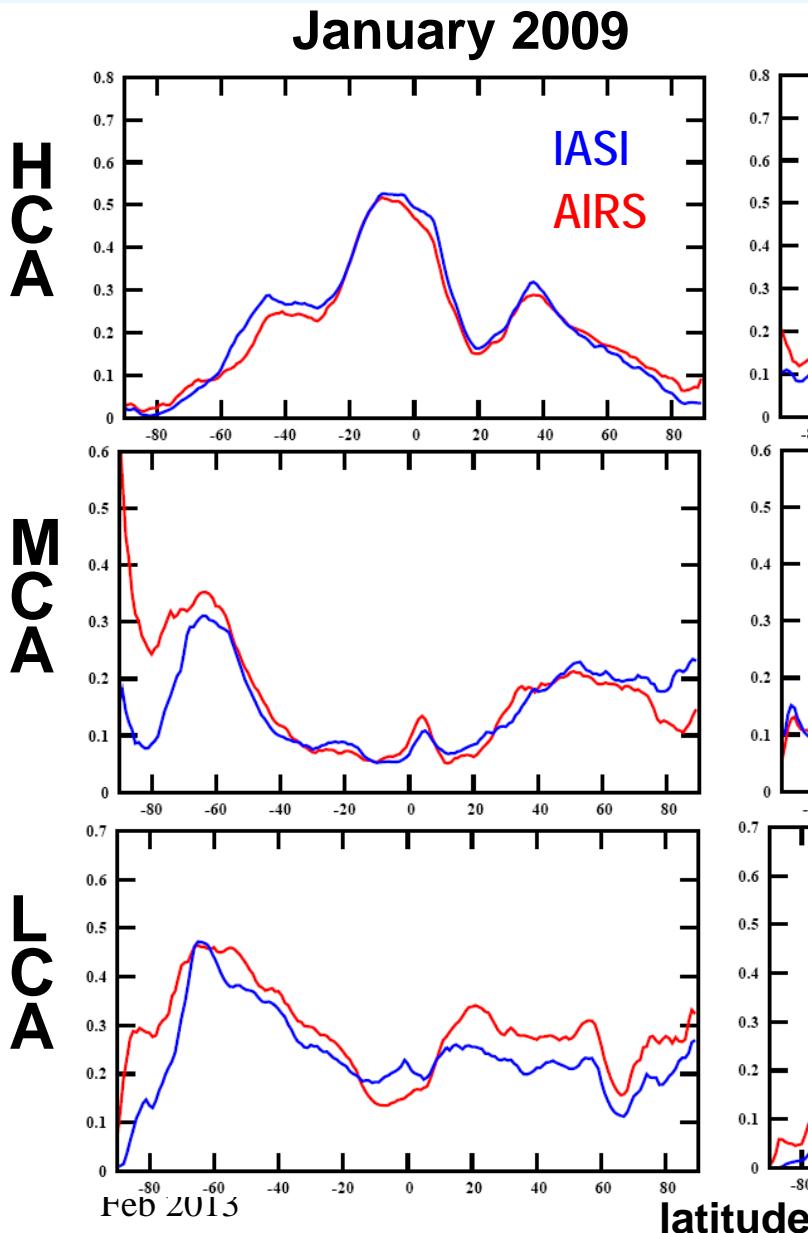
latitude



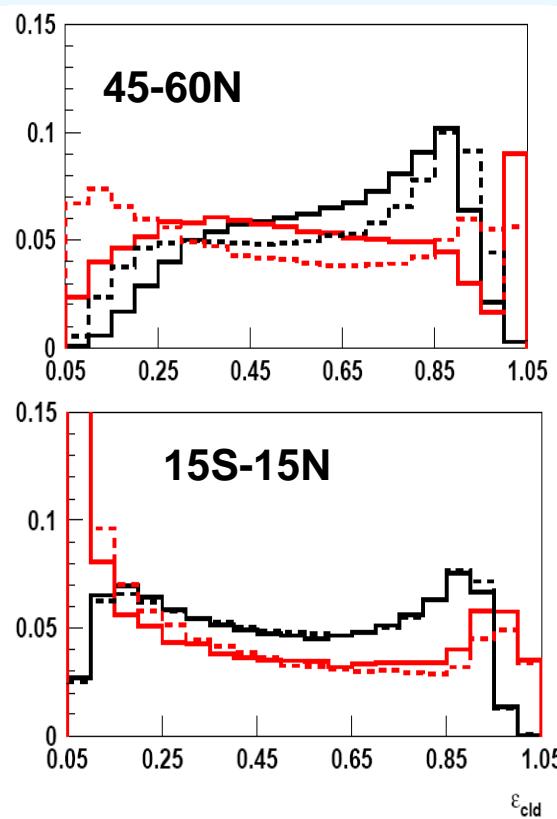
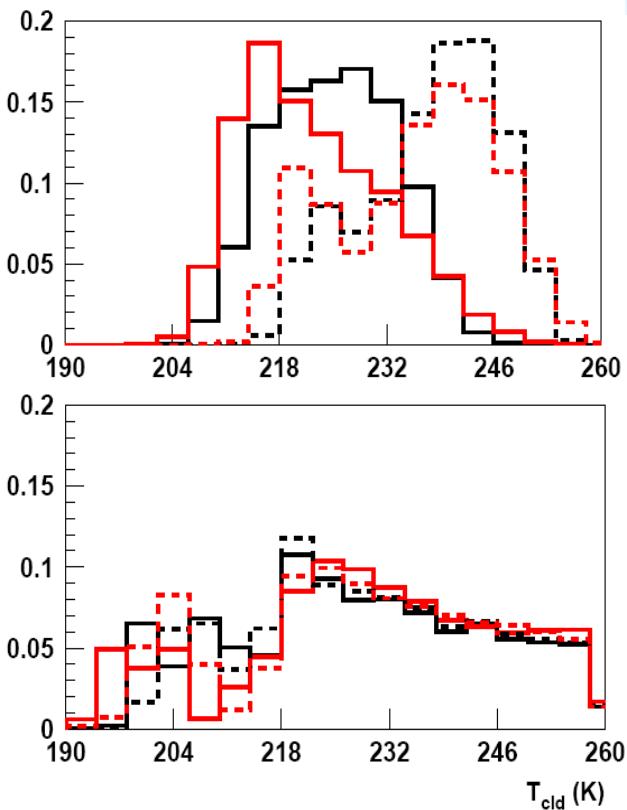
AIRS cloud detection agreement with CALIPSO:
85%/75% over ocean/land (*Stubenrauch et al. 2010*)

IASI CA : in general good agreement with AIRS
except over Antarctica

IASI – AIRS comparison: *height-stratified CA*



IASI – AIRS comparison: T_{cld} & ε_{cld} distributions of high-level clouds



AIRS — Jan
IASI - - Jul

T_{cld} distributions in good agreement
more optically thin clouds → better sensitivity?
in midlatitudes solutions with $\varepsilon_{\text{cld}} > 1$; tropopause too low?

Microphysical properties of semi-transparent cirrus

spectral ε difference increases with decreasing De

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

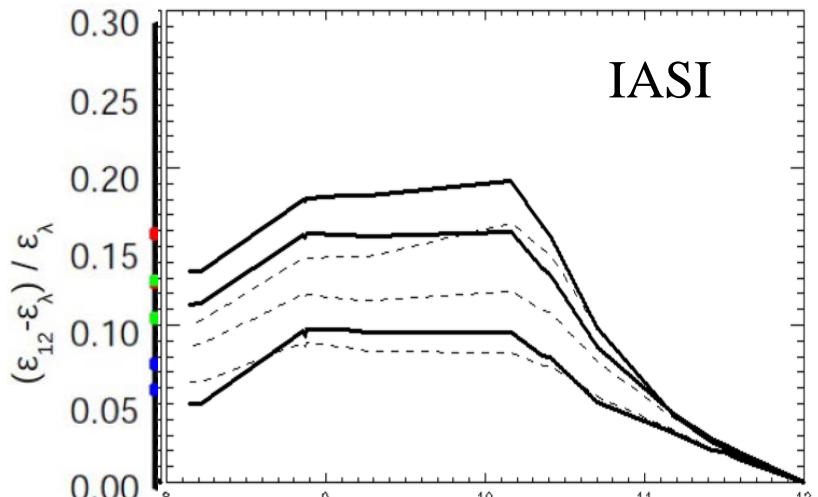
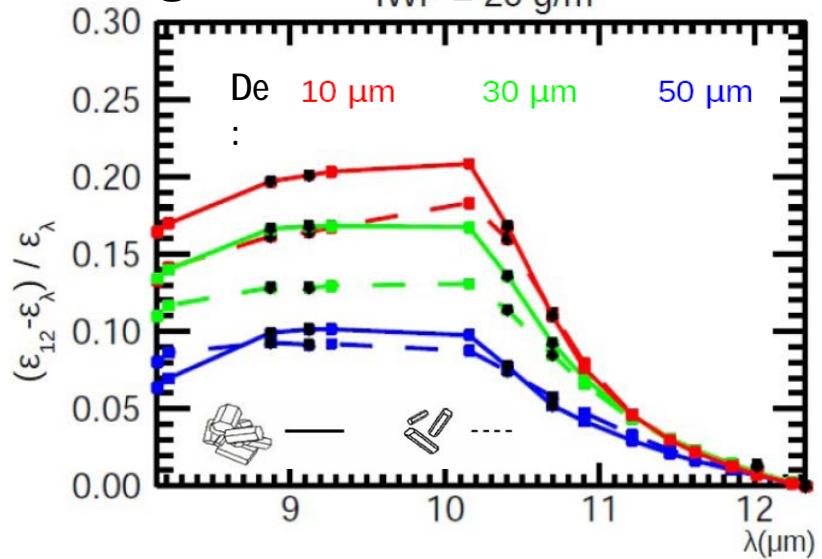
bimodal size distribution assumed

for semi-transparent cirrus :

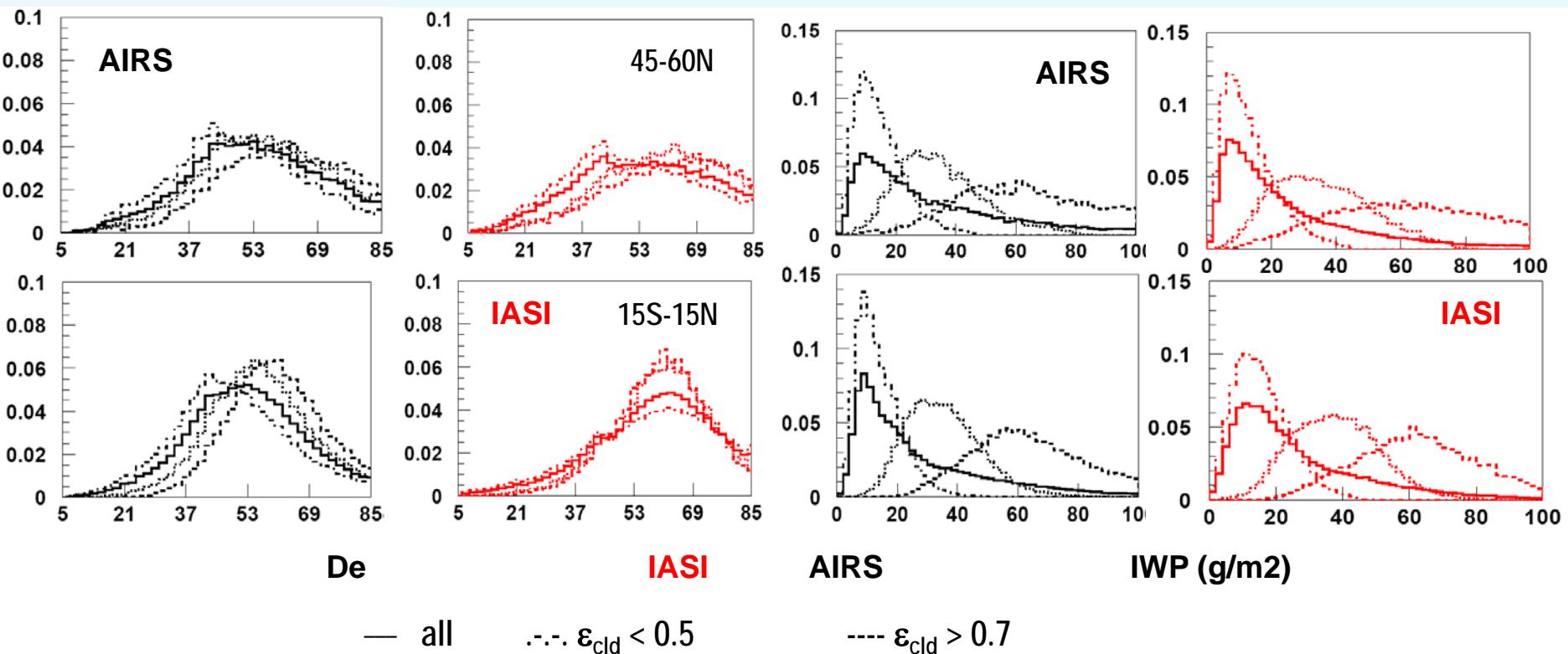
- $p_{\text{cld}} < 440 \text{ hPa}$
- $0.20 < \varepsilon_{\text{cld}} < 0.85$
- sensitivity: $D_e < 90 \mu\text{m}$, $IWP < 120 \text{ g m}^{-2}$
- indication of most probable crystal habit
- Sensitivity to assumptions:
 - like in Rädel et al. JGR 2003:
 - small on cloud parameters ($z, \Delta z, T$)
 - horizontal heterogeneity : 3%
 - partial cloudy pixels: up to 10%
 - small on crystal habit (5%)

Guignard et al. ACP 2012

IWP = 20 g/m²

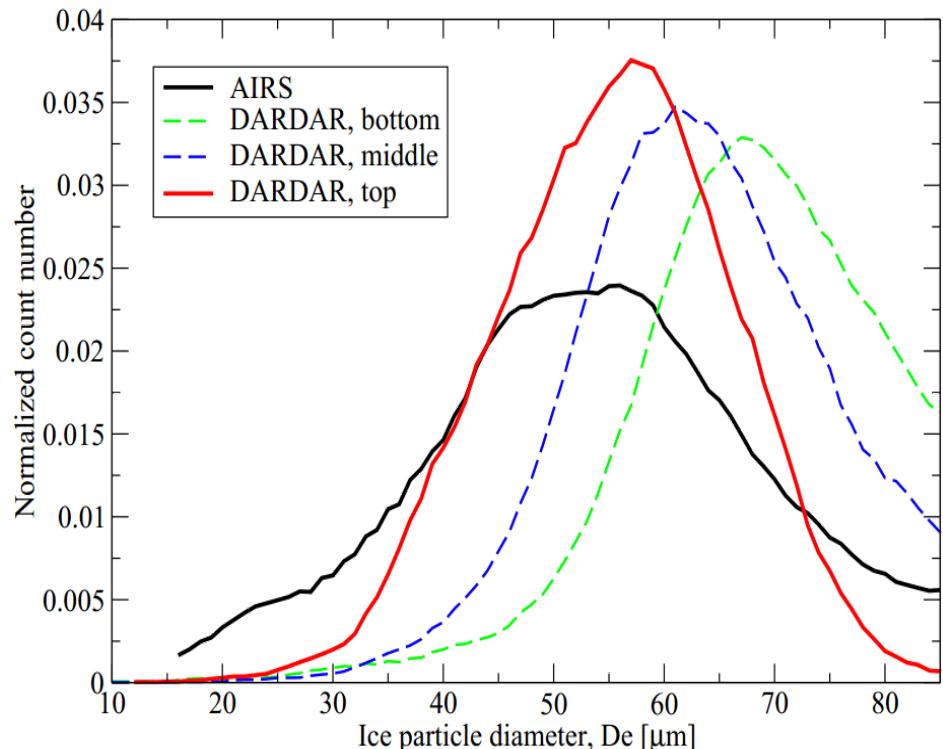
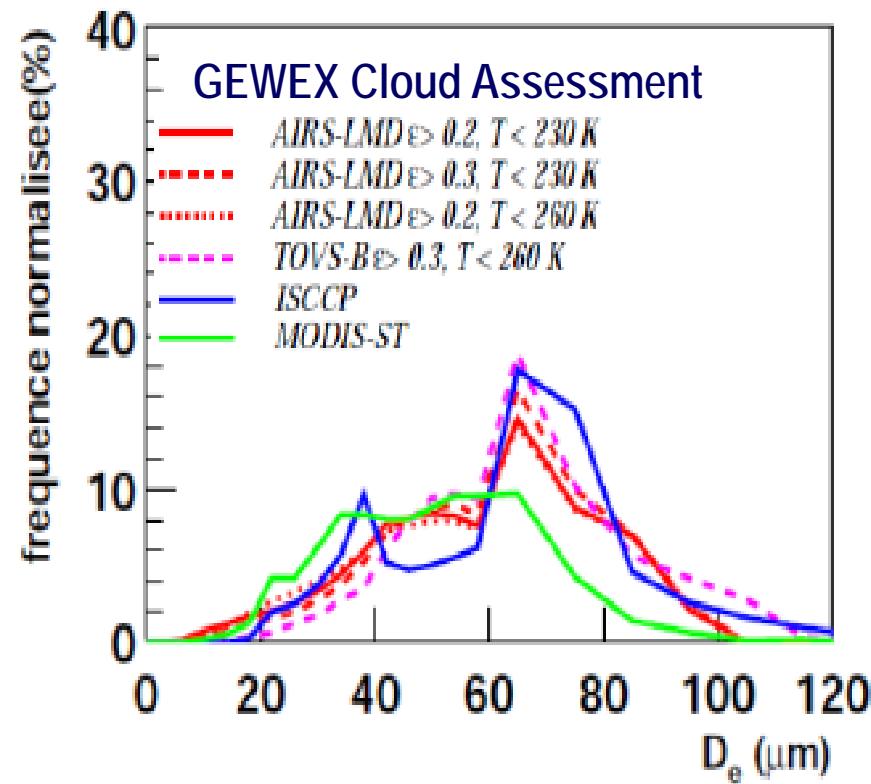


AIRS - IASI comparison: D_e & IWP



IWP increases with ϵ_{cld} , D_e less
first comparison encouraging

Comparison of D_e with other datasets



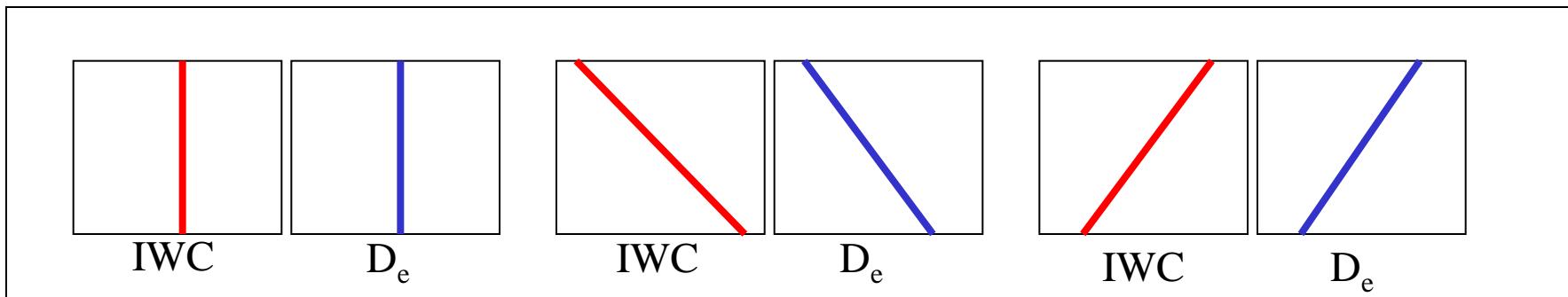
D_e distributions from passive remote sensing similar, differences due to retrieval subsampling

- AIRS D_e centered around $\sim 55 \mu\text{m}$
- DARDAR D_e increases from top to base: $56 / 60 / 67 \mu\text{m}$
- Radar less sensitive to $D_e < 30 \mu\text{m}$

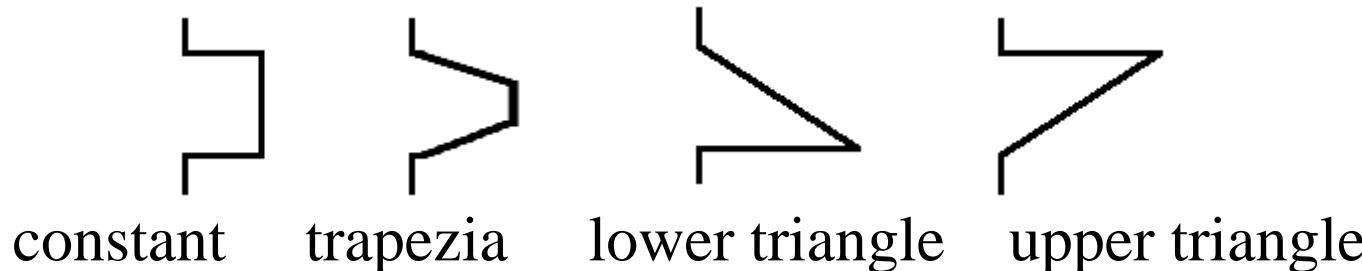
A-Train Synergy: Classification of IWC profiles

Clouds with same IWP may have different IWC and D_e profiles
→ influence on radiation ?

Is it possible to give a shape probability in dependence of cloud properties or atmospheric properties?



IWC profile classes & dependency on IWP



IWP (g/m ²)	constant	trapezia	low trian	upp trian
0-10	54%	20%	10%	16%
10-30	31%	48%	13%	8%
30-100	28%	56%	14%	3%
100-300	26%	51%	21%	2%
300-1000	38%	35%	26%	1%

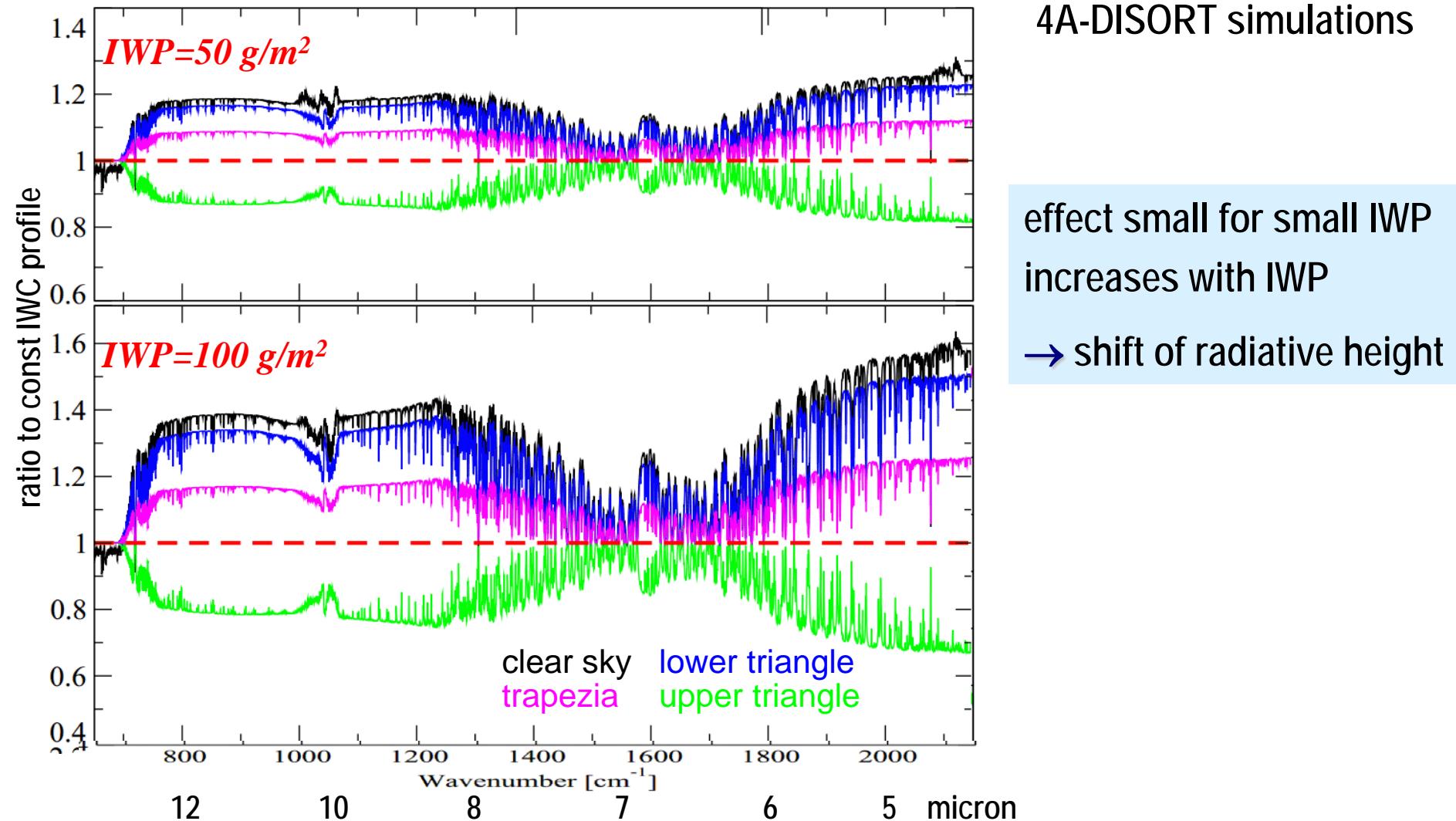
constant & trapezia correspond to 80% of the profiles

Lower triangle increases with IWP from 10 to 26%

Upper triangle only for IWP < 30 g/m²

independent of location / season !

Influence of IWC profile on radiation

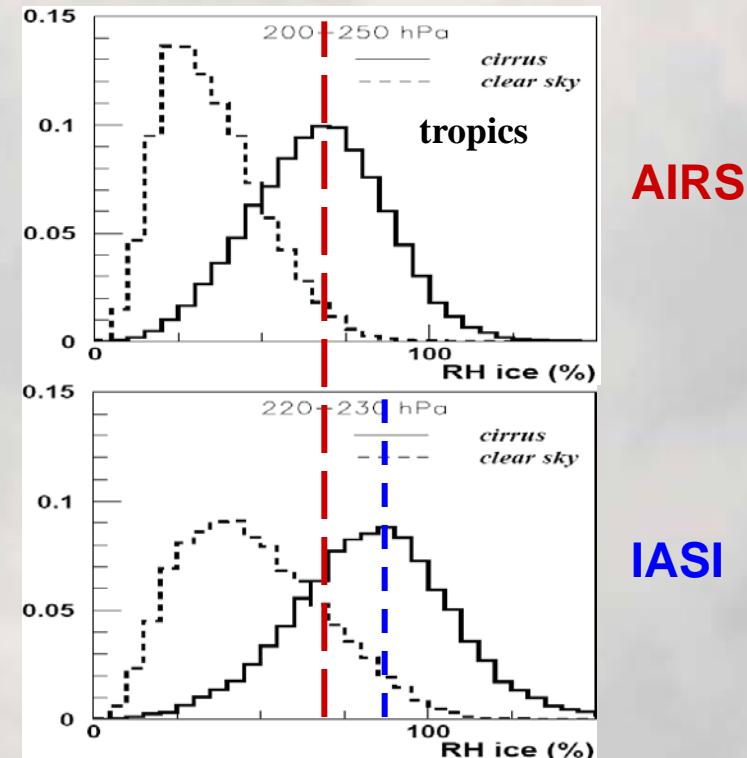
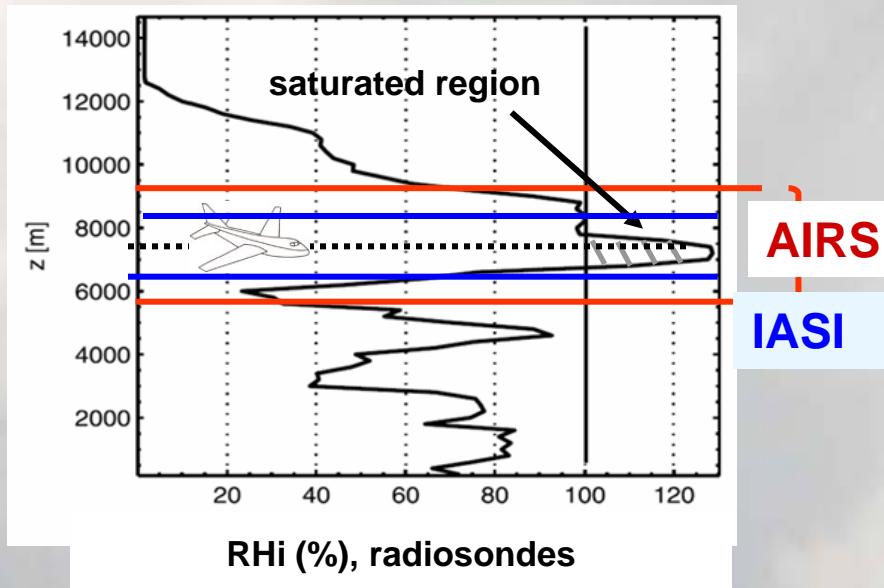


Detection of ice supersaturation (ISS)

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



Conclusions & Outlook

- IR sounders sensitive to cirrus (also for multi-layered cloud systems, day & night)
- p_{cld} corresponds to midlevel of apparent cloud depth (COD<3)
- uncertainty estimation from χ^2 : on average 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 distributed by ICARE: <http://www.icare.univ-lille1.fr/>

➤ 40% of all clouds are high-level clouds

- 70% semi-transparent, 50% pure ice (more aggregates at larger IWP)

Cloud properties from IASI in good agreement with AIRS

- refine cloud detection channels & p(tropopause)

➤ Retrieval of D_e , IWP, ice crystal shape seems to be coherent:

- D_e increases logarithmically with IWP → parameterization for GCM's

➤ Classification of IWC profiles: 80% const & trapezia, lower triangle increases with IWP, radiative effect linked to radiative height

➤ RH_{ice} determined over coarse atmospheric layers

- RH_{ice} of Ci peaks at 70% for AIRS / 85% for IASI (*instead of 100% in-situ*)

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data processing possible thanks to Ether, Icare and ClimServ centers