

Global Cloud Climatologies from satellite-based InfraRed Sounders (TOVS, AIRS and IASI)

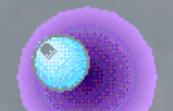
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Atmospheric Radiation Analysis (ARA) team

Atmosphere Biosphere Climate per remote sensing ABC(t)

IPSL - Laboratoire de Météorologie Dynamique, France



I P S L



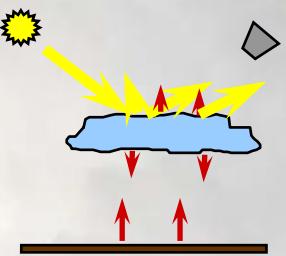
+ A. Baran
MetOffice, UK



(SSP's for cirrus microphysics)

Cloud properties from space:

1) multi-spectral cloud detection 2) cloud property retrieval



Passive remote sensing (>1980)

info on highest cloud layer
good spatial coverage

- CA (*tot, high, midlevel, low*)
- p/z, T, τ_{VIS} / ϵ_{IR}
- horizontal extension
- bulk microphysical properties

Active (A-Train, >2002)

info on all cloud layers
sampling every 1000km

- Z, τ_{VIS}
- vertical extension
- cloud layering
- microphys. prop. profiles

IR sounders :

- good spectral resolution -> esp. reliable Ci properties (day & night)
- atmospheric T, H₂O profiles (RH) + clouds + aerosols

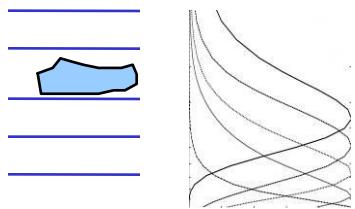
A-Train synergy (AIRS-CALIPSO-CloudSat) :

- choose variables & thresholds for AIRS cloud detection
- AIRS cloud height evaluation -> retrieval transfer to IASI

IR Sounders: TOVS, AIRS, IASI

>1980 NOAA, ≥2002 NASA, ≥2006 CNES

$I_m(\lambda_i)$ along H₂O, CO₂ absorption bands, *good spectral resolution*



Inversion



3I - TOVS

(Scott et al. 1999)

AIRS-L2

(Susskind et al. 2003)

- atmospheric temperature & water vapor profiles, T_{surf}

+ atm. transmissivities from TIGR

min weighted $\chi_w^2(p_k)$
on cloud emissivities
(I_m, I_{cld}, I_{clr}) of CO₂ abs.
channels

- eff. cloud emissivity, cloud pressure (Stubenrauch et al. 1999, 2008, 2010)

+ cirrus emissivities (8 - 12 μm)



simulated LUT

De, IWP

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

Mitchell, Baran

4A-DISORT + SSP of ice crystals



(<http://www.noveltis.fr/4AOP>)

AIRS / IASI cloud property retrieval:

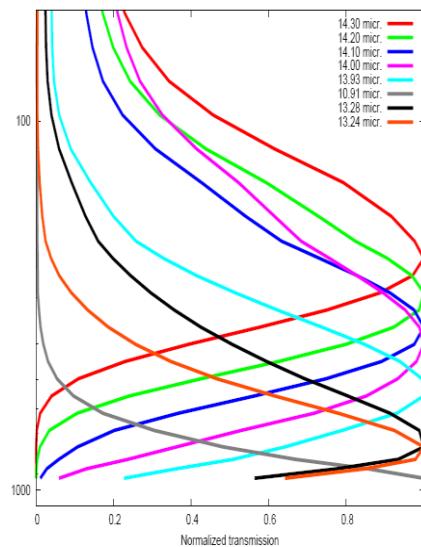
v5



/



L1b radiances I_m



L2 atm. profiles (T, H_2O), T_{surf}

TIGR atm. profiles

proximity recognition

TIGR transmissions

clear / cloudy
radiances I_{clr}, I_{cld}
of TIGR prof. close to obs

surface
emissivities

Pequignot
Seemann

χ^2 minimization

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

$p_{cld}, \varepsilon_{cld}, T_{cld}, Z_{cld}, \varepsilon_{\lambda(=8 - 12 \mu m)}$

v2



CALIPSO L1/L2 data

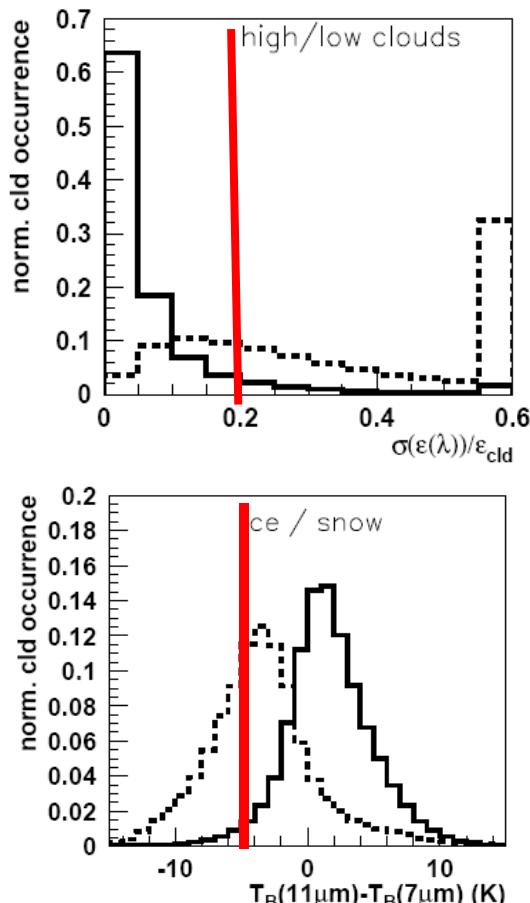
'A posteriori' cloud detection

based on spectral coherence of ε_λ



1) Development of ‘a posteriori’ cloud detection

CALIPSO sampling: (5 km x 0.07 km) in (13.5 km x 13.5 km)



CALIPSO samples indicate reality

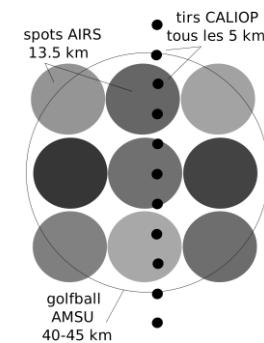
— CALIPSO cloudy
····· CALIPSO clear sky

cloudy:

$$\varepsilon_{\text{cld}} > 0.05$$

$$\sigma(\varepsilon_\lambda)/ \varepsilon_{\text{cld}} < 0.2$$

& over land: $T_{\text{cld}} - T_{\text{surf}} > -3\text{K}$



ice/snow (*detected by microwave*):

$$\sigma(\varepsilon_\lambda)/ \varepsilon_{\text{cld}} < 0.3 \text{ & } T_B(11\mu\text{m}) - T_B(7\mu\text{m}) > -5\text{K}$$

similar to MODIS-ST

Cloud detection comparison & sensitivity:

agreement with CALIPSO: 85 (80) % over ocean (sea ice)
75 (70) % over land (snow)

what is a cloudy AIRS footprint?

global CA : 66 % (*0% for not cloudy*) - 74% (*30% for not cloudy*)
HCA/CA: 40% - 36% **LCA/CA:** 42% - 47%

agreement with LMD multi-spectral cloud detection (ΔT_B):

(for determination of trace gases, aerosols & surface emissivity)

70% over ocean (30°N-30°S)
72% over land (30°N-30°S)

Multi-spectral cloud detection about 15% more cloudy footprints
(lowlevel cloud fields)

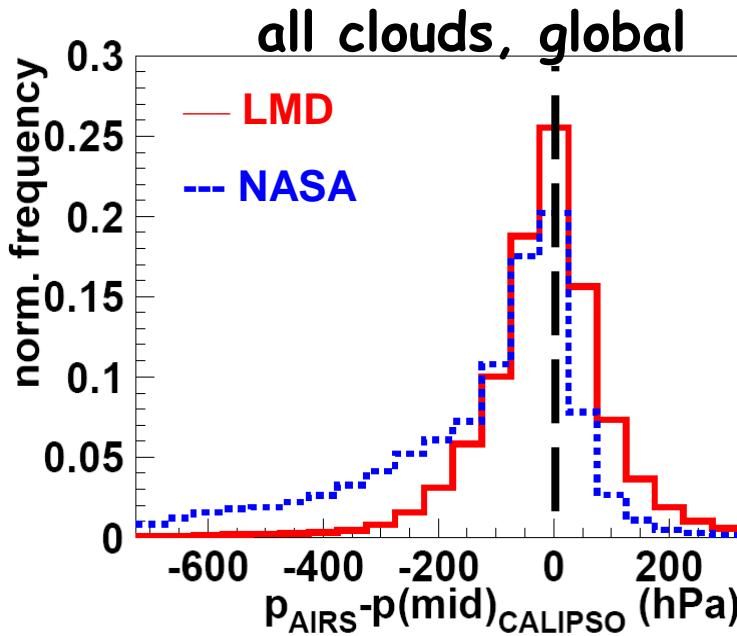
for IASI see also poster of Lydie Lavanant



A-Train: synergy of passive & active instruments

2) Evaluation of AIRS cloud height with CALIPSO

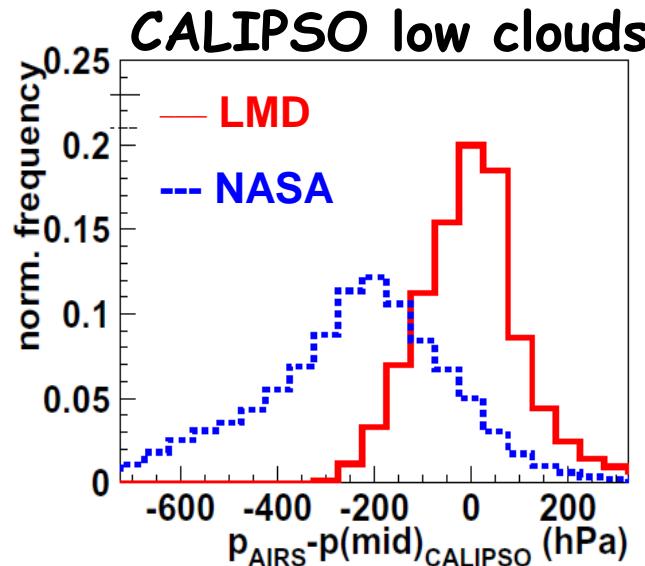
(highest cloud, detected at $\leq 5\text{km}$)



Stubenrauch *et al.* 2008

in agreement with Kahn *et al.* 2008

good agreement with CALIPSO cld midlevel
(or pos. of max. backscatter)
properties also depend on retrieval method





A-Train: synergy of passive & active instruments

3) Vertical extent (Δz) of high opaque clouds / Ci / thin Ci

AIRS: cloud type

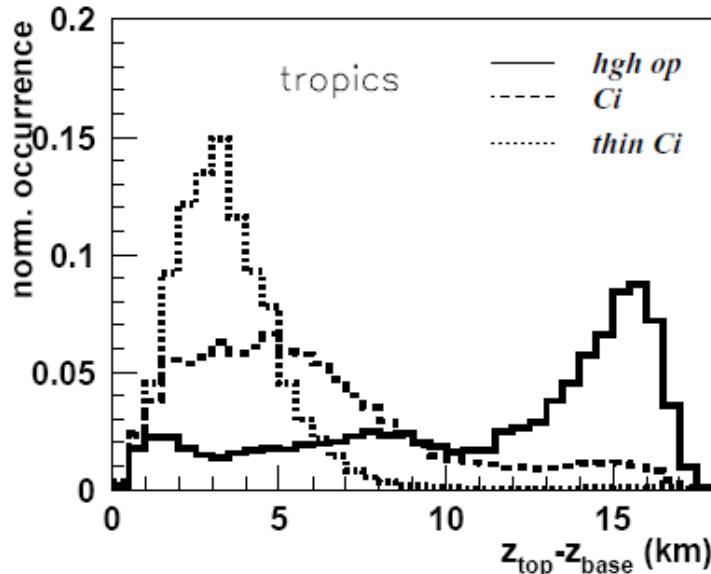
CALIPSO: 'apparent' geometrical cloud thickness

CloudSat: real geometrical cloud thickness

Winker / Mace et al. 2009

GEOPROF data

Cloudsat.cira.colostate.edu

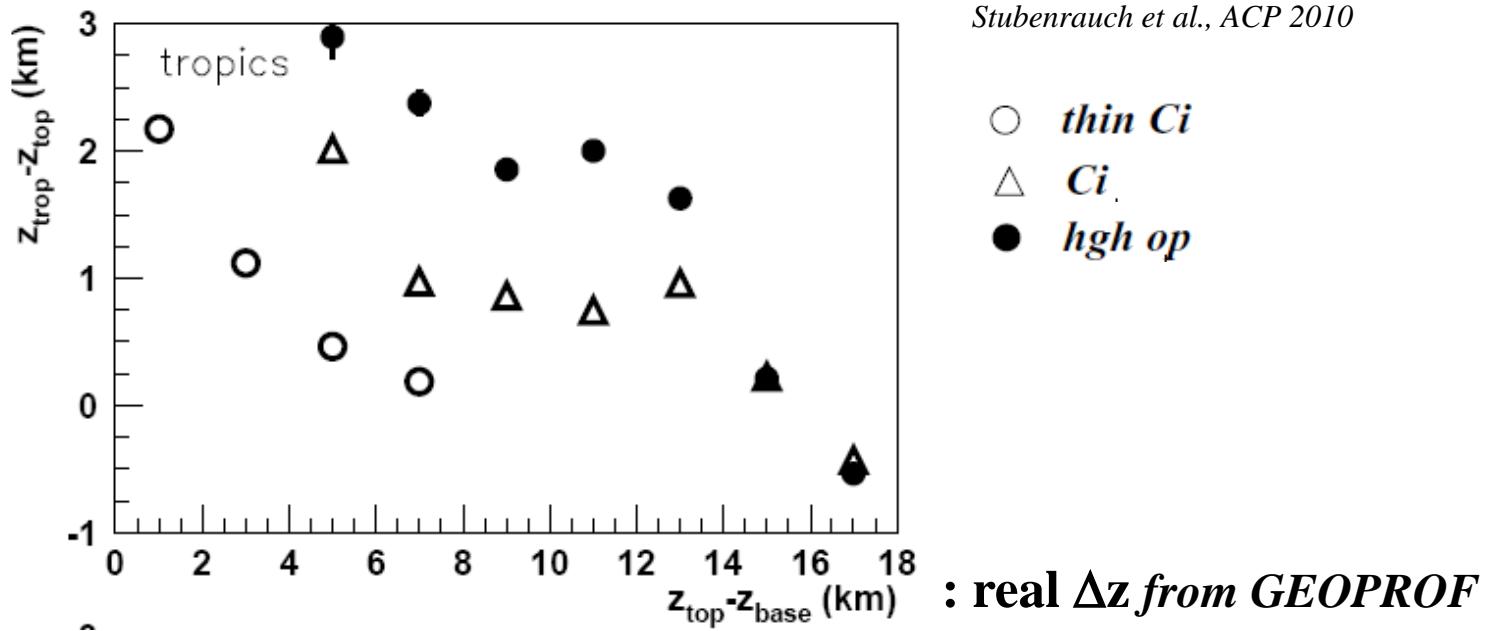


- $\Delta z(\text{thin Ci}) < \Delta z(\text{Ci}) < \Delta z(\text{high op})$
- real Δz much larger than apparent Δz for high opaque cloud
- good quality of AIRS cloud type identification



A-Train: synergy of passive & active instruments

4) Cloud height relative to tropopause



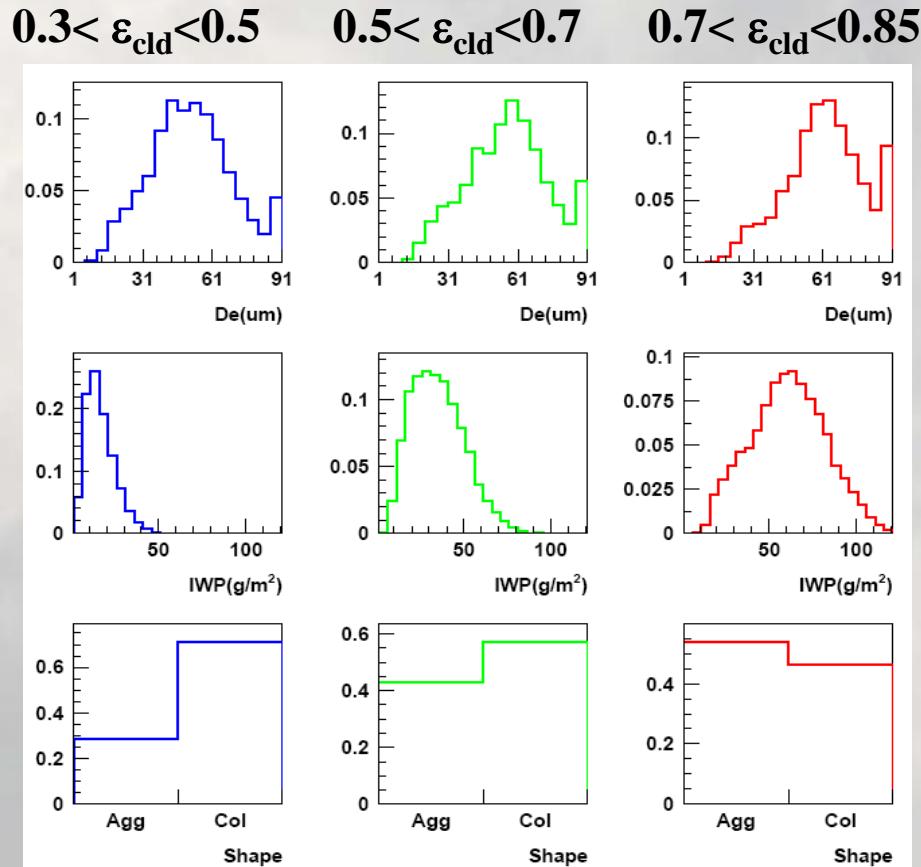
Tropics: only the very thickest opaque clouds (& surrounding anvils) penetrate stratosphere

Rossow & Pearl 2007: larger, organized, convective systems penetrate

Retrieval of bulk microphysical properties of semi-transparent Ci

based on spectral difference of cirrus emissivity

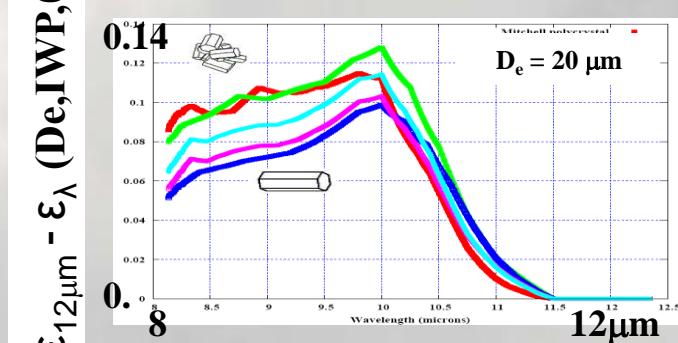
single layer cirrus (detected by CALIPSO), 2 year averages



De & IWP increase with ε_{cld}

optically thicker cirrus
include
more aggregates

4A-DISORT simulation

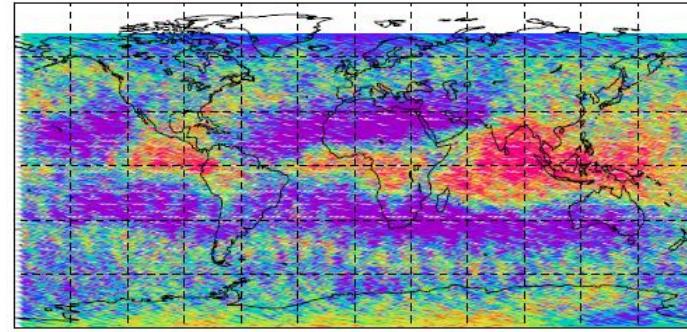
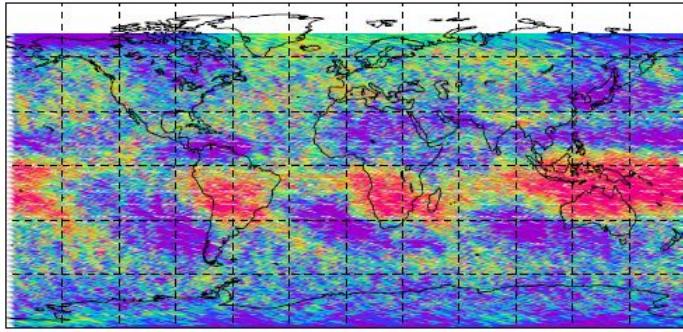


HCA geographical distributions

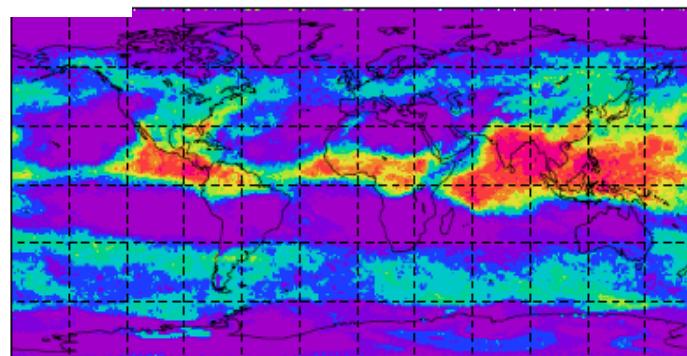
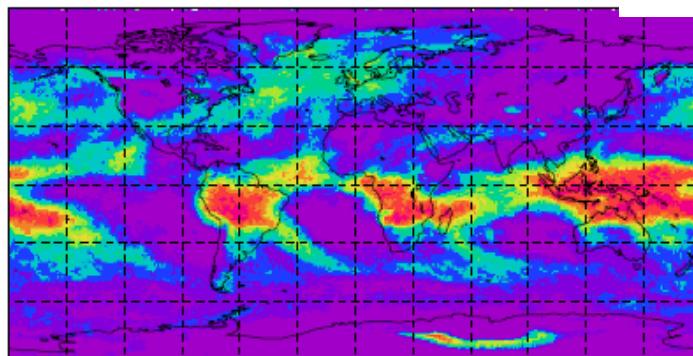
Januarv

CALIPSO

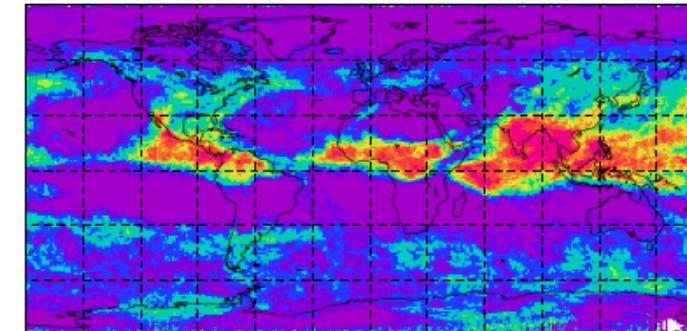
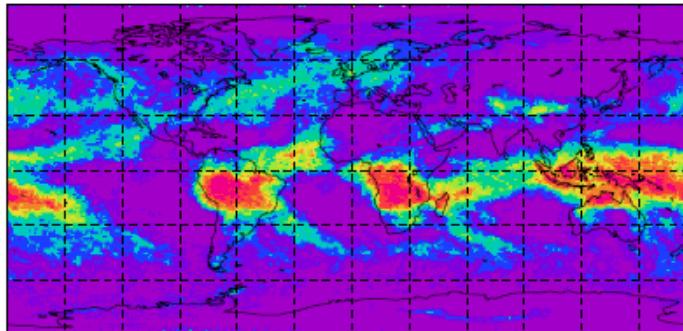
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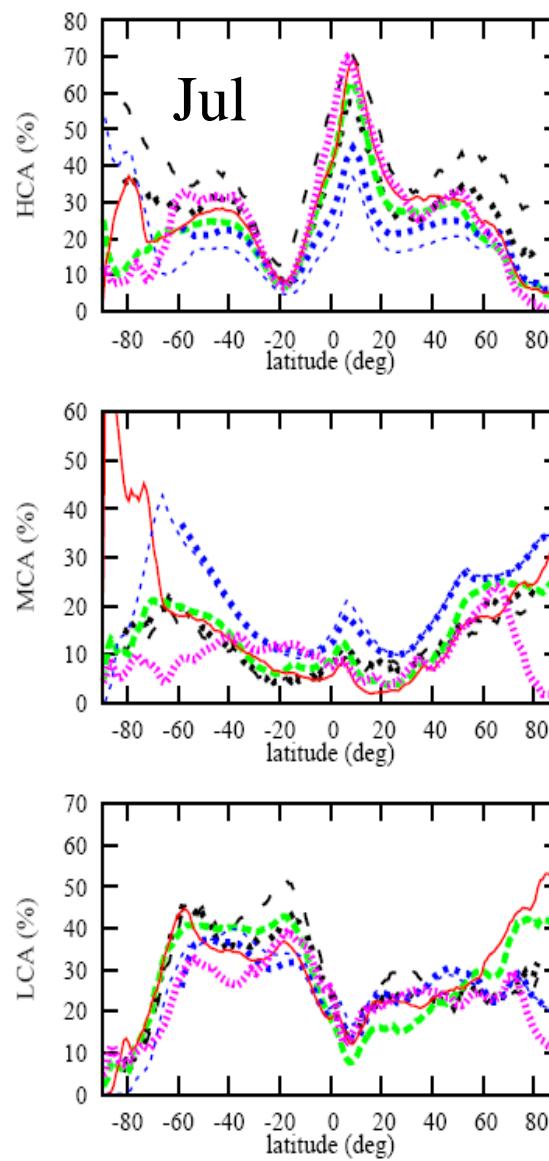
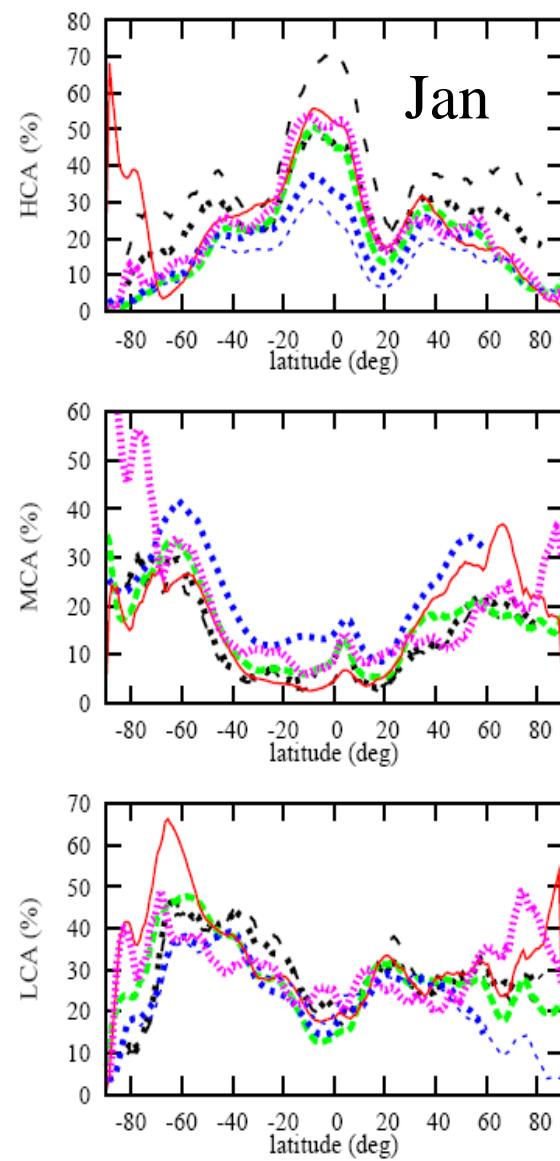
IASI-LMD



AIRS-LMD



Zonal averages of HCA, MCA and LCA



CALIPSO	2007-2008
ISCCP	1984-2004
TOVS-B	1987-1995
AIRS	2003-2008
IASI	2008

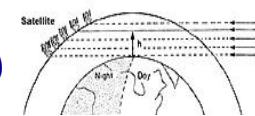
*IASI preliminary:
use of av. AIRS L2 atm. profiles*

latitudinal behavior similar
HCA/CA:
CALIPSO highest
TOVS ~ AIRS ~ IASI
ISCCP lowest
LCA/CA:
agreement,
except at higher latitudes

CALIPSO	- - -	ISCCP	-----
CALIPSO 5km	· · · ·	TOVS-B	—
AIRS-LMD	- - - -	AIRS	- - -
		LMD-08	······

Longterm cloud climatologies:

*ISCCP GEWEX cloud dataset	1984-2007	(Rossow <i>et al.</i> 1999)
PATMOS-x AVHRR	1981-2007	(NESDIS/ORA; Heidinger)
*TOVS Path-B 7h30/19h30	1987-1995	(Stubenrauch <i>et al.</i> 2006)
HIRS-NOAA 13h30/1h30	1985-2001	(Wylie <i>et al.</i> 2005)
SAGE limb solar occultation	1984-2005	(Wang <i>et al.</i> 1996, 2001)
SOBS Surface OBSevations	1952-1996	(Hahn & Warren 1999; 2003)



EOS cloud climatologies (since 2001, 2002):

MODIS-ST (Ackerman <i>et al.</i> ; Platnick <i>et al.</i>)	*MODIS-CE (Minnis <i>et al.</i>)
*AIRS-LMD (Stubenrauch <i>et al.</i> 2008, 2010)	MISR (DiGirolamo)

+ A-Train (since 2006):

CALIPSO (Winker <i>et al.</i> 2007, 2009)	CloudSat (Mace <i>et al.</i> 2009)
GOCCP (Chepfer <i>et al.</i> 2009)	POLDER (Riedi)

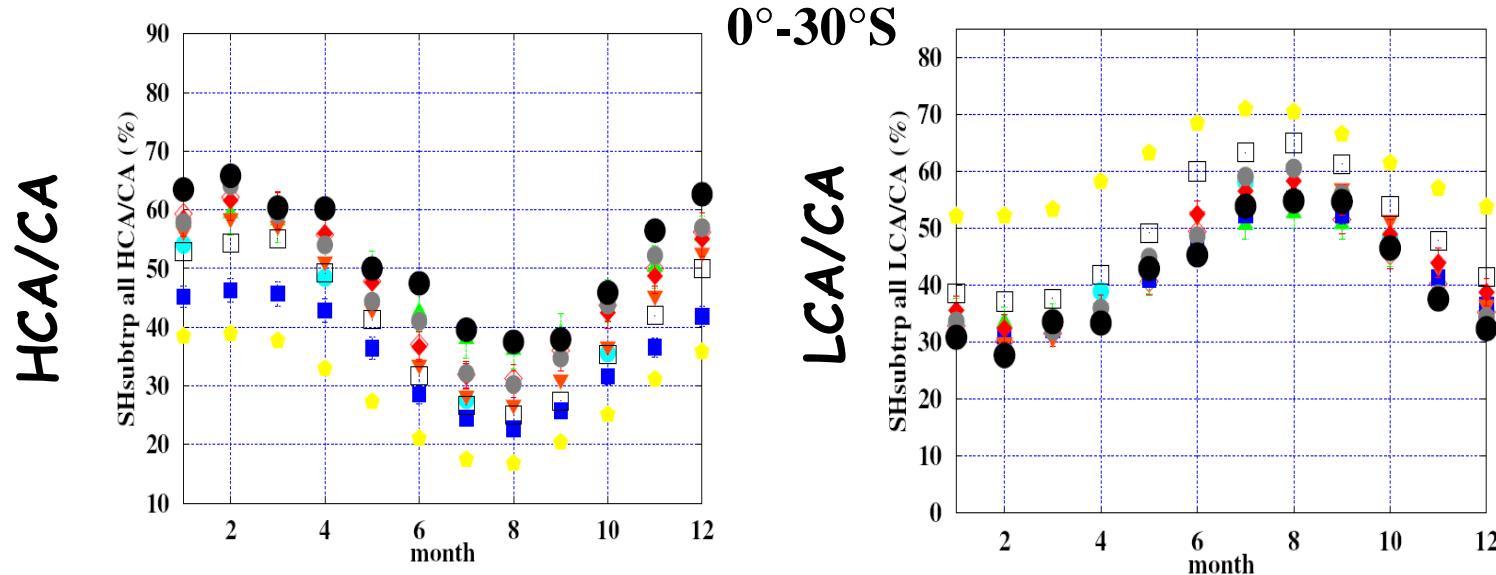
***ATSR-GRAPE ERS, 1997-2000** (Poulsen)

netCDF data
 * most complete variables

seasonal cycle of HCA/CA & LCA/CA

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

Stubenrauch et al. 2009, GEWEX news



CALIPSO: highest cloud layer

CALIPSO Winker	SAGE Wang	AIRS	HIRS-NOAA	TOVS-B	ISCCP Rossow	PATMOS-x Heidinger	MODIS-ST Ackerman	MODIS-CE Minnis
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seasonal cycles in agreement

HCA/CA: CALIPSO > SAGE/TOVS/AIRS > MODIS-CE/PATMOS > ISCCP> MODIS-ST

LCA/CA: within 10%, MODIS-ST larger (misidentification of thin cirrus)

- ❖ IR sounders passive instruments most sensitive to cirrus
- ❖ A-Train: unique possibility to evaluate IR sounder retrieval & to give insight into vertical structure of different cloud types
- ❖ TOVS Path-B (1987-1994) & AIRS-LMD (2003-2008) cloud climatologies participate in GEWEX Cloud Assessment:

monthly mean cloud parameters (CA, HCA, MCA, LCA, T_{cld} , ε , τ , D_{eff} , WP), variabilities, histograms, uncertainties will be available in netcdf at:

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

next meeting 22-25 June 2010 in Berlin

- ❖ first results for IASI encouraging
- ❖ more detailed checking necessary
- ❖ replace AIRS L2 atmosph. profiles by IASI L2 profiles
- ❖ prepare retrieval of Ci microphysical properties

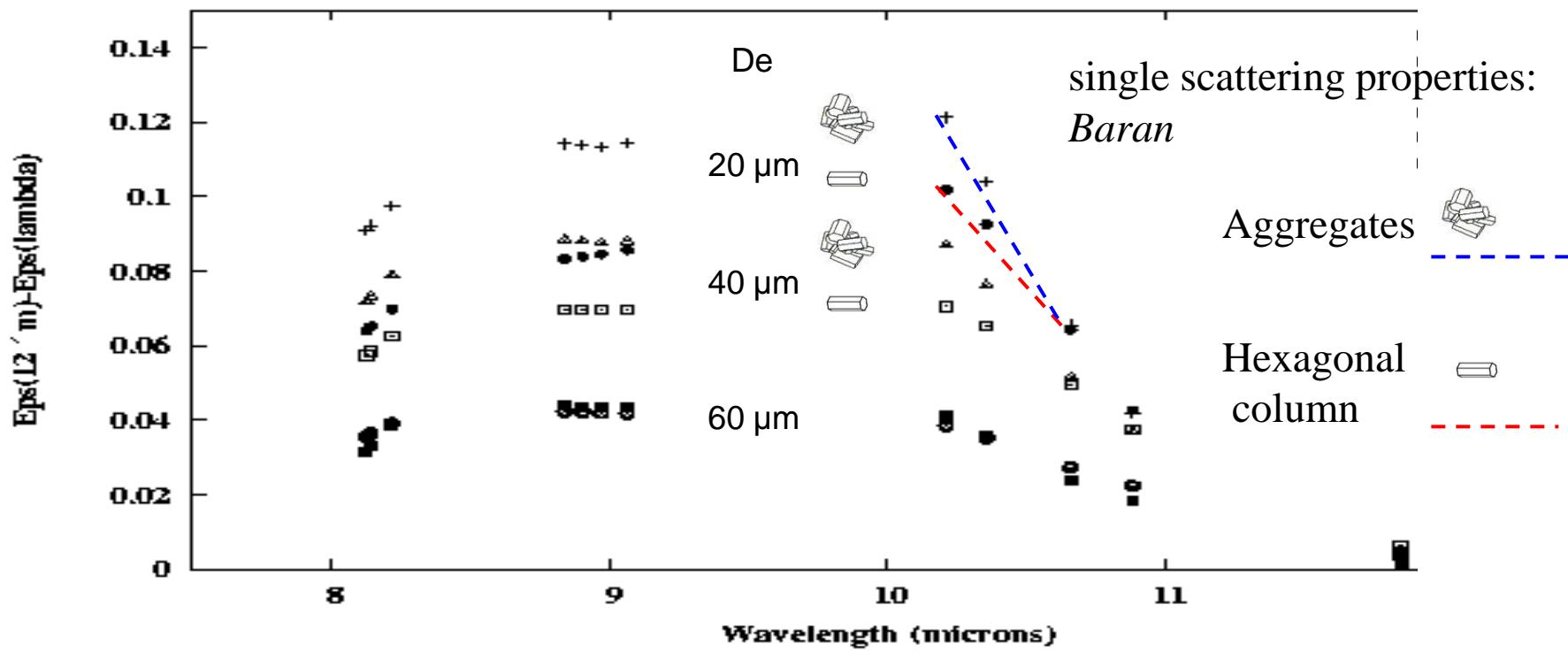


D_e , IWP & crystal shape retrieval with AIRS

based on spectral emissivity difference

for $0.3 < \varepsilon_{11\mu\text{m}} < 0.85$ sensitivity up to $D_e \leq 80\mu\text{m}$
 $0.7 < \tau_{\text{VIS}} < 3.8$

4A-DISORT simulation of radiances: I_{clr} , I_{cld} , I_{meas} $7 < D_e < 90\mu\text{m}$, $1 < \text{IWP} < 130\text{ g.cm}^{-2}$



CALIPSO: distinguish single layer clouds



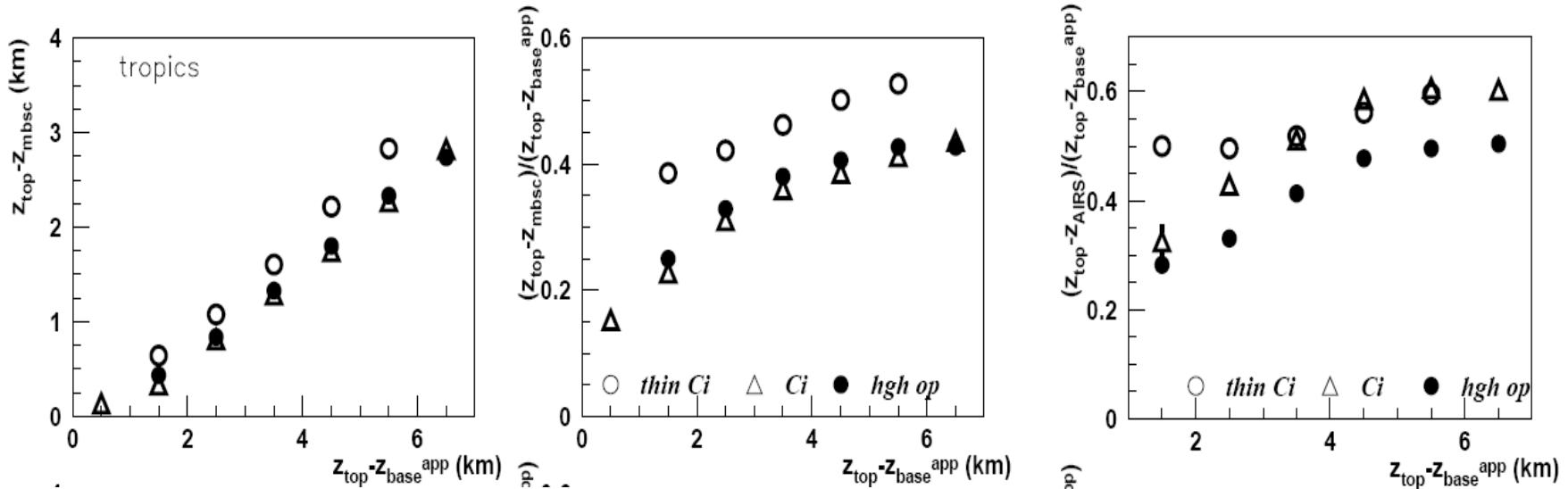
A-Train: synergy of passive & active instruments

Vertical insight into high opaque clouds / Ci / thin Ci

AIRS: cloud type

CALIPSO: ‘apparent’ geometrical cloud thickness, position of max. backscatter

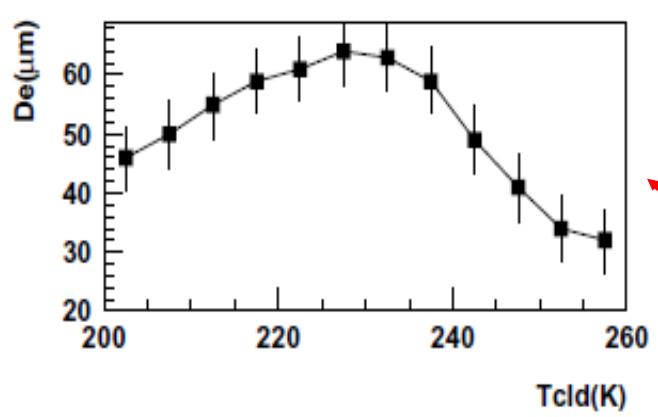
CloudSat: real geometrical cloud thickness



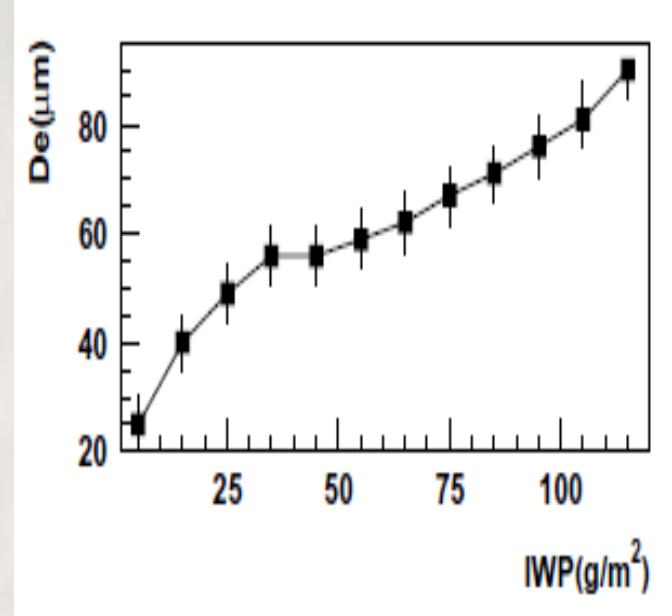
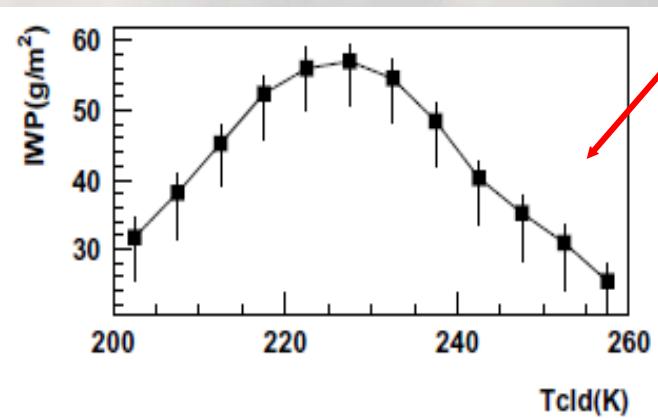
even for high opaque clouds, position of max backscatter depends on ‘apparent’ Δz
and can reach 3 km below cloud top

‘radiative’ height lies about 5% below pos. of max backscatter, for thin clds lower

single layer cirrus over ocean, 2 year averages



probably ice/liquid



D_e & IWP smaller for cold cirrus

D_e increases with IWP

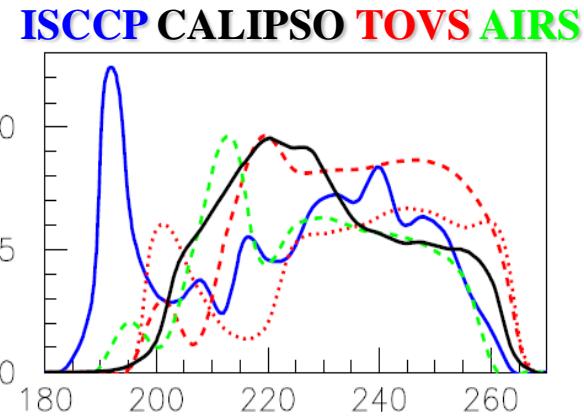
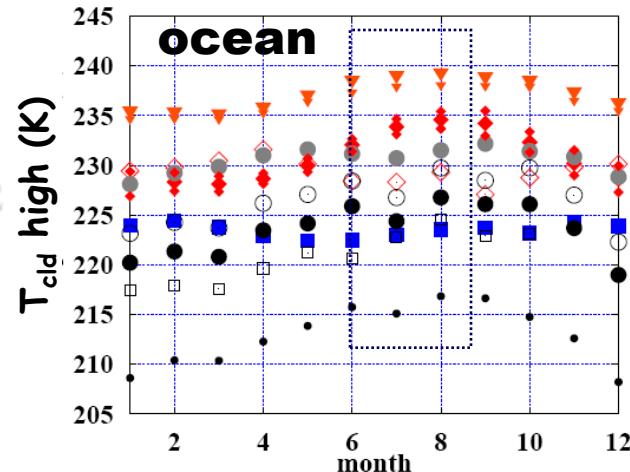
(similar to Stubenrauch *et al.* 2004, 2007)

SH

 0° - 30°

Tropical high clouds: T_{cld} distributions

TOVS-B (red)
ISCCP (blue)
PATMOSX
MODIS-CE (orange)
AIRS (grey)
CALIPSO:
 all (black dots)
 $\tau > 0.1$ (black circles)
 $\tau > 0.2$ (open circles)



Clouds in tropics have diffuse cloud tops:

CALIPSO max backscatter $\geq 1\text{km}$ below cloud top

AIRS-LMD:
 — $\varepsilon_{\text{cld}} > 0.95$
 --- $0.95 > \varepsilon_{\text{cld}} > 0.50$
 $0.50 > \varepsilon_{\text{cld}} > 0.05$

