Global Cloud Climatologies from satellite-based InfraRed Sounders (TOVS, AIRS and IASI) + Synergy AIRS–CALIPSO–CloudSat

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Cloud properties from space:

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

**Passive remote sensing (>1980)**
- info on uppermost cloud layer
- good spatial coverage

  • CA (tot, high, midlevel, low)
  • p/z, T, $\tau_{\text{VIS}} / \varepsilon_{\text{IR}}$
  • horizontal extension
  • bulk microphysical properties

**Active (A-Train, >2002)**
- info on all cloud layers
- sparse sampling (track/1000km)

  • z, $\tau_{\text{VIS}}$
  • vertical extension
  • cloud layering
  • microphys. prop. profiles

**IR sounders**:
- good spectral resolution -> esp. reliable Ci properties (day & night)
- atmospheric $T$, $H_2O$ 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 CO$_2$, H$_2$O absorption bands, good spectral resolution

Inversion

- atmospheric temperature & water vapor profiles, $T_{surf}$
- eff. cloud emissivity, cloud pressure (Stubenrauch et al. 1999, 2008, 2010)
+ cirrus emissivities (8 - 12 µm)

$\min \text{weighted } \chi^2(p_k)$
$\varepsilon(p_k) = \sum_{i=1}^{N} \frac{I_m(\lambda_i) - I_{clr}(\lambda_i)}{I_{cld}(p_k, \lambda_i) - I_{clr}(\lambda_i)}$

+ atm. transmissivities from TIGR
Thermodynamic Initial Guess Retrieval
<- 4A radiative transfer <- radiosondes
(http://www.noveltis.fr/4AOP)

$De, IWP$
(CIRAMOSA, Rädel et al. 2003, Stubenrauch et al. 2004)

$4A$-DISORT + SSP of ice crystals
Mitchell, Baran

talk A. Guignard, Friday 14h, session AS3.3
HCA geographical distributions

January ISCCP July

1984-2004

TOVS Path-B

1987-1995

AIRS-LMD

2003-2008
HCA geographical distributions

**January**

2007-2008

**CALIPSO**

July

1987-1995

**TOVS Path-B**

2008

**IASI-LMD**

May 2010

**Color Scale:**

10 20 30 40 50 60 70 80 90
Comparison with other data sets:

Stubenrauch et al. 2009, GEWEX news

**HCA/CA:** compares well (except polar regions)

**LCA/CA:** MODIS-ST larger (misidentification of thin cirrus)

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**CALIPSO:** highest cloud layer

**CALIPSO** > SAGE/TOVS/AIRS > MODIS-CE/PATMOS > ISCCP > MODIS-ST

**seasonal cycles agree well** (except polar regions)

**HCA/CA:** depends on sensitivity to thin cirrus

**LCA/CA:** agrees quite within 10%
Zonal averages of HCA & zonal $p_{\text{cld}}$ distributions

Latitudinal behavior similar; CALIPSO > TOVS ~ AIRS ~ IASI > ISCCP
A-Train Synergy: AIRS-CALIPSO-CloudSat

1) Evaluation of AIRS cloud height
2) Vertical extent (Δz) of high opaque clouds / Ci / thin Ci
3) Vertical insight into high opaque clouds / Ci / thin Ci
4) Cloud height relative to tropopause

Stubenrauch et al. ACP Disc. 2010
1) Evaluation of AIRS cloud height with CALIPSO

(highest cloud, detected at ≤5km)

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

also in agreement with Kahn et al. 2008
A-Train: synergy of passive & active instruments

2) Vertical extent ($\Delta z$) of high opaque clouds / Ci / thin Ci

- **AIRS**: cloud type
- **CALIPSO**: ‘apparent’ geometrical cloud thickness
- **CloudSat**: real geometrical cloud thickness

$\Delta z$ for high opaque cloud much larger than apparent $\Delta z$ for high opaque cloud

Good quality of AIRS cloud type identification

$\Delta z$ (thin Ci) < $\Delta z$ (Ci) < $\Delta z$ (hgh op)

GEOPROF data
Cloudsat.cira.colostate.edu

Winker / Mace et al. 2009

May 2010 EGU, Vienna
3) 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

- Position of max backscatter depends on ‘apparent’ $\Delta z$  
- & can reach 2 km below cloud top, even for high opaque clouds  
- Rel. position less dependent, 1/3 – 1/2 below top (thin Ci)  
- ‘Radiative’ height lies about 1/2 below top, for all cloud types

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**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
IR sounders passive instruments most sensitive to cirrus:
- 40% of all clouds are high clouds (50% if including subvis Ci)
- more high clouds over land than over ocean
- 40% of all clouds are single-layer low clouds

A-Train: unique possibility to evaluate IR sounder retrieval & to give insight into vertical structure of different cloud types


monthly mean cloud parameters ($CA, HCA, MCA, LCA, T_{cld}, \varepsilon, \tau, D_{eff}, WP$), 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

<table>
<thead>
<tr>
<th>TOVS-B</th>
<th>TOVS-R</th>
<th>AIRS</th>
<th>IASI ($1,2,3$), IASI-NG</th>
<th>~2020</th>
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