Cloud climatologies from satellite-based infrared soundings: a new 5-year dataset derived from AIRS

S. Cros, C. Stubenrauch, R. Armante, A. Chédin, N. Scott

CNRS / IPSL - Laboratoire de Météorologie Dynamique, Palaiseau, France.

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Clouds properties from IR sounders

IR sounders : high spectral resolution

=> more sensitive to semi-transparent cirrus than ISCCP (day + night)

8 year (1987-1995) TOVS Path-B (ISCCP)

<table>
<thead>
<tr>
<th></th>
<th>globe</th>
<th>NH midlat.</th>
<th>tropics</th>
<th>SH midlat.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cirrus amount (%)</td>
<td>27 (19)</td>
<td>25 (20)</td>
<td>45 (25)</td>
<td>22 (17)</td>
</tr>
</tbody>
</table>

High cloud amount geographical distributions

January

July

TOVS Path-B

ISCCP

(%)
AIRS (Atmospheric InfraRed Sounder) on Aqua
L2 atmospheric profiles at 45 km spatial resolution (Susskind et al. 2003)
at LMD: cloud property retrieval ($p_{cld}$ $e_{cld}$) at **13 km** spatial resolution.
Available since may 2002

CALIPSO: active lidar, only nadir viewing
L2 cloud products at 5 km spat. resolution: **nb cld layers**, $p_{top}$, $p_{base}$
footprint $\sim$70 m x 70 m, orbits every 1000 km, vertical resolution 60 m
(sensitive to very thin cirrus)  Available since aug 2006
**AIRS cloud properties retrieval**

Based on TOVS Path-B retrieval *(Stubenrauch et al. J. Climate 1999):*

- use AIRS L2 atmospheric profiles *(Susskind et al. 2003)* to find closest TIGR atm (monthly averaged profile is used when instant profile is not available)
- compute \( I_{\text{cld}} \) and \( I_{\text{clr}} \) from L2 temperature profiles and TIGR transmissivities
- compute eff. cloud emissivity for 30 pressure levels:
  (using 5 channels along the 15 \( \mu \text{m} \) \( \text{CO}_2 \) absorption band)
  \[
  \varepsilon(p_k) = \sum_{i=4}^{8} \frac{I_m(\lambda_i) - I_{\text{clr}}(\lambda_i)}{I_{\text{cld}}(p_k, \lambda_i) - I_{\text{clr}}(\lambda_i)}
  \]
- minimize weighted \( \chi^2 (p_k) \) \( \Rightarrow p_{\text{cld}}, \varepsilon \)
  (weights take into account temp. profiles uncertainties)

**a posteriori cloud detection**: rejection of cases with non-physical emissivities and with low T contrast (\( T_{\text{cld}} - T_{\text{surf}} \))
Evaluation of AIRS cloud height with CALIPSO

Stubenrauch et al. 2008 (JGR, in press)

good agreement with CALIPSO midlevel of cloud \((\text{highest with } \tau > 0.1)\)
slightly broader distributions for optically thinner clouds, but no bias

\(\Delta z_{\text{mid}}(\text{AIRS-CALIPSO}) \pm 1.5 \text{ km}:\)
High: 51%  55%  66%
Low: 70%  74%  80%

\(\Delta p_{\text{mid}}(\text{AIRS-CALIPSO}) \pm 75 \text{ hPa}:\)
High: 72%  81% (thick); 63% (thin)
Low: 59%  69%  ; 38%

hghst / hghst w \(\tau > 0.1 / \text{ closest layer} \)
AIRS cloud retrieval sensitivity tests

- all spots (13.5 km) for retrieval
- multispectral cloud detection
- a posteriori cloud detection
- 6 channels
- 45 km resolution

Cloud detection:
- Only small effect on HCA,
much stronger on LCA

Better spatial resolution:
- Slightly less HCA and LCA

Use of monthly av. profile
Comparison with other datasets

- CALIPSO (2007)
- AIRS-LMD (2007)
- TOVS Path-B (87-95)
- ISCCP (84-04)

AIRS results very close to TOVS Path-B
IR sounder HCA between CALIPSO & ISCCP
LCA in good agreement
Comparison with retrieval method used for AIRS Level 2 data

single layer AIRS-L2 clouds

AIRS-L2 low clouds show a strong bias in cloud height !!!
A 5-year dataset of AIRS cloud data

ISCCP-D2 (198307-200706) Mean Cloud Amount (%): Deviations and Anomalies Of Region Monthly Mean From Total Period Mean

GLOBAL Monthly Mean = 66.42 ± 1.48%
GLOBAL Deviation Mean = 0.00 ± 1.48%
GLOBAL Deseasonalized Anomaly Mean = -0.00 ± 1.34%

AIRS cloud amount anomalies from 2003 to 2008

AIRS-LMD Cloud amount stable within 1% (30N-30S), 1h30AM
**GEWEX cloud assessment**

**Longterm cloud climatologies:**

<table>
<thead>
<tr>
<th>Dataset</th>
<th>GEWEX cloud dataset</th>
<th>Period</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISCCP</td>
<td></td>
<td>1983-2006</td>
<td>(Rossow et al. 1999)</td>
</tr>
<tr>
<td>PATMOS-x</td>
<td>AVHRR</td>
<td>1981-2006</td>
<td>(NESDIS/ORA; Heidinger)</td>
</tr>
<tr>
<td>HIRS-NOAA</td>
<td>13h30/1h30</td>
<td>1985-2001</td>
<td>(Wylie et al. 2005)</td>
</tr>
<tr>
<td>TOVS Path-B</td>
<td>7h30/19h30</td>
<td>1987-1995</td>
<td>(Stubenrauch et al. 2006)</td>
</tr>
</tbody>
</table>

**EOS cloud climatologies (since 2000, 2002):**

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>MODIS-ST (Ackerman et al.; Platnick et al.)</td>
<td></td>
</tr>
<tr>
<td>MODIS-CE (Minnis et al.)</td>
<td></td>
</tr>
<tr>
<td>AIRS-LMD (Stubenrauch et al. 2008)</td>
<td></td>
</tr>
<tr>
<td>(AIRS-L2 (Susskind et al.2003) )</td>
<td></td>
</tr>
</tbody>
</table>

**A-Train (since 2006):**

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>CALIPSO L2 data (V2) (Winker et al.)</td>
<td>active lidar</td>
</tr>
</tbody>
</table>

**Cloud Assessment co-chairs:**

C. Stubenrauch, S. Kinne

http://climserv.ipsl.polytechnique.fr/gewexca
Seasonal cycles: HCA/CA

0°-30°N

0°-30°S

CALIPSO
SAGE
HIRS-NOAA
TOVS-B
AIRS-LMD
ISCCP

PATMOS-x
MODIS-ST
MODIS-CE
Monthly means of cloud temperatures (high and low clouds)

NH Subtropics

NH mid-latitudes

TOVS-B
ISCCP
AIRS
CALIPSO $\tau > 0.1$
Conclusion and outlook

**AIRS–LMD cloud property retrieval:**
- AIRS-LMD cloud height = CALIPSO height of middle of the cloud, whereas low clouds in AIRS-L2 data show strong bias (~200 hPa)
- Reliable a-posteriori cloud detection (down to Tcld – Tsurface < -4.5 K for lowest clouds)
- Cloud type amounts compatible with previous IR sounder data
- Retrieval stable over 5 years

**Outlook:**
- Geographical extension (mid-latitudes and polar areas)
- Improve vertical resolution for cloud height solutions (adding IR CO2 band channels and TIGR atm profiles with higher vertical resolution)
- Semi-transparent cirrus microphysical properties retrieval
- Cloud retrieval application on new sounder data (IASI on Metop)