Survey of atmospheric and cirrus properties using longterm datasets (TOVS Path-B, ISCCP)

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Longterm global satellite climatologies

- ISCCP: cloud & surface properties
- TOVS: cloud, atmospheric & surface properties
  data reanalysis

Cirrus <-> atmospheric properties

- regional and seasonal variations
- compared to results of measurement campaigns (INCA)
- correlations to volcanic eruptions and cosmic ray intensity
- longterm variability?
Longterm global cloud climatologies

Imagers on geostationary and polar satellites: since 1983

ISCCP (Rossow et al., BAMS Nov 1999) 1983-2001

♦ 2 radiances during daylight (1 IR + 1 VIS)
♦ every 3 hours, 5 km resolution sampled to 30 km, 2.5°

CA, T_{cld}, \tau, p_{cld}

TOVS vertical sounders on polar satellites: since 1979

Path-B (Scott et al., BAMS Dec 1999) \ldots, 1987-1995,\ldots

♦ good spectral resolution (HIRS:19 IR, 1 VIS, MSU: 4 \mu w)
♦ every 6 hours, 20 km resolution, averaged over 1°

CA, p_{cld}, N_e, T_{cld}


♦ Near-nadir, sampled HIRS observations
**3I Inversion** (Chédin, Scott 1985)

T, H₂O profiles + cloud properties

Based on: controlled use of a priori information

T(pₖ), H₂O(pₖ), Tₛ from radiosondes

4A radiative transfer

R_{clr}(λᵢ,θ), R_{cld}(λᵢ,pₖ,θ) per airmass (5), land – sea

**MSU+HIRS** \( R_m(λᵢ,θ) \) along H₂O, CO₂ absorption bands

**TIGR** dataset

*Thermodynamic Initial Guess Retrieval*
Extension of TOVS Path-B database

- Collocate **ERA40** radiosonde collection with TOVS (100 km, 3h)

- Identify *clear sky* scenes

- Computation of **bias corrections** $T_{\text{obs}}(\lambda_i) - T_{\text{calc}}(\lambda_i)$ using improved 3R (*seasonal averages*)

- Comparison with NOAA - DSD5 dataset

- Reanalysis
TOVS multispectral cloud detection

**MSU probes through clouds**

\[ |T_B(\text{MSU}_2) - \Sigma b_i T_i(\sim 15\mu m)| > 1.5K \]

peak: 700hPa 100, 400, 600, 800, 900hPa

Cloud property retrieval (from averaged radiances)

4 channels in 14\(\mu\)m \(CO_2\)-band + 11 \(\mu\)m
max weights: 400-900 hPa surface

\[ N_{\varepsilon}(p_k) \text{ coherence} \]

\[ N_{\varepsilon}(p_k) = \sum_{i=4}^{8} \frac{R_m(\lambda_i) - R_{cl}(\lambda_i)}{R_{cl}(p_k,\lambda_i) - R_{cl}(\lambda_i)} \]

\[ \min \chi_w^2(p_k) \rightarrow p_{\text{cl}, N_{\varepsilon}} \]

(Stubenrauch et al.1999)
Average regional cloud properties

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

<table>
<thead>
<tr>
<th>Cloud type amounts (%)</th>
<th>NH midlat.</th>
<th>tropics</th>
<th>SH midlat.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep convection</td>
<td>3.0</td>
<td>3.3</td>
<td>2.5</td>
</tr>
<tr>
<td>Cirrus</td>
<td>24.7</td>
<td>20.3</td>
<td>44.8</td>
</tr>
<tr>
<td>Mid-level</td>
<td>16.2</td>
<td>22.5</td>
<td>4.1</td>
</tr>
<tr>
<td>Low-level</td>
<td>27.1</td>
<td>26.4</td>
<td>20.6</td>
</tr>
</tbody>
</table>

IR vertical sounders:
identify Ci day + night
more sensitive to Ci: globe +8%
                   midlat. +4%
                   tropics +20%
High clouds not observed by radiometers

**SAGE II:** 1984 – 1991,  **SAGE III:** since 2002

*Limb occultation sunrise / sunset at 1µm, 0.5 µm, (7 / 11 λ’s)*

*Path: 200km   (x 2.5 km)*

<table>
<thead>
<tr>
<th>L (km)</th>
<th>High cloud amount (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>January / July</strong></td>
</tr>
<tr>
<td>200</td>
<td>74.6 / 69.0</td>
</tr>
<tr>
<td>75</td>
<td>32.1 / 29.7</td>
</tr>
</tbody>
</table>

**ISCCP-SAGE => L=75 km**  
(Liao et al. 1995)

**HIRS-SAGE => L=130 km**  
(Wylie + Wang 1997)

<table>
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<th>subvisible Ci</th>
<th>Cirrus</th>
</tr>
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<tr>
<td><strong>January / July</strong></td>
<td><strong>January / July</strong></td>
</tr>
<tr>
<td>200</td>
<td>24.4 / 22.5</td>
</tr>
<tr>
<td>75</td>
<td>10.5 / 9.3</td>
</tr>
</tbody>
</table>

1/3 of high clouds: subvisible Ci
*(not observed by radiometers)*

\[ CA_{\text{high SAGE}} > CA_{\text{high TOVS}} > CA_{\text{high ISCCP}} \]

C. Stubenrauch  
Final CIRAMOSA meeting 20-21/11/2003
Time series of TOVS Path B high cloud frequencies

NOAA10/12 7h30 AM&PM

- Ci, thin Ci stable over 8 years within 2%
- NH mid: strong seasonal cycle of thin Ci
- SH mid: seasonal cycle of Ci
- Perhaps slight decrease of Ci in midlat.?
**Trend analysis**

*Changes in eff. high CA and T of high clouds*

Slight decrease of T of high clouds in subtropics?

Or stronger activity in ITCZ?

*be careful of satellite change*

*Dataset not yet long enough for trend analysis*
**Analysis of field campaign measurement regions**

**INCA measurement campaigns:** Apr/May 2000 in SH and Sep/Oct 2000 in NH

More variability in regions than in latitude bands

**NH INCA:**
- thin Ci no seas. cycle
- max Ci in spg/aut

**SH INCA:**
- max thin Ci and Ci in spg
Relative humidity \( RH = \frac{e^{\text{ice}}}{e^{\text{sat}}} \) \( \text{ice}(T) \)

in case of clear sky and thin cirrus \( (N_\varepsilon < 0.5) \)

- TOVS Path-B precipitable water columns: 500 – 300 hPa, < 300 hPa
  \[ W = \int_{p}^{p_0} q_s \frac{dp}{g \rho} \]
  \[ q_s = \frac{mv}{md+mv} = \frac{wv}{1+wv} = 0.622 \frac{e}{p-(1-0.622)e} \]

- Use closest TIGR atmospheric T profile (30 levels)
  to compute \( e^{\text{sat}}_\text{ice}(T) \) and integrate \( q^{\text{sat}}_\text{ice} \) over column
  \[ RH(\text{column}) = g \rho \frac{W}{\int q^{\text{sat}}_\text{ice}(p)dp} \]

8-year distribution of RH for clear sky, very thin Ci and thin Ci

- More large RH values for Ci than clear sky
- SH INCA thin Ci have more RH than those in NH INCA region
TOVS $D_e$ analysis in INCA regions

4-year averages of $D_e$ and IWP as fct of RH
for thin Ci ($0.3 > \varepsilon_{cl} > 0.4$)

Interannual $<D_e>$ variability

<table>
<thead>
<tr>
<th>Year</th>
<th>NH</th>
<th>SH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1988</td>
<td>44µm</td>
<td>34µm</td>
</tr>
<tr>
<td>1989</td>
<td>44µm</td>
<td>40µm</td>
</tr>
<tr>
<td>1990</td>
<td>46µm</td>
<td>33µm</td>
</tr>
</tbody>
</table>

$D_e$, IWP increase with RH
- slightly larger in NH than in SH
(in agreement with MODIS analysis)
cannot be explained by different cloud thickness

INCA flight measurements:

$D_e$ of young Ci slightly smaller in NH!
Crystal shapes in NH and SH similar
IWP and vertical $D_e$ profiles?

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High cloud amount evolution: 
correlation with cosmic rays, volcanic eruptions?

Stubenrauch + Eddounia, CERN Proceedings 2001
Workshop on Ion-Aerosol-Cloud Interactions

TOVS high effective CA stable (IR)!

Svensmark
Satellite observations:
- unique possibility to survey cloud properties over long period
  30% high clouds (+ 15% subvisible Ci),
  stable within 2% over globe
- synergy of satellite data and field measurements
- Trend analysis: careful of satellite drifts, calibration etc.
- Volcanic aerosols -> overestimation of $\tau_{\text{VIS}}^{\text{ISCCP}}$
  -> underestimation of high CA$^{\text{ISCCP}}$ (4.5% in tropics)
  high eff. CA$^{\text{TOVS}}$ stable (IR)

Svensmark’s ‘cosmic ray intensity - CA correlation’ analysis could not be confirmed!
Trends in global cloud fraction?

Effective cloud amount

TOVS Path B:
slight increase in Southern tropics

ISCCP:
slight decrease in tropics