Cirrus properties from IR Sounders & analyses in synergy with other instruments

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


- long time series -> climate studies
- retrieval day & night
- increasing spectral resolution:
  - increasing vertical resolution (H$_2$O & T profiles)
  - decreasing noise (cirrus)

A-Train synergy (AIRS-CALIPSO-CloudSat):
- unique opportunity for global retrieval method validation
- vertical structure of cloud types

Outline

- retrieval & evaluation
- cirrus phys. & microphys. properties, vertical profiles, (horizontal extent)
- RH$_{\text{ice}}$ & ice supersaturation in atmospheric layers (MOZAIC synergy) & link with cirrus
Cloud property retrieval: TOVS, AIRS, IASI

\( R_m(\lambda_i) \) along CO\(_2\) absorption band around 15 \( \mu \)m

multi-spectral cloud detection

cloud clearing & T, H\(_2\)O inversion

3I-TOVS

(Scott et al. 1999)

NASA-AIRS

(Susskind et al. 2003)

NOAA-IASI

(Gambacorta et al.)

atmospheric temperature & water vapor profiles, \( T_{surf} \)

\[ \varepsilon(p_k, \lambda_i) \] coherence

\[ \varepsilon(p_k) = \frac{\sum_{i=1}^{N} \frac{R_m(\lambda_i) - R_{clr}(\lambda_i)}{R_{cld}(p_k, \lambda_i) - R_{clr}(\lambda_i)}}{N} \]

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

'\( a \) posteriori' cloud detection

\( \varepsilon(\lambda, De, IWP) \) simulated

\( \chi_w^2(p_k) \) min on spectral cloud emissivites

no assumption on microphysics

\( \varepsilon(\lambda, De, IWP) \)

4A-DISORT + SSP of ice crystals

hex. columns, aggregates

\( De, IWP \)


Mitchell 1996, Baran 2003

Aug 2012

IRS, Berlin
**Occurrence of high clouds** $(p_{\text{cld}} < 440 \text{ hPa})$

- **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 distributions similar**

- **40% (50%) of all clouds are high** (+ subvis)

- **land – ocean**: +10%

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**Hilton et al., BAMS 2012**

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Coordinators: C. Stubenrauch, S. Kinne

IRS, Berlin
**A-Train Synergy: variables & datasets**

**AIRS-LMD:** p, e of uppermost cloud -> cloud types
De, IWP of semi-transparent cirrus, aggregates/columns

**CALIPSO V3 5km** *(Winker et al. 2012)*: sub-visible Ci, cloud top, apparent base, thermodynamical phase.

**Lidar-Radar GEOPROF V4** *(Mace et al. 2009)*: number of cloud layers, cloud top & base height

**liDARradDAR** *(Delanoë and Hogan 2010)*: OE retrieval profiles of thermodynamical phase, IWC, De.
A-Train Synergy: evaluation of cloud height

Stubenrauch et al. ACP, 2008, 2010

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

for clouds with diffusive tops: $z_{\text{cld}}(\text{AIRS})$ on av. 1.5 km below cloud top
A-Train Synergy: vertical extent of cloud types

- Vertical extent increases from thin Ci to optically thicker high-level clouds.
- Clouds thicker in SH than in NH midlatitudes (& in winter than in summer).
- Vertical extent of thin Ci limited to about 5 km.

Climatology of cloud vertical extent per cloud type important input for Earth radiation budget.
Relationship between ice crystals and IWP

Fraction of aggregate-like ice crystals & De increase with IWP

Guignard et al. ACP 2012
Comparison of De with other datasets

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

- AIRS De centered around ~55 μm, retrieval sensitive up to max 90 μm
- DARDAR De increases from top to base: 56 / 60 / 67 μm
- Radar less sensitive to De < 30μm
IWC profiles of cloud types

Cb

Ci

Thin Ci

IWC distributions as function of cloud vertical extent
Horizontal dashed lines correspond to average position of AIRS cloud
• max of IWC shifts towards base with increasing vertical extent
• next step: combine with humidity & dynamics to parameterize IWC vertical profile
How can we detect ice supersaturation (ISS)?


Sounders retrieve water vapour within layers of km’s
=> underestimation of RH_{ice} : Ci peak at 70% (instead of 100%)

*improved spectral resolution (IASI) -> Ci peak at 80%*

ISS often occurs in vertical layers < 500 m
Influence of ISS occurrence on Cirrus occurrence

Ci occurrence from CALIPSO (including subvisible Ci)

extending results of Gierens (2000) (using MOZAIC data in NH midlat)

Ci occurrence increases with ISS occurrence

stronger increase in tropics than in midlatitudes (different formation mechanism?)
Conclusions & Outlook

- IR sounders sensitive to cirrus (also for multi-layered cloud systems, day & night)
- $p_{\text{cl}d}$ corresponds to midlevel of apparent cloud depth (COD<3)
- Uncertainty estimation from $\chi^2$: on av 40 hPa (4 K in $T_{\text{cl}d}$)

- 40% of all clouds are high-level clouds
  - 70% semi-transparent, 50% pure ice (more aggregates at larger IWP)

- Retrieval of De, IWP, ice crystal shape seems to be coherent:
  - De increases logarithmically with IWP -> parameterization for GCM’s
  - DARDAR: De & IWC increase from top to base when clouds are vertically extended

- $R_H_{\text{ice}}$ determined over coarse atmospheric layers
  - $R_H_{\text{ice}}$ of Ci peaks at 70% for AIRS / 85% for IASI (instead of 100% in-situ)
  - Ice SuperSaturation can be detected after calibration (Ci peak or MOZAIC)
  - Ci occurrence increases with ISS occurrence

relate properties of cloud systems (vert, hor extent, microphys) to state of atmosphere
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