Physical properties of mesoscale high-level cloud systems in relation to their atmospheric environment deduced from Sounders

Claudia Stubenrauch, Sofia Protopapadaki, Artem Feofilov, Theodore Nicolas & ABC(t) team

Laboratoire de Météorologie Dynamique / IPSL, France

Earth Observation for Water Science, ESRIN, 20-23 Oct 2015, Italy
Importance of Upper Tropospheric Clouds

High-altitude clouds represent ~40% of total cloud cover.

Cirrus play a vital role in the climate system by:
- Modulating Earth’s energy budget and upper tropospheric heat transport.
- Influencing the response of Earth’s water cycle to climate forcings.

What is the role of cirrus in regulating the Earth’s climate and hydrological sensitivities?
Why using IR Sounders to derive cirrus properties?

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

- long time series & good areal coverage -> climate studies
- good spectral resolution -> sensitive to cirrus
- retrieval day & night
- synergy with: RH_{ice}, aerosols

modular retrieval code: LMD-CIRS
(LMD Cloud retrieval from IR Sounders)

used for AIRS, IASI (LMD) & for TOVS/ATOVS (CM-SAF), etc

relative high cloud amount: CAHR = CAH/CA

from GEWEX Cloud Assessment Database

 Stubenrauch et al. BAMS 2013

cloud height evaluation with CALIPSO

AIRS-LMD 2003-2014 reanalysis V2
Identification of mesoscale high cloud systems (1)

clouds are extended objects, driven by dynamics -> organized systems

Method 1: ‘Weather States’
build clusters by occurrence of cloud classes per mesoscale grid (2.5°)
-> ISCCP (e.g. Tselioudis et al. 2013), \((p_{\text{cld}} - \tau_{\text{cld}})\) histograms
-> AIRS (Nicolas 2014), \((p_{\text{cld}} - \varepsilon_{\text{cld}})\) histograms

Comparison with ISCCP
good agreement;
but thin Ci & Ci over low cld : often indicated by ISCCP as fair weather (7)
properties of mesoscale high cloud systems

AIRS weather states, vertical structure from coloc. CALIPSO-CloudSat GEOPROF

RH profiles

WS – clear sky LW heating rate

distinct vertical & horizontal structures, atmos. environment & radiative effects

interesting for model evaluation (e.g. Gehlot & Quaas 2012, Berry & Mace 2013)

observational radiative-convective feedback (e.g. Lebsock et al. 2010)

but no information of system size!
High cloud systems: horizontal extent & composition

Method 2: merge adjacent grids containing high clouds ($p_{\text{cld}} - p_{\text{tropopause}} < 250 \text{ hPa}$) & build statistics over convective cores / thick Ci anvil / thin Ci

$\varepsilon_{\text{cld}}>0.98 \quad / \quad 0.98>\varepsilon_{\text{cld}}>0.50 \quad / \quad \varepsilon_{\text{cld}}<0.50$

distinguish systems with & without convection, count convective cores

AIRS 2 Jul 2009
1h30PM

~70% cirrus anvil & 20-30% thin cirrus
Fraction of thin Ci increases with increasing system size -> life stage of systems (formation, mature, dissipating)

tropics:
• non-convective Ci cover ~25%
• 50% of Ci originate from convection (Luo & Rossow 2004, Riihimaki et al. 2012)
proxies of convective strength

- large area of heavy rainfall
  CloudSat-AMSR-E-MODIS *(Yuan and Houze 2010)*

Convective cloud systems from AIRS

- min $T$ in convective cores

Cirrus anvil size increases with decreasing $T_{\text{min}}$ in convective cores & with increasing ascending wind within convective cores
proxies of convective strength

Convective cloud systems on CloudSat track

- width of convective core

Igel et al. 2014
Igel & van den Heever 2015

Cirrus anvil size increases with convective core width \( \frac{2}{3} \)

over ocean & land; slope stronger for multi-core systems
How do convective systems behave when $T_{\text{surf}}$ increases?

Igel et al. 2014: oceanic systems: *convection rises higher* ($T_{\text{Cb}}$ decreases) & anvil seems to narrow when SST increases -> compatible with negative feedback

Oceanic systems:
- $T_{\text{Cb}}$ smaller in regions with large $T_{\text{surf}}$ - *convection rises higher*
- System size not much affected
- Average emissivity slightly smaller in regions with large $T_{\text{surf}}$ *linked to thin cirrus increase*

Terrestrial systems:
- $T_{\text{Cb}}$ only slightly smaller in regions with large $T_{\text{surf}}$
- System size & average emissivity not much affected

-> more detailed studies using both data sets & dynamical information
IR Sounders well suited for studying cirrus

GEWEX Cloud Assessment

AIRS-LMD L3 cloud data (V1) available at http://climserv.ipsl.polytechnique.fr/gewexca
AIRS-LMD L2 cloud data (V1) distributed by ICARE: http://www.icare.univ-lille1.fr/
AIRS-LMD V2 & IASI follow soon, TOVS/ATOVS will be distributed by CM-SAF

Analyses of cloud systems essential to advance our understanding

Synergies (between data, data analyses and data analysis – modeling)

of uttermost importance
Future Synergies

synergetic data base:

A-Train (AIRS-CALIPSO-CloudSat-AMSR-E):

➢ vertical structure of cloud types (as function of distance to convective cores ?)
➢ comparison of proxies for convective strength

ISCCP-Meghatropiques-AIRS-IASI-TRMM : life cycle of cloud systems

Meteorological reanalyses : mesoscale winds, thermodynamics

atmosph./cloud properties & Lagrangian transport model
-> cirrus origin & evolution

atmosph./cloud properties & radiative transfer model
-> cirrus heating rates

vertical layering, vertical IWC / De profiles important parameterization as fct of IWP (e.g. Feofilov et al. 2015)
International framework: GEWEX UTCC PROES

Process Evaluation Study on Upper Tropospheric Clouds & Convection

Coordinators: C. Stubenrauch, G. Stephens

motivation:
coordinated advance on understanding feedback of high-level clouds

focus on
1) tropical convective systems
understand relation between convection, cirrus anvils & radiative heating,
provide obs. based metrics to evaluate detrainment processes in models
2) cirrus originating from large-scale forcing

integrate synergetic data, transport & radiative transfer
& modeling at different scales (CRM, GCM)

building working group, kick-off meeting 16 Nov 2015 in Paris

~30 participants from data & model communities