Upper Tropospheric Cloud Systems from Satellite Observations: what can be achieved? A GEWEX Perspective

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Outline

- GEWEX Cloud Assessment (2005-2012) & Database:
  1rst coordinated intercomparison of 12 ‘state of the art’ cloud climatologies

  *one step further* ->

- GEWEX PROcess Evaluation Studies (PROES)
  use observations to probe process understanding

  -> PROES on Upper Tropospheric Clouds & Convection
     understanding their feedback to climate change
Clouds are extended objects
of many very small liquid / ice particles

*Cirrus* (high ice clouds)

*Cumulonimbus* (vertically extended)

<table>
<thead>
<tr>
<th>Satellite radiometers</th>
<th>bulk quantities:</th>
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<tbody>
<tr>
<td>CA (tot, high, mid, low)</td>
<td></td>
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<tr>
<td>CP, CT, COD/CEM</td>
<td></td>
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<tr>
<td>CWP, CRE</td>
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Cloud structures over Amazonia

Cumulus (low fair weather clouds)

Copyright: 1998 Wadsworth Publishing Company;
C. Donald Ahrens, Essentials of Meteorology
**GEWEX Cloud Assessment: Key results**

Stubenrauch et al., BAMS 2013

IR-NIR-VIS Radiometers, IR Sounders, VIS-SWIR Radiometers

*exploit different parts of EM spectrum:*

*How does this affect climatic averages & distributions?*

**Database (monthly statistics) available at**

http://climserv.ipsl.polytechnique.fr/gewexca

to facilitate further assessments, climate studies, model evaluation

Update foreseen: MISR, AIRS-LMD, IASI-LMD, ISCCP, ESA CCI ...

global CA: 68% ± 3% (COD > 0.1), +5% subvisible

CAH depends on instrument performance to identify thin Ci

=> uncertainties are scene dependent!

similar geographical distributions & seasonal cycles

passive remote sensing determines ‘radiative’ height

global trends difficult to determine
NASA obs4mip meeting (April 2014)

-> need to use observations more intelligently to probe process understanding

5 GEWEX-related PROES activities developing:

- **Upper Tropospheric Clouds & Convection** (lead C. Stubenrauch, G. Stephens), SPARC
- **Ice mass balance** (lead E. Larour, S. Nowicki), GEWEX - CLiC
- **Radiative Kernels for Climate** (lead B. Soden)
- **Mid-latitude storms** (lead G. Tselioudis, C. Jakob)
- **Soil moisture climate** (lead S. Seneviratne)
GEWEX UTCC PROES
Process Evaluation Study on Upper Tropospheric Clouds & Convection

Motivation: understanding feedback of upper tropospheric clouds

focus on
1) tropical convective systems
explore relation between convection, cirrus anvils & radiative heating,
provide obs. based metrics to evaluate detrainment processes in models

2) cirrus originating from large-scale forcing

Ressources:
- observations of cloud systems & atmospheric environment
- including the atmospheric flow: Cirrus origin & life cycle
- simulation of processes at different scales (parcel, CRM, GCM)
- radiative transfer

1rst meeting Nov 2015 (Paris), next informal meetings in Apr 2016:
during IRS (Auckland) & in Paris
Importance of Upper Tropospheric Clouds

High ice clouds (cirrus) represent ~40% of total cloud cover

Cirrus play a vital role in climate system by
- modulating Earth’s energy budget & upper tropospheric heat transport
- influencing response of Earth’s water cycle to climate forcings
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\textsubscript{ice}, aerosols

cloud height evaluation with CALIPSO

high cloud amount: CAH

AIRS-LMD 2003-2014

January

ISCCP 1984-2007

from GEWEX Cloud Assessment Database
High Cloud Systems: horizontal extent & composition

Analyses of cloud systems essential to advance our understanding

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

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

• 20% of systems: non-convective Ci
• 50% of these Ci originate from convection (Luo & Rossow 2004, Riihimaki et al. 2012)

AIRS 2 Jul 2009
1h30PM
distinguish systems with & without convection, count convective cores

Convective systems:
~70% Ci anvil & 25% thin Ci
Fraction of thin Ci increases with increasing system size
--> life stage of systems

Analyses of cloud systems essential to advance our understanding
Tropical Mesoscale Convective Systems: life cycle

use high time resolution of geostationary satellite imagers to study life cycle
merge adjacent footprints containing cold clouds using $T_B^{IR}$ window

Yuan & Houze 2010  (<260 K, Cb from AMSR-E rain rate),
Fiolleau & Roca 2013  (< 233 K, Cb from TRMM rain rate) ....

Track all cold (< 245K), sufficiently large (> 45 km) & long-lived (≥ 3 hr) containing at least one convective cloud (< 218 K) at one time

coldest systems reach longest life-times

$T_{cld}$ & $\varepsilon_{cld}$ are independent variables, whereas $T_B^{IR}$ depends on $T_{cld}$ & on $\varepsilon_{cld}$:

increasing $T_B^{IR}$ threshold includes opaque clouds with $T_{cld} \sim T_B^{IR}$ & clouds with colder $T_{cld}$ & smaller $\varepsilon_{cld}$:

215K / 233K / 245K / 260K
0.98 / 0.92 / 0.8 / 0.6

complement AIRS/IASI with geostationary data...
proxies of convective strength

- large area of heavy rainfall
- min T in convective cores

CloudSat-AMSR-E-MODIS *(Yuan and Houze 2010)*

Convective cloud systems from AIRS *(Protopapadaki et al. 2016)*

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

\[ \text{width of convective core} \]

Igel et al. 2014
Igel & van den Heever 2015

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

over ocean & land; slope slightly stronger for multi-core systems

AIRS single cores

AIRS multi-cores

(Protopapadaki et al. 2016)
UTCC PROES Synergies

A-Train (AIRS-CALIPSO-CloudSat-AMSR-E):
- vertical structure of cloud types (as fct of distance to convective cores)
- comparison of proxies for convective strength

GridSat-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. ACP 2015)

 Simulator of high-altitude cloud systems for evaluation of different convection schemes / microphysics in GCMs
Summary

even if instantaneous cloud properties are not very accurate, the synergy of different variables provide invaluable potential for improving our understanding of clouds

synergy also important for model evaluation: compare correlations of physical variables or statistics organized by weather states or cloud systems

**UTCC PROcessEvaluationStudy activity:**
to advance on understanding feedback of high-level clouds

**focus on high-altitude cloud systems**
& examine their horizontal extent, composition, vertical structure
  -> heating rates

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