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

Sofia Protopapadaki,
Claudia Stubenrauch, Artem Feofilov

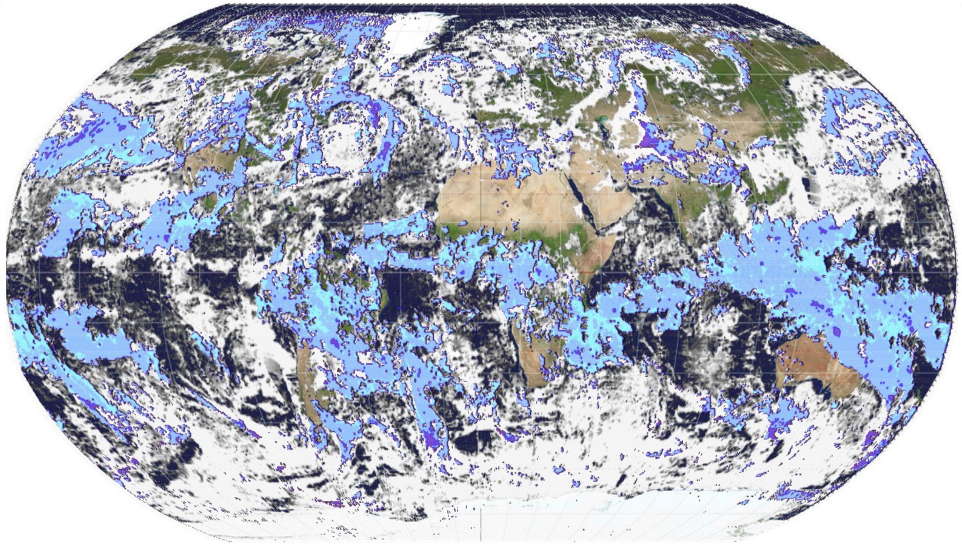
Laboratoire de Météorologie Dynamique / IPSL, France

IASI Conference,
April 2016, Antibes, France

Importance of Upper Tropospheric Clouds

- High altitude clouds represent ~40% of total cloud cover *(Stubenrauch et al. 2013)*

AIRS-LMD



Blue : High clouds , (Dark → light decreasing ε_{cld})
White: other clouds

Formation:

- when cold air is supersaturated with water
- as the outflow of convective systems

Modulation of Earth's energy budget and heat transport depends on :

- area coverage of high cloud systems
- emissivity distribution within high cloud systems
- temperature difference between highest clouds & surface/clouds underneath

Cloud feedbacks → main uncertainty in climate models!

What is the role of cirrus in regulating the Earth's climate & hydrological sensitivities?

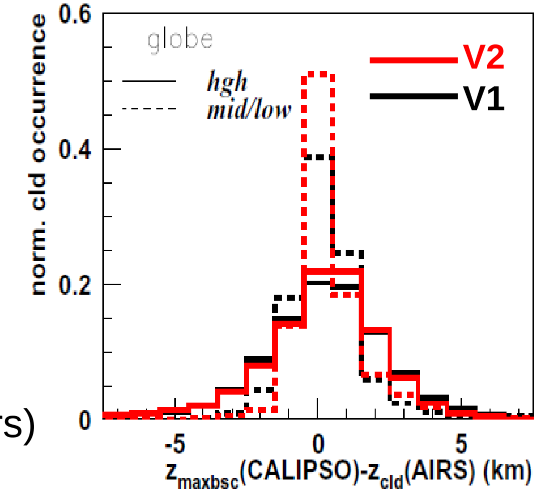
Artem Feofilov's poster
Session 7 : S7-14

Why using IR Sounders to derive cirrus properties?

TOVS, ATOVS,	**AIRS, CrIS,**	**IASI (1,2,3), IASI-NG**
>1979/ ≥ 1995	**≥2002 / ≥ 2012**	**≥2006 / ≥ 2012 / ≥ 2020**
7:30 AM/PM,	1:30 AM/PM,	9:30 AM/PM

- good spectral resolution → sensitive to cirrus
- retrieval day & night, land & sea
- synergy with RH_{ice}, aerosols etc.
- long time series & good areal coverage → climate studies

AIRS cloud height evaluation with CALIPSO

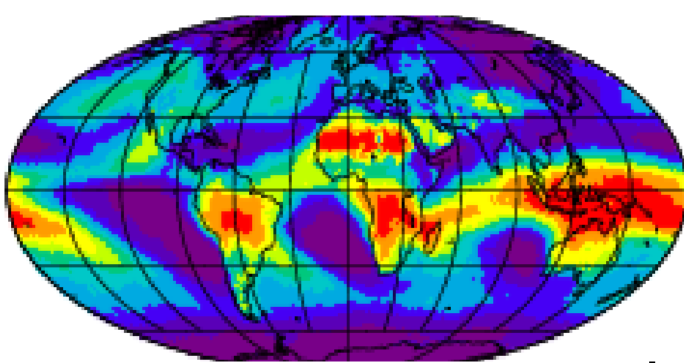


modular retrieval code: LMD-CIRS (LMD **C**loud retrieval from **IR S**ounders)
used for AIRS, IASI (LMD) & for TOVS/ATOVS (CM-SAF)

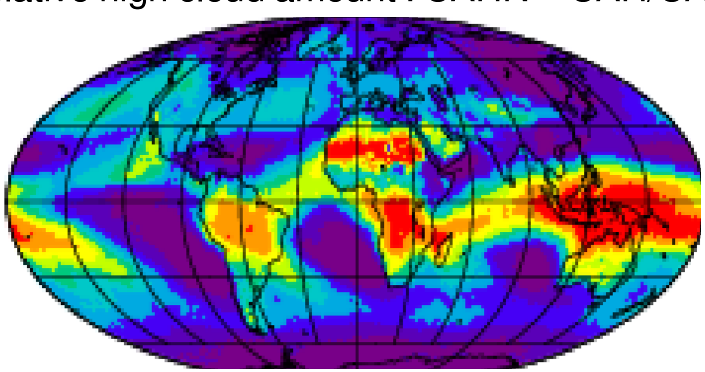
Weighted χ^2 method → get cloud properties: ε_{cld}, p_{cld}, T_{cld}

relative high cloud amount : CAHR = CAH/CA

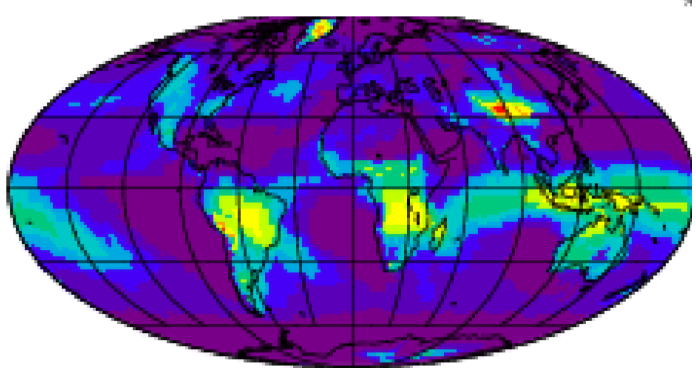
IASI-LMD
2008-2015 (reanalysis V2)



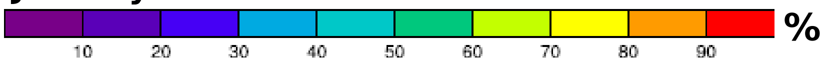
AIRS-LMD
2003-2015 (reanalysis V2)



ISCCP *1984-2007*
from GEWEX Cloud assessment Database *(Stubenrauch et al. 2013)*



January



AIRS and IASI -LMD L2 Data :
distributed by: http://www.icare.univ-lille1.fr/

From pixels to cloud systems

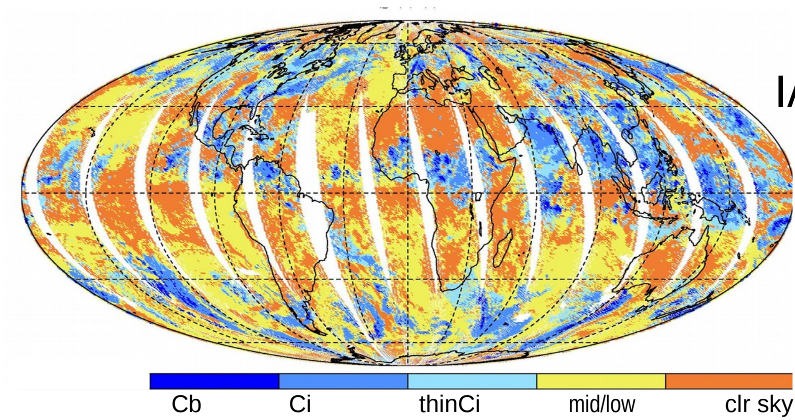
Clouds are **extended objects**, driven by dynamics → **organized systems**

Method : regroup adjacent grids containing high clouds & build statistics over:

convective cores / **thick Ci anvil** / **thin Ci**

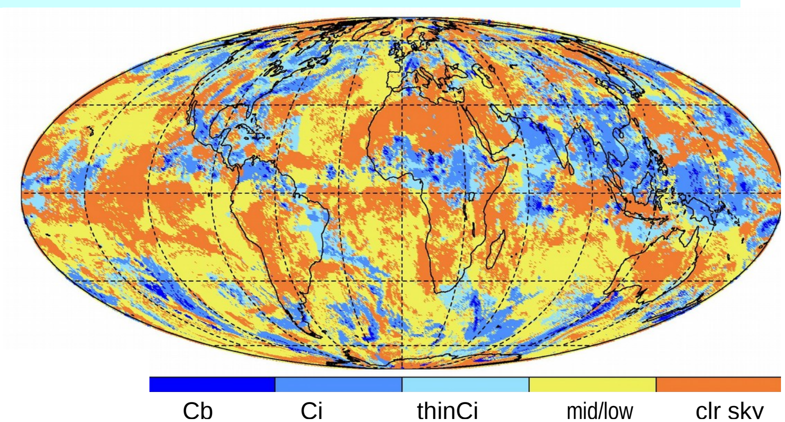
ε_{cld} >0.98 / **$0.5<\varepsilon_{cld}<0.98$** / **$\varepsilon_{cld}<0.50$**

distinguish systems with & without convection, count convective cores

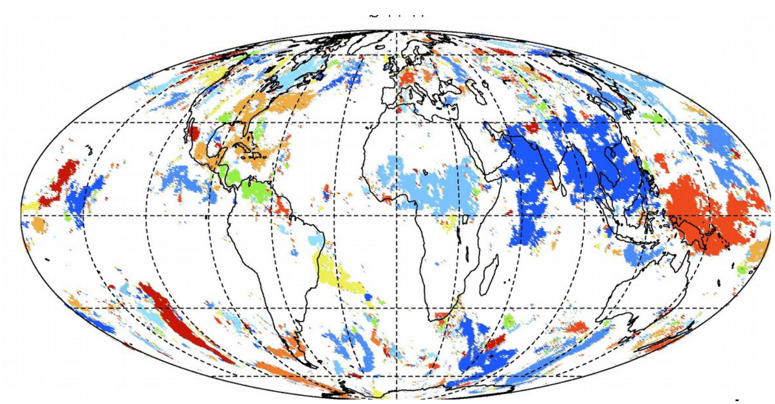


IASI : 1 July 2007, AM

Fill data gaps using a statistical method



Cloud systems



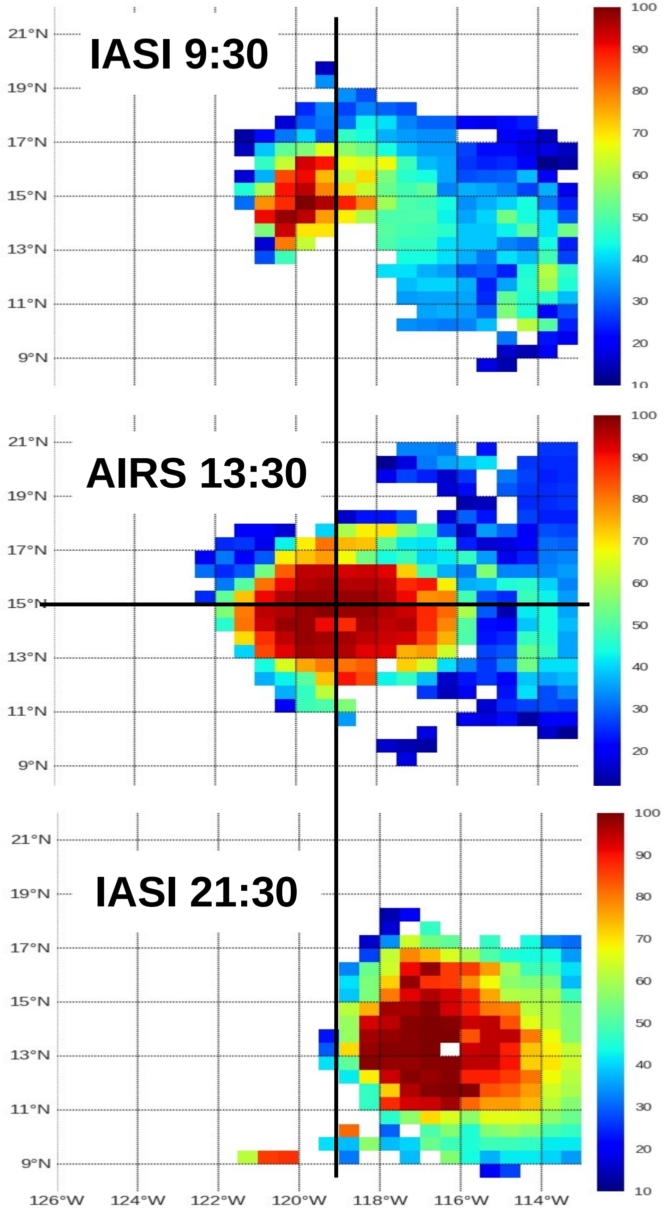
High cloud definition : P_{cld} - P_{tropo}<250 hPa

Spatial continuity constrains on cloud systems:

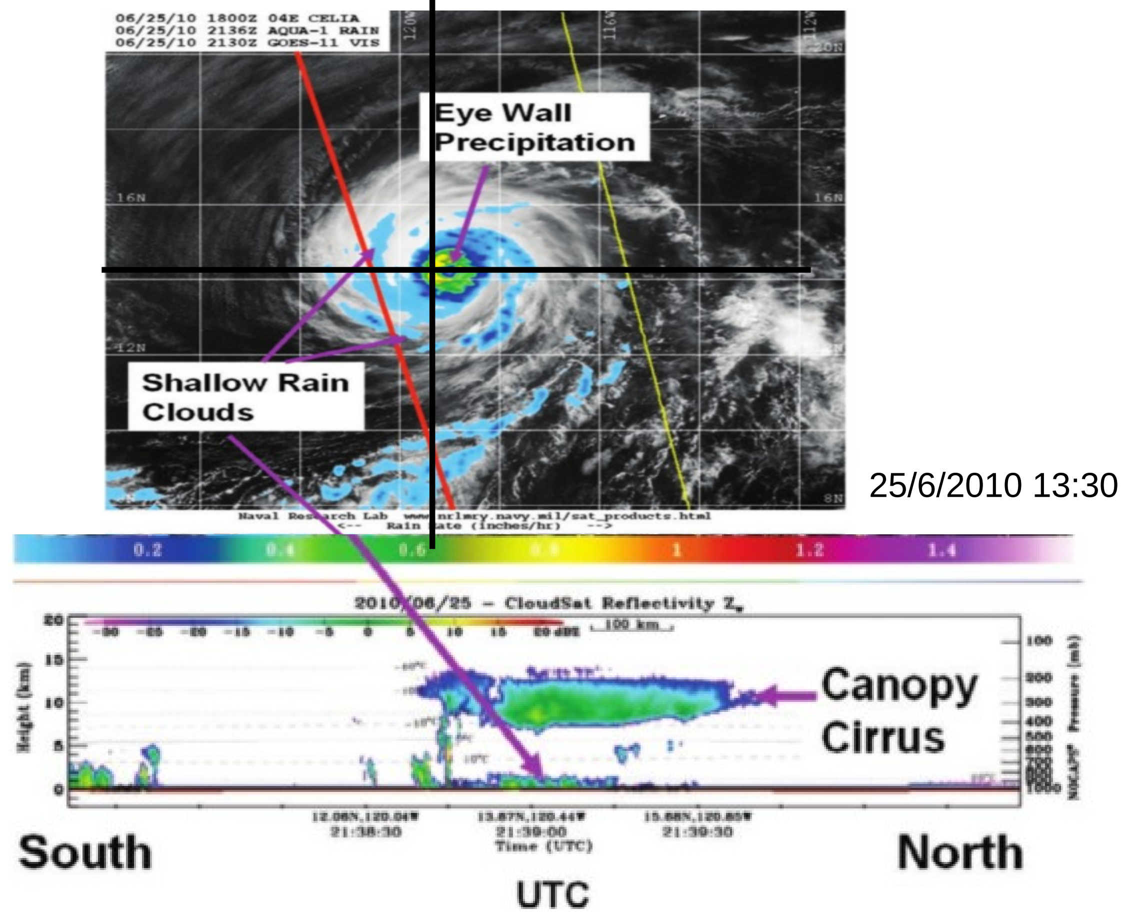
- adjacent high clouds (70% in 0.5° x 0.5°)
- P_{cld} difference < 50 hPa

→ 2003-2015 AIRS-LMD dataset
→ 2007-2015 IASI-LMD dataset
All months included, tropics (+/- 30 degrees)

Data synergies: A-train and IASI



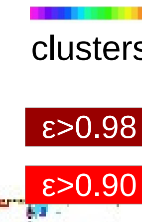
BAMS, May 2012 : METEOROLOGICAL EDUCATION AND TRAINING USING A-TRAIN PROFILERS

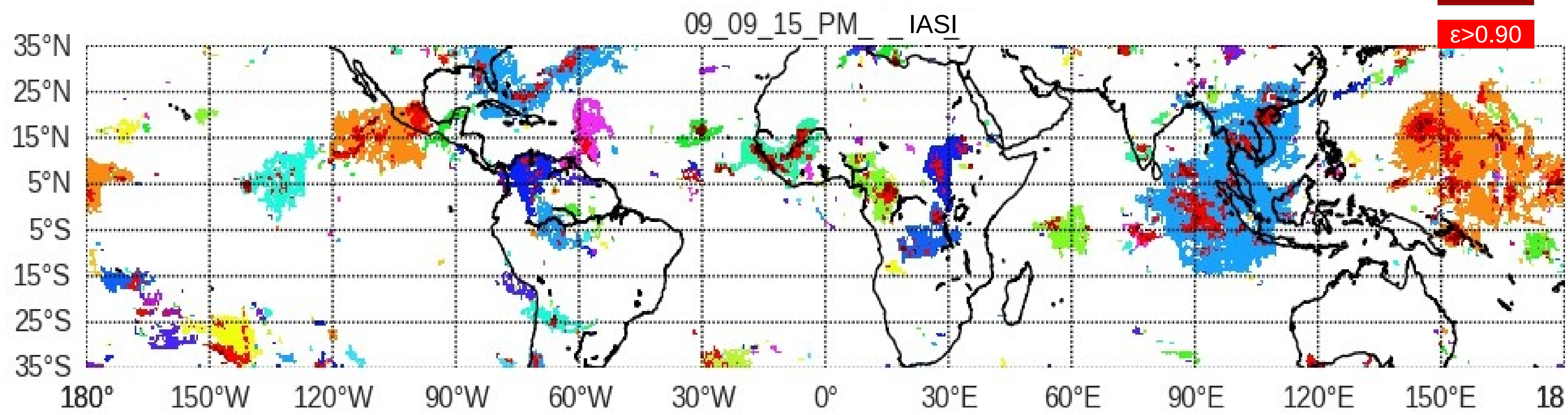


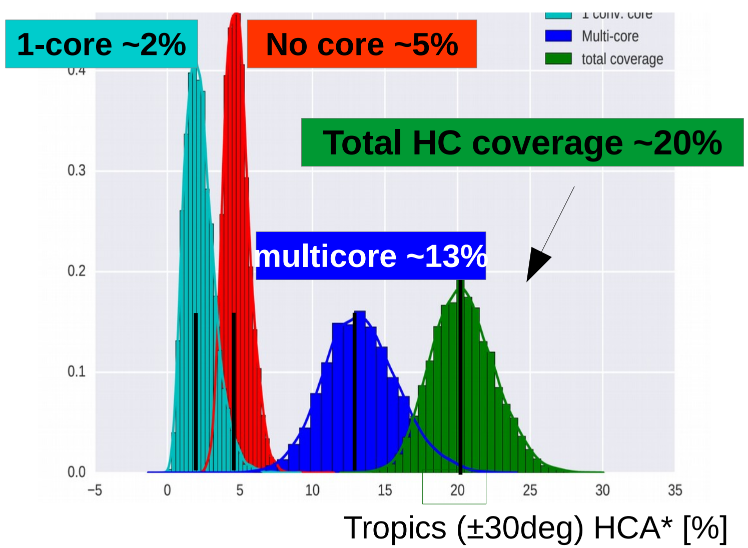
Data synergies with A-train allows to parametrize

- Vertical structure (CALIPSO-CLOUDSAT)
- Rain rate (AMSR-E) → convective core definition

Cloud system statistics







Core ε_{cld} >0.98	Multi-core	single-core	No core
Numb.of systems	<1%	<4%	~95%
coverage	~65%	~10%	~25%
Average size	~200*10^4 Km^2	~10*10^4 Km^2	~10^4 Km^2

- Non-convective Ci : ~25% of high cloud cover

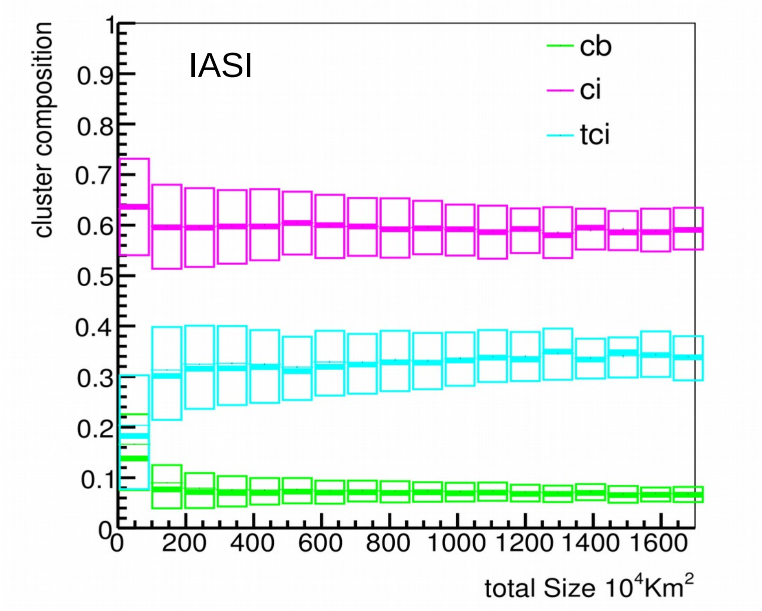
50% of isolated Ci originate from convection
(Luo & Rossow 2004, Riihimaki et al. 2012)

*HCA → **H**igh (P-Ptropo <250 hPa) **C**loud **A**mount

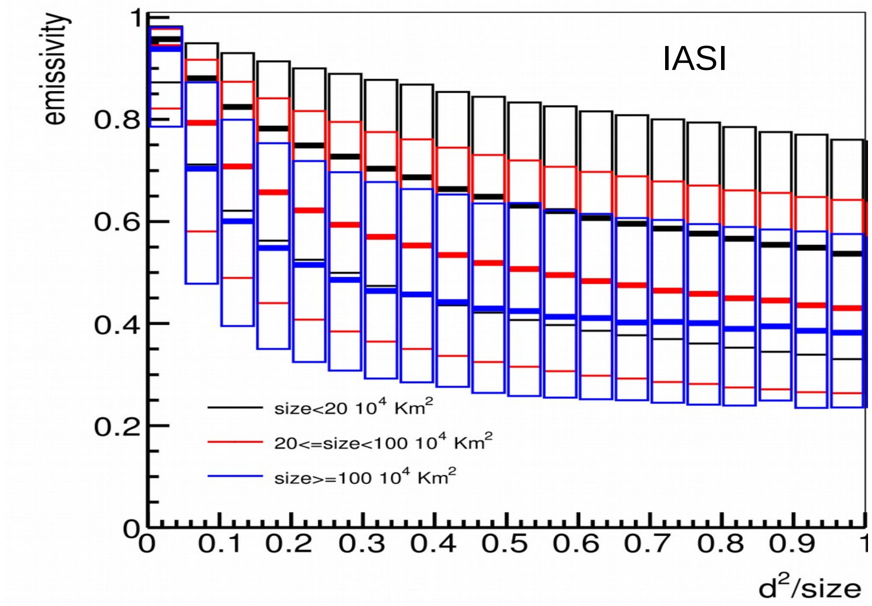
Cloud system composition

- Convective systems represent ~ 75% of the total high cloud cover

Fraction of cloud parts VS cluster size



Emissivity as a function of normalized distance to the core for different sizes



- In larger systems emissivity decreases faster

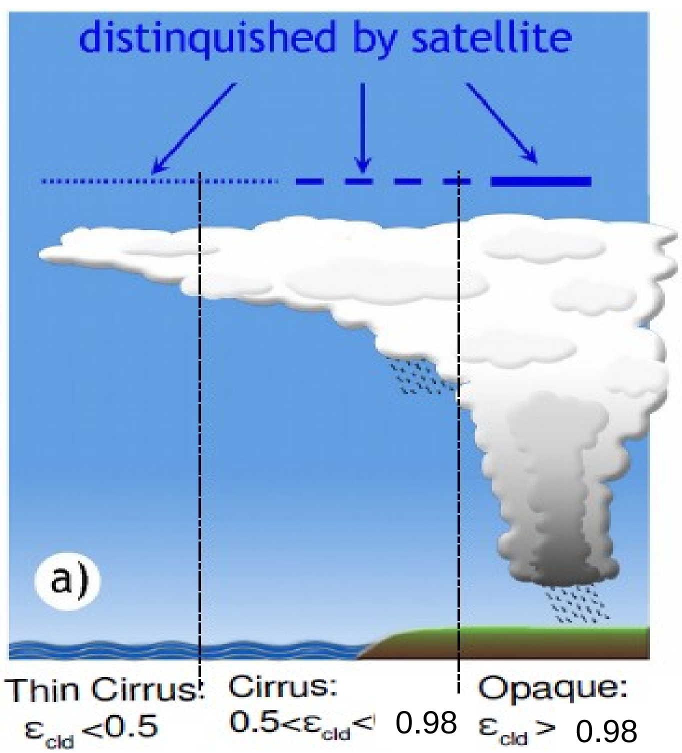
- ~60% cirrus anvil and ~30% thin cirrus
- Fraction of thin cirrus increase with increasing system size

- **Larger systems tend on average to have larger fraction of thin cirrus**

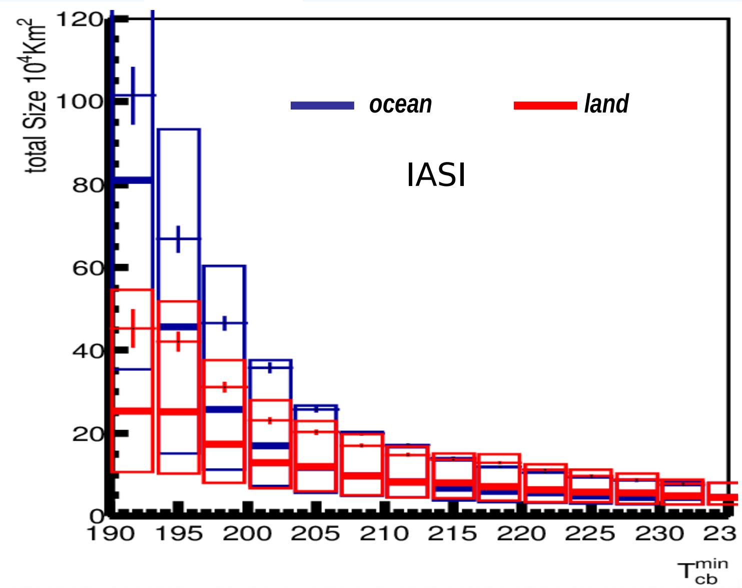
Proxies of convective strength (1)

large area of heavy rainfall

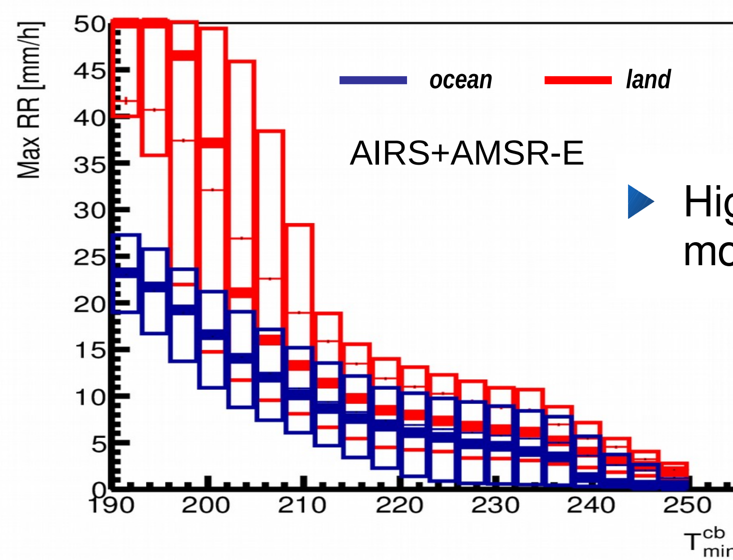
CloudSat-AMSR-E-MODIS
(Yuan and Houze 2010)



min T in convective cores



- Cirrus anvil size increases with decreasing Tmin in convective cores
- AIRS same behavior



- Higher systems precipitate more → Rain – Tmin correlation

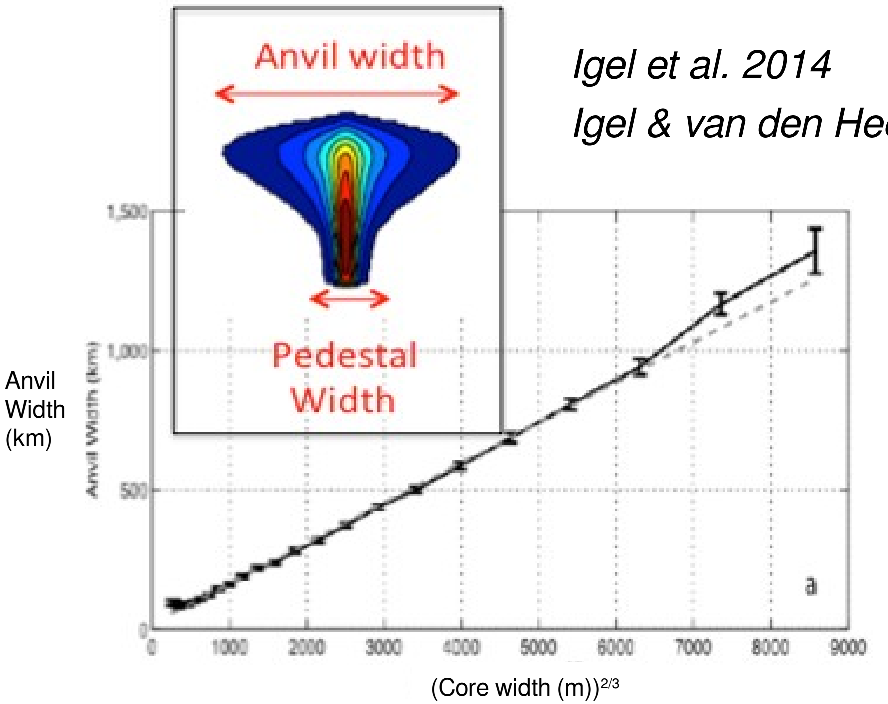
Proxies of convective strength (2)

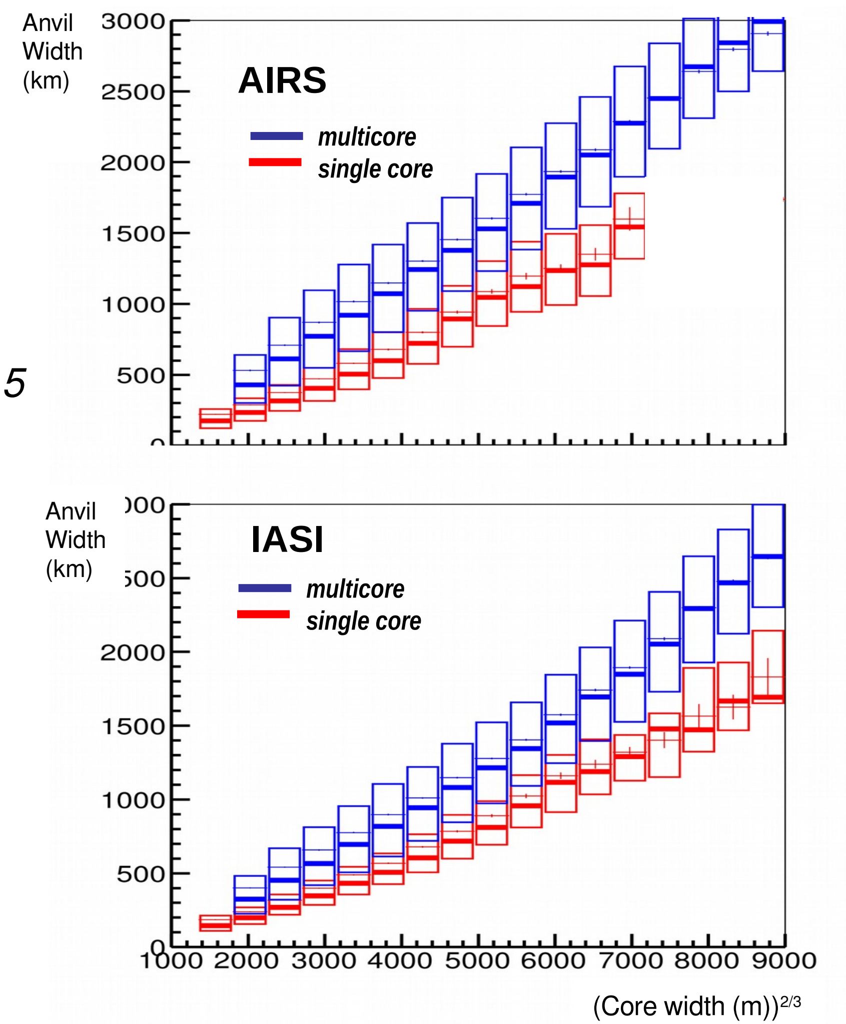
- **width of convective core**

Convective cloud systems
on CloudSat track

Igel et al. 2014

Igel & van den Heever 2015



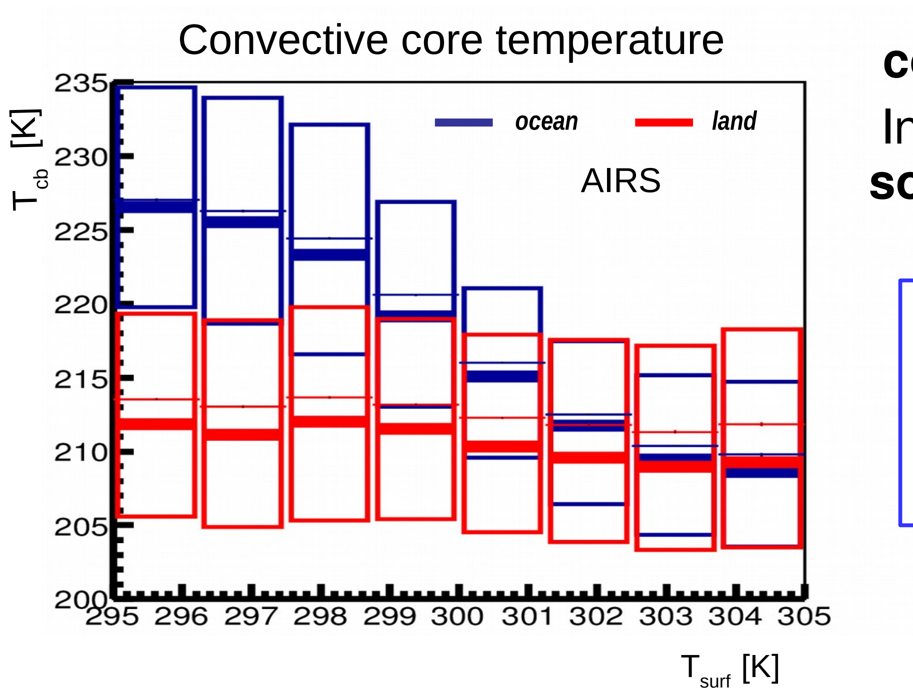


- **Cirrus anvil size increases with convective core width**
  - → slope stronger for multi-core systems
  - → reasonal agreement betwee IASI and IARS

Cloud system properties and climate change

- Will Ci anvils decrease in a warming climate ? How cloud properties and thus atm IR heating will be affected → large-scale circulation?
  - Several hypothesis to be tested: Thermostat (Ramanathan & Collins 1991), Humidistat (Stephens et al. 2004, Lebsock et al. 2010) ,IRIS effect (Lindzen et al. 2001)

Examine cloud behavior with increasing surface temperature



convection rises higher on ocean (T_{Cb} decreases)
In agreement with Igel *et al. 2014* over ocean ;
so far no effect over land

- more detailed studies using both data sets & dynamical information needed
- Study el-ninio / la-ninia years

Summary

IR sounders are able to identify convective core, thick anvil & surrounding thin cirrus of mesoscale convective systems, using cloud emissivity

- High cloud convective systems are complex
  → can be composed of several cores & represent ~75% of HC cover
- Convective systems are composed of:
  ~10% convective core ~60% cirrus anvil and ~30% thin cirrus
- System size increases with convective strength (T_{cb}^{Min}, core size)
- IASI cluster's behavior compatible with AIRS results

International framework:

GEWEX group :

UpperTroposphericClouds&ConvectionPROcessEvaluationStudy:

Coordinated by : C. Stubenrauch and G. Stephens

AIM : to advance on understanding feedback of high-level clouds

1rst meeting Nov 2015 (Paris), next informal meetings during IRS 2016 conference (Auckland) & on the 29th April in Paris

Outlook

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

ISCCP-Meghatropiques-AIRS-IASI-TRMM :

- life cycle of cloud systems

Meteorological reanalyses :

- mesoscale winds

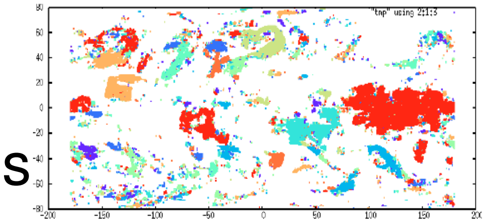
atmosph./cloud properties & radiative transfer model
→ cirrus heating rates

atosph./cloud properties & Lagrangian transport model
→ cirrus origin & evolution

Cooperation with M. Bonazzola

Simulator of AIRS high-altitude cloud systems for evaluation of different Convection schemes/microphysics in GCMs

data



simulator