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

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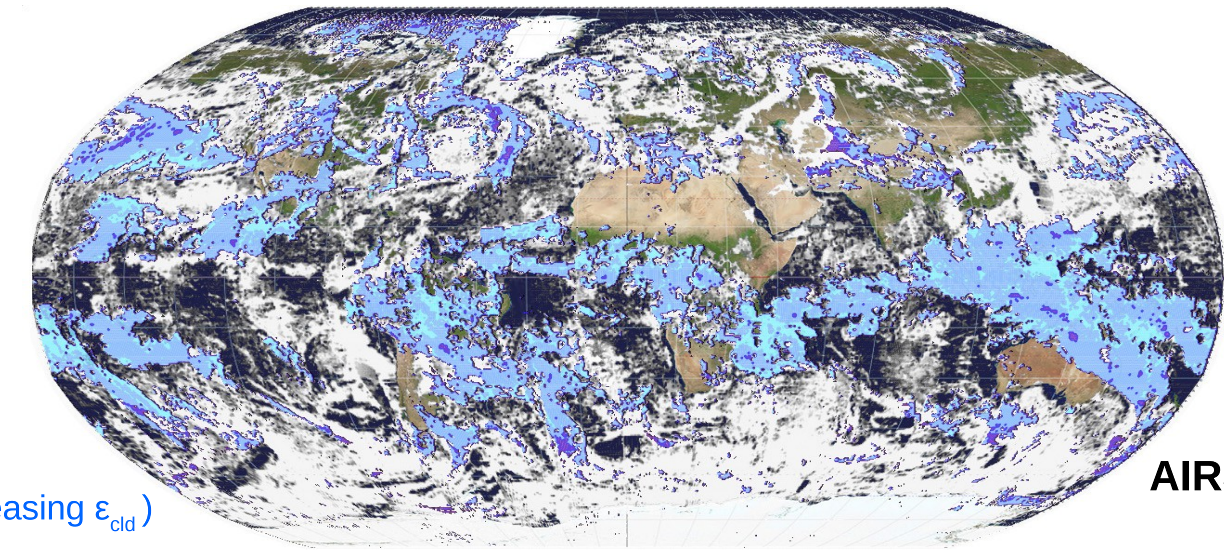
GEWEX UTCC PROES meeting
16 November 2015, Paris, France

Importance of Upper Tropospheric Clouds

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



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

AIRS-LMD

Cirrus play a vital role in climate system by

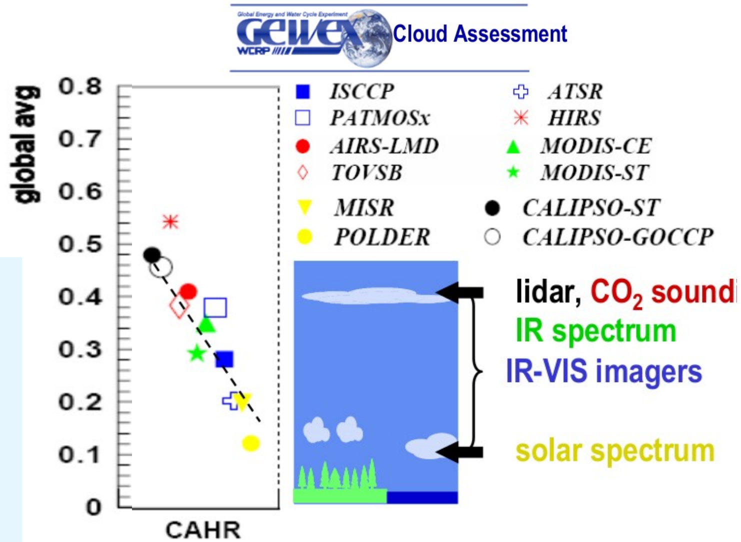
- modulating Earth’s energy budget & upper tropospheric heat transport
- influencing response of Earth’s water cycle to climate forcings

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

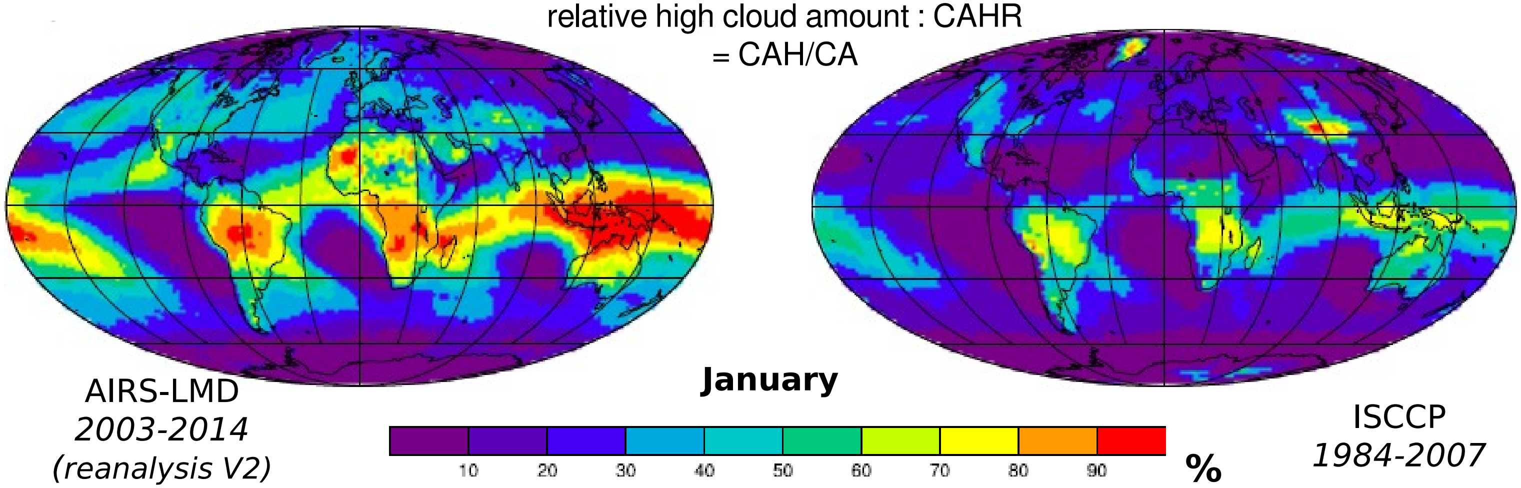
Why using IR Sounders to derive cirrus properties?

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

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



relative high cloud amount : CAHR
= CAH/CA



AIRS-LMD
2003-2014
(reanalysis V2)

ISCCP
1984-2007

from GEWEX Cloud assessment
Database *(Stubenrauch et al. 2013)*

AIRS-LMD L2 Data 2003-2009 :
distributed by: http://www.icare.univ-lille1.fr/

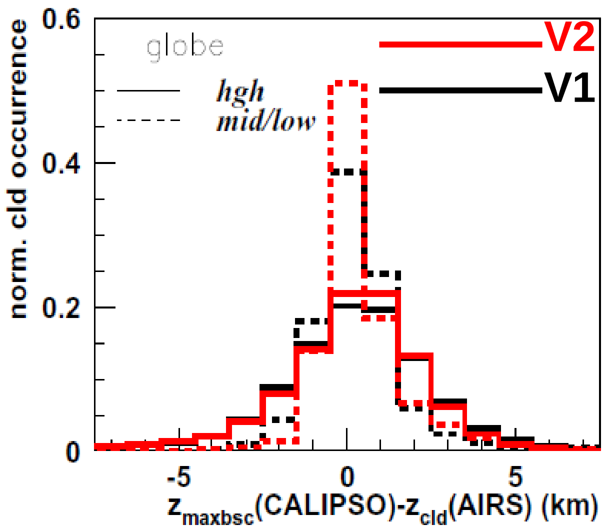
Cloud property retrieval: AIRS → IASI

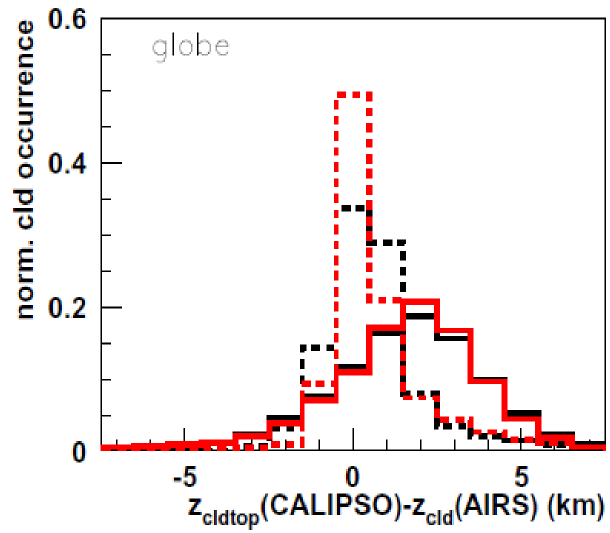
ε_{cld}, p_{cld} from min χ^2 (using CO_2 channels sounding the atmosphere) → **T_{cld} , z_{cld}**
for semi-transparent cirrus: **De, IWP** (based on 8-11 mm absorption/scattering)

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

- improved ancillary data (atm. profiles, T_{surf}, ε_{surf}, simulated spectral transmissivities)
- improvement in radiative transfer & χ^2 method for layers close to ground (reflection)
- rescaling of spectral transmissivities with respect to CO_2 concentration in atmosphere

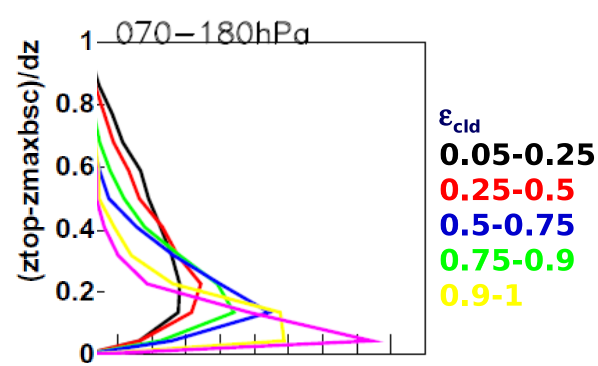
cloud height evaluation with CALIPSO:





new treatment → improvement in low clouds

Cirrus have diffuse cloud tops



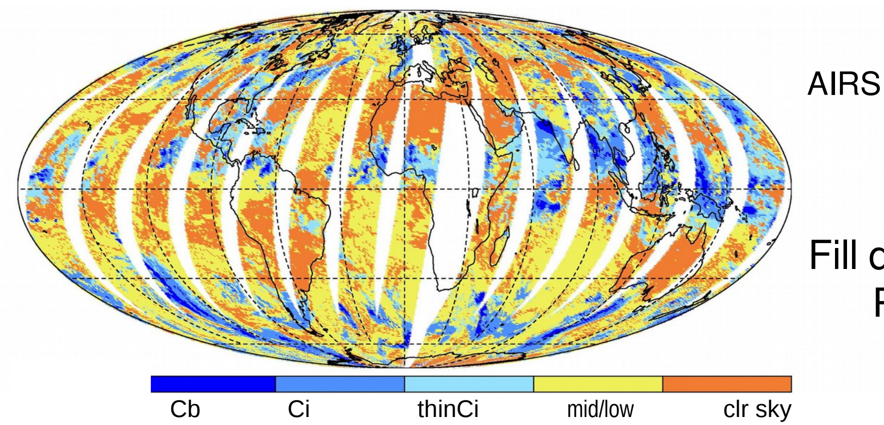
From cloud retrieval to cloud systems

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

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

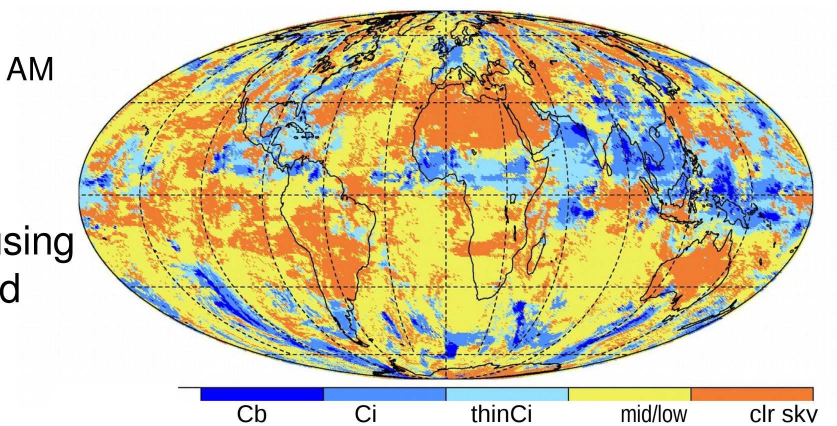
ε_{cld} >0.98 / **$0.5<\varepsilon_{cld}<0.98$** / **$\varepsilon_{cld}<0.50$**

distinguish systems with & without convection, count convective cores

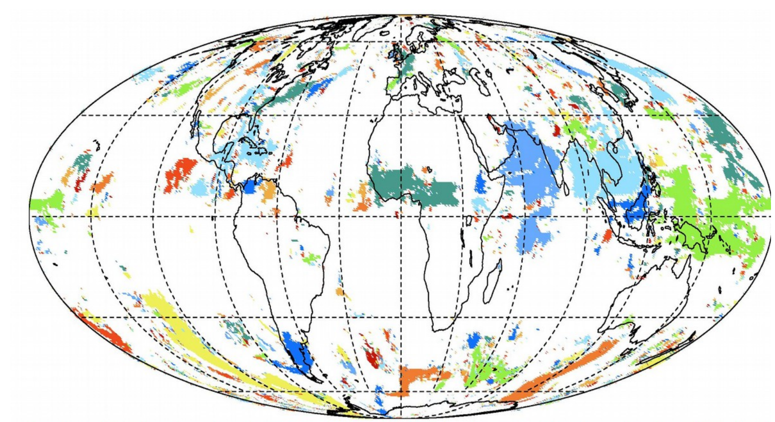


AIRS :1 July 2007, AM

Fill data gaps using PDF method



Cloud systems



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

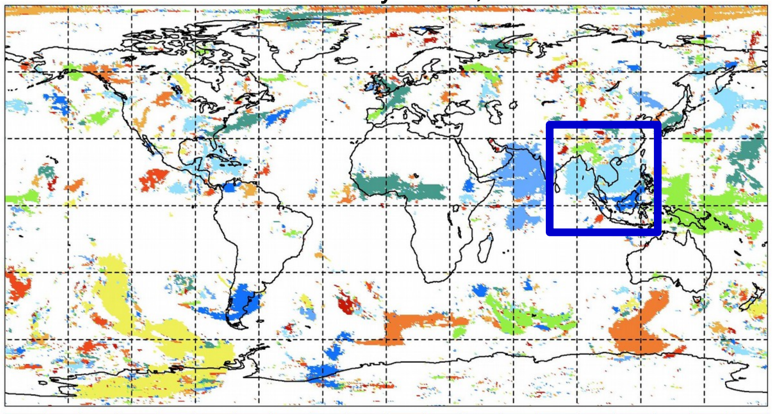
Spatial continuity constrains on cloud systems:

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

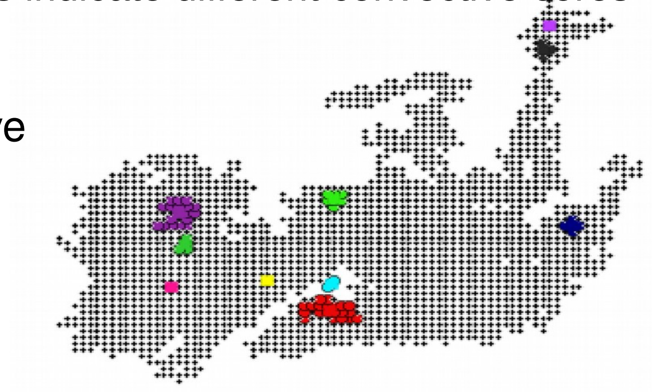
In the following analysis :
results using the 2003-2014 AIRS dataset
All months included, tropics (+/- 30 degrees)

High cloud systems

AIRS: 1 July 2007, AM



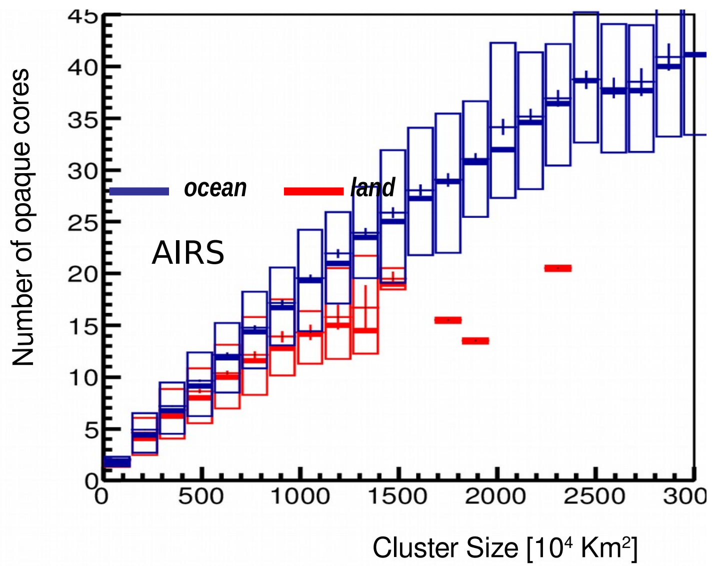
colors indicate different convective cores



- reconstruct convective cores by regrouping adjacent grids with **ε_{cld} >0.98**

- High cloud cover mainly from multi-core systems

Core ε_{cld} >0.98	Multi-core	single-core	No core
Numb.of systems	<2%	<3%	>95%
coverage	~75%	~5%	~20%
Average size	~300*10⁴ Km²	~10*10⁴ Km²	~10⁴ Km²



- Non-convective Ci : ~20% of high cloud cover

50% of isolated Ci originate from convection

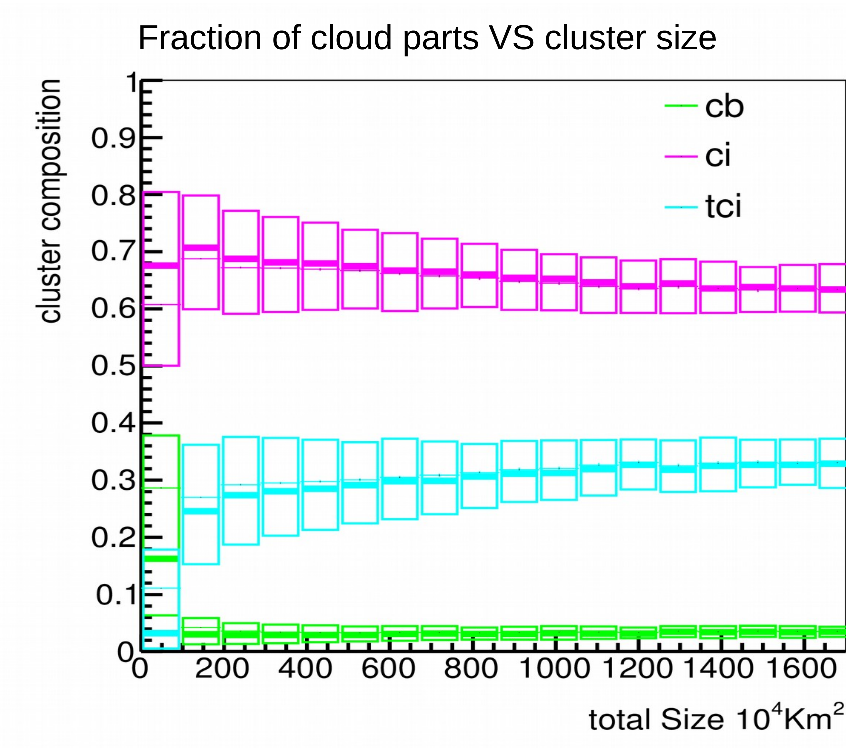
(Luo & Rossow 2004, Riihimaki et al. 2012)

→ ~10% from dissipating convection

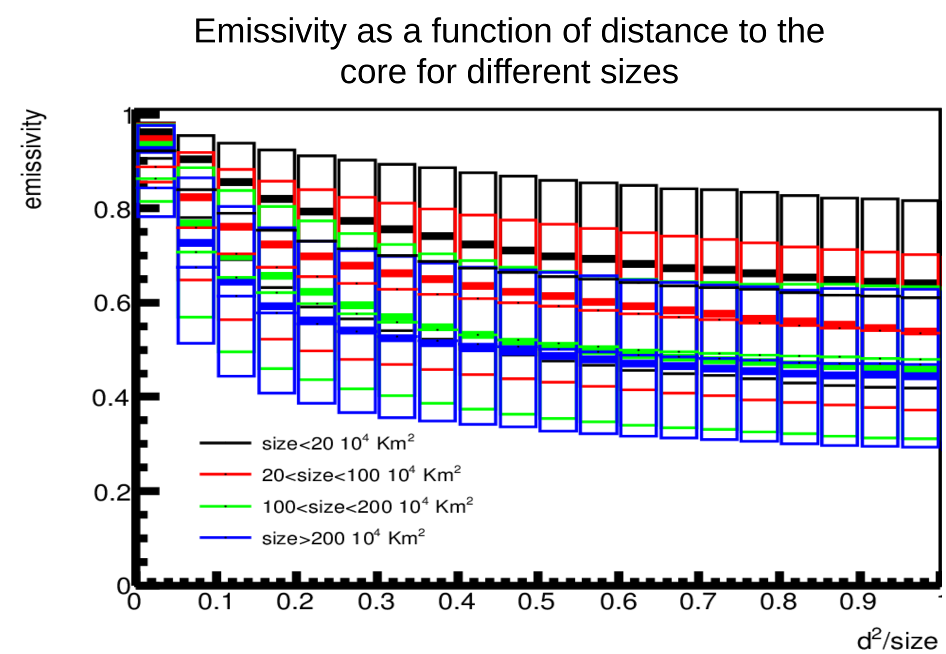
- number of cores increases with size

Cloud system composition

- Convective systems represent ~ 80% of the total high cloud cover



- ~70% cirrus anvil and
  ~ 20-30% thin cirrus
- Fraction of thin cirrus increase with increasing system size

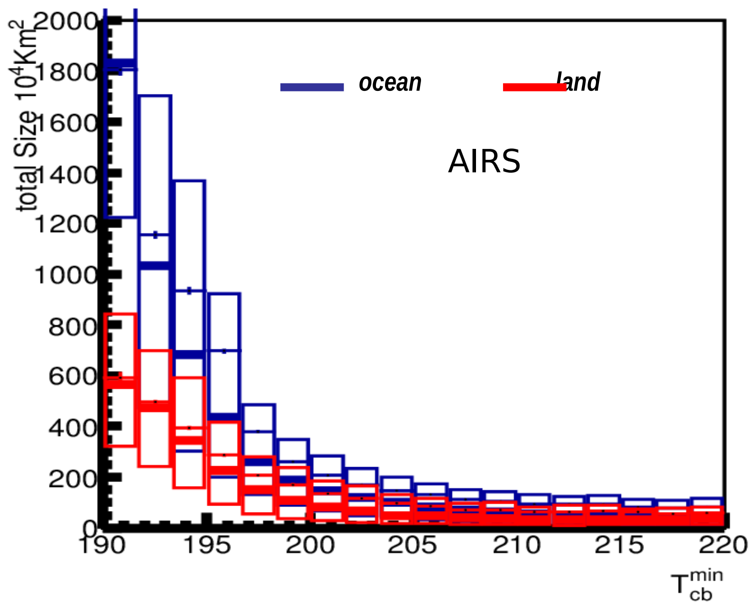


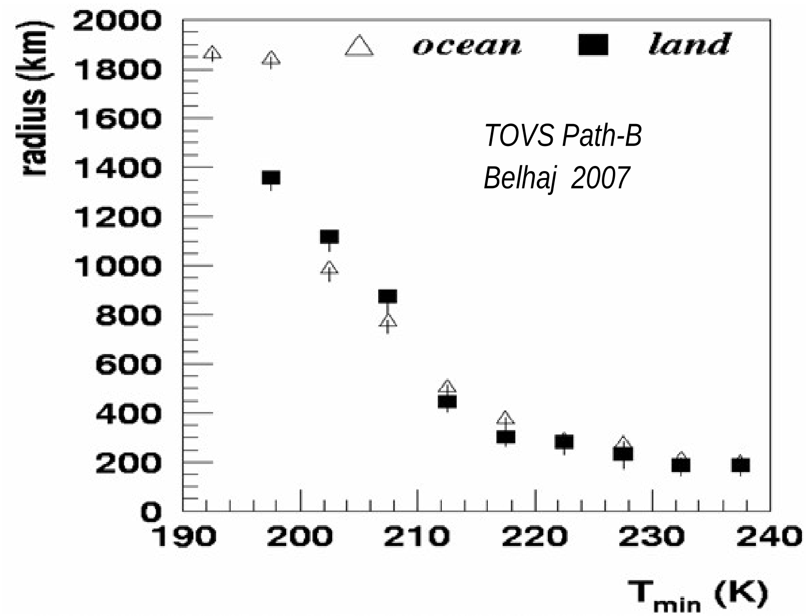
- In larger systems emissivity decreases faster

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

Proxies of convective strength (1)

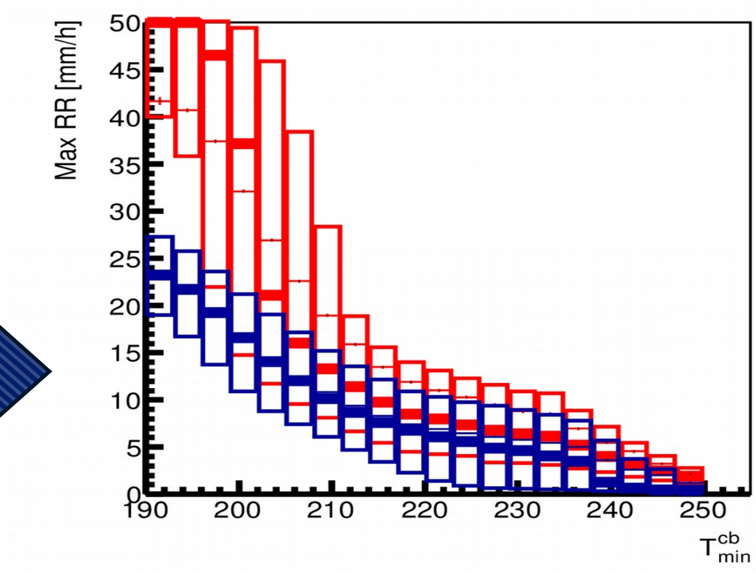
- **min T in convective cores**





> ▶ **Cirrus anvil size increases with decreasing Tmin in convective cores**

- **large area of heavy rainfall**



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

Proxies of convective strength (2)

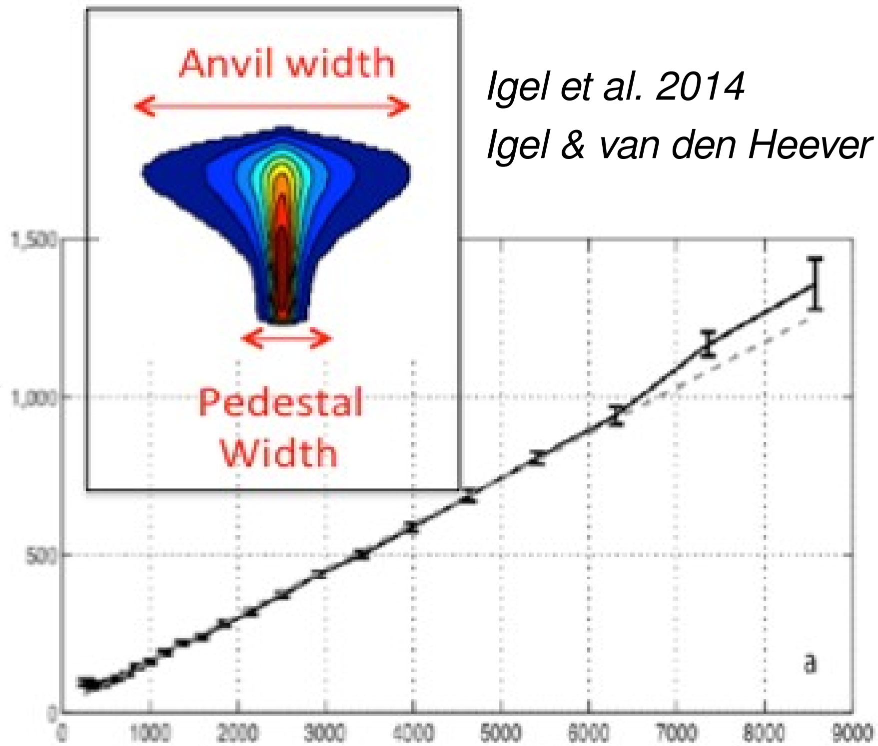
- **width of convective core**

Convective cloud systems
on CloudSat track

Igel et al. 2014

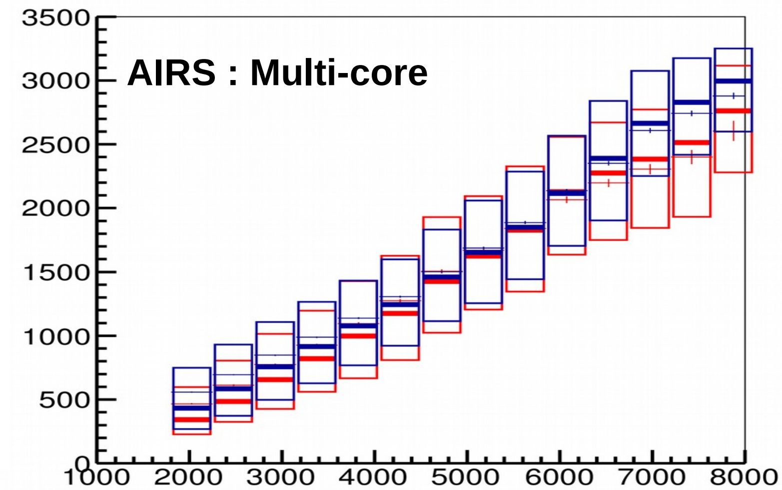
Igel & van den Heever 2015

Anvil Width (km)

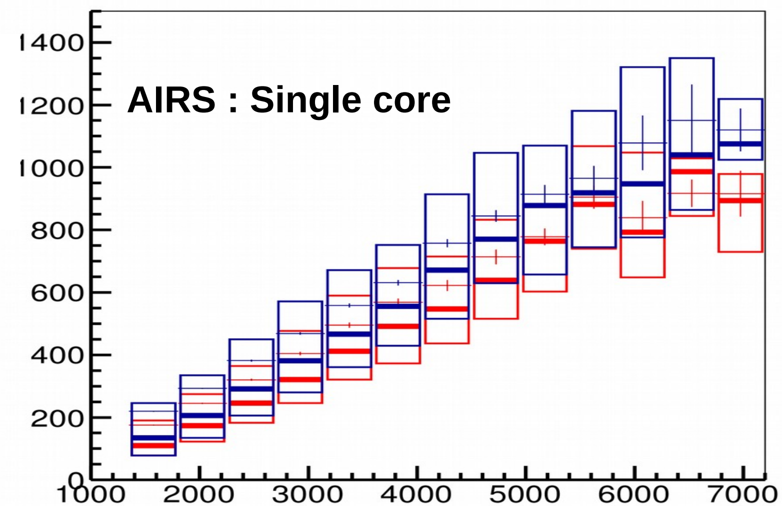


(Core width (m))$^{2/3}$

Anvil Width (km)



Anvil Width (km)

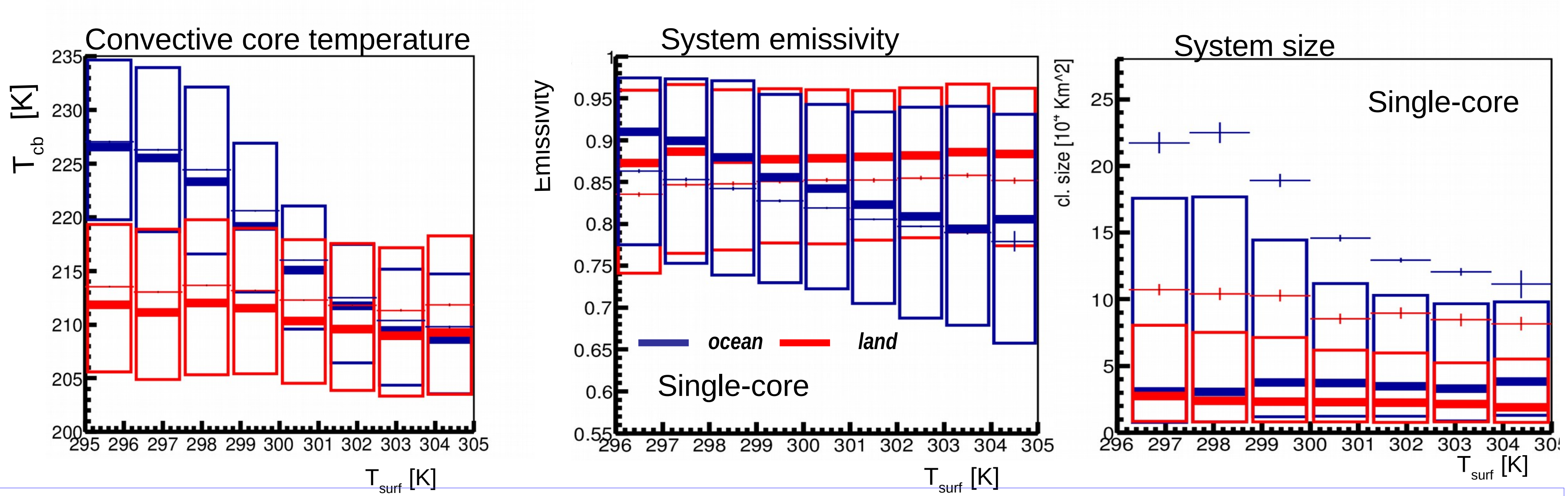


(Core width (m))$^{2/3}$

▶ **Cirrus anvil size increases with convective core width**
→ **over ocean & land; slope stronger for multi-core systems**

How do convective systems behave when T surf increases?

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



Oceanic systems:

- T_{Cb} smaller in regions with large T surf → **convection rises higher**
- Average emissivity slightly smaller in regions with large T surf , **linked to thin cirrus increase**
- System size not much affected

Terrestrial systems:

- T Cb only slightly smaller in regions with large T surf
- System size & average emissivity not much affected

→ *more detailed studies using both data sets & dynamical information*

Conclusion & Outlook

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

- Complex systems are composed of several cores & represent ~75% of HC cover
- Average emissivity decreases with system size
- System size increases with convective strength
  good agreement with CloudSat analysis for single-core systems
- Cloud system altitude increases and average opacity decreases over ocean with increasing T_{surf}. Systems over land not much affected

Future synergies

- A-Train (AIRS-CALIPSO-CloudSat-AMSR-E):
  retrieval evaluation ,vertical structure of cloud types,
  comparison of proxies for convective strength
- AIRS-IASI-ISCCP : life cycle of cloud systems
- ERA Interim: mesoscale winds, thermodynamics

atmosph./cloud properties & AIRS simulator → see Marine's talk
atmosph./cloud properties & Lagrangian transport model → cirrus origin & evolution
atmosph./cloud properties & radiative transfer model → cirrus heating rates