Upper tropospheric convective and cloud processes as a function of convective intensity, aggregation and life cycle: a multi-dataset synergy

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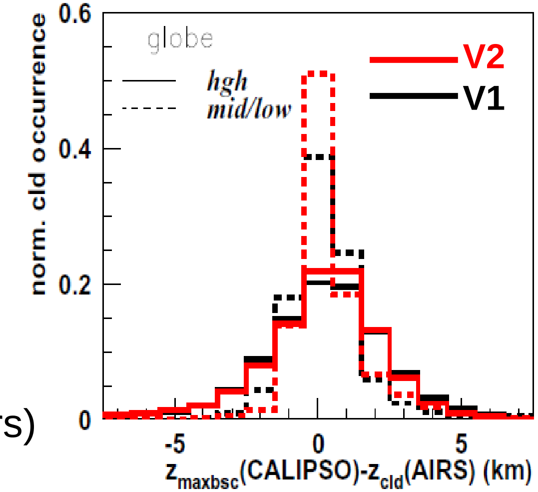
Why using IR Sounders to derive cirrus properties?

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

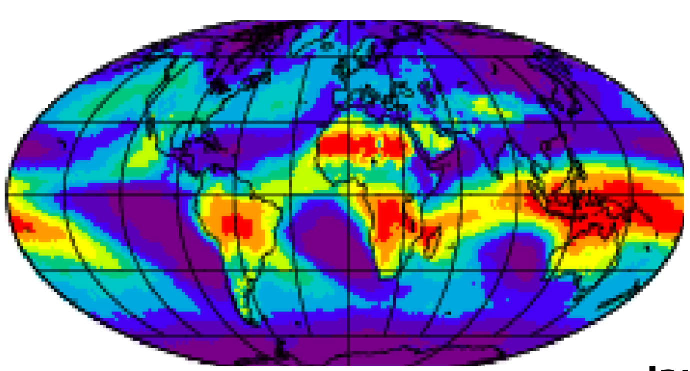


modular retrieval code: LMD-CIRS (LMD **C**loud retrieval from **IR S**ounders)
used for AIRS, IASI (LMD) & for TOVS/ATOVS (CM-SAF)

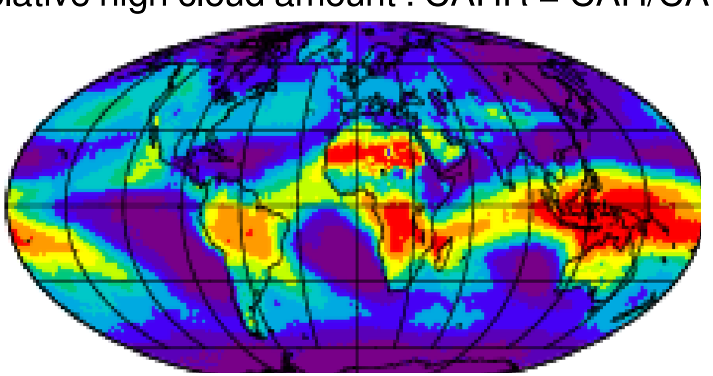
Weighted χ^2 method → get cloud properties: ε_{cld}, p_{cld}, T_{cld}

relative high cloud amount : CAHR = CAH/CA

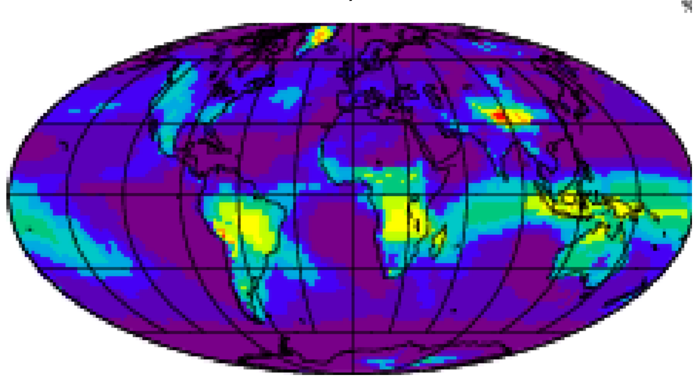
IASI-LMD
2008-2015 (reanalysis V2)

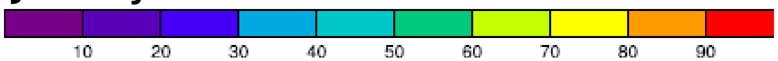


AIRS-LMD
2003-2015 (reanalysis V2)



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





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

From pixels to cloud systems

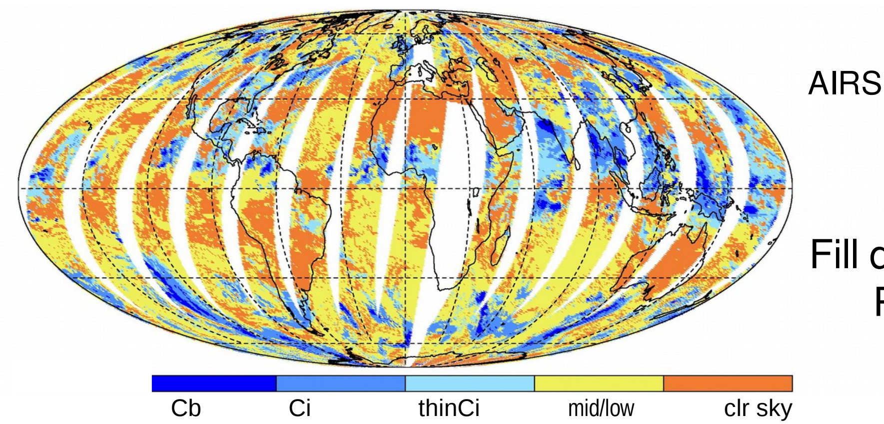
Clouds are **extended objects**, driven by dynamics → **organized systems**

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

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

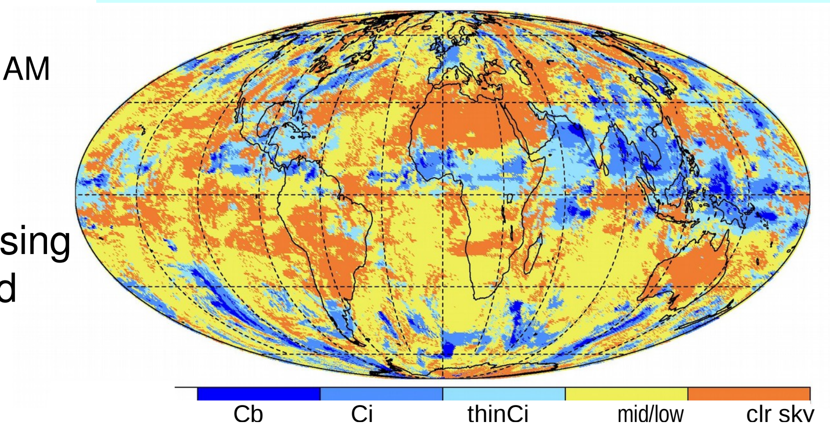
ε_{cld} >0.98 / **$0.5<\varepsilon_{cld}<0.98$** / **$\varepsilon_{cld}<0.50$**

distinguish systems with & without convection, count convective cores

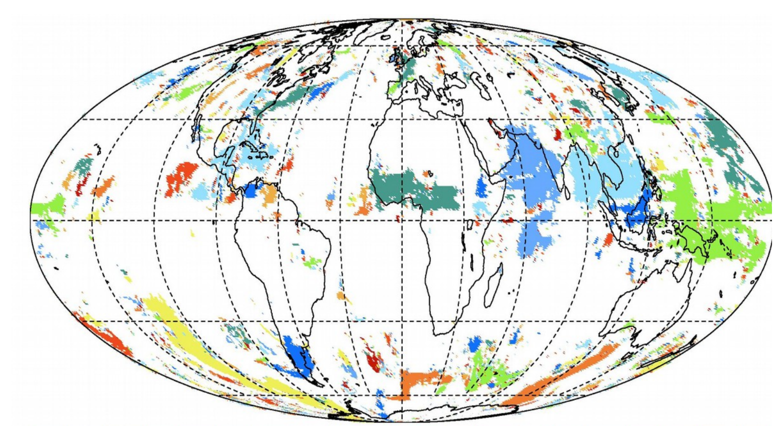


AIRS :1 July 2007, AM

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

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

Since last November...

- Improvements :
  - Gap filling method
  - Introduce correction on cloud fractions for multicore systems
  - Definition of convective cores ✔

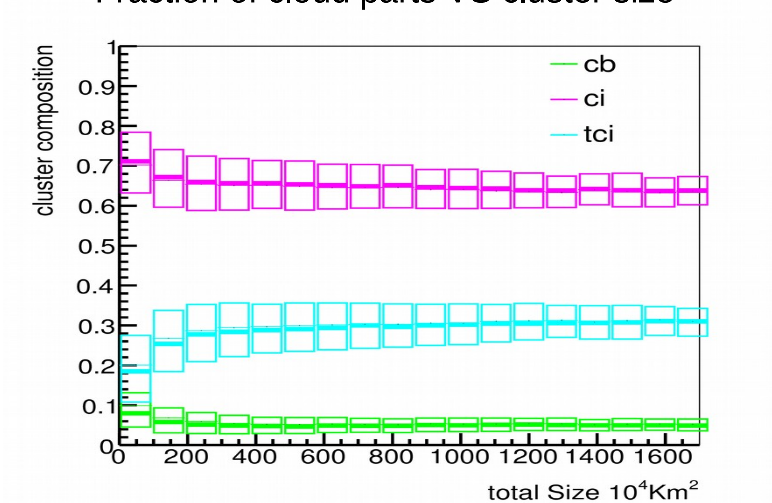
- New Level 2 data :
  - AIRS new reanalysis (L2 data) ready! $\rightarrow$ no impact on results!
  - IASI (L2) data ready ✔

- Cooperations :
  - with H. Takahasi (JPL): collocation with CloudSat convective objects
  - with M.Bonazzola (LMD): constrain model parameters

Reminder :

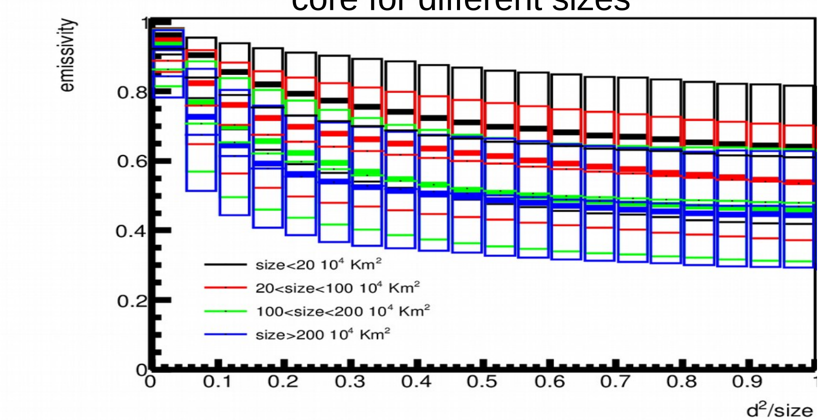
Statistics and composition:

Fraction of cloud parts VS cluster size



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

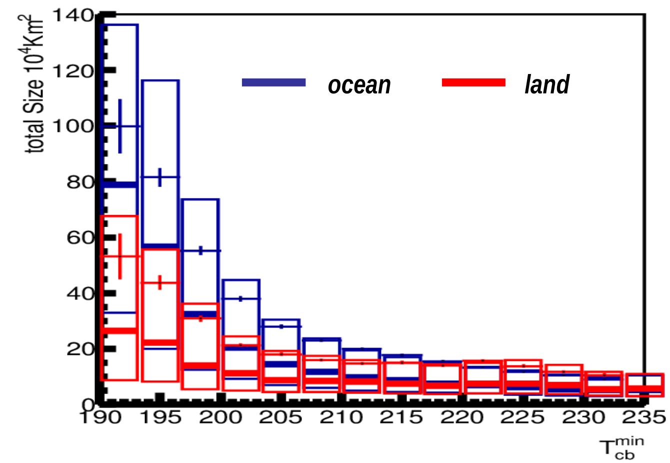
Emissivity as a function of distance to the core for different sizes



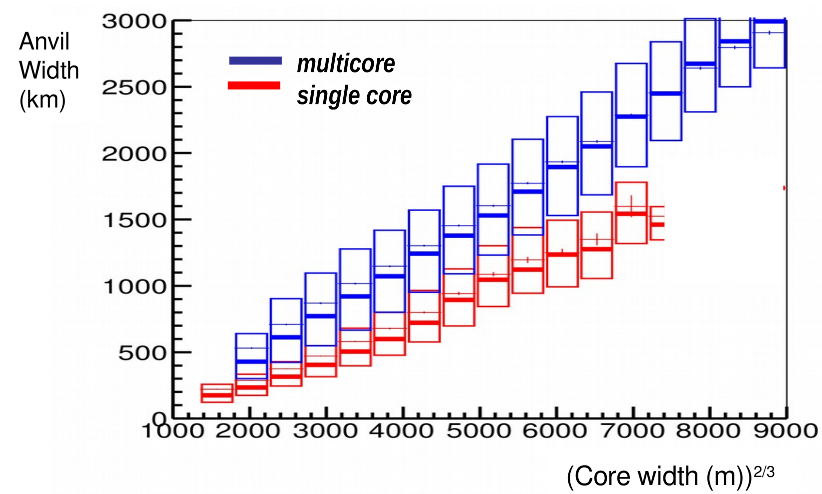
- In larger systems emissivity decreases faster

Convective strength:

cluster size VS Minimum Temperature in cb



- Cirrus anvil size increases with decreasing Tmin in convective cores



- Cluster size increases with convective core width both over ocean & land; multicore stronger slope

Tropical Mesoscale Convective System

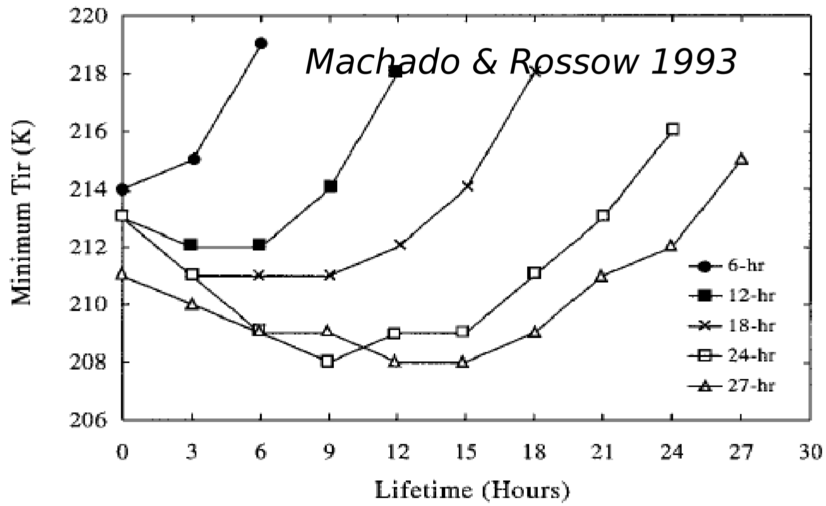
- use high time resolution of geostationary satellite imagers to study life cycle

merge adjacent footprints containing cold clouds using $T_B^{IR\ window}$

Yuan & Houze 2010 (<260 K, Cb from AMSR-E rain rate)

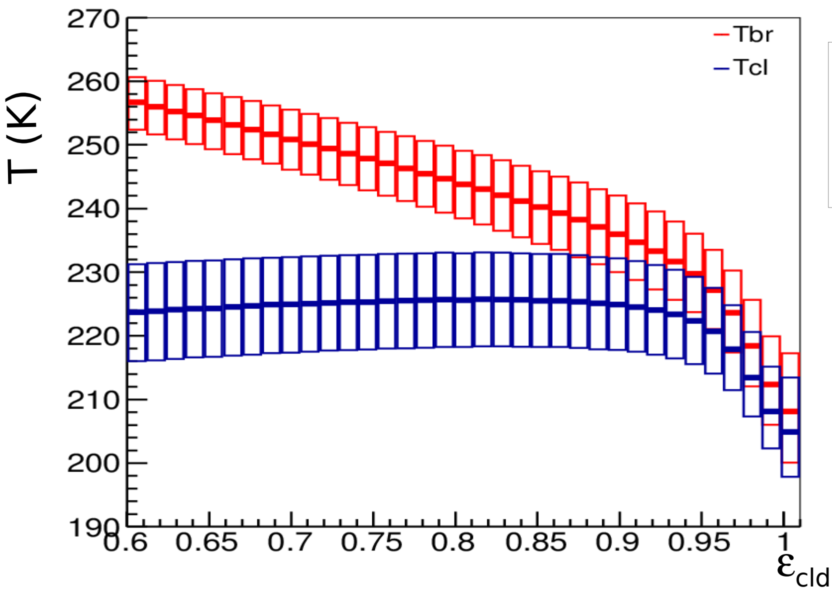
Fiolleau & Roca 2013 (< 233 K, Cb from TRMM rain rate)

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

AIRS analysis 30N-30S



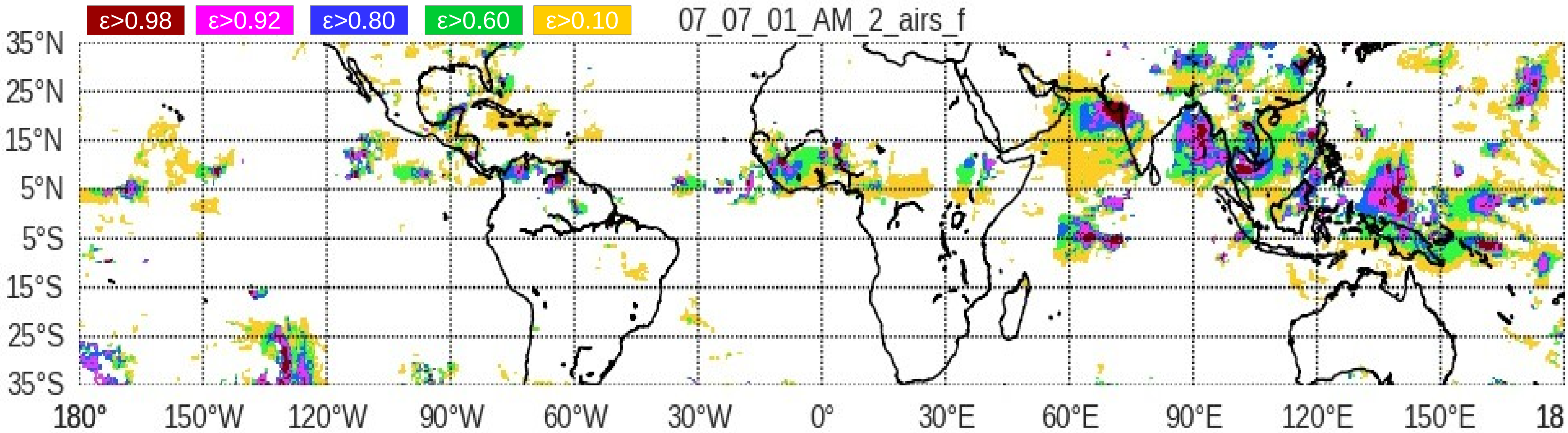
T_{cld} & ε_{cld} are independent variables , whereas T_B^{IR} depends on T_{cld} & on ε_{cld}

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

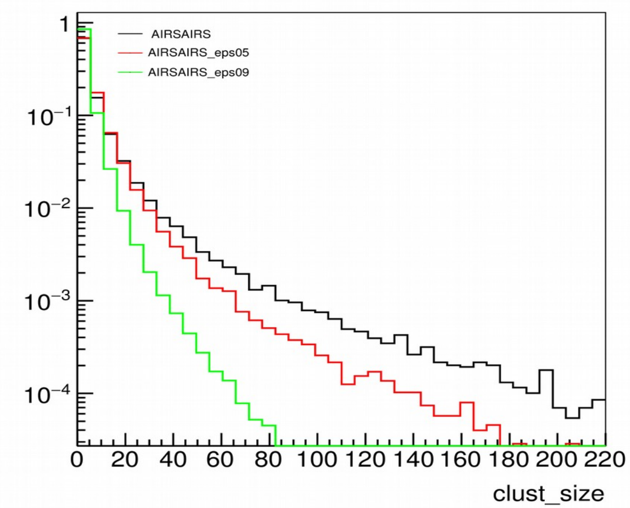
215K / 233K / 245K / 260K

0.98 / 0.92 / 0.8 / 0.6

Cloud system definition

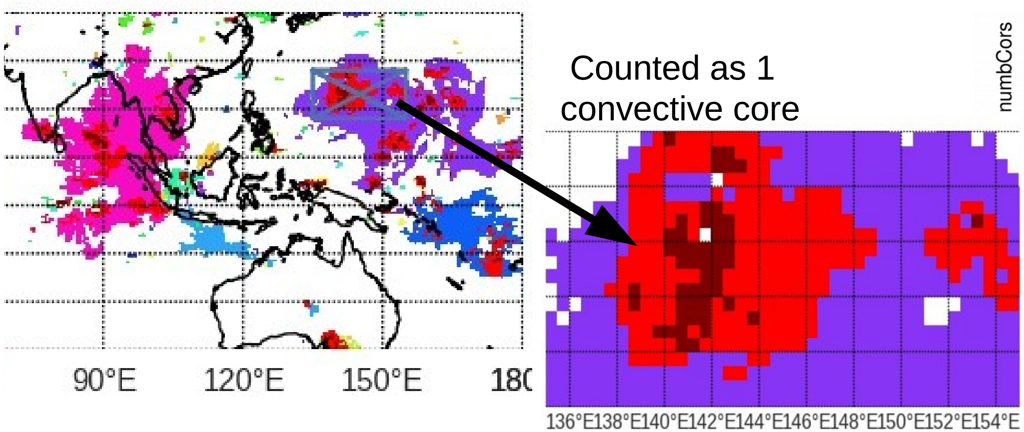


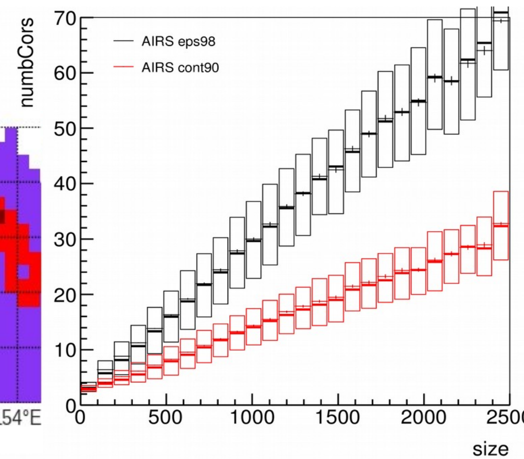
- Excluding grids with eps<0.6 → single core systems increase from ~5% of HCLd cover to ~ 25%, with a respective multi-core decrease.
  - Large multicore systems "split" → average multicore size drops by a factor of 10
  - But.. thin cirrus crucial radiative impact on earth's budget

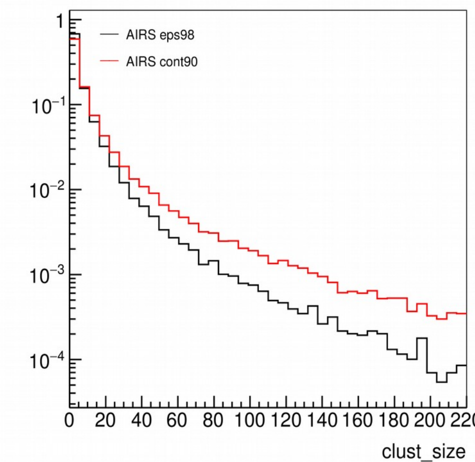


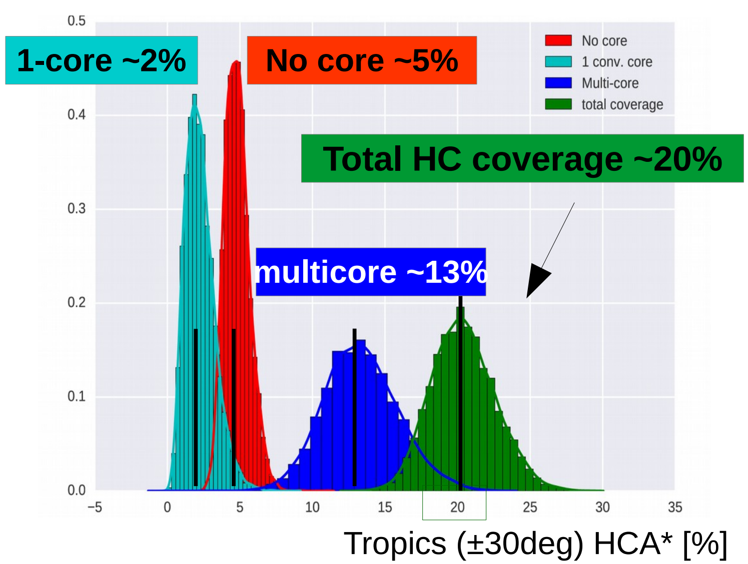
Cloud core definition & system statistics

- New core definition: contours of emissivity >0.9 containing at least one convective (eps>0.98) → reduce noise + increase statistics of single-core systems : from 5% of HCL coverage to 10%







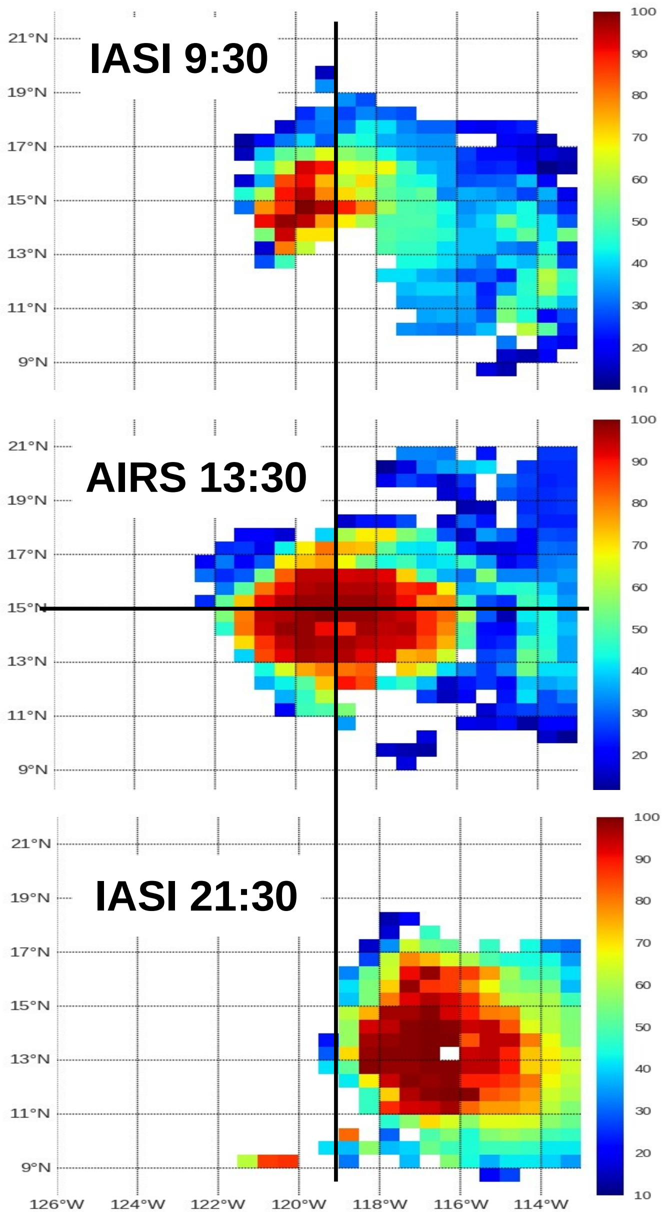


Core ε_{cld} >0.98	Multi-core	single-core	No core
Numb.of systems	~1%	<4%	~95%
coverage	~65%	~10%	~25%
Average size	~200*10^4 Km^2	~10*10^4 Km^2	~10^4 Km^2

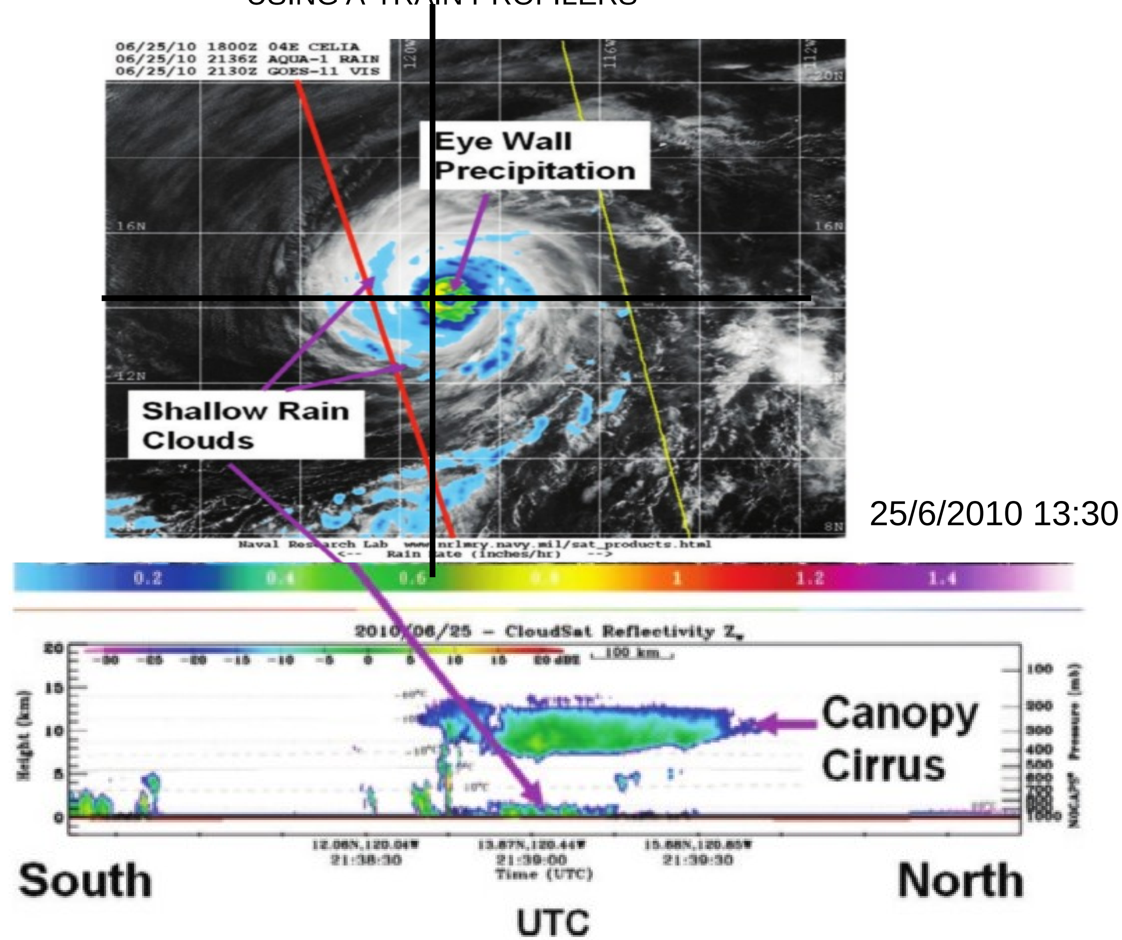
*HCA → **H**igh (P-Ptropo <250 hPa) **C**loud **A**mount

- Non-convective Ci : ~25% of high cloud cover 50% of isolated Ci origina from convection *(Luo & Rossow 2004, Riihimaki et al. 2012)*

Data synergies: A-train and IASI



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

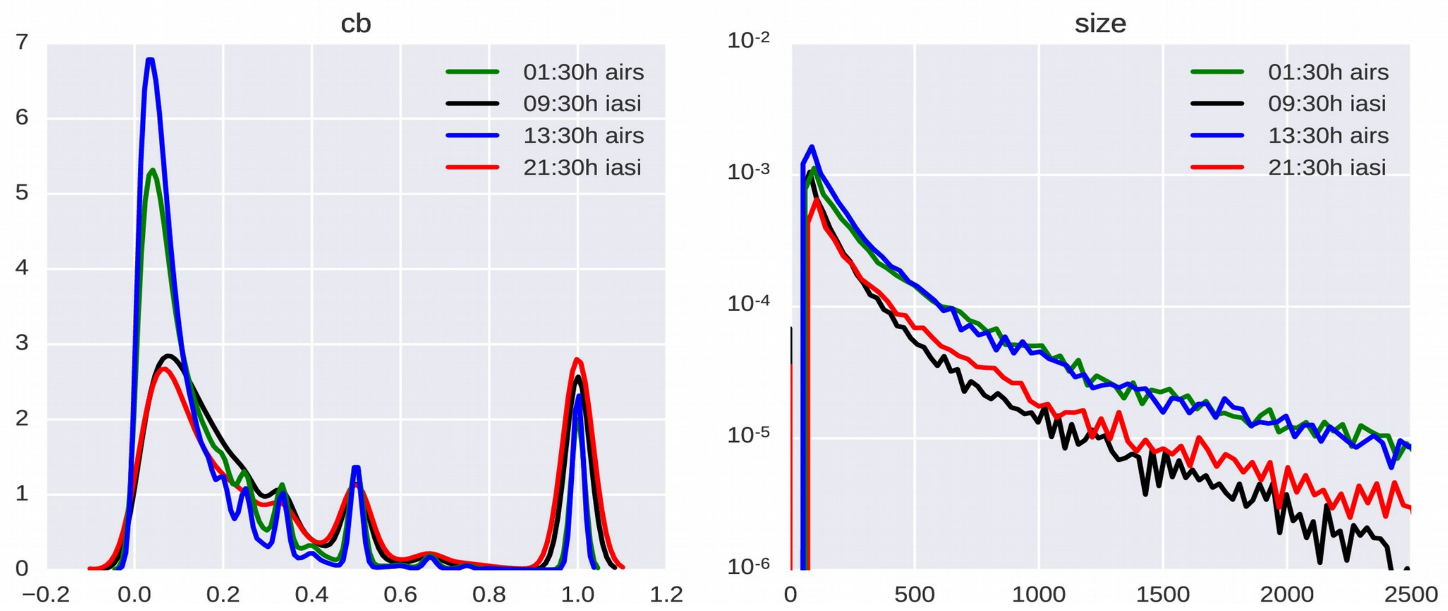


Data synergies with A-train allows to parametrize

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

AIRS + IASI

- Pixels: AIRS-IASI diurnal cycle in level ok → compatible with model!!
  → see Marine's talk
- Clusters:
  - AIRS-IASI coverage per cluster type **in agreement**
  - IASI clusters slightly smaller → larger cb fractions : noise?

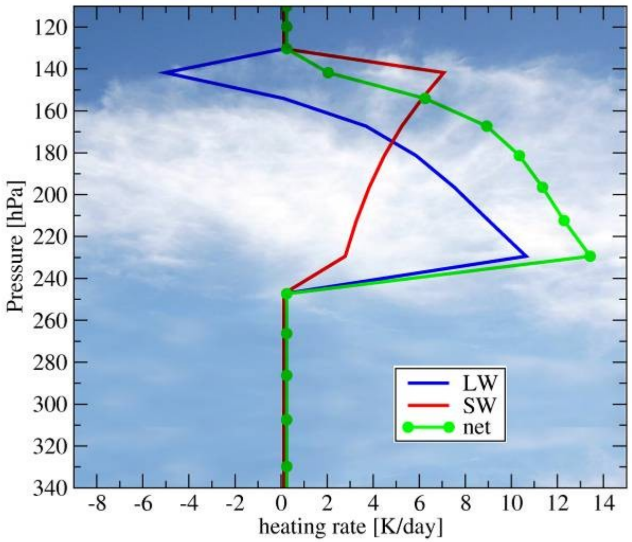


IASI 4 spots while AIRS 9 : IASI more noise → smaller size
→ need to apply smearing to IASI data

Cirrus Radiative Heating

Critical to feedbacks : cirrus radiative heating in upper troposphere

- Cirrus anvils might regulate convection as they stabilize the atmospheric column by their heating *(Stephens et al. 2008, Lebsock et al. 2010)*

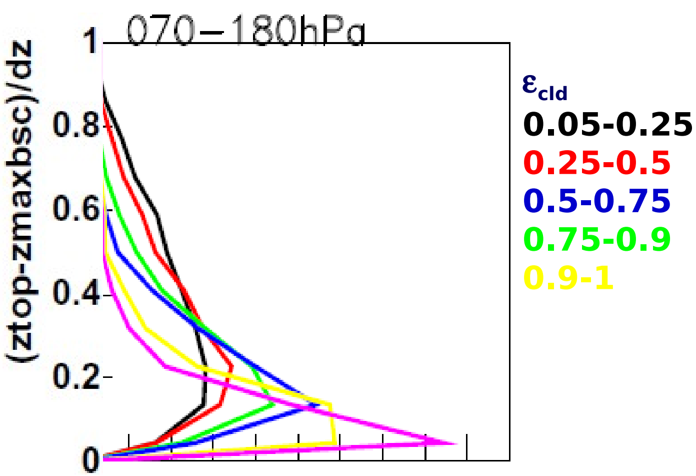


Heating will be affected by:

- areal coverage
- emissivity distribution
- vertical structure of cirrus anvils

(microphysics & multiple layering)

Goal: gain a better understanding of relation between convection and heating induced by cirrus anvils



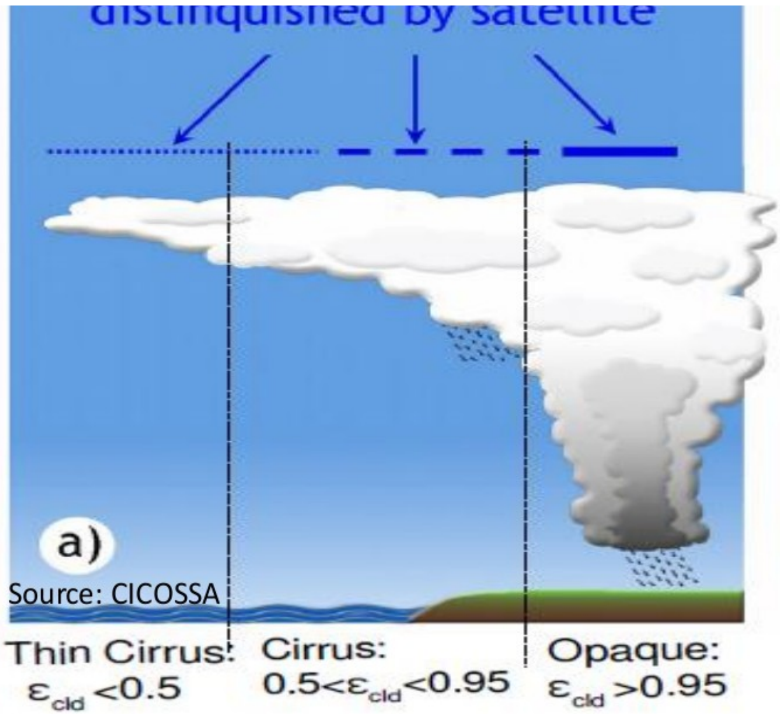
→ determine radiative fluxes & heating rates

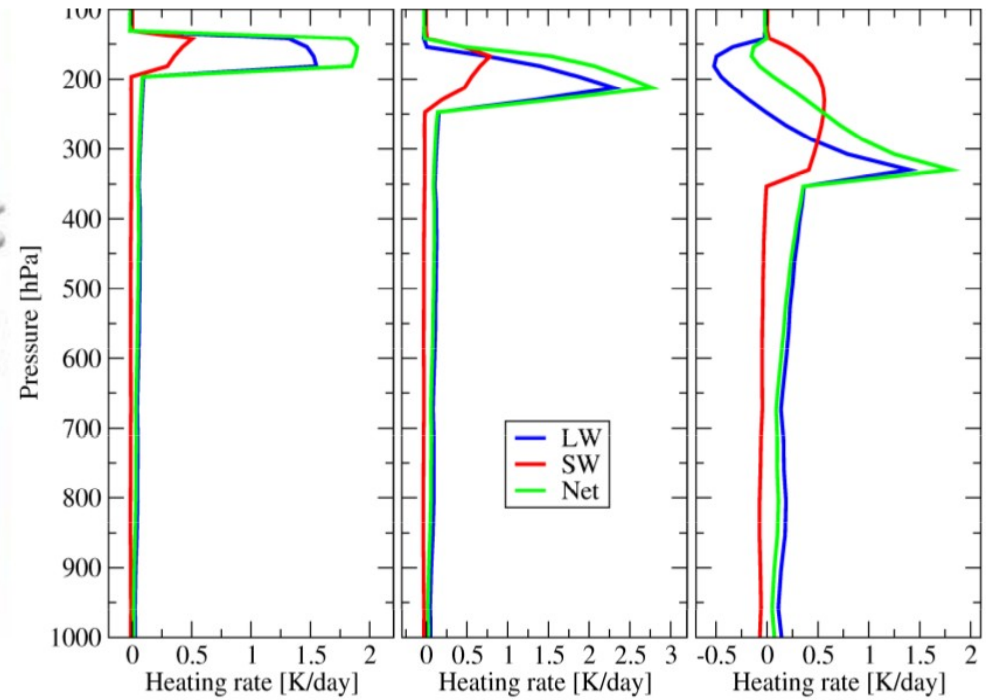
by categorizing atmospheric situation wrt T & H_2O profiles

by categorizing vertical structure wrt ε_{cld} (IWP) & p_{cld}

by interpretation of retrieved cloud height

Heating rates of anvil parts



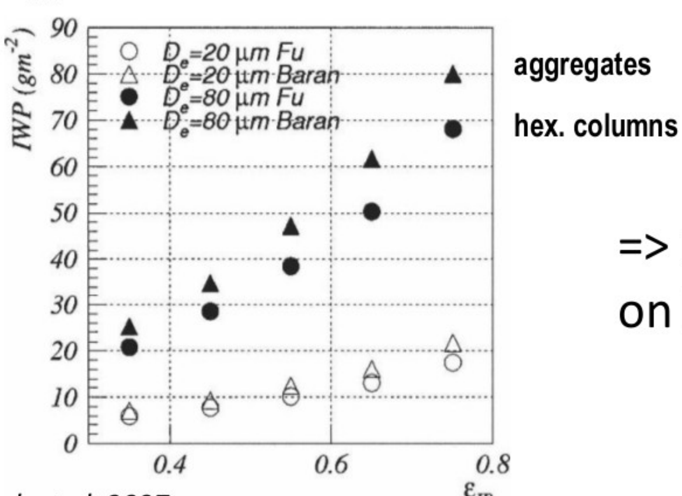


IWP= 10, 30, 300 gm^{-2}

De = 30, 50, 80 μm

const. IWC profile IWC trapezia increas. IWC profile

same ε_{cld} reached by small or large (IWP,De)



Stubenrauch et al. 2007

IWC classification as fct of IWP
(*Feofilov et al. ACP 2015*)

=> need information
on De or IWC / De profiles

Conclusion & Outlook

- ε -T_{br} relation $\rightarrow$ comparison with T_{br} studies possible
- Improved definition of convective core
- Ongoing: write the paper,IASI-AIRS synergy, constrain model parameters...

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

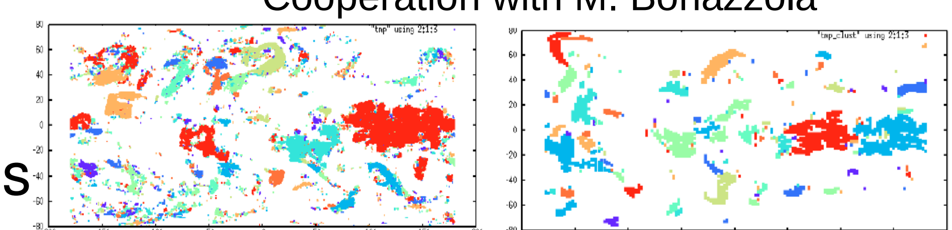
Meteorological reanalyses : mesoscale winds

atm./cloud properties & radiative transfer model $\rightarrow$ cirrus heating rates

atm./cloud properties & Lagrangian transport model $\rightarrow$ cirrus origin & evolution

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

Cooperation with M. Bonazzola



data simulator