Coupling tropical convection to anvil properties using a cloud system approach

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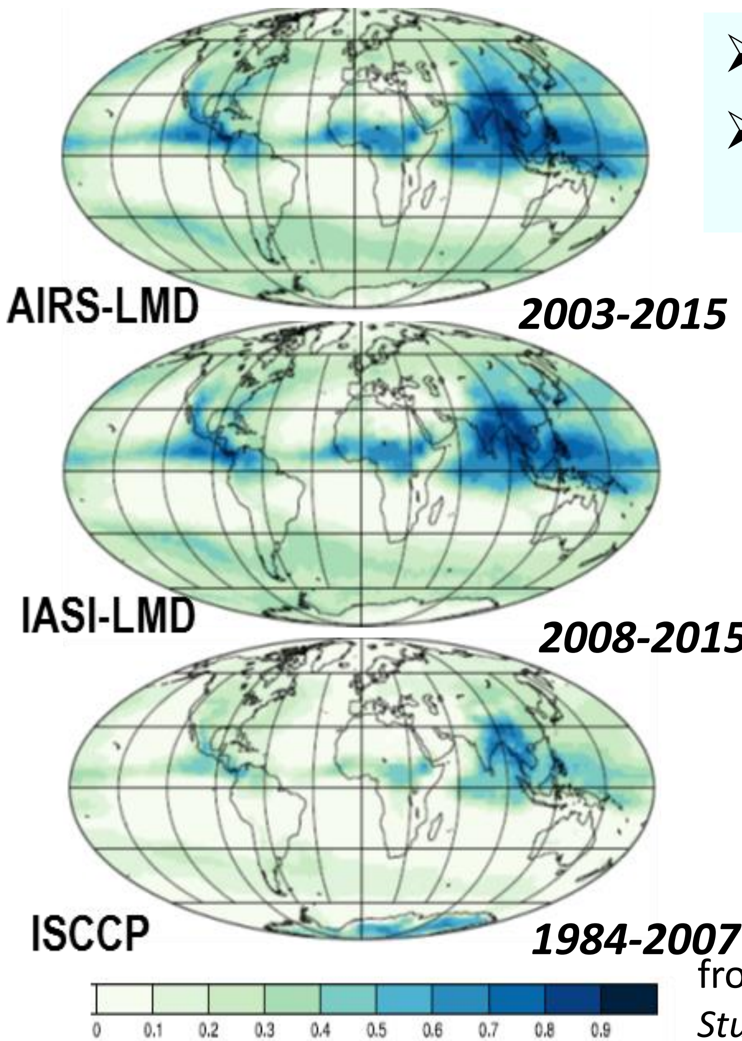
Upper Tropospheric Clouds play a vital role in the climate system

Why using IR Sounders to derive cirrus properties ?

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

high cloud amount July



- long time series & good areal coverage
- good IR spectral resolution -> sensitive to cirrus
  day & night, COD > 0.2, also above low clouds

CIRS (Cloud retrieval from IR Sounders):

ATBD: *Feofilov & Stubenrauch 2017* (DOI: 10.13140/RG.2.2.15812.63361)

Stubenrauch et al., J. Clim. 1999, 2006; ACP 2010, 2017 (in prep.)

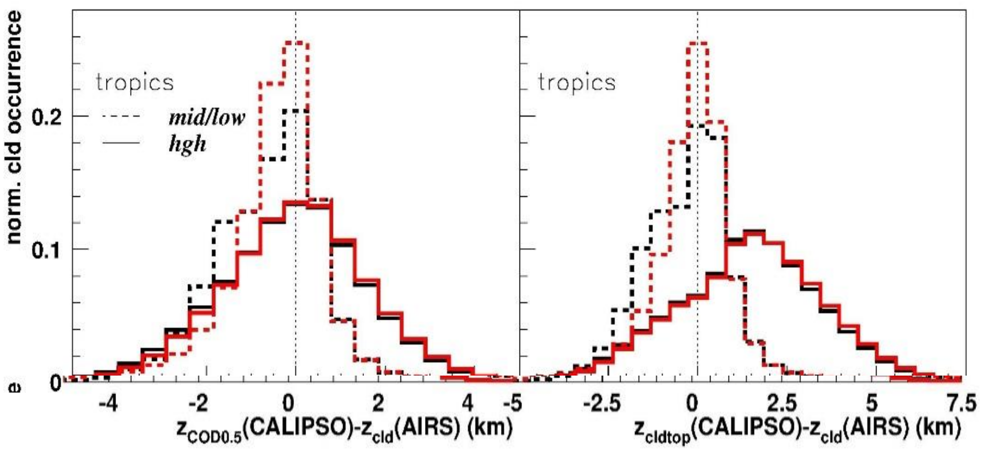
Climatologies will be available at French data centre AERIS (L2 and L3, 2017)

from GEWEX Cloud Assessment Database

Stubenrauch et al. BAMS 2013

Evaluation of CIRS cloud properties

Stubenrauch et al. 2017, in prep.

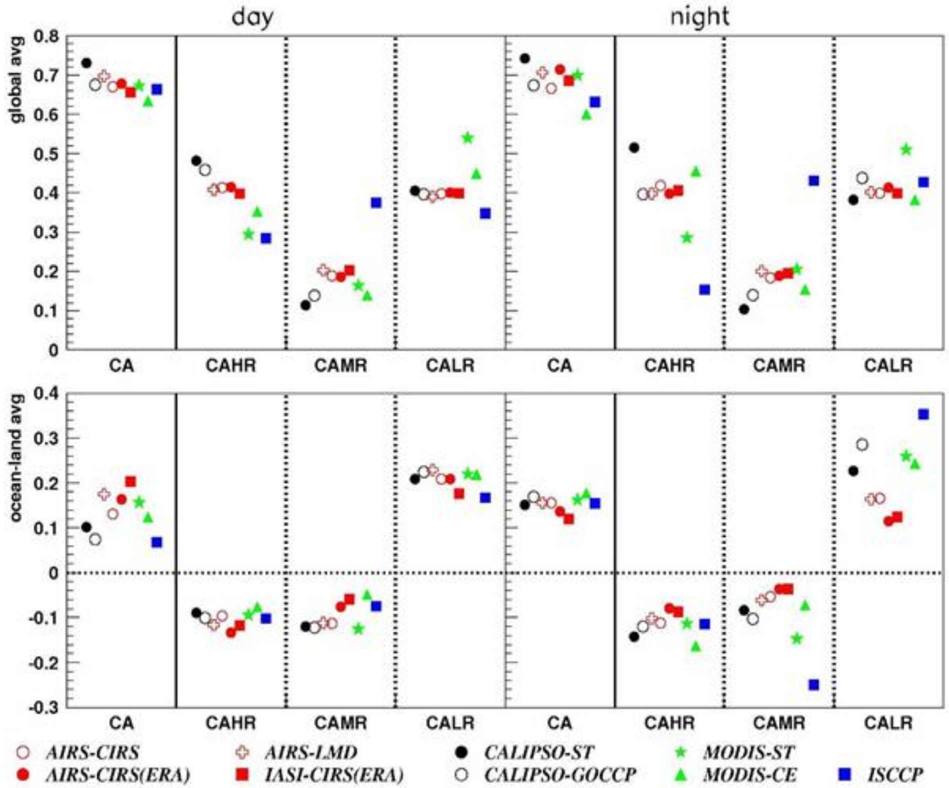


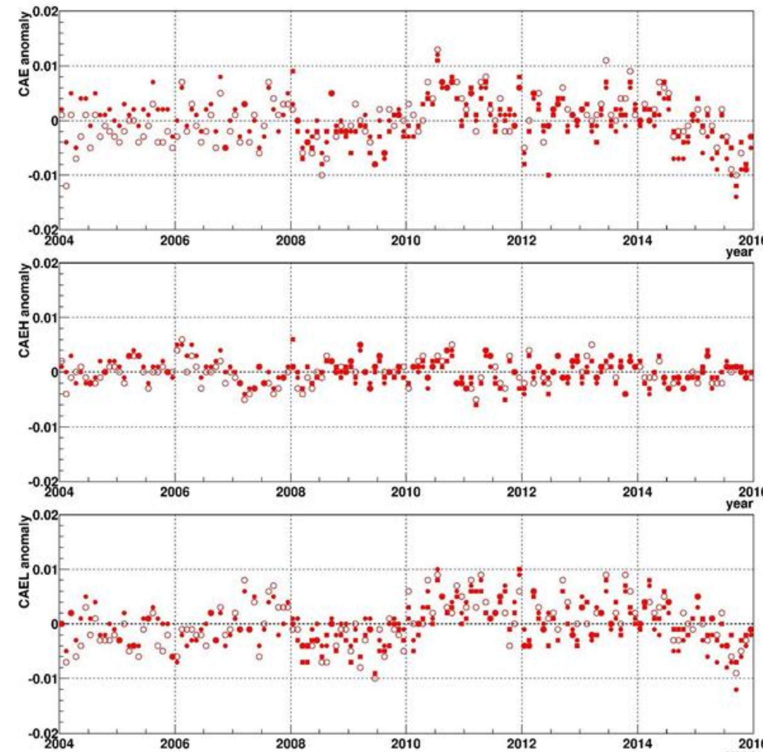
2 sets of atm ancillary data (NASA AIRS / ERA-Interim) -> uncertainty determination

AIRS-CALIPSO-CloudSat synergy:
cloud detection agreement 84-85% over ocean, 79-82% over land, 70-73% over ice/snow
cloud height = cloud height (COD= 0.5)

cloud partitioning: 40% high clouds,
40% single layer low clouds

longterm record looks coherent



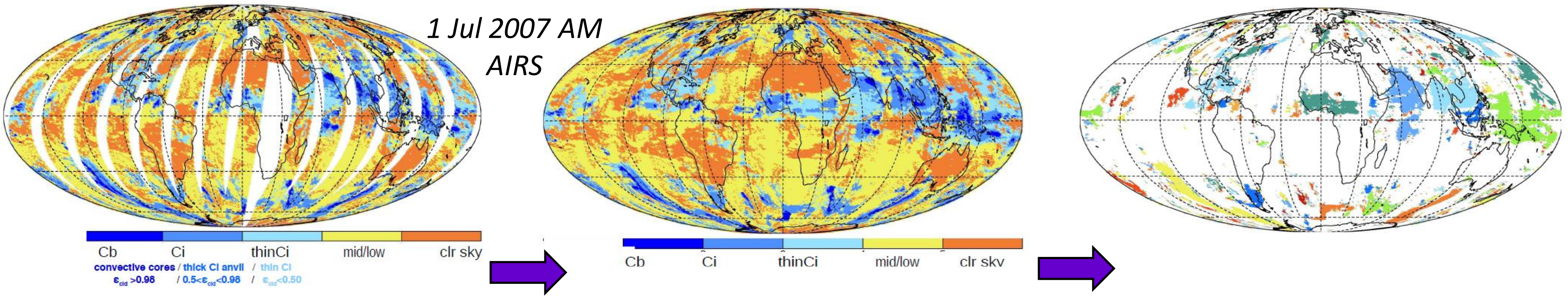


From cloud retrieval to cloud systems

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

Method: 1) group adjacent grid boxes with high clouds of similar height (p_{cld})

1 Jul 2007 AM AIRS

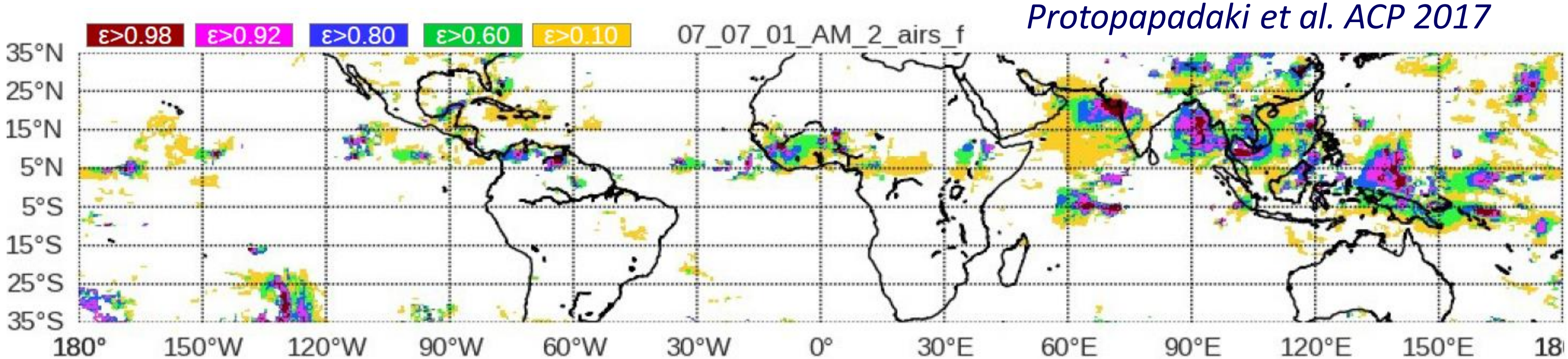


fill data gaps using PDF method

build UT cloud systems

2) use ε_{cld} to distinguish convective core, thick cirrus, thin cirrus

Protopapadaki et al. ACP 2017



X-Y-t: IR sounder (p_{cld},ε_{cld}) vs Imager T_B^{IR} method

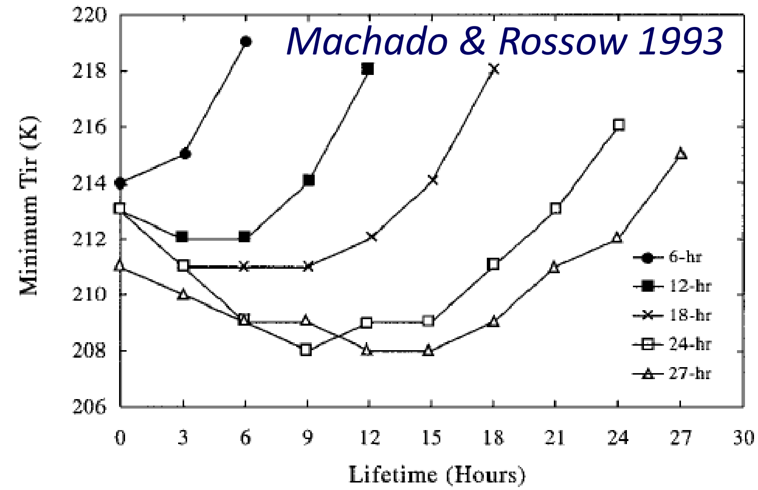
high time resolution of geostationary satellite imagers for life cycle study

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

Yuan & Houze 2010 (<260 K + AMSR-E rain rate), *Fiolleau & Roca 2013* (< 233 K + 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_B^{IR} depends on T_{cld} & on ε_{cld}

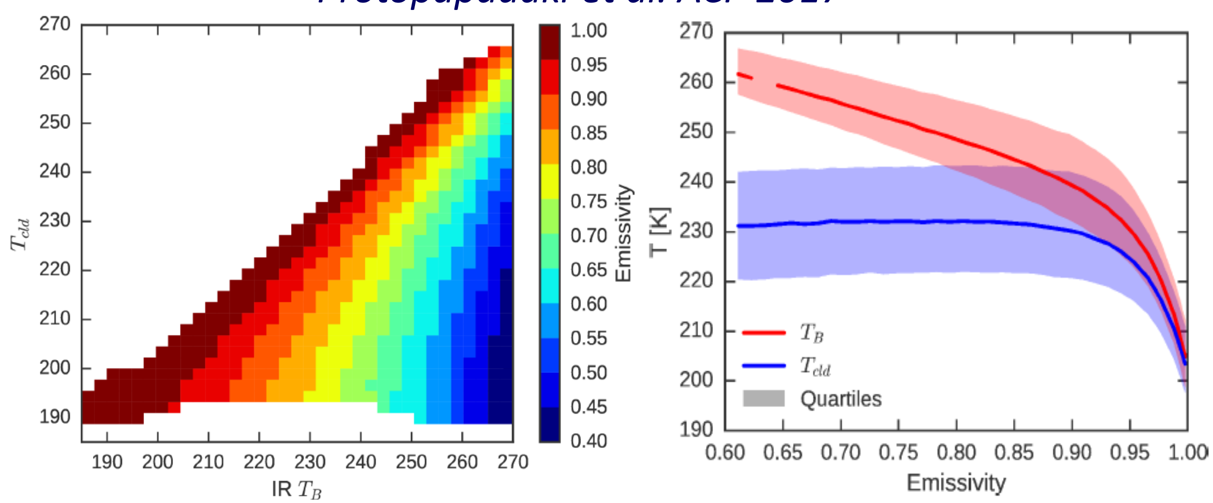
T_{cld} & ε_{cld} are independent variables:

T_B^{IR} threshold ->
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

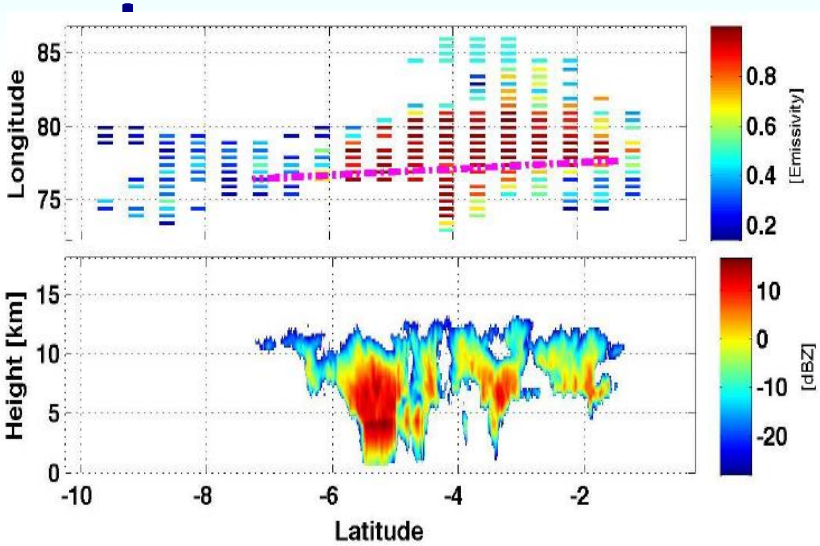
tracking of cores from geostat.
+ cirrus from AIRS/IASI

Protopapadaki et al. ACP 2017



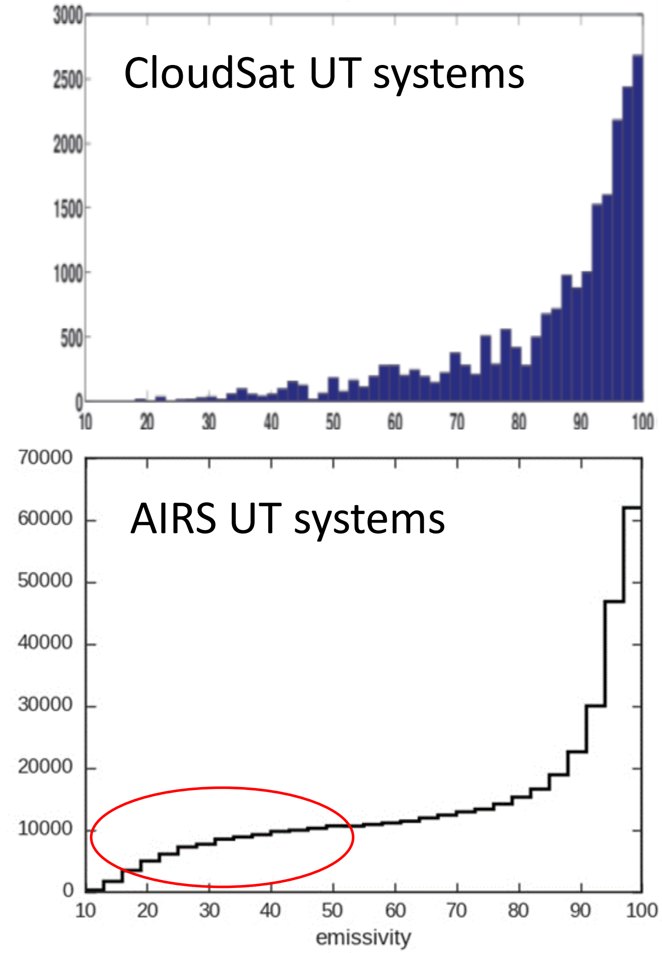
X-Y-Z: AIRS – CloudSat synergy on convective cloud systems

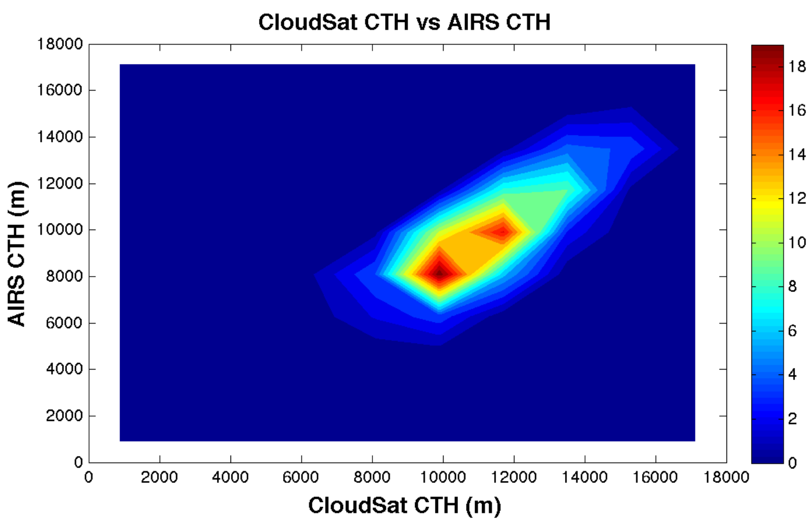
collaboration with *Hanii Takahashi, JPL*



- AIRS adds to horizontal dimension
- AIRS extends systems beyond $\varepsilon_{cld} < 0.5$

ε_{cld} distributions





good correlation between AIRS & CloudSat cloud height : r=0.73

Goal: relate anvil properties to convective strength

Strategy:

need proxies

- to identify convective cores

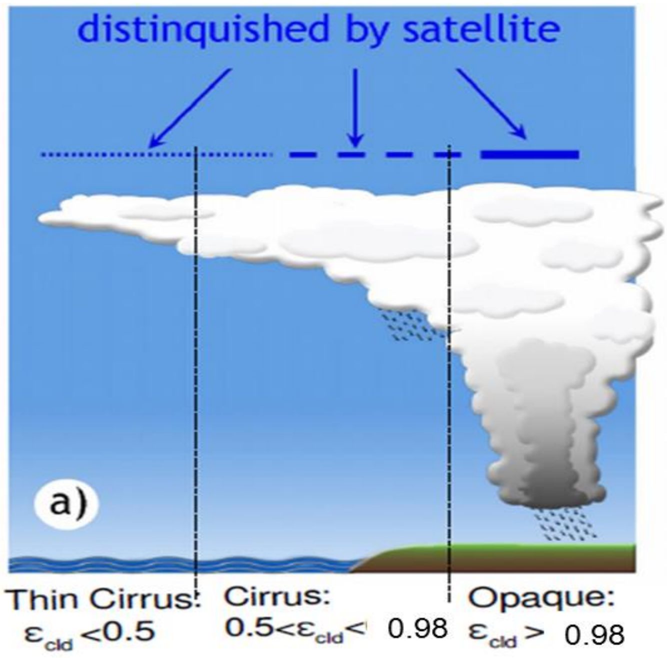
  $\varepsilon_{cld} > 0.98$

- to identify mature convective systems

  Cb/system: 0.1 – 0.3

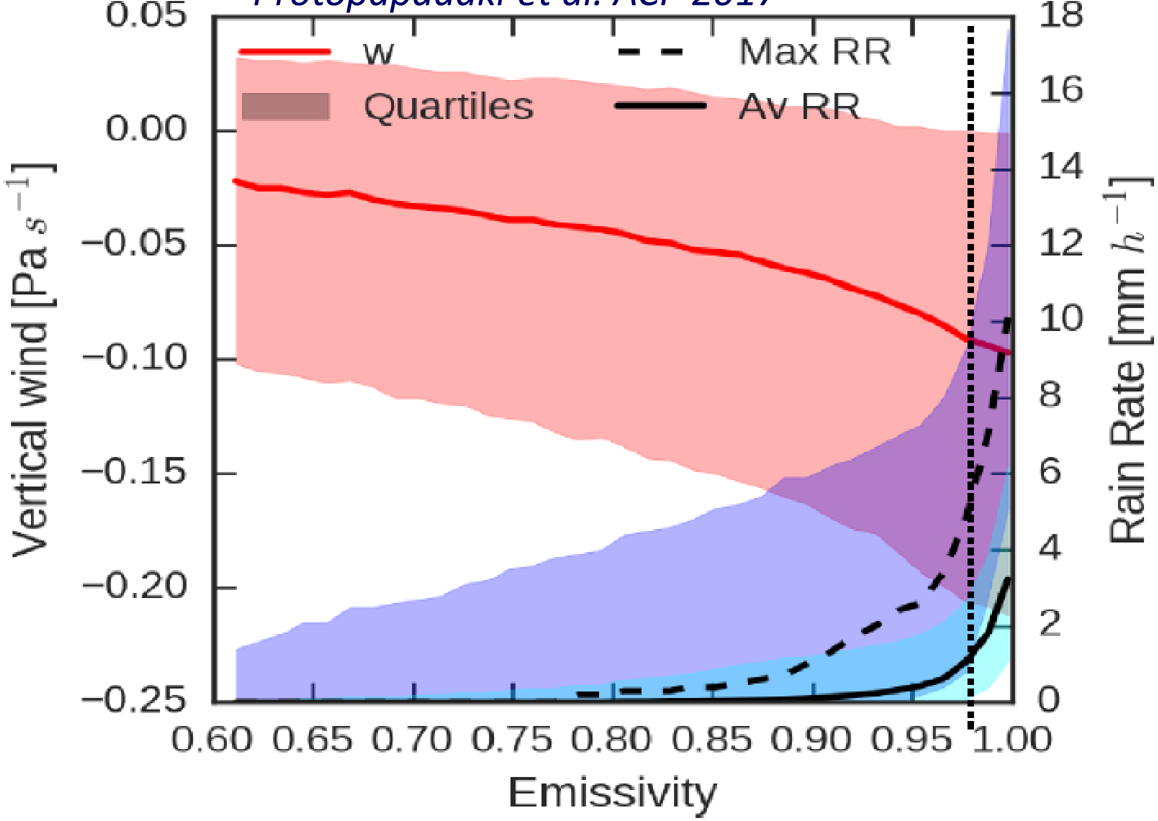
- to describe convective strength

  T_{min}^{Cb}



Identify convective cores

Protopapadaki et al. ACP 2017



Synergies:

AIRS -> ε_{cld}

AMSR-E -> rain rate

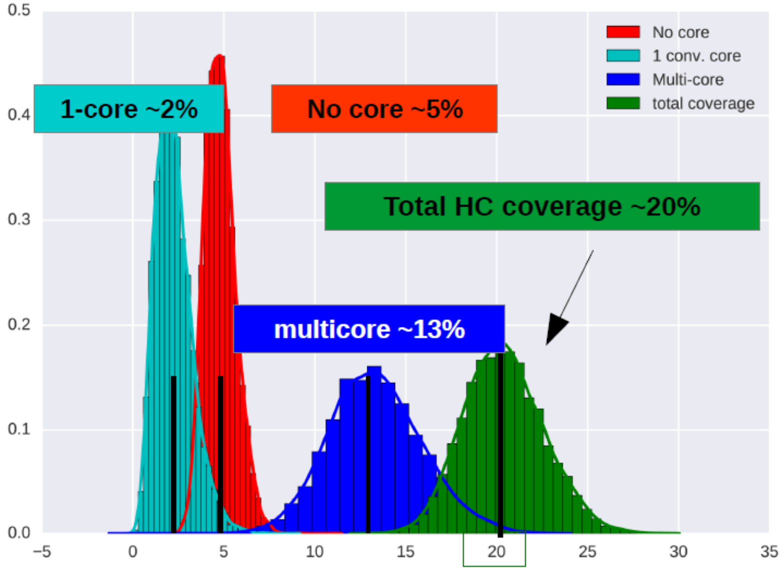
ERA-Interim -> vertical wind

convective core defined by ε_{cld}>0.98
since RR sharply increases, compatible with larger updrafts

- distinguish systems with / without convective core
- distinguish systems with single / multi convective cores

UT Cloud System Statistics

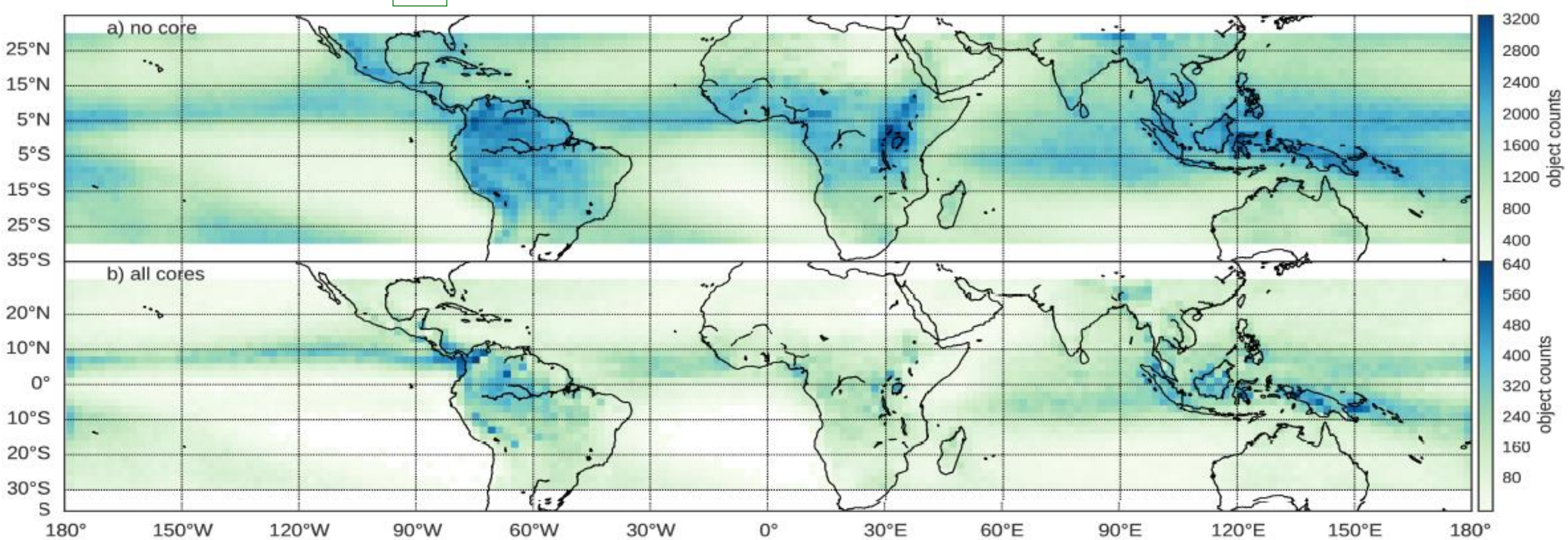
UT cloud systems cover 20% of the latitude band 30N-30S



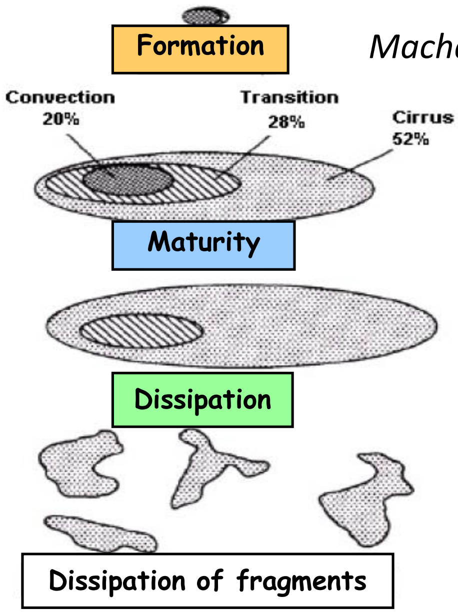
Core ε_{cld} >0.98	Multi-core	single-core	No core
Systems count	~1%	<4%	~95%
coverage	~65%	~10%	~25%
Average size [km²]	~200*10⁴	~10*10⁴	~10⁴

UT cloud systems without convective core cover about 5% of 30N-30S
50% of these are originating from convection
(Luo & Rossow 2004, Riihimaki et al. 2012)

Protopapadaki et al. ACP 2017



Proxies for life stage of convective system

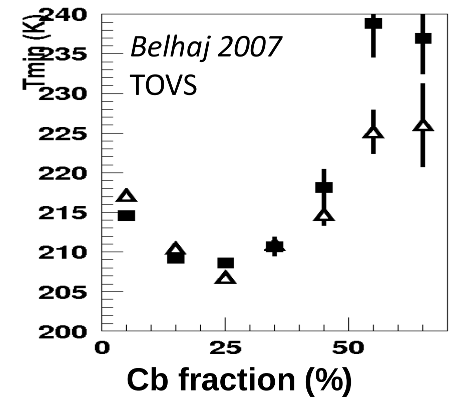


Machado & Rossow 1993

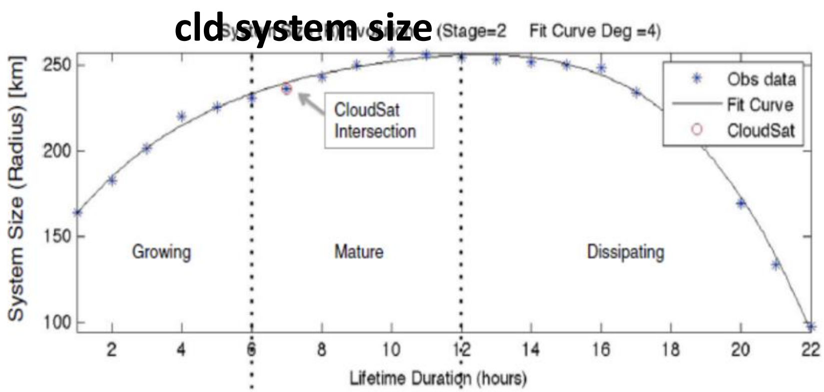
convective core fraction within system

Formation (Cb>40%): ***small size, warm***
Maturity (10-30% Cb): ***max size, min temperature***
Dissipation (Cb<10%): ***small size, slightly warmer***

in agreement with *Futyan & DelGenio 2007* over Africa

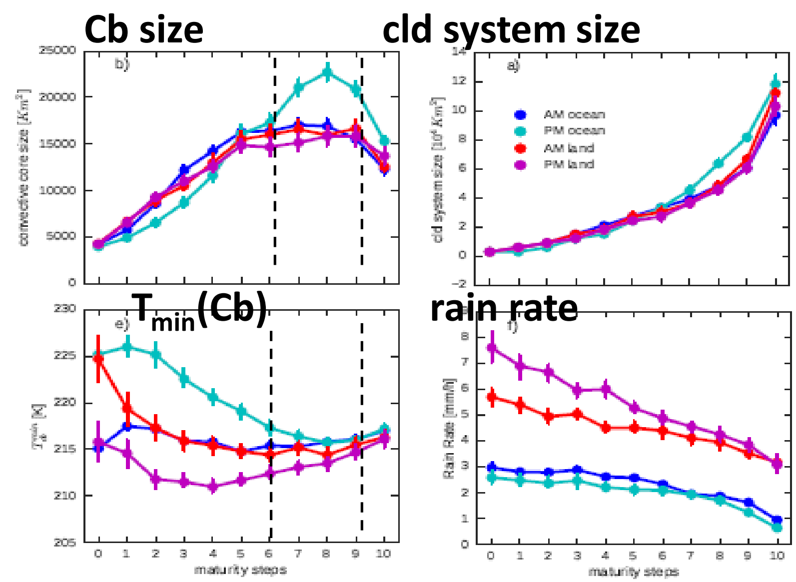


max of convection over land (ocean) 16-18h (during night)
problem: most polar sunsynchroneous observations do not catch this



anchor CloudSat to ISCCP-CT database:
use $TB(IR)_{min}$ & r(conv system) to follow development

Takahashi & Luo 2014



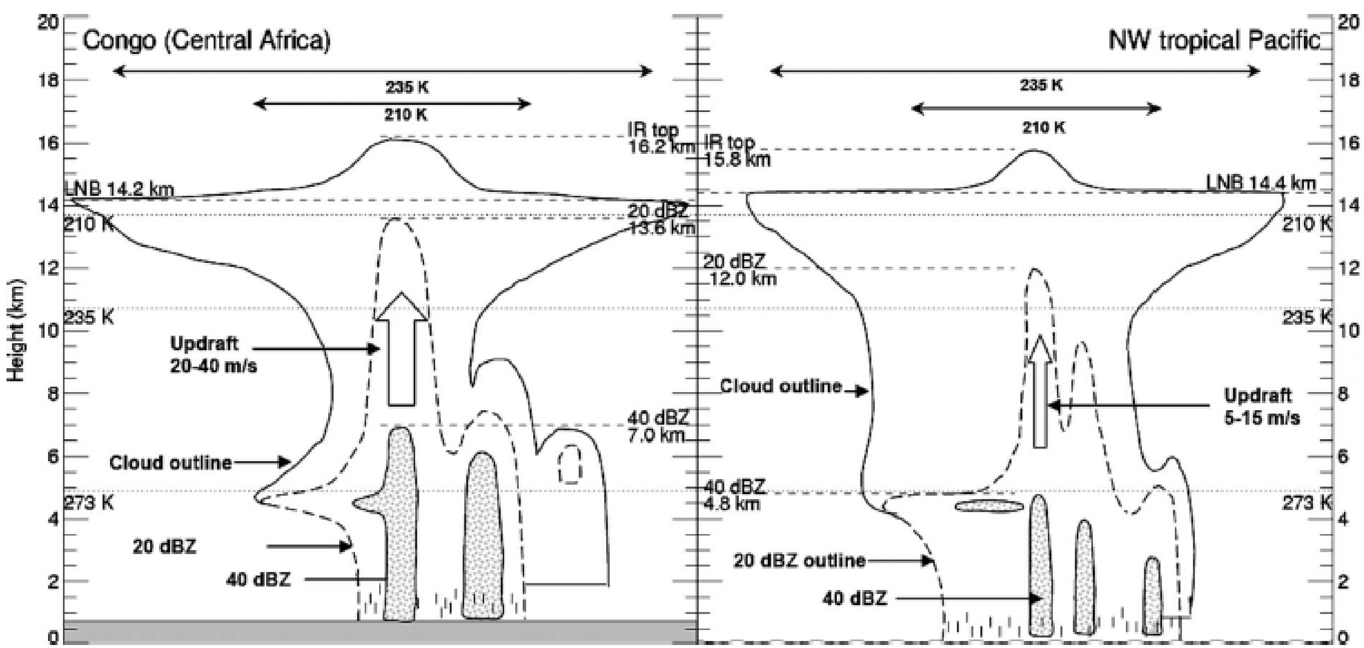
use Cb fraction 0.1-0.3 as proxy of maturity

Protopapadaki et al. 2017

Proxies of convective intensity - strength – depth

vertical updraft : TRMM / CloudSat Echo Top Height *(Liu & Zipser 2007, Takahashi & Luo 2014)*
Level of Neutral Buoyancy : soundings / max mass flux outflow *(Takahashi & Luo 2012)*
area of heavy rainfall : CloudSat-AMSR-E-MODIS *(Yuan & Houze 2010)*
width of convective core (CC): CloudSat *(Igel et al. 2014)*
cold cloud top : T_B^{IR} *(Machado & Rossow 1993)*, T_{cld} *(Protopapadaki et al. 2017)*
mass flux : ERA-Interim + Lagrangian approch *(Tissier et al. 2016)*,
A-Train + 1D cld model *(Masunaga & Luo 2016)*

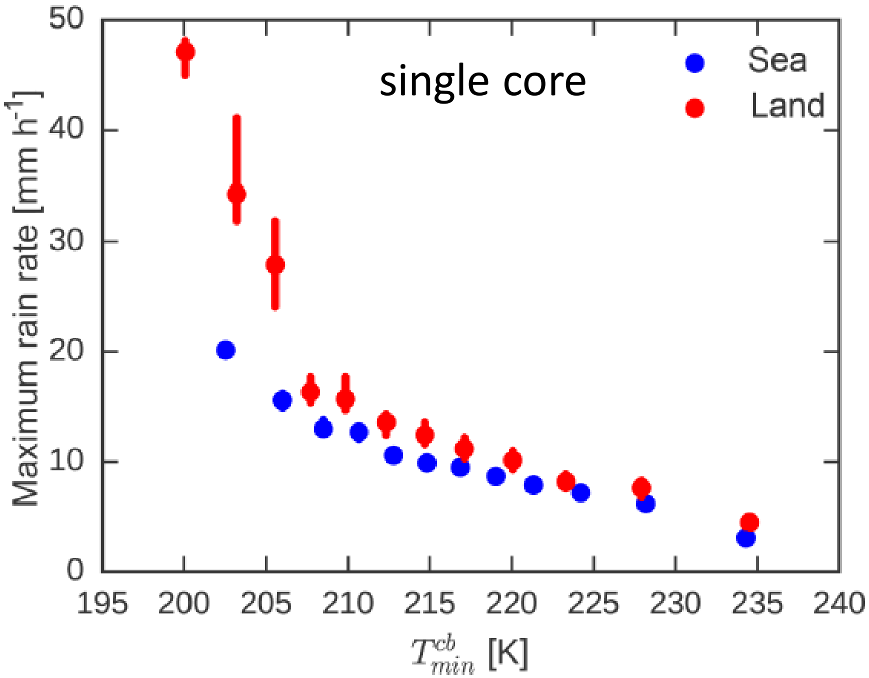
land : large updraft & CC, large ETH (large particles at high altitude), small systems
ocean: smaller updraft & CC, large systems

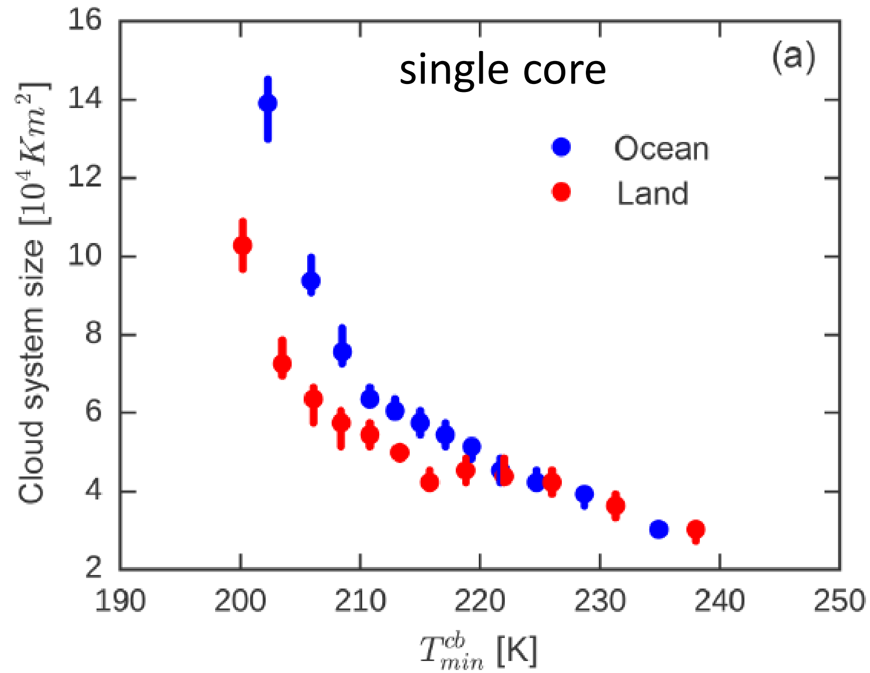


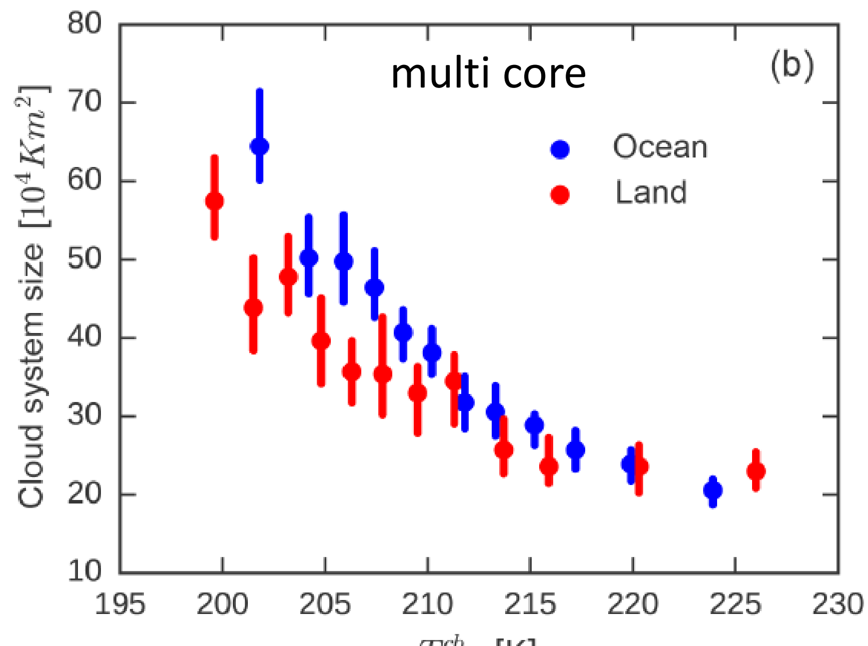
typical strong systems
6-yr TRMM statistics

Liu, Zipser and Nesbitt 2007

relate cloud system properties to convective strength







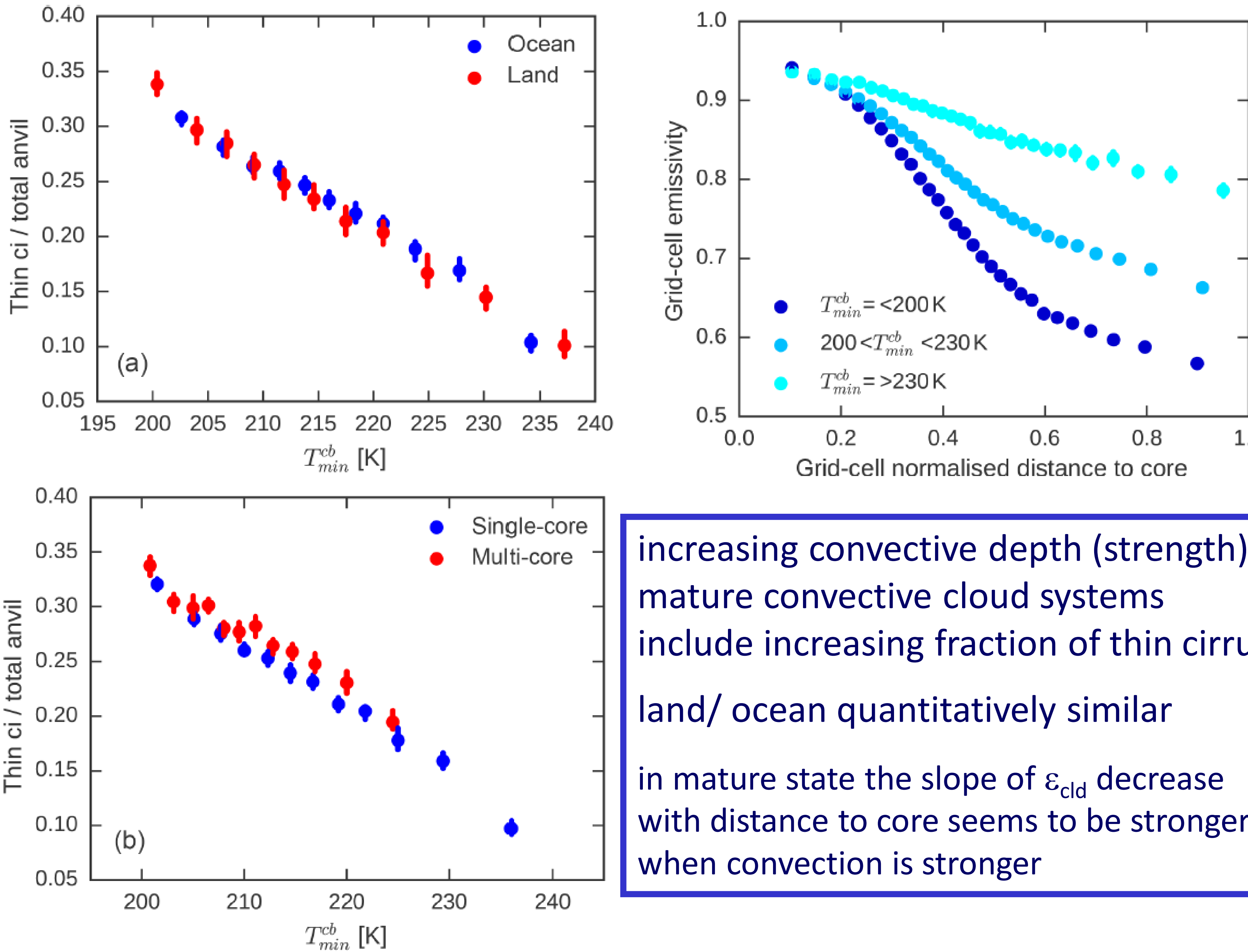
mature colder (higher) cloud systems

- have a higher max RR
- are larger

land/ ocean quantitatively different

in agreement with other analyses

relate anvil properties to convective strength



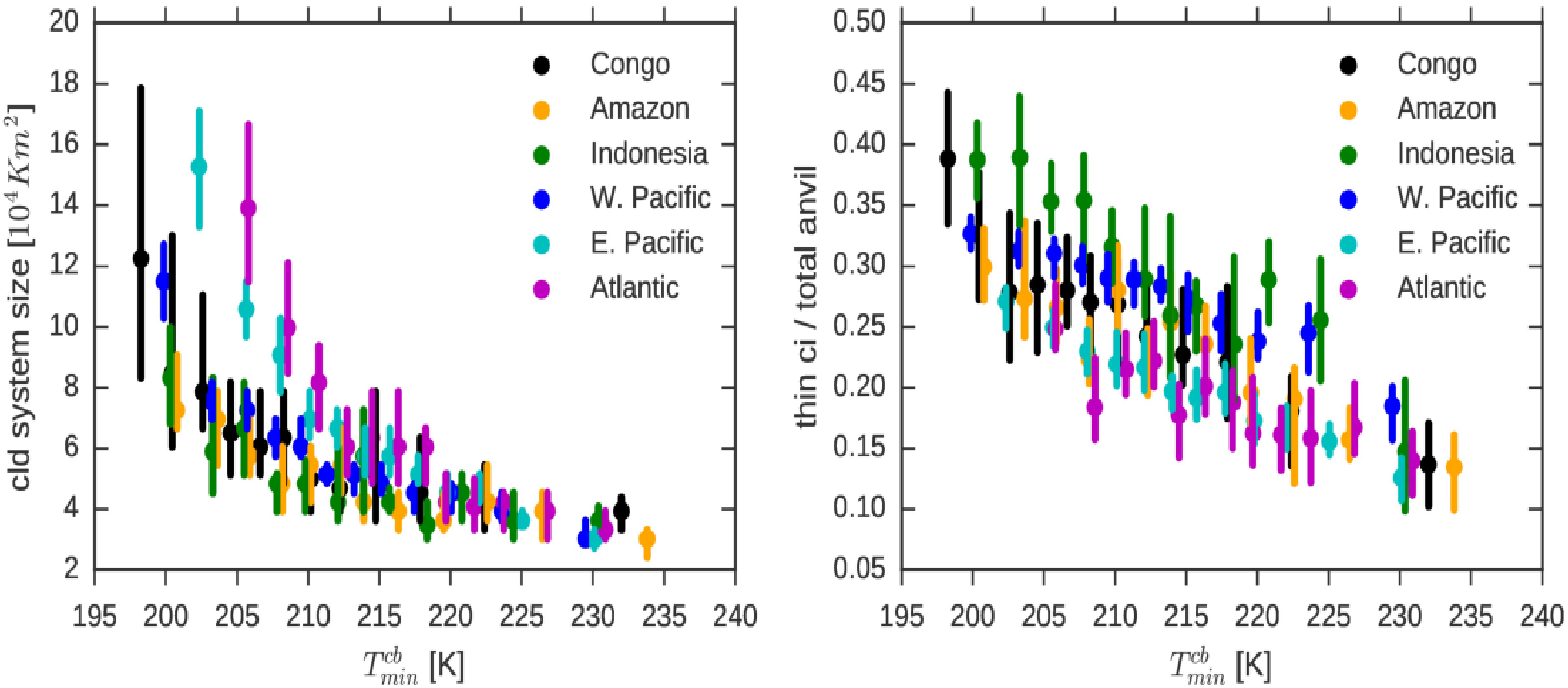
increasing convective depth (strength): mature convective cloud systems include increasing fraction of thin cirrus

land/ ocean quantitatively similar

in mature state the slope of ε_{cld} decrease with distance to core seems to be stronger when convection is stronger

relate anvil properties to convective strength

regional



results robust when considered over specific regions