The role of upper tropospheric cloud systems in climate: building observational metrics for Process Evaluation Studies (PROES)

GEWEX **UTCC PROES: on Upper Tropospheric Clouds & Convection**

Å ***advance understanding on feedback of UT clouds***

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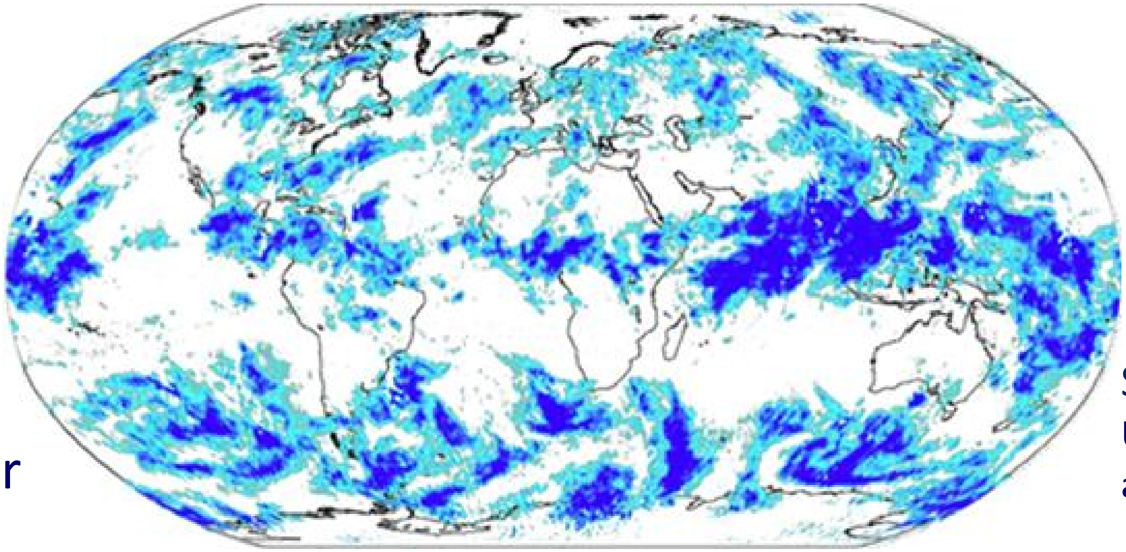
21rst International TOVS Study Conference (ITSC-21)

29 Nov – 5 Dec 2017, Darmstadt, Germany

Motivation



UT clouds: 40% of Earth's cloud cover

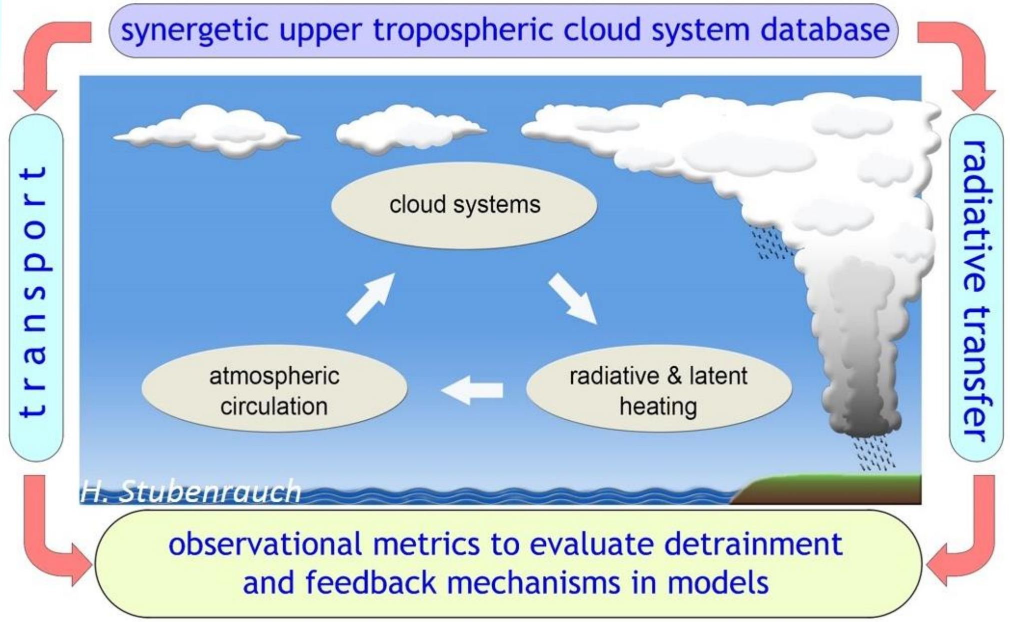
Snapshot AIRS-CIRS
UT clouds: dark -> light blue, according to decreasing ε_{cld}

UT clouds play a vital role in climate system by modulating Earth's energy budget & UT heat transport

They often form mesoscale systems extending over several hundred kilometres.
as outflow of convective / frontal systems
or in situ by large-scale forcing

large-scale modelling necessary to identify most influential feedback mechanisms
-> models should be in agreement with observations

Goals: **-** understand relation between convection, cirrus anvils & radiative heating
- provide observational metrics to probe process understanding



UTCC PROES Strategy

meetings: Nov 2015, Apr 2016, Mar 2017

***working group* links communities** from observations, radiative transfer, transport, process & climate modelling
GEWEX News May 2017, pp. 4-6

https://www.gewex.org/resources/gewex-news/

focus on tropical convective systems *& cirrus originating from large-scale forcing*

- **cloud system approach, anchored on IR sounder data**

horizontal extent / convective cores/cirrus anvil/thin cirrus ***based on*** p_{cld}, ε_{cld}

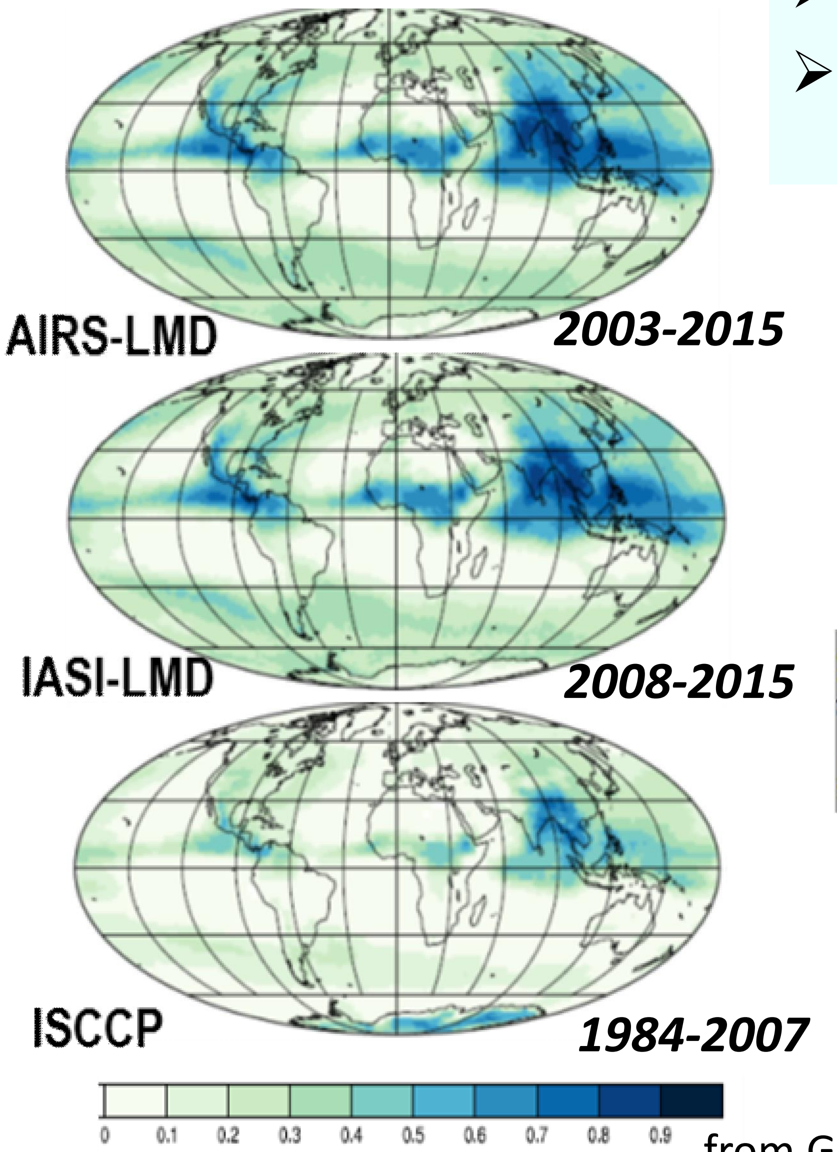
- **explore relationships between 'proxies' of convective strength & anvils**
- **build synergetic data,** incl. vert. dimension & atmosph. environment
- **determine heating rates** of different parts of UT cloud systems
- **follow snapshots** by Lagrangian transfer -> **evolution & feedbacks**
- **investigate how cloud systems behave in CRM studies**

& in GCM simulations *(under different parameterizations of convection/detrainment/microphysics)*

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

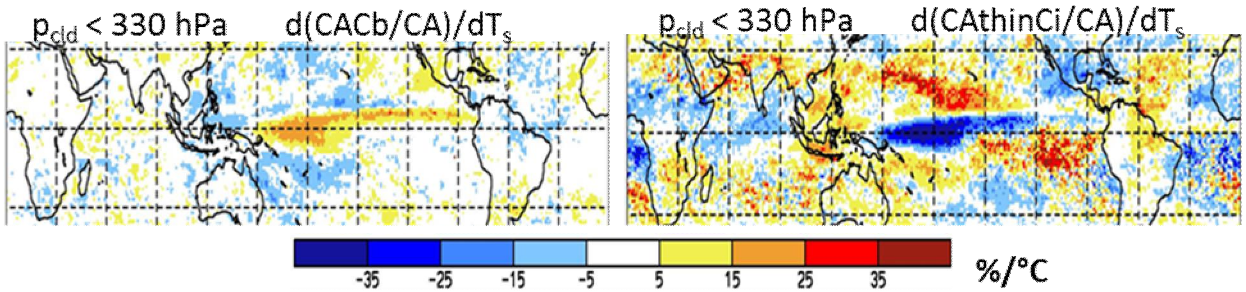
CIRS (Cloud retrieval from IR Sounders):

Stubenrauch et al.**, J. Clim. 1999, 2006; ACP 2010, **ACP 2017

AIRS / IASI climatologies -> French data centre AERIS

HIRS climatology -> EUMETSAT CM-SAF (DWD)

*Stubenrauch et al., **ACP 2017***



Changes in relative amount of high opaque & thin Ci clouds per °C warming show different geographical patterns

-> UT cloud feedbacks

from GEWEX Cloud Assessment Database

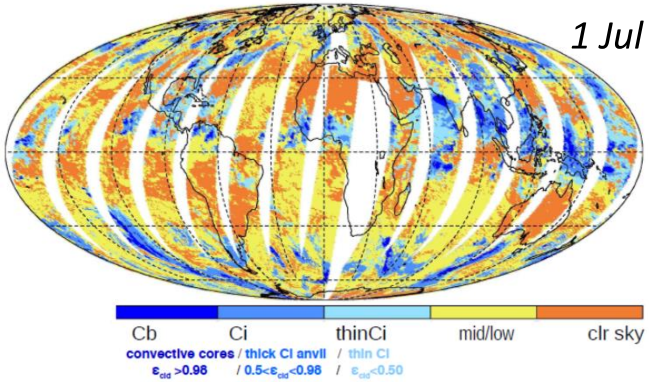
Stubenrauch et al. BAMS 2013

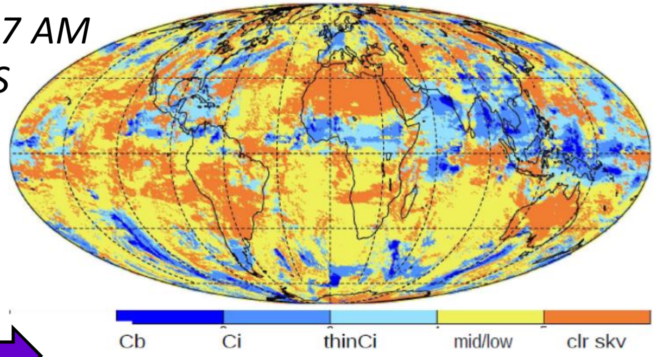
From cloud retrieval to cloud systems

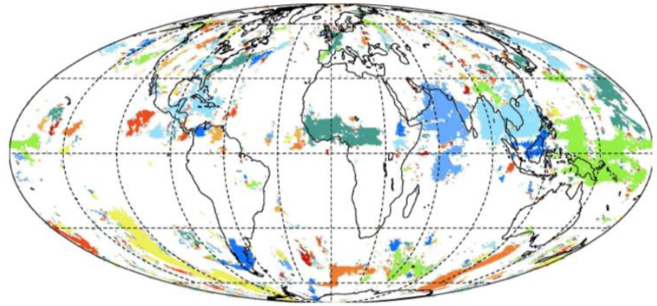
clouds are **extended objects**, driven by dynamics -> **organized systems**

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

1 Jul 2007 AM
AIRS





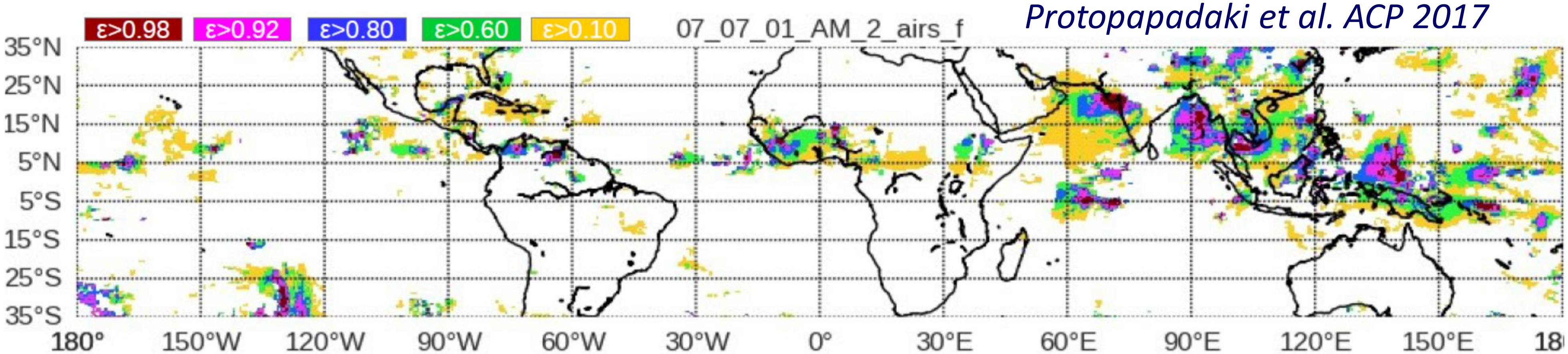


fill data gaps using PDF method

build UT cloud systems

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

Protopapadaki et al. ACP 2017



30N-30S: UT cloud systems cover 20%, those without convective core 5%

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

convective strength -> cloud system properties

proxies to describe convective strength:

core temp. : T_{min}^{Cb} *(Protopapadaki et al. 2017),* T_B^{IR} *(Machado & Rossow 1993)*

vertical updraft : *CloudSat Echo Top Height (Takahashi & Luo 2014)* / TRMM *(Liu & Zipser 2007)*

Level of Neutral Buoyancy: soundings / *max mass flux outflow (Takahashi & Luo 2012)*

heavy rain area: CloudSat-AMSR-E-MODIS *(Yuan & Houze 2010)*

core width : CloudSat *(Igel et al. 2014)*

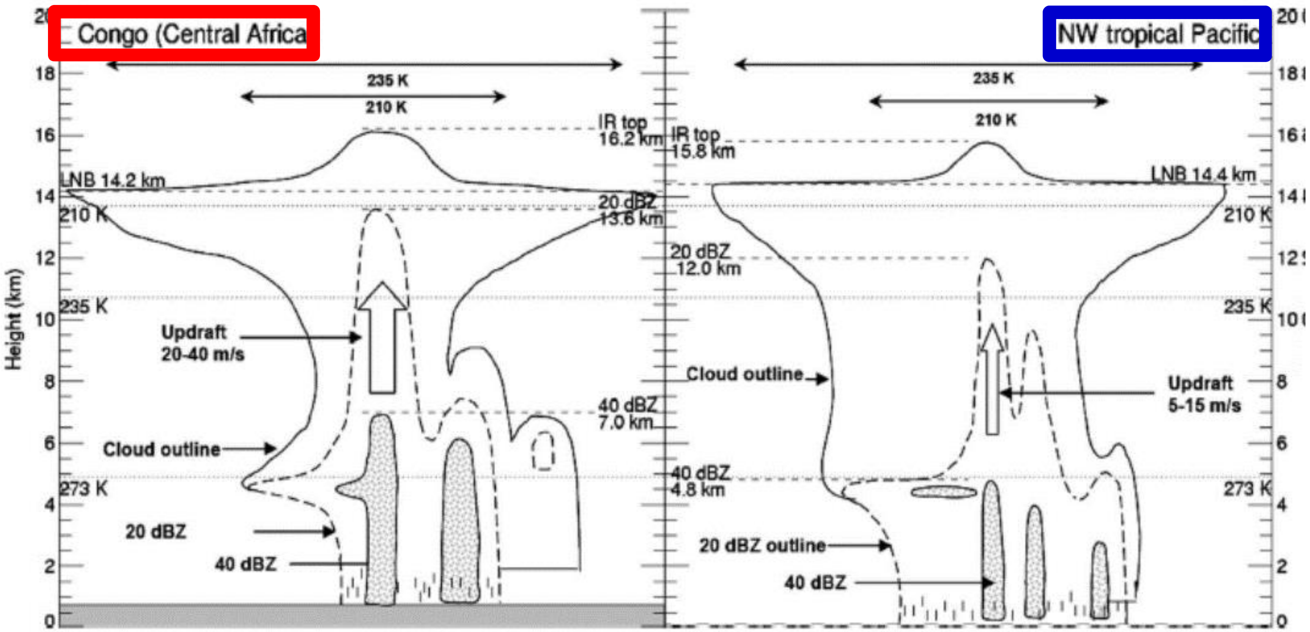
mass flux : ERA-Interim + Lagrangian approch *(Tissier et al. 2016)*

A-Train + 1D cld model *(Masunaga & Luo 2016)*

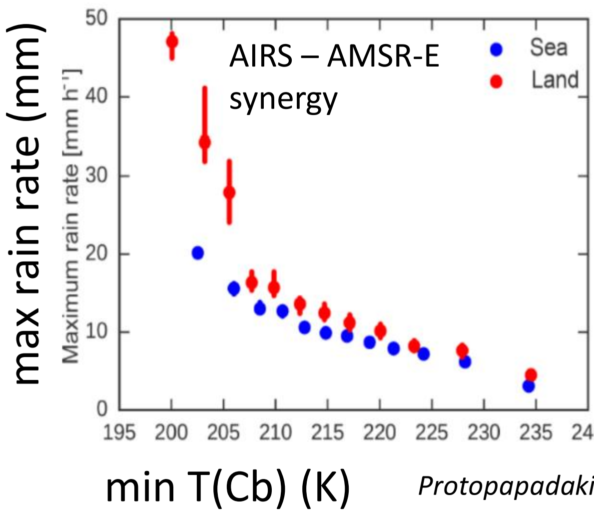
Cloud system sizes increase with convective strength, but **land – ocean** differences :

larger updraft & CC, smaller systems - smaller updraft & CC, larger systems

Liu et al. 2007 **typical strong convective systems** (6-yr TRMM statistics)

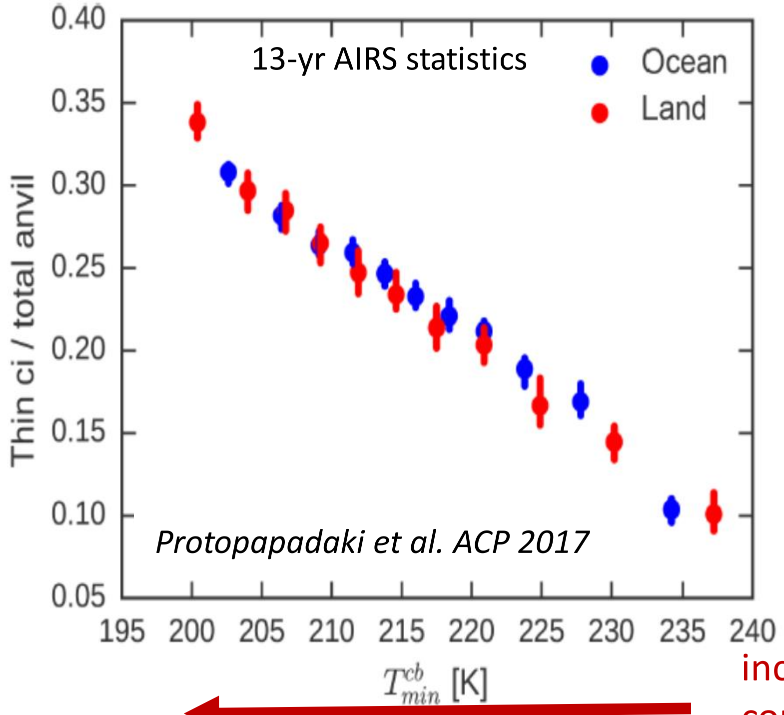


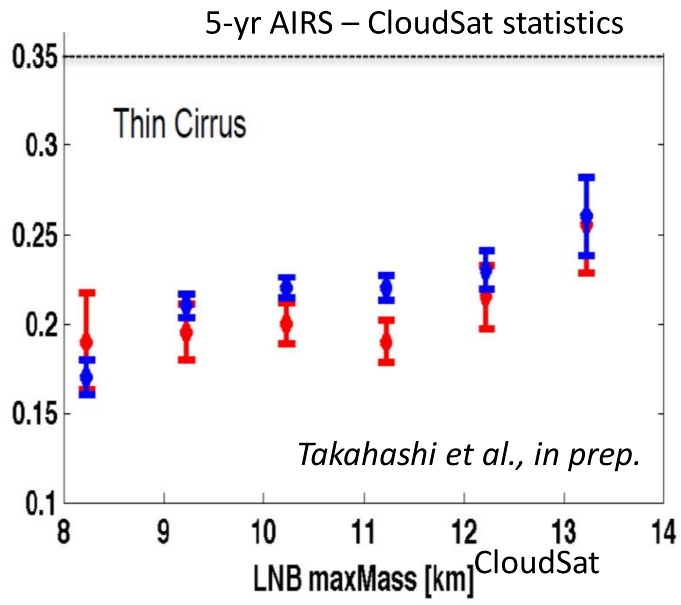
colder systems have a larger max rain rate



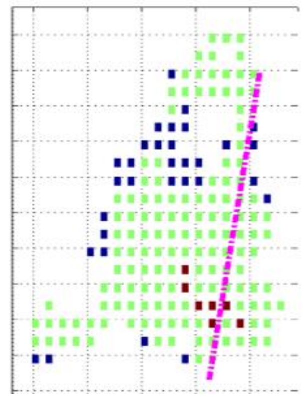
Protopapadaki et al. 2017

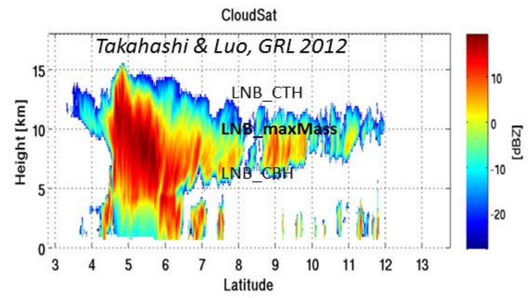
convective strength -> anvil properties





CloudSat





increasing
convective strength

Mature convective systems:
increase of thin Ci with increasing convective strength !
similar land / ocean

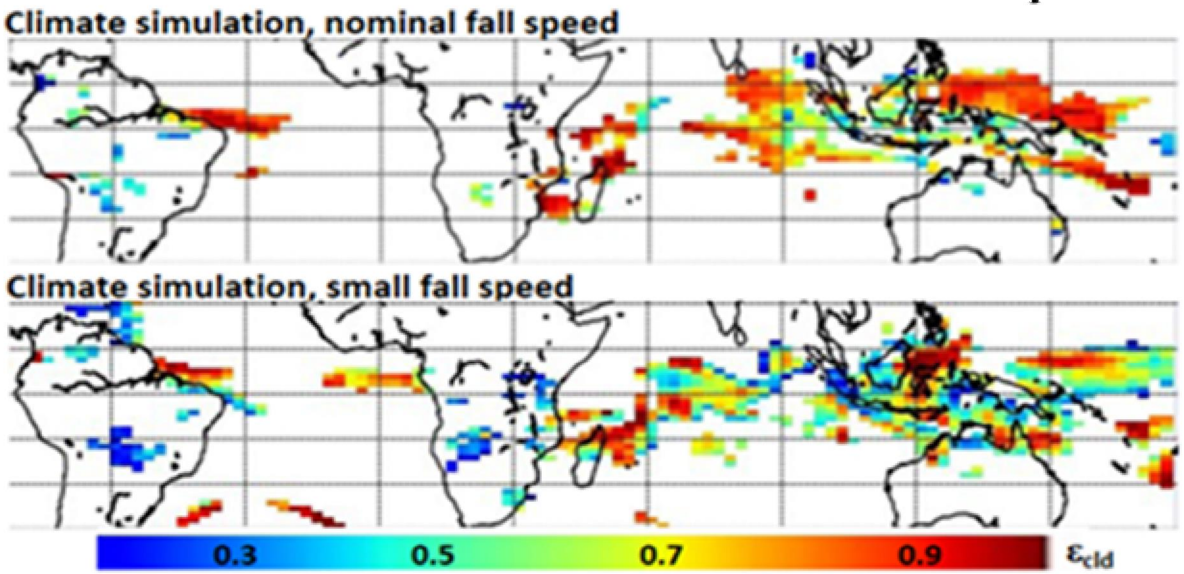
relation robust *using different proxies :*
T_{min}^{Cb} / *LNB(max mass)*

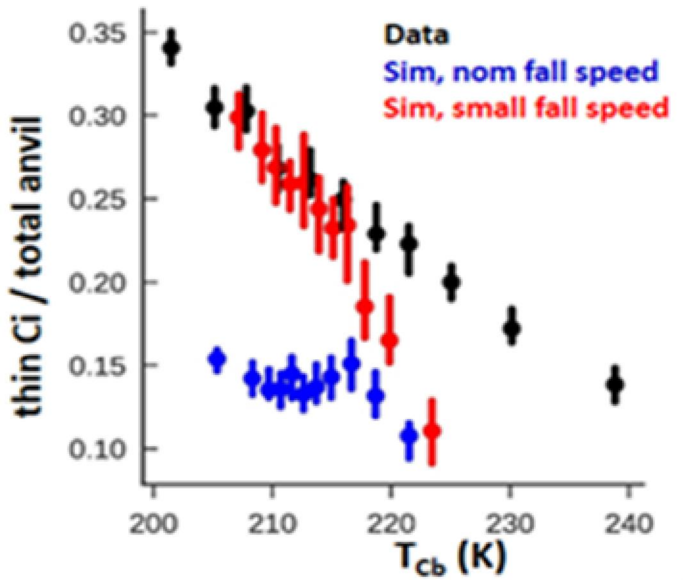
Diagnostics for UT cloud assessment in climate models

analyze GCM clouds as seen from AIRS/IASI, via simulator
& construct UT cloud systems
-> evaluation of GCM convection schemes / detrainment / microphysics

spatial res. 2.5° x 1.25°

LMDZ UT cloud systems



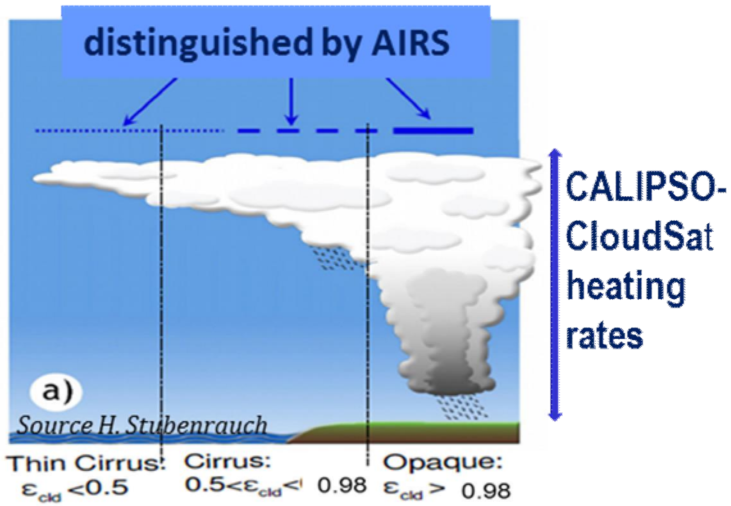


horizontal cloud system emissivity structure sensitive to fall speed

LMDZ behaviour closer to observations, when fall speed is reduced (longer lasting cirrus)

heating rates of UT cloud systems

UT heating due to cirrus -> impact on large-scale tropical atmospheric circulation

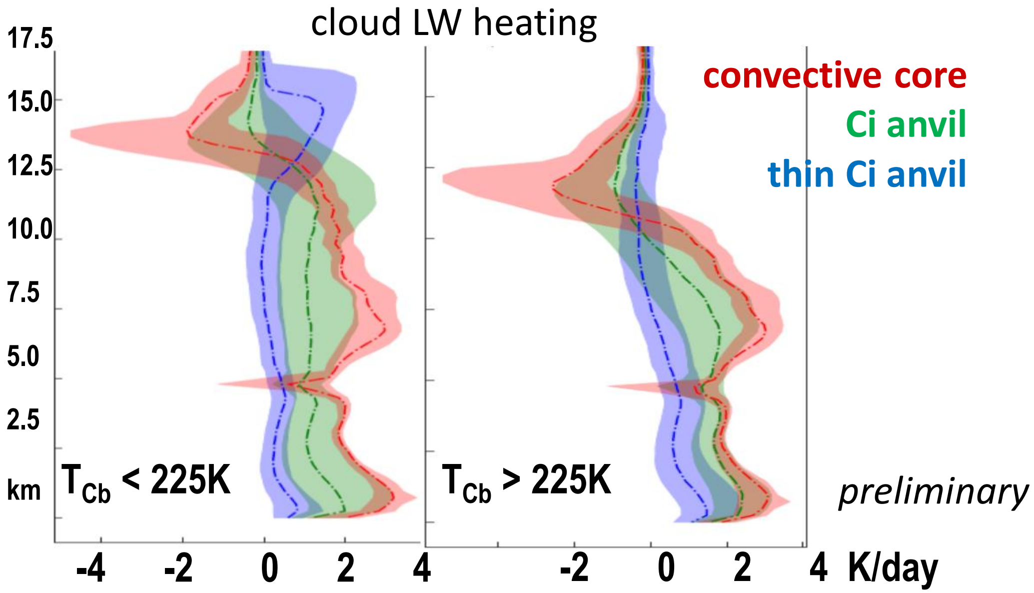


Heating will be affected by:

- areal coverage
- emissivity distribution
- vertical structure of cirrus anvils (layering & microphysics)

use nadir track info on vertical structure to propagate properties across UT cloud systems

categorize CloudSat FLXHR-LIDAR heating rates wrt to ε_{cld}, p_{cld}, vert. layering, thermodyn.



clear distinction of heating associated with each category

Thin Ci heating increases with convective strength

Summary & Outlook

WG *meetings: Nov 2015, Apr 2016, Mar 2017* ***-> first cooperations***

focus on

1) tropical convective systems *2) cirrus originating from large-scale forcing*

- **synergetic cloud system approach based on IR sounder data**
  powerful tool to study relation between convection & anvil properties
  & to evaluate GCM parameterizations
  of convection/detrainment/microphysics

- **investigate how cloud systems behave in CRM studies**

- **classification of heating rates (A-Train synergy) encouraging**
  -> extend to UT cloud systems & integrate into feedback studies
  using Lagrangian transport & advanced analysis methods

GEWEX UTCC PROES WG

Coordination: C. Stubenrauch & G. Stephens; **next meeting:** *end Sept or mid Oct 2018 in Paris*

Observations / radiative transfer :

G. Stephens, H. Takahashi (NASA JPL), C. Stubenrauch, S. Protopapadaki, G. Sèze (LMD),

J. Luo, W. B. Rossow (CUNY), H. Masunaga (Nagoya Univ.), Roca (LEGOS), D. Bouniol (CNRM),

T. L'Ecuyer (Uni Wisconsin), S. Kato (NASA Langley), C. Schumacher (Texas Univ),

G. Mace, E. Zipser (Utah Univ), E. Jensen (NASA Ames), M. Krämer (FZ Jülich), A. Baran (MetOffice)

C. Kummerow (CSU), B. J. Sohn (Seoul Univ), H. Okamoto (Kyushu Univ)

Lagrangian transport, UTLS cirrus:

B. Legras, A.-S. Tissier, A. Hertzog (LMD)

Small scale process modelling :

S. van den Heever (CSU), R. Storer (NASA JPL), R. Plougonven, C. Muller (LMD),

W.-T. Chen (Nat Taiwan Univ), B. Kärcher (DLR)

Climate modelling :

T. Del Genio, G. Elsaesser (GISS), R. Ramaswamy, L. Donner (GFDL), B. Gasparini (ETHZ), U. Burkhardt (DLR), T. Mauritsen (MPI), M. Bonazzola, J.-B. Madeleine, C. Rio, C. Risi, S. Bony (LMD), R. Roehrig (CNRM)

Thank you