Determining radiative heating rates of UT cloud systems

C. Stubenrauch, S. Protopapadaki, A. Feofilov

LMD

Institut Pierre Simon Laplace
Sciences de l'environnement

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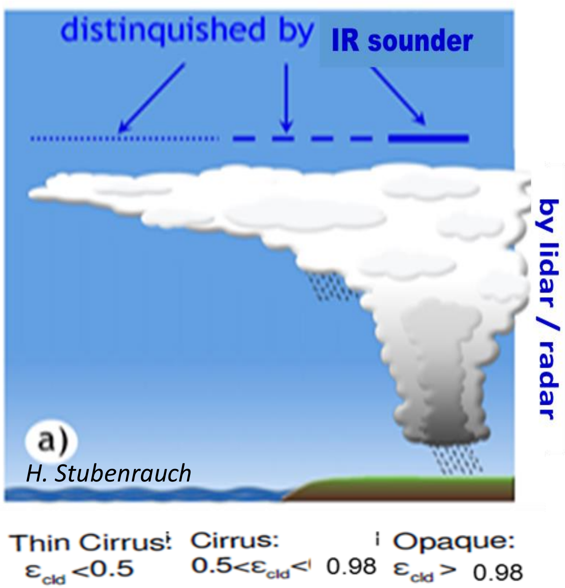
H.Stubenrauch

Motivation

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)*

tropical convective regions: > 50% of total heating UT heating due to cirrus *(Sohn 1999)*
-> widespread impact on large-scale tropical atmospheric circulation



Heating will be affected by:

- areal coverage
- ε_{cld} distribution
- vertical structure of cirrus anvils (layering & microphysics)

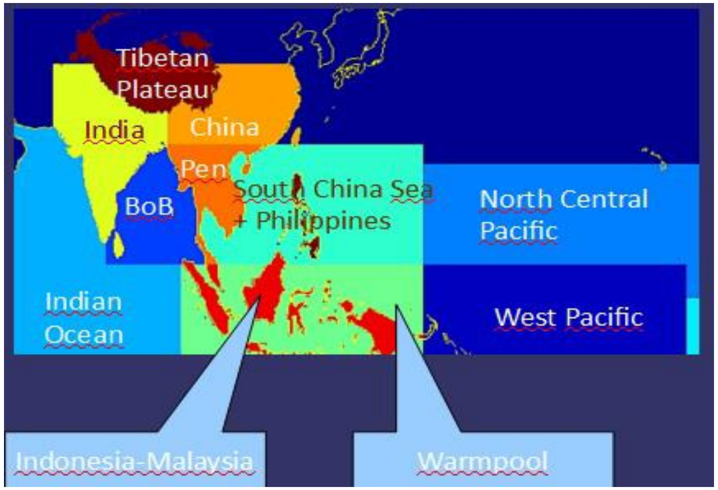
use nadir track info on vertical structure to propagate properties across UT cloud systems

Heating rates of UT cloud systems:

1) **sort FLXHR-LIDAR heating rates by cloud type**

2) **compute heating rates using RRTM**
by categorizing atmospheric situation wrt T & H_2O profiles
*by categorizing **cloud types** wrt ε_{cld} & vertical structure*

Glance on actual heating rates

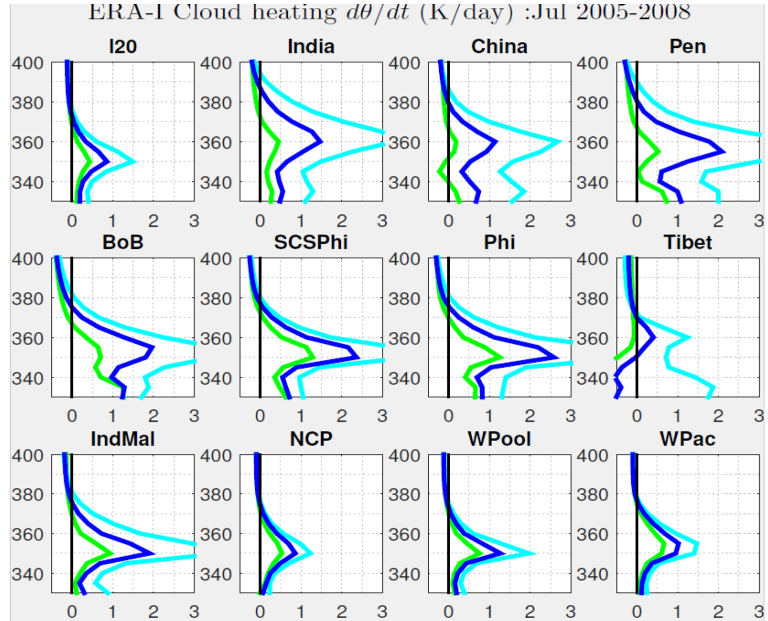


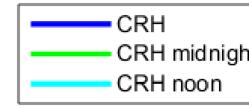
Reanalysis cloud heating rates disagree over convective regions, esp. over Asian monsoon region

Tissier & Legras ACP 2016

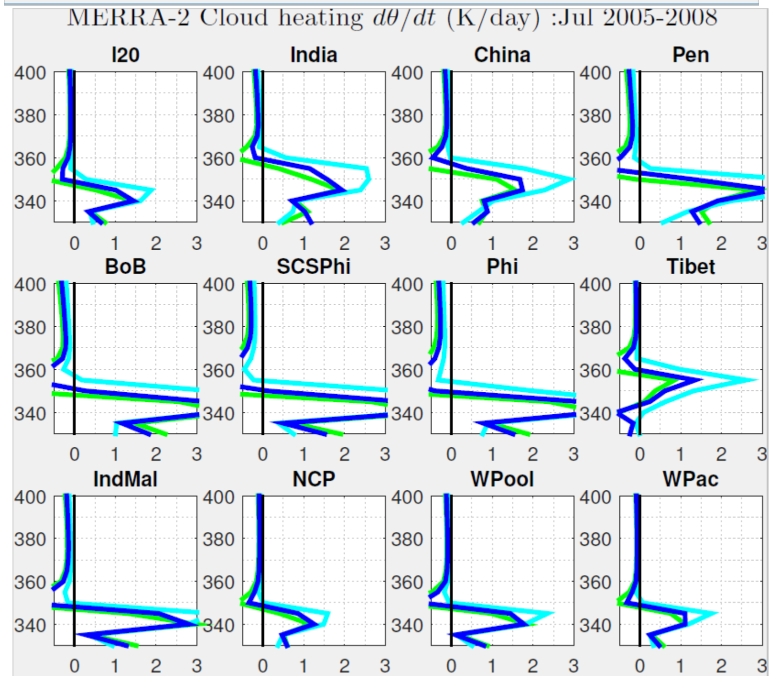
Obs. cloud heating rates disagree:
Johansson et al. 2015 (FLX-LIDAR)
-> warming above clr sky LZRH
Yang et al. 2016 (CALIPSO)
-> cooling above 16km

B. Legras, UTCC PROES meeting
29 Apr 2016, Paris



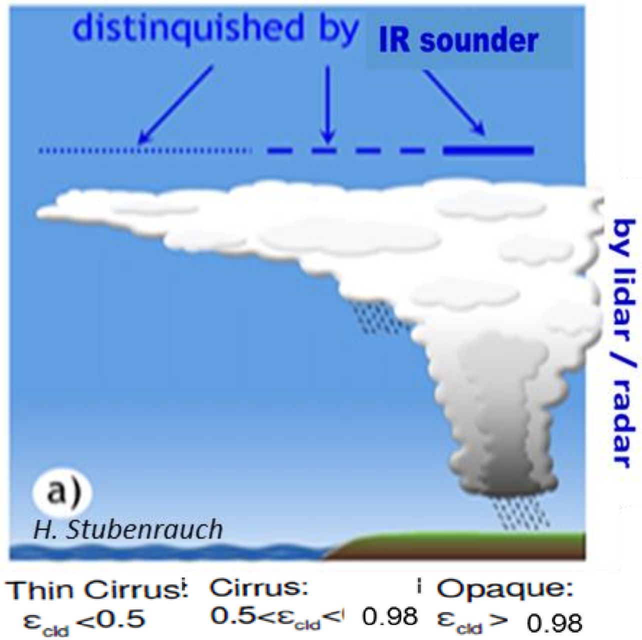


ERA-Interim



MERRA-2

heating rates of anvil parts



Challenges:

- IWP, vertical profile of IWC
- ice crystal habit, size distribution -> SSP
- retrieval uncertainties in IWC / De profiles
- multiple cloud layering

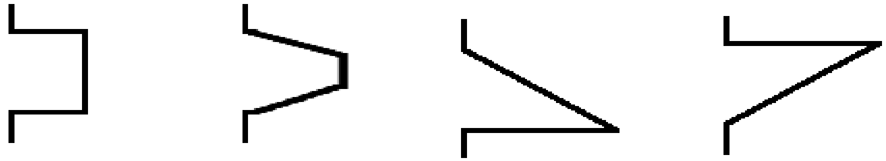
use nadir track info on vertical structure to propagate properties across UT cloud systems

-> build classifications of IWC/De vertical profiles & multiple layering

- as fct of ε_{cld},
- as fct of distance to convective core
- …

IWC profile dependency on IWP

Clouds with same IWP may have different IWC & De profiles
-> influence on radiation? Shape probablility parameterization wrt IWP



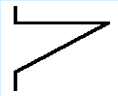
AIRS-GEOPROF-liDARraDAR data

RFO	IWP(g/m²)	const	trapezia	increas	decreas
18	0-10	**42%**	**32%**	**12%**	**14%**
21	10-30	**28%**	**51%**	**14%**	**7%**
23	30-100	**25%**	**55%**	**16%**	**3%**
17	100-300	**18%**	**59%**	**21%**	**2%**
12	300-1000	**13%**	**53%**	**33%**	**1%**

Feofilov et al., ACP 2015

const & trapezia ≈ 80% of all profiles

increases with IWP from 10 to 30%



only for IWP < 30 g/m²

independent of location / season !

Effect of strong vertical winds:

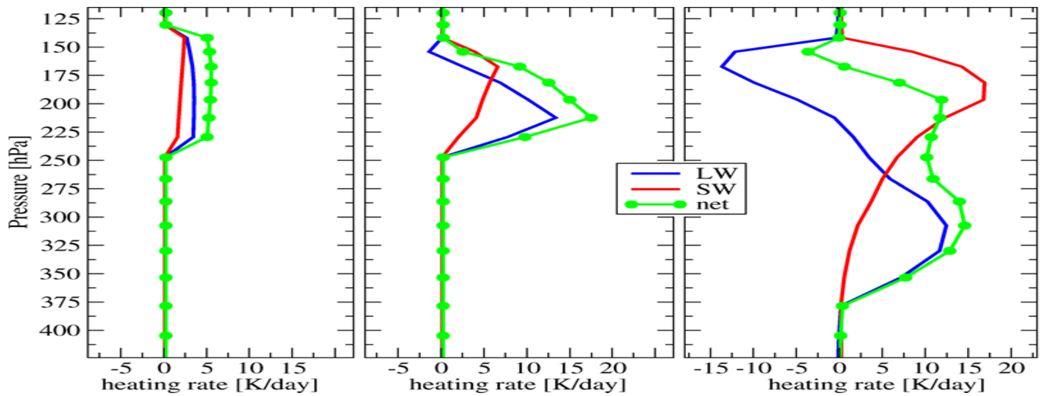
increas. prof. 30% more often

decreas. prof. 20% less often for small IWP

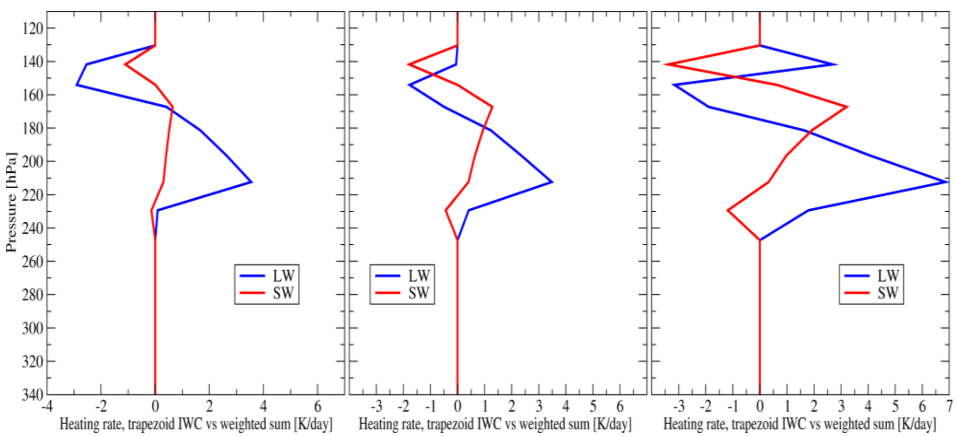
heating rates : use most probable IWC profiles

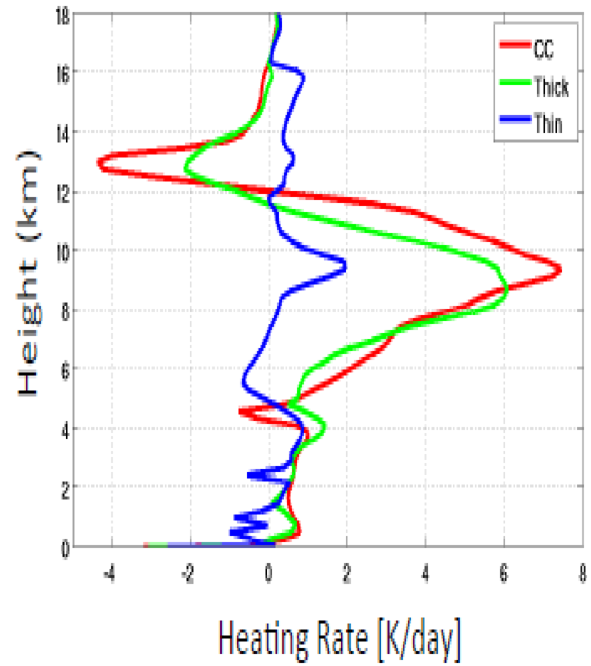
example computations using RRTM

thin Ci	Ci	Cb
IWP= 10,	30,	300 gm^{-2}
De = 30,	50,	80 μm
mostly const	trapezium	increas. IWC profile



sensitivity wrt to IWC profile shape: use trapezium





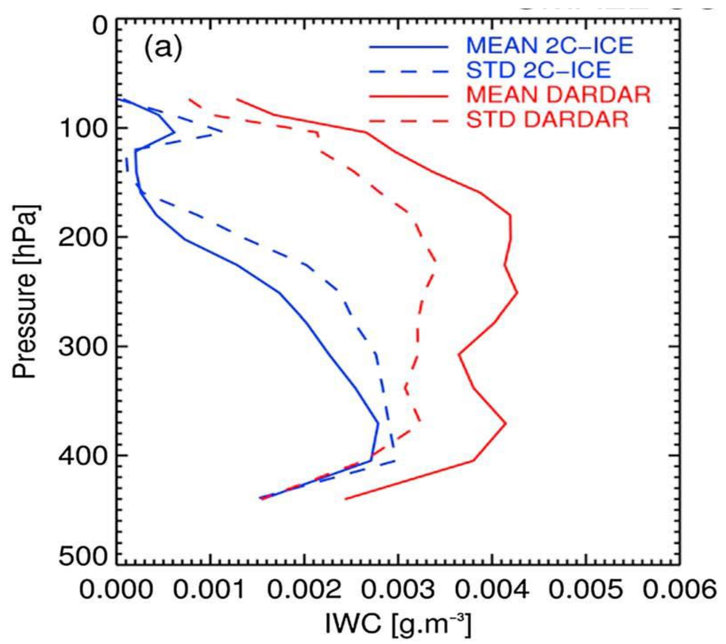
FLXHR-LIDAR heating rates sorted by AIRS cloud classes within CloudSat cloud objects *(H. Takahashi talk)*

similar, with additional features of multiple layering

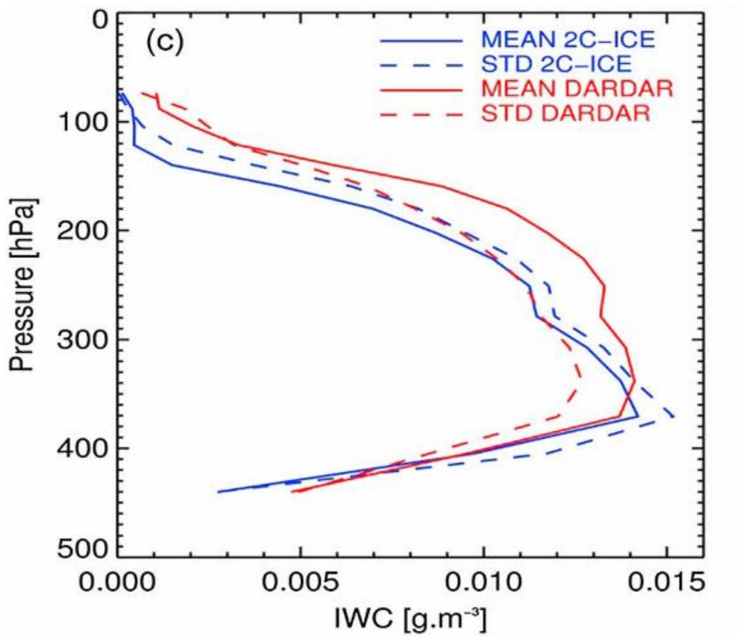
Uncertainty in IWC profile retrieval

Vidot et al. JGR 2015

small COD: 0.03-0.5



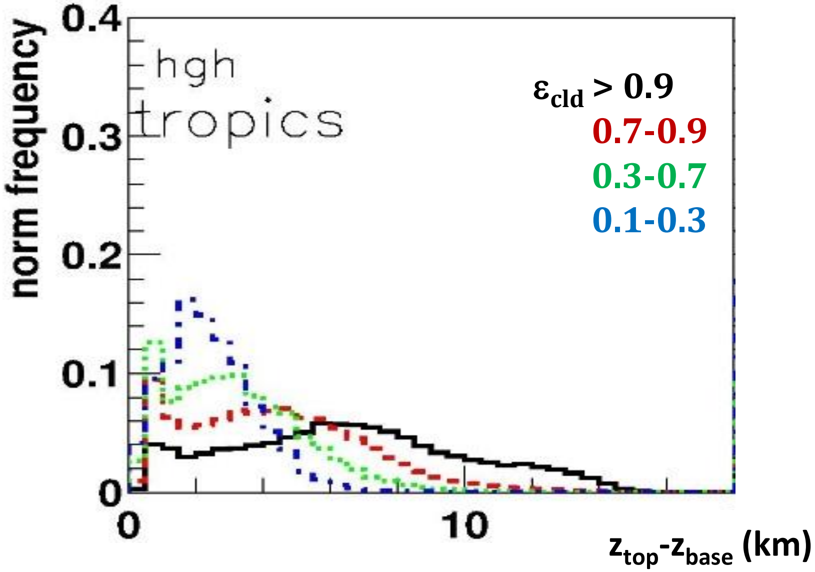
large COD: 0.5-4

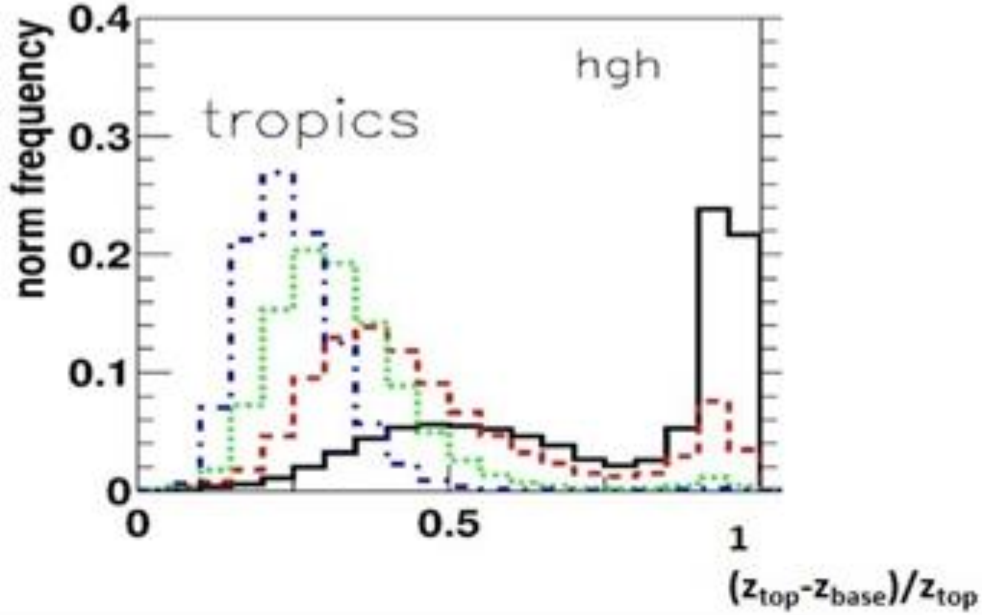


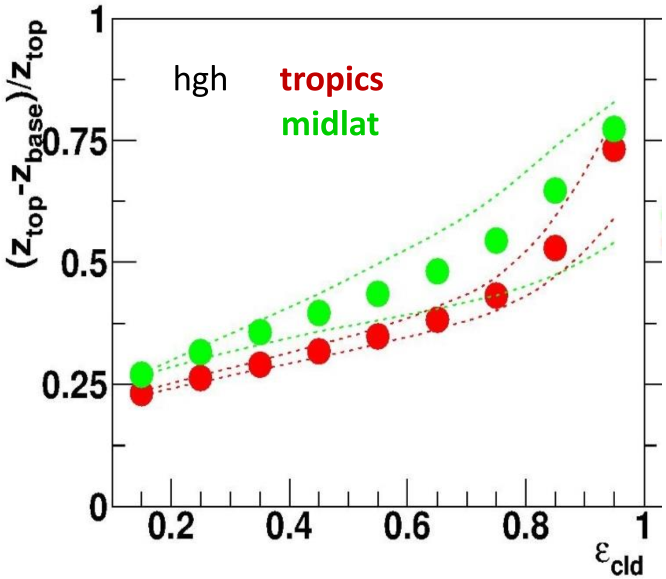
DARDAR retrieval provides larger values than 2C-ICE retrieval, esp. for small COD *(up to a factor of 4)*

cloud vertical extent dependency on ε_{cld}

AIRS - CALIPSO-CloudSat GEOPROF







scaling by z_{top} -> better distinction

vertical extent increases with ε_{cld}

next step:

decrease distribution widths
by stratifying wrt
dynamics, humidity,T, etc

cloud vertical layering & subvisible cirrus

AIRS - CALIPSO-CloudSat GEOPROF

preliminary

		Cb	Ci	thin Ci	mid	low	clr
tropics	occurrence	2%	13%	10%	5%	12%	20%
	single layer	74%	42%	47%			
	subvisible	22%	29%	22%	27%	16%	1%
midlat	occurrence	2%	12%	5%	15%	22%	11%
	single layer	86%	61%	57%			
	subvisible	6%	10%	9%	20%	17%	1%

tropics:

- 50% of thin Ci appear on top of other clouds
- 20-30% of UT clouds have subvisible cirrus (COD < 0.2) on top
- only very few subvisible cirrus appear alone

next step:

Understand which of the cases have multi-layering by stratifying wrt dynamics, humidity, T, UT humidity, etx

Conclusions & Outlook

2 strategies to distinguish heating rates within UT cloud systems:

1) sort FLXHR-LIDAR heating rates by AIRS cloud type :

first results, using AIRS-CloudSat-FLXHR-LIDAR synergy, encouraging *(presented by H. Takahashi)*

Next steps:

- add to AIRS-CALIPSO-GEOPROF-DARDAR data set *(Feofilov et al. 2015)* FLXHR-LIDAR and precipitation data (at JPL)

  use this data set to stratify heating rates wrt to AIRS cloud types and other variables

- collocate with AIRS UT cloud systems and with ERA-Interim (ERA5) information on dynamics / thermodynamics

  stratify heating rates further wrt to distance to convective core etc

2) compute heating rates with RRTM, using categorized cloud properties

provides additional potential for uncertainty estimations