

CLASSIFYING ICE WATER CONTENT PROFILES OF HIGH-LEVEL CLOUDS FROM AIRS/CALIPSO/CLOUDSAT OBSERVATIONS TO BETTER ASSESS CLOUD RADIATIVE EFFECTS

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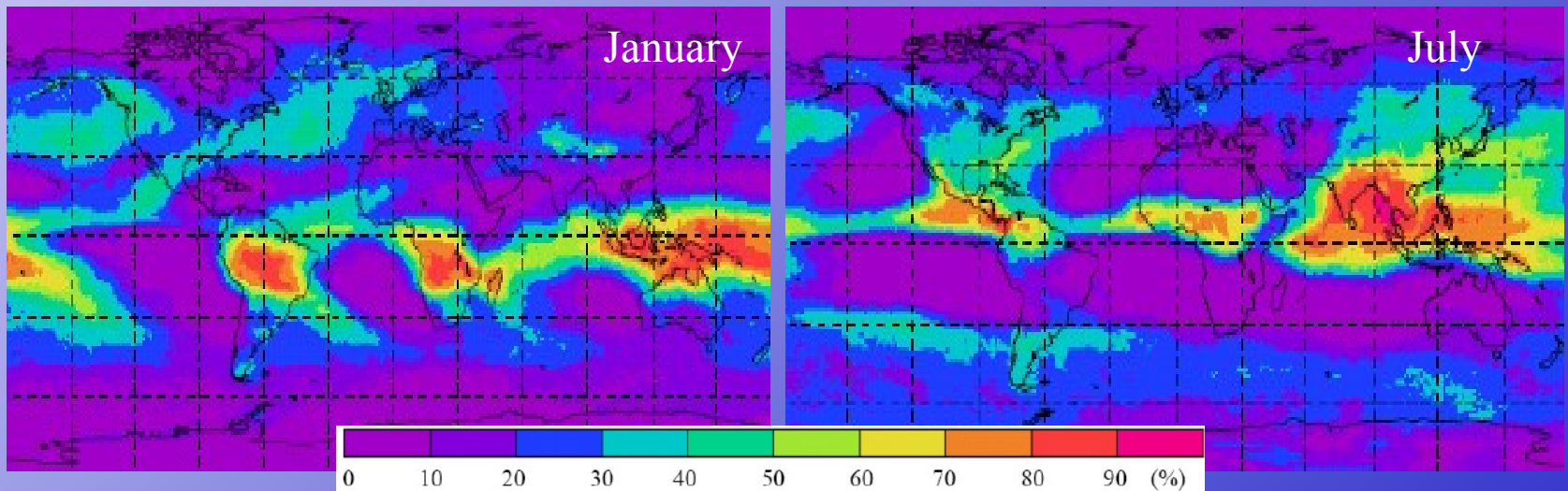
European Geophysical Union, April 10, 2013

High-level clouds

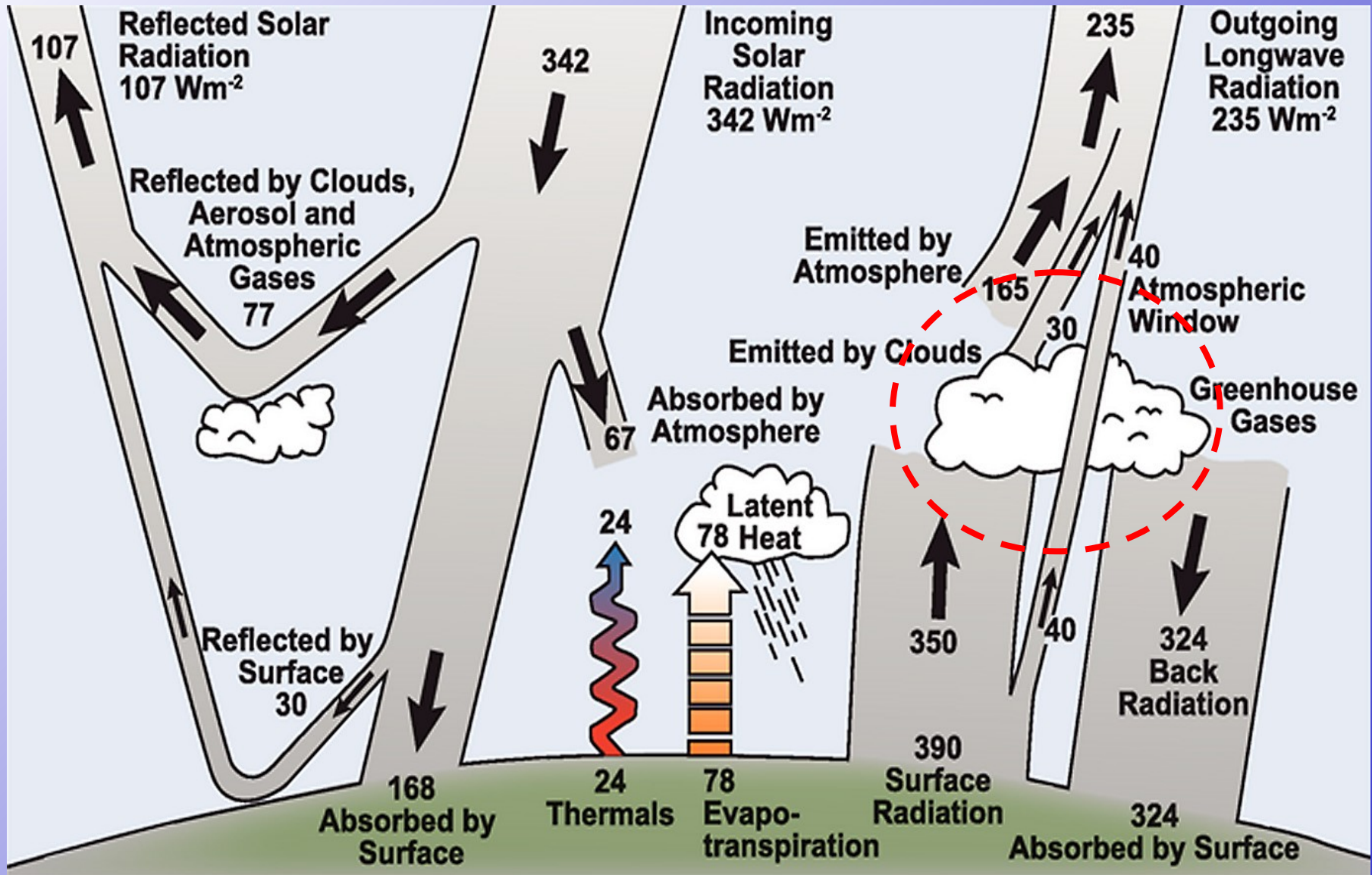
- High-level clouds: $P_{\text{cloud}} < 440$ hPa
- 40-50% (including subvisible Ci) of all clouds
- Tropics: 60%, NH midlatitudes: 40%, SH midlatitudes: 30%
- 10% more high-level clouds over land than over ocean
- Opaque clouds: $\varepsilon_{\text{cld}} > 0.95$ 11%
- Cirrus: $0.5 < \varepsilon_{\text{cld}} < 0.95$ 44%
- Thin Cirrus: $\varepsilon_{\text{cld}} < 0.5$ 45%

(from AIRS, *Stubenrauch et al., ACP 2010*)

High level cloud amount

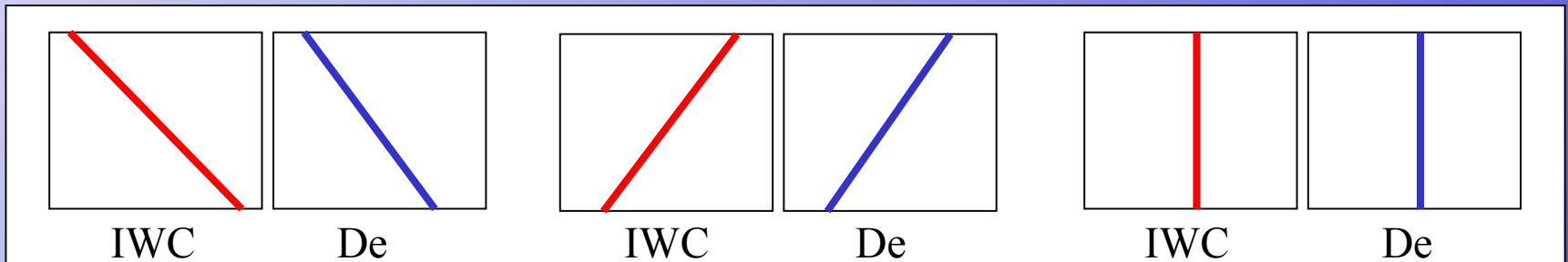


How does $IWC(z)$ affect radiative energy balance?



Motivation

- Knowledge of cloud amount and IWP may be not sufficient for calculating radiative transfer in ice clouds.
- The same IWP can have different IWC(z) profiles
- Applications in GCMs: radiative flux calculations
- Retrieval of bulk microphysical properties (De, IWP) from infrared satellite observations.

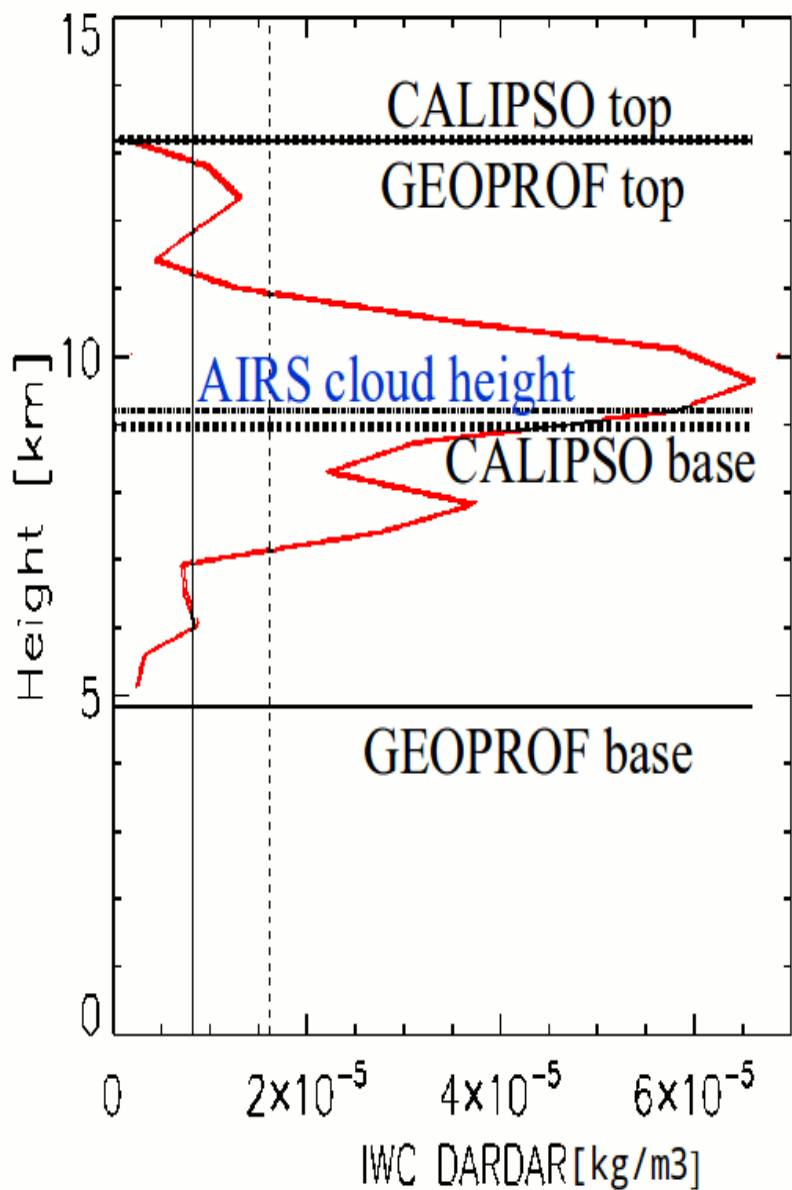


Experimental information available for studies:

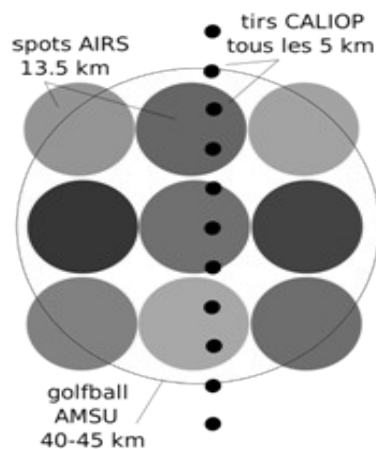
- Active instruments (radar/lidar) provide IWC(z) & De(z) since 2006
- A-Train synergy (AIRS-CALIPSO-CloudSat)

A-Train Synergy: Level 2 data

AS 1.7 Poster 6354



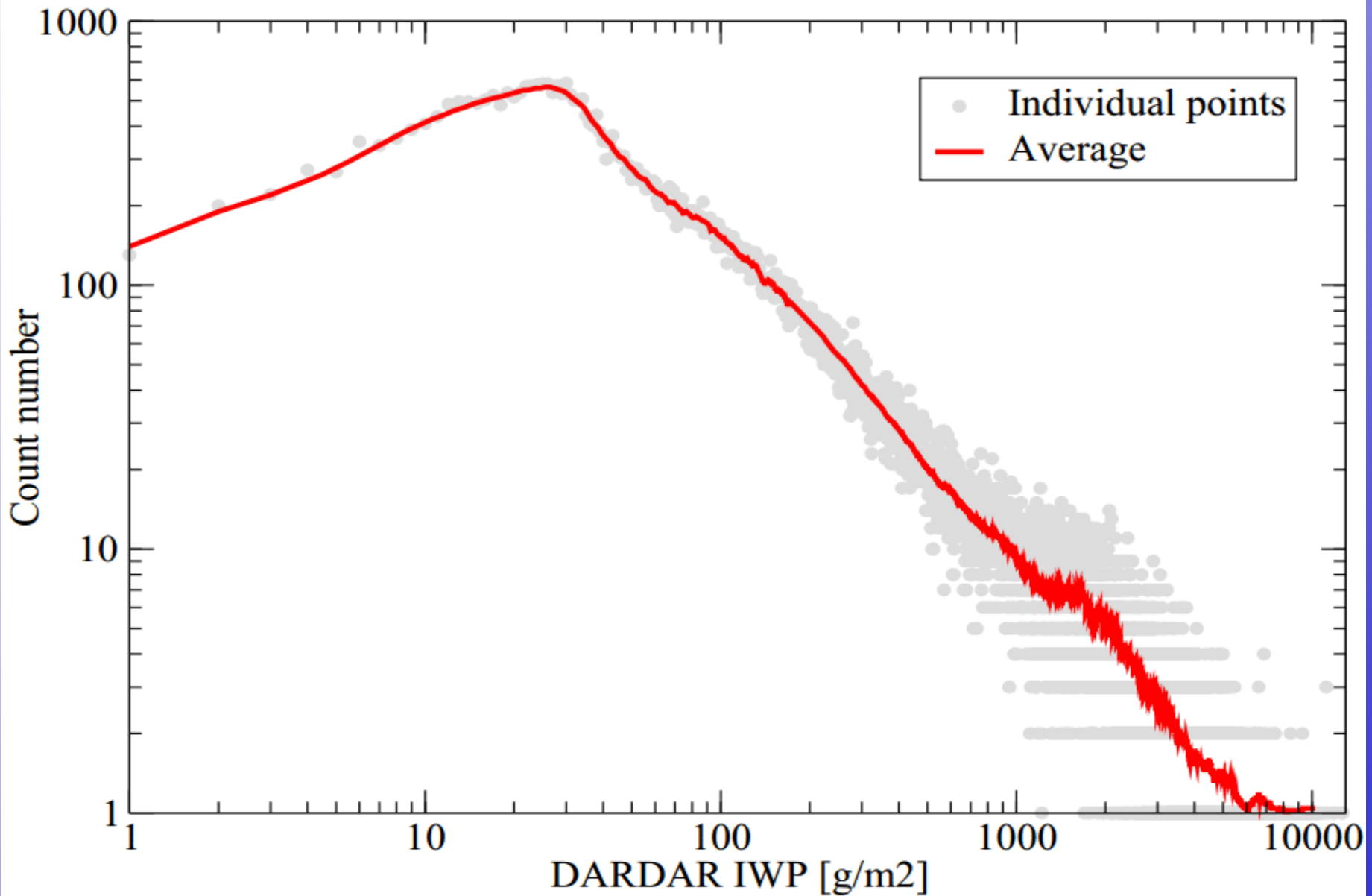
- **AIRS-LMD** (*Stubenrauch et al. 2010*) : P, ϵ of uppermost cloud \rightarrow cloud types De, IWP of semi-transparent cirrus, aggregates/column
- **CALIPSO V3 5km** (*Winker et al. 2012*) : sub-visible Ci, cloud top, apparent base, thermodynamical phase
- **Lidar-Radar GEOPROF V4** (*Mace et al. 2009*): number of cloud layers, cloud top & base height
- **liDARradDAR** (*Delanoë and Hogan 2010*) : retrieval profiles of thermodynamical phase, IWC(z), De(z).
- **ERA-Interim reanalyses**: winds, H₂O column



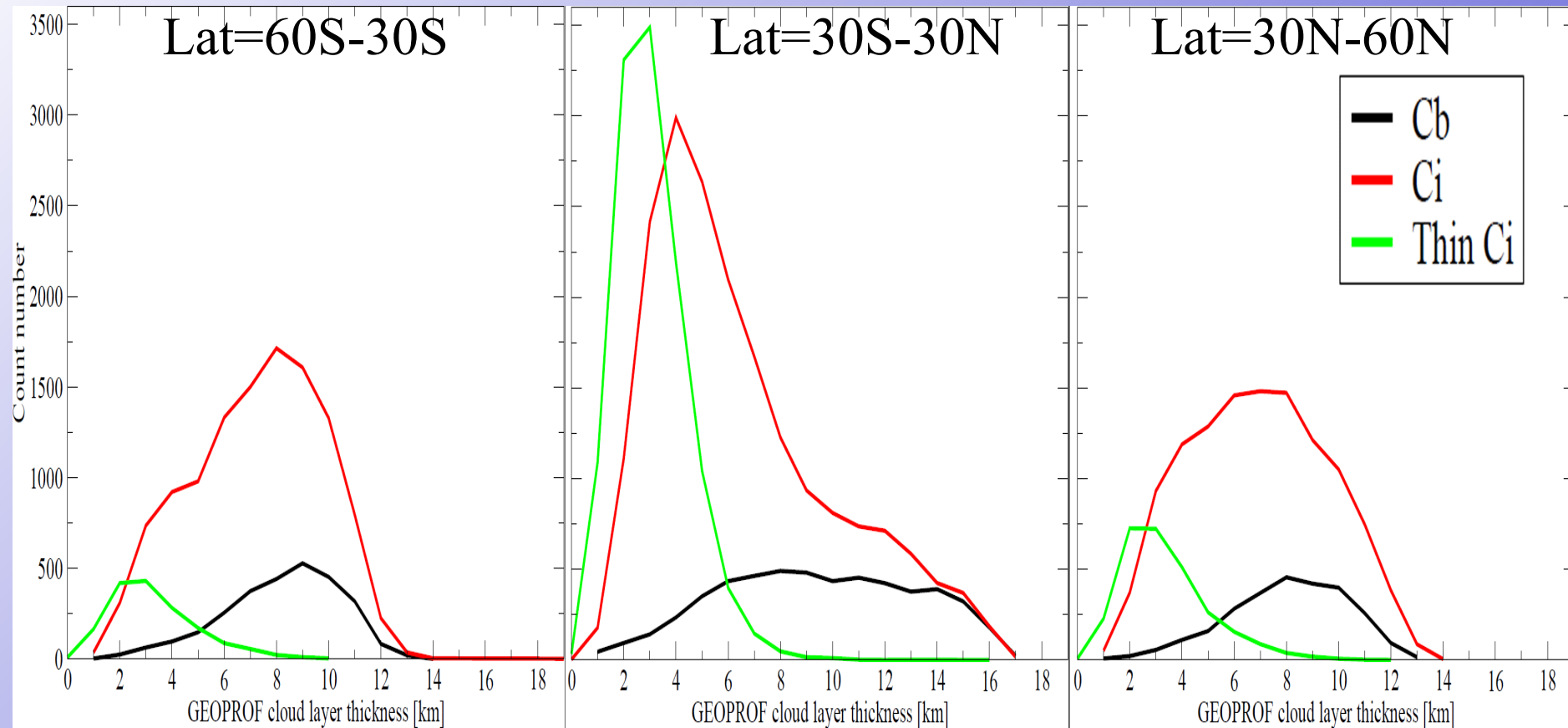
Observation parameters:

- AIRS has 9×13.5 km spots per “golf ball”
- CALIOP’s footprint is 300 m, 5 km apart
- same orbit, good spatio-temporal overlaps

DARDAR Ice water paths

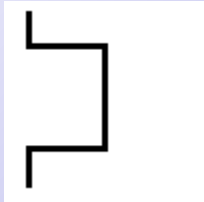


A-Train synergy: vertical extent of different cloud types

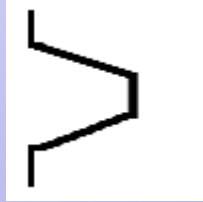


- vertical extent increases from thin Ci to optically thicker high-level clouds
- clouds thicker in SH than in NH midlatitudes (& in winter than in summer)
- vertical extent of thin Ci limited to about 5 km
- climatology of cloud vertical extent per cloud type is an important input for Earth radiation budget

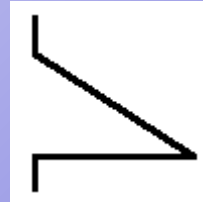
Classification of IWC(z)



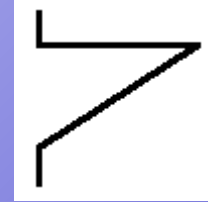
Boxcar



Trapezoid

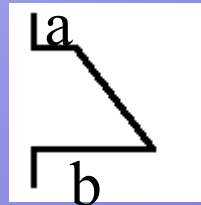


Lower triangle



Upper triangle

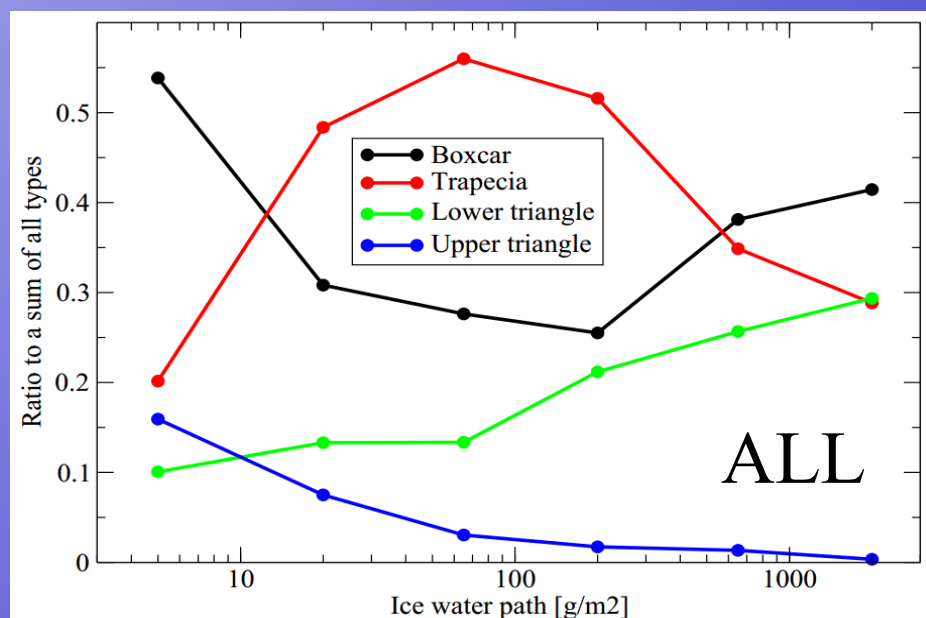
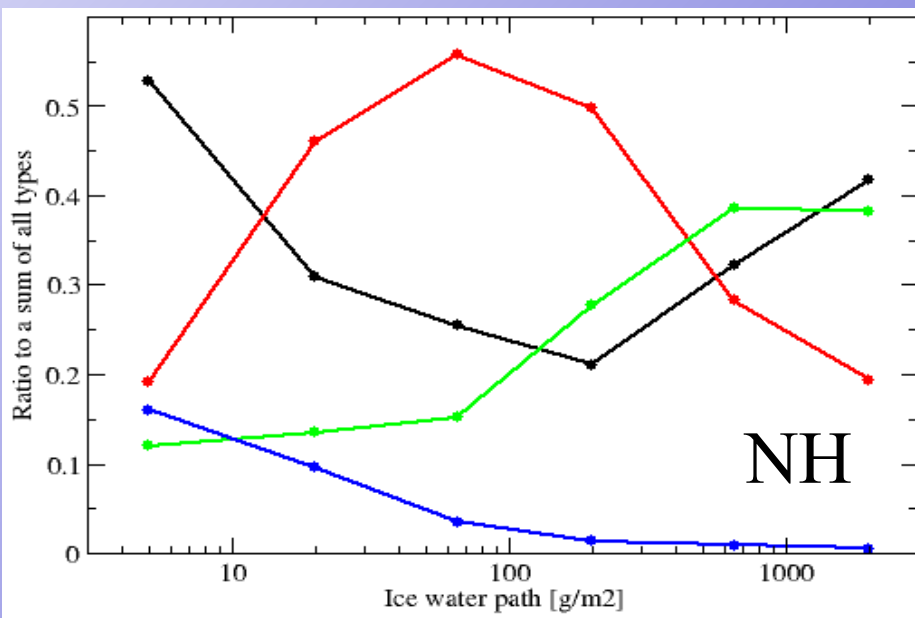
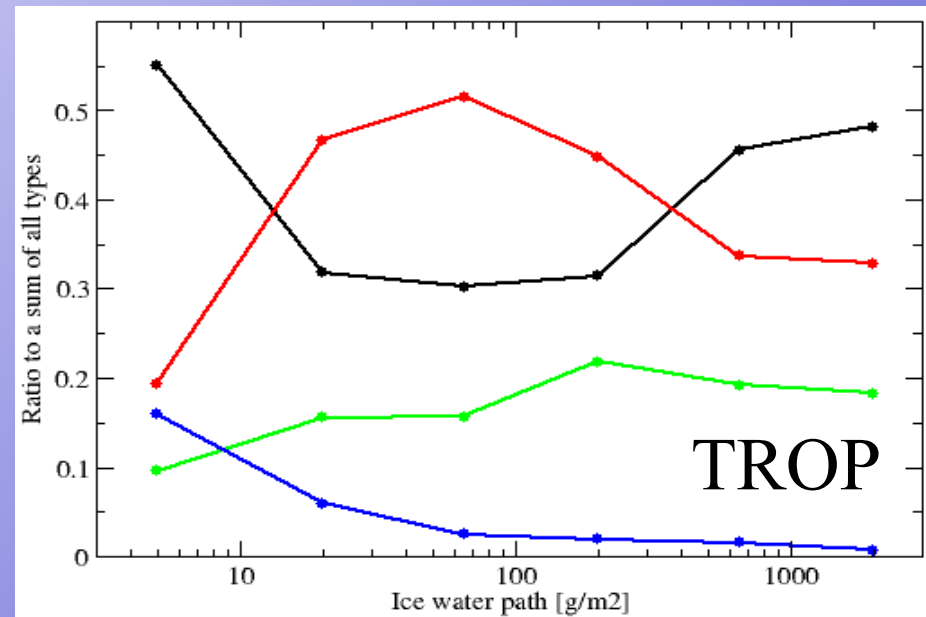
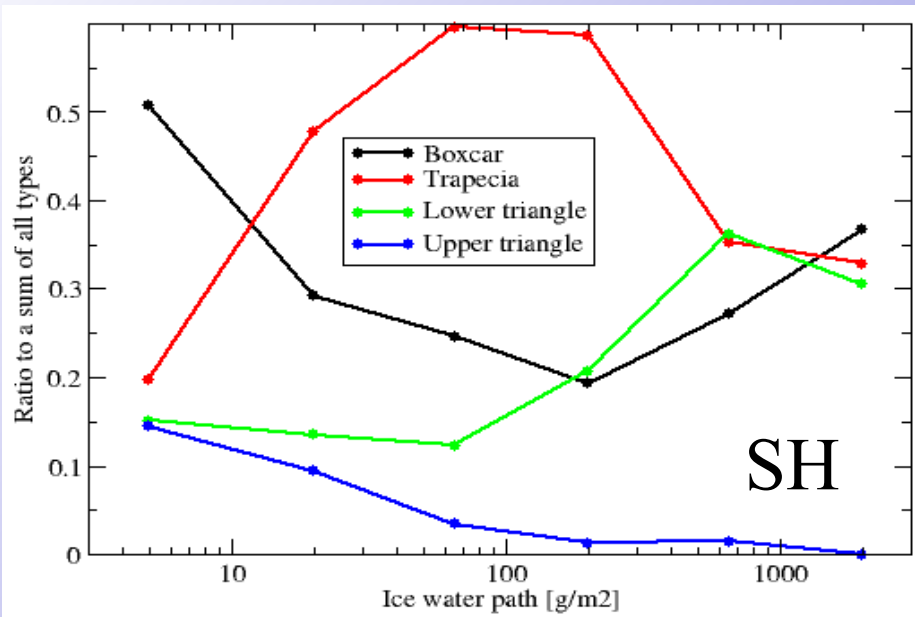
Classification of De(z)



$$a:b = 1:2, 2:3, 3:4$$

Profile types vs latitude/longitude, IWP, w,u,v, H₂O, etc?

IWC(z) type dependence on IWP

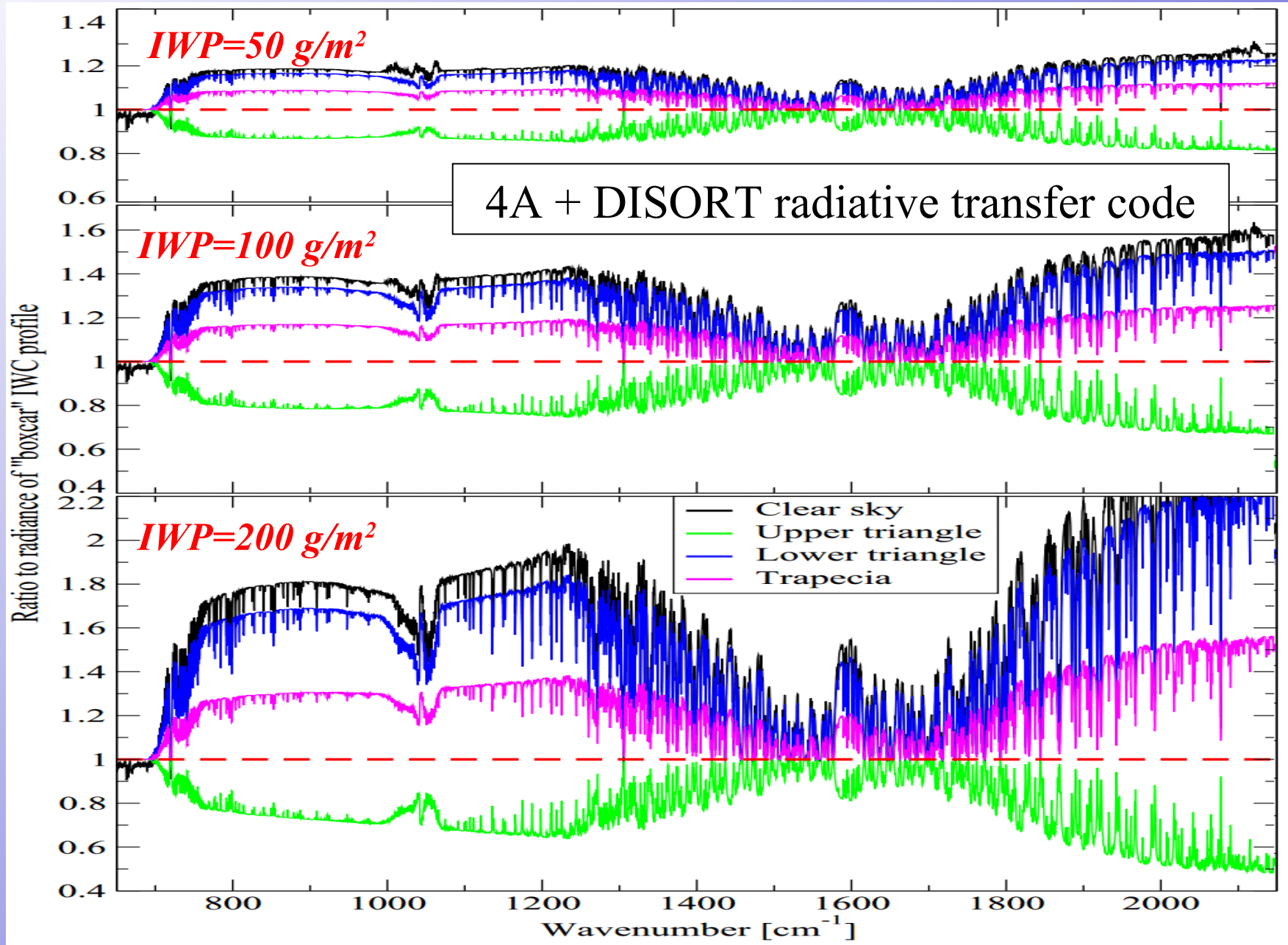


Vertical IWC profile type statistics

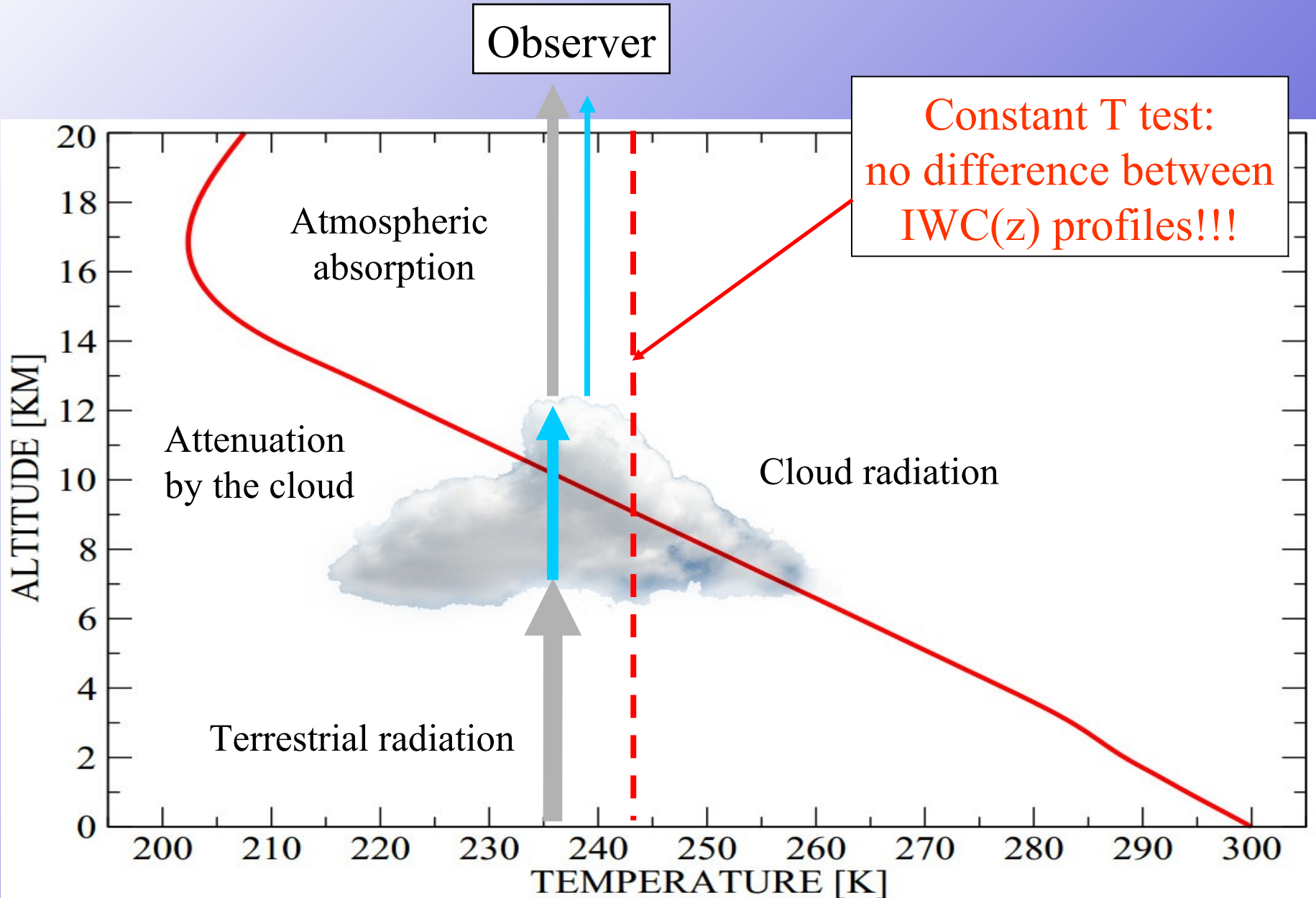
IWP (g/m ²)	boxcar	trapecia	lower triangle	upper triangle	Histogram value
0-10	54%	20%	10%	16%	51%
10-30	31%	48%	13%	8%	29%
30-100	28%	56%	14%	3%	17%
100-300	26%	51%	21%	2%	3%
300-1000	38%	35%	26%	1%	<1%

- “Boxcar” and trapecia correspond to 80% of the profiles !
- Lower triangles increase with IWP from 10 to 26%
- Upper triangles only for IWP < 30 g/m²
- Only strong vertical wind affects upper/lower triangles

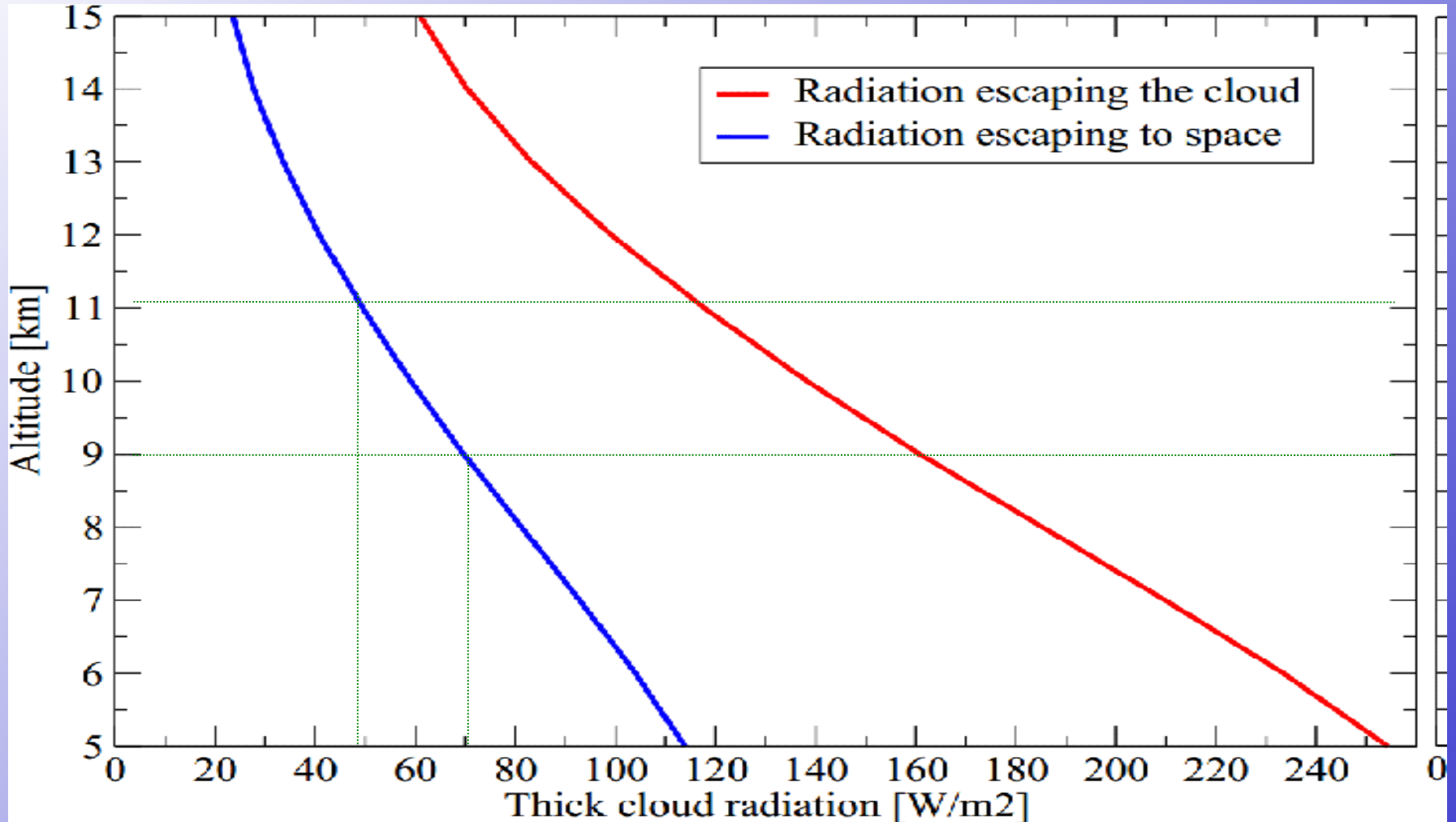
Radiative effects: comparing to boxcar profile



Radiative effects: explanation



Radiative effects: cooling the atmosphere



- For lower triangles vs boxcar cloud type, $\Delta Z_{\text{eff}} = 2\text{-}3$ km
- Optically thick clouds: $\sim 20\text{-}30$ W/m² stronger cooling of atmosphere
- If averaged over all clouds, the effect reduces to ~ 2 W/m² extra cooling

Conclusions

- IWC(z) profiles analyzed for 3 years of global observations: the results for the upper ice cloud do not depend on a number of cloud layers/type below.
- 80% of the clouds can be represented by boxcar / trapezoid
- Lower triangle clouds ratio increases while the ratio for upper triangle clouds decreases with IWP increase
- Radiative effects of different IWC(z) profiles are explained by thermal radiation of the cloud and T(z) variation
- Energetic effect of using boxcar cloud type instead of real distributions is underestimation of atmospheric cooling rate by $\sim 2 \text{ W/m}^2$

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