Regional Differences in Congestus Clouds and Surrounding Environment from CloudSat/AIRS

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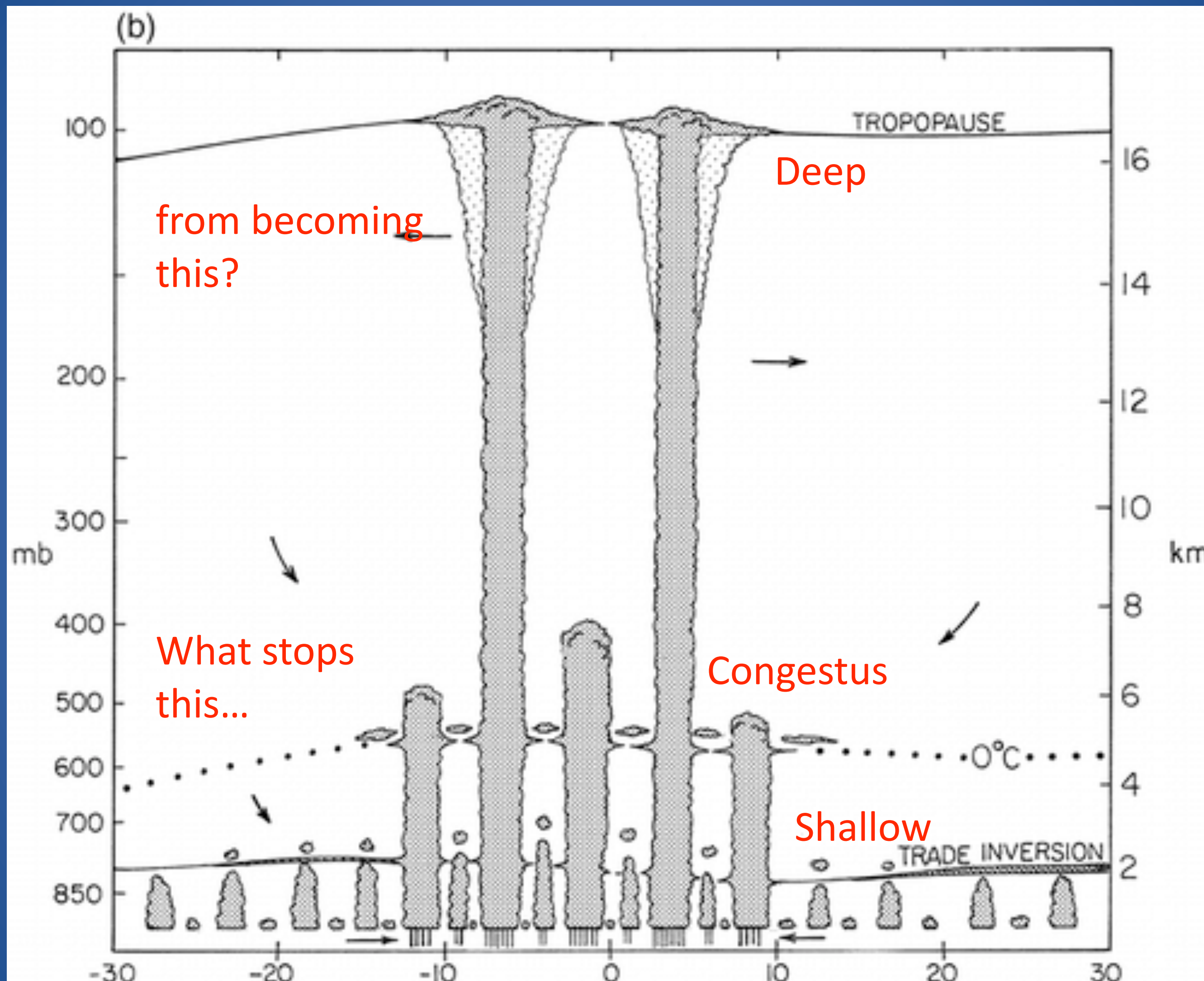
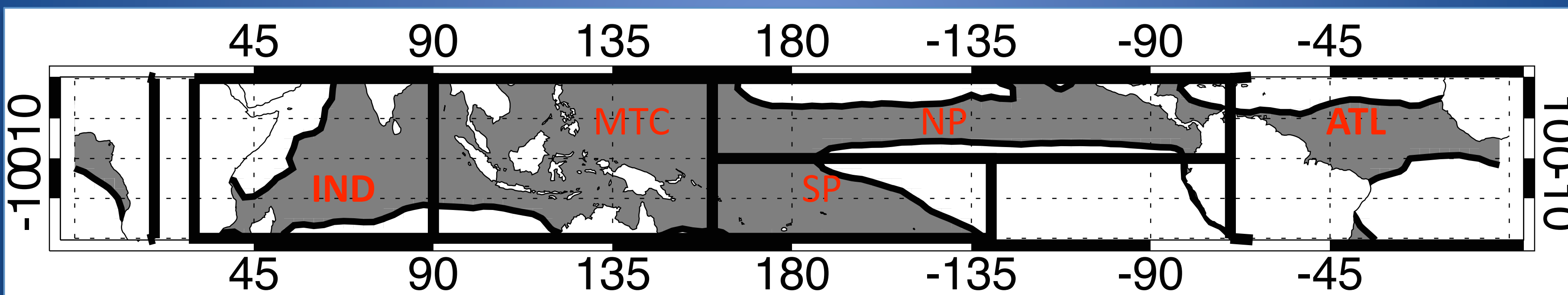
Looking for differences in deep and shallow tropical convection



Johnson et al. [1999]

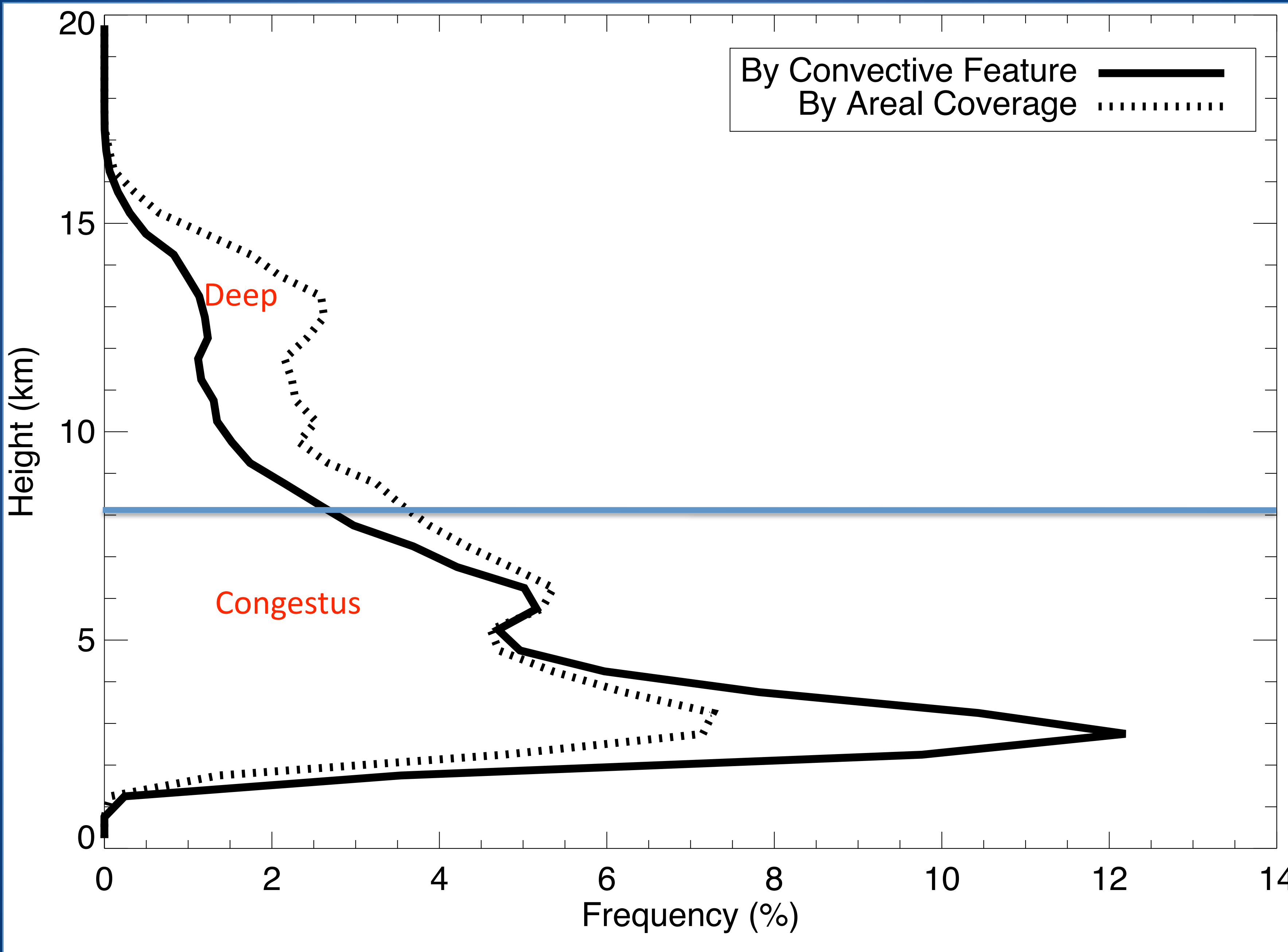
Identification of Active Convection (using CloudSat; based on TRMM/CloudSat collocation, looking at TRMM-identified convection)

1. Cloud Certain from Cloud-Top Height (CTH) to 1 km above surface
2. Presence of >0 dBZ echo
3. CALIPSO CTH within 1 km of CloudSat CTH (proxy for optically thick)



Gray marks actively-convective regions of the tropical oceans (long-term-mean OLR < 240 W/m^2 for one month)

Occurrence frequencies of deep and shallow convection.



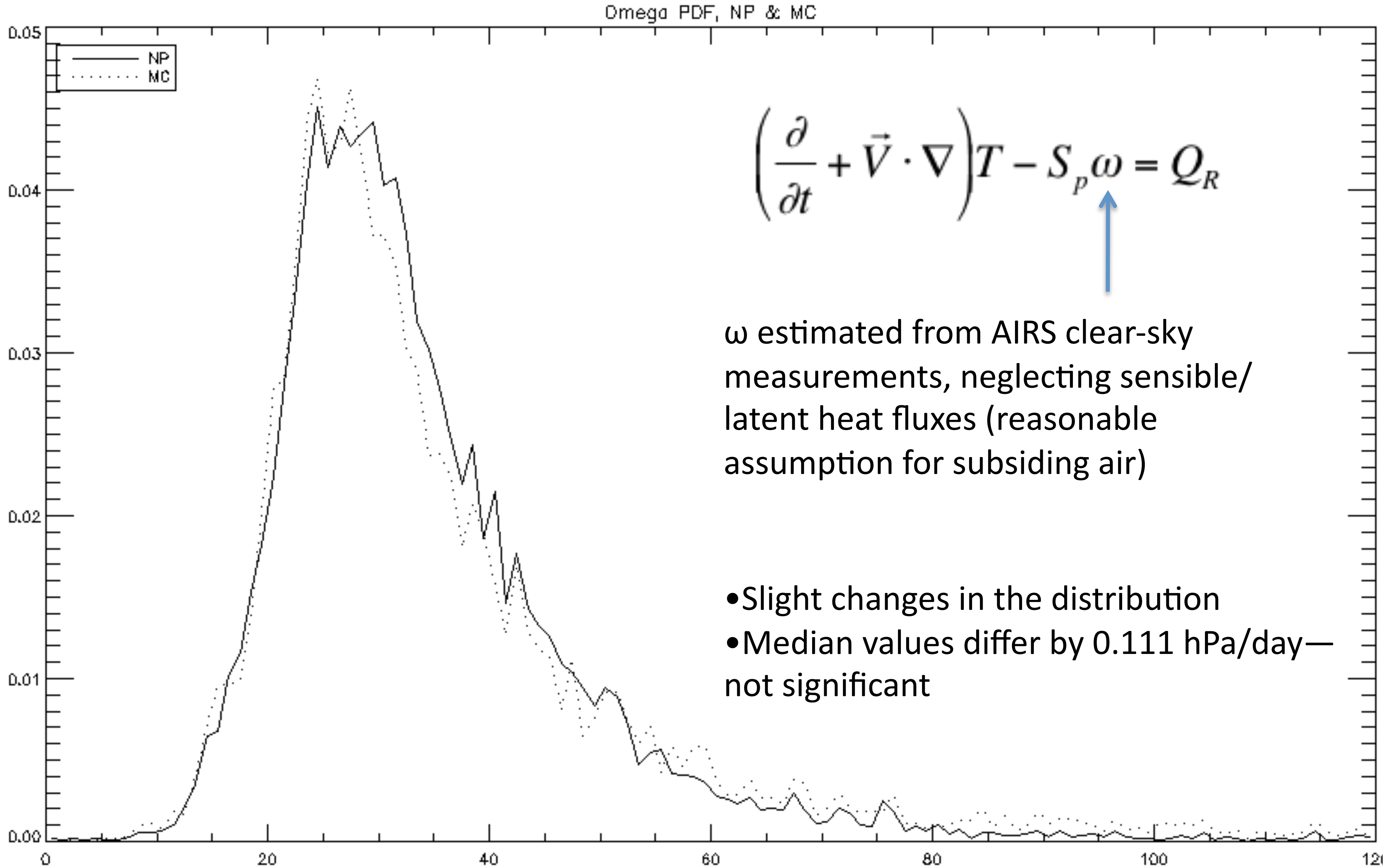
Counts/Occurrence frequencies by region.

	Total	ATL	IND	MTC	NP	SP
# Convective Clouds	69265	6403	10149	23929	19024	9760
# Congestus	55890	5250 (82%)	8243 (81%)	18100 (76%)	16539 (87%)	7758 (79%)
# Deep	13375	1153 (18%)	1906 (19%)	5829 (24%)	2485 (13%)	2002 (21%)
Congestus/Deep	4.2	4.6	4.3	3.1	6.7	3.9

Possible reasons for greater amounts of Congestus:

- Differences in environmental vertical velocity
- Changes in vertical temperature gradient
- Differences in midtropospheric moisture

1. Differences in Environmental Vertical Velocity / Heating rate?



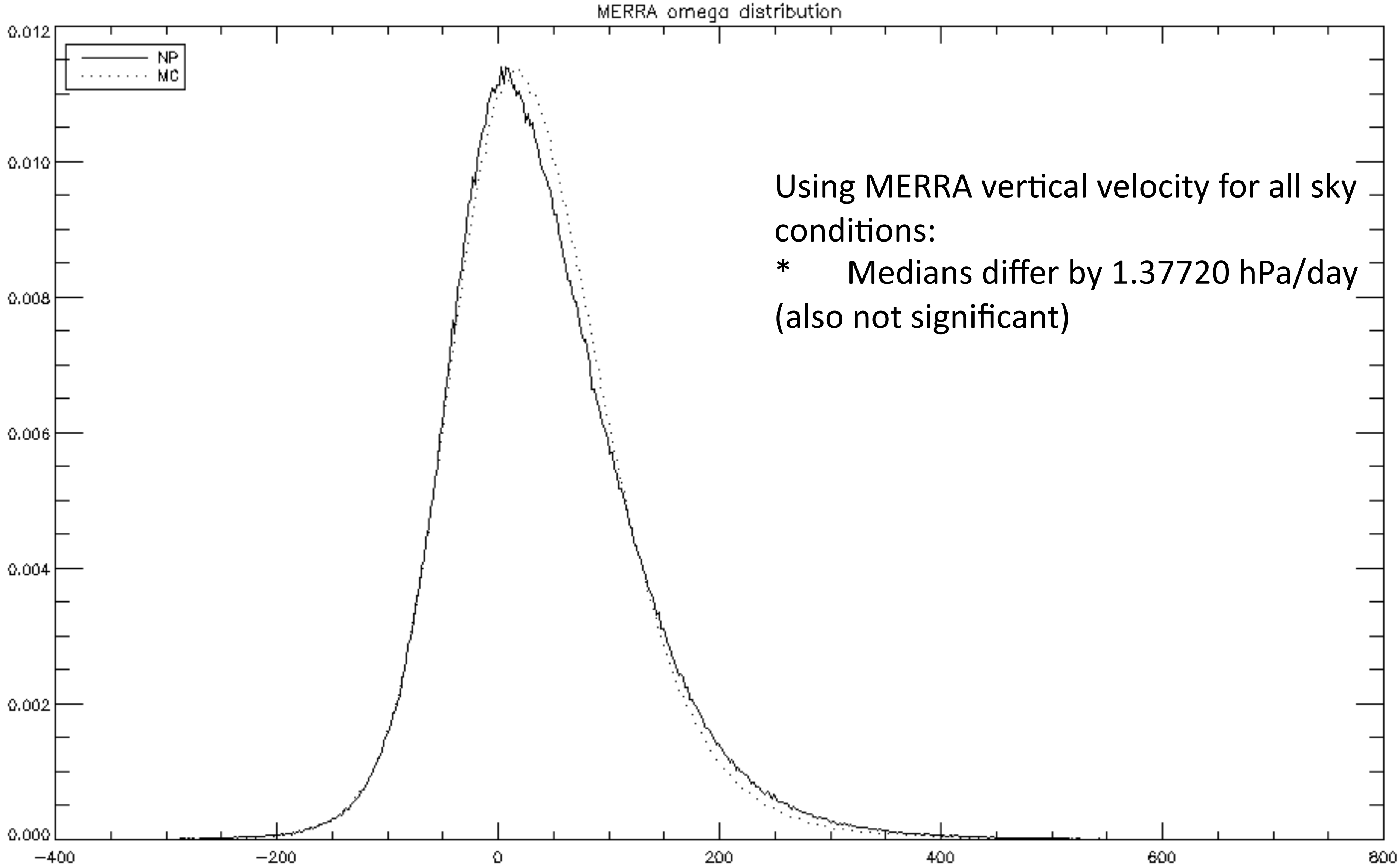
$$\left(\frac{\partial}{\partial t} + \vec{V} \cdot \nabla\right) T - S_p \omega = Q_R$$

ω estimated from AIRS clear-sky measurements, neglecting sensible/ latent heat fluxes (reasonable assumption for subsiding air)

- Slight changes in the distribution
- Median values differ by 0.111 hPa/day— not significant

Vertical Velocity (hPa/day)

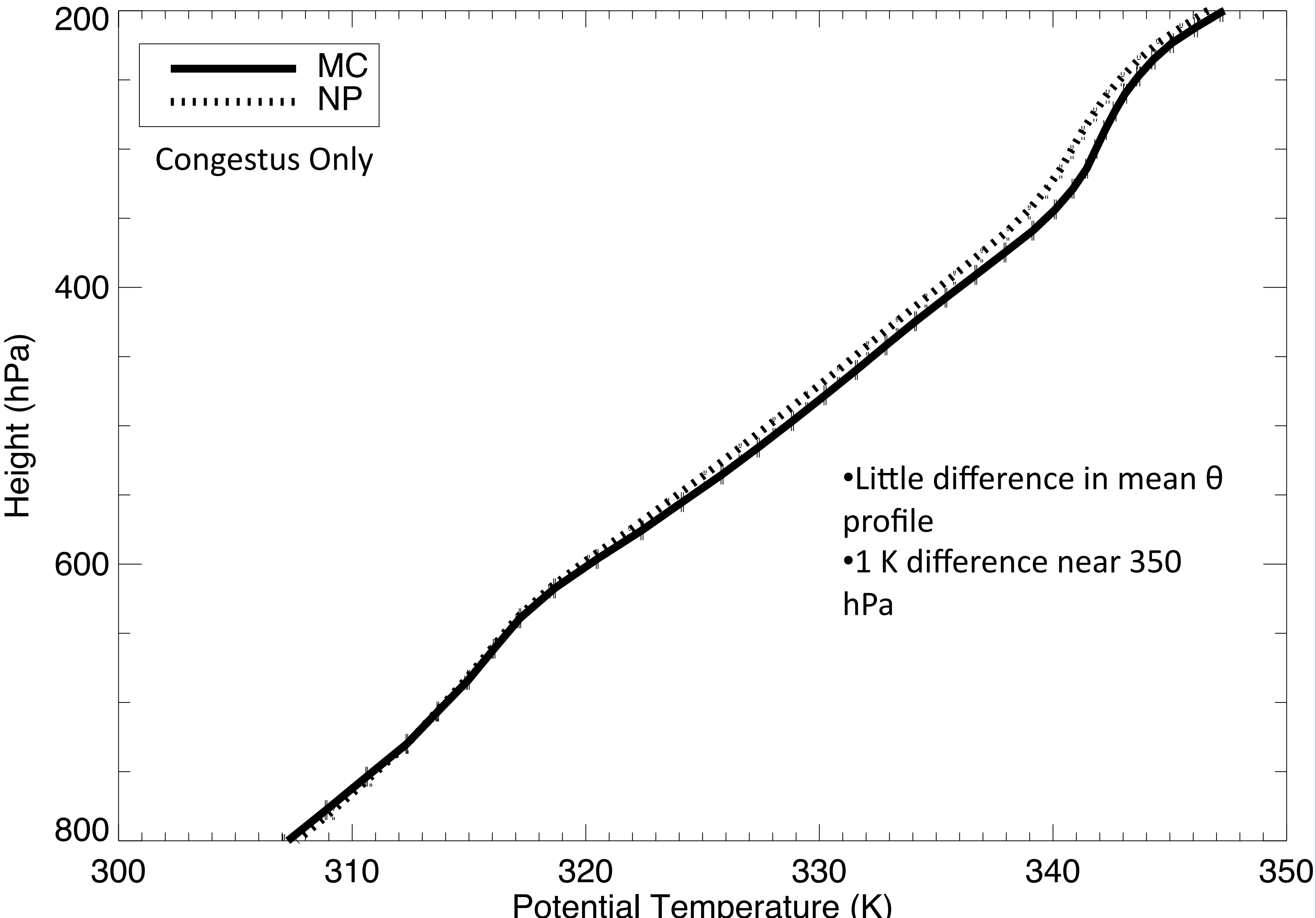
1. Differences in Environmental Vertical Velocity in models?



Using MERRA vertical velocity for all sky conditions:

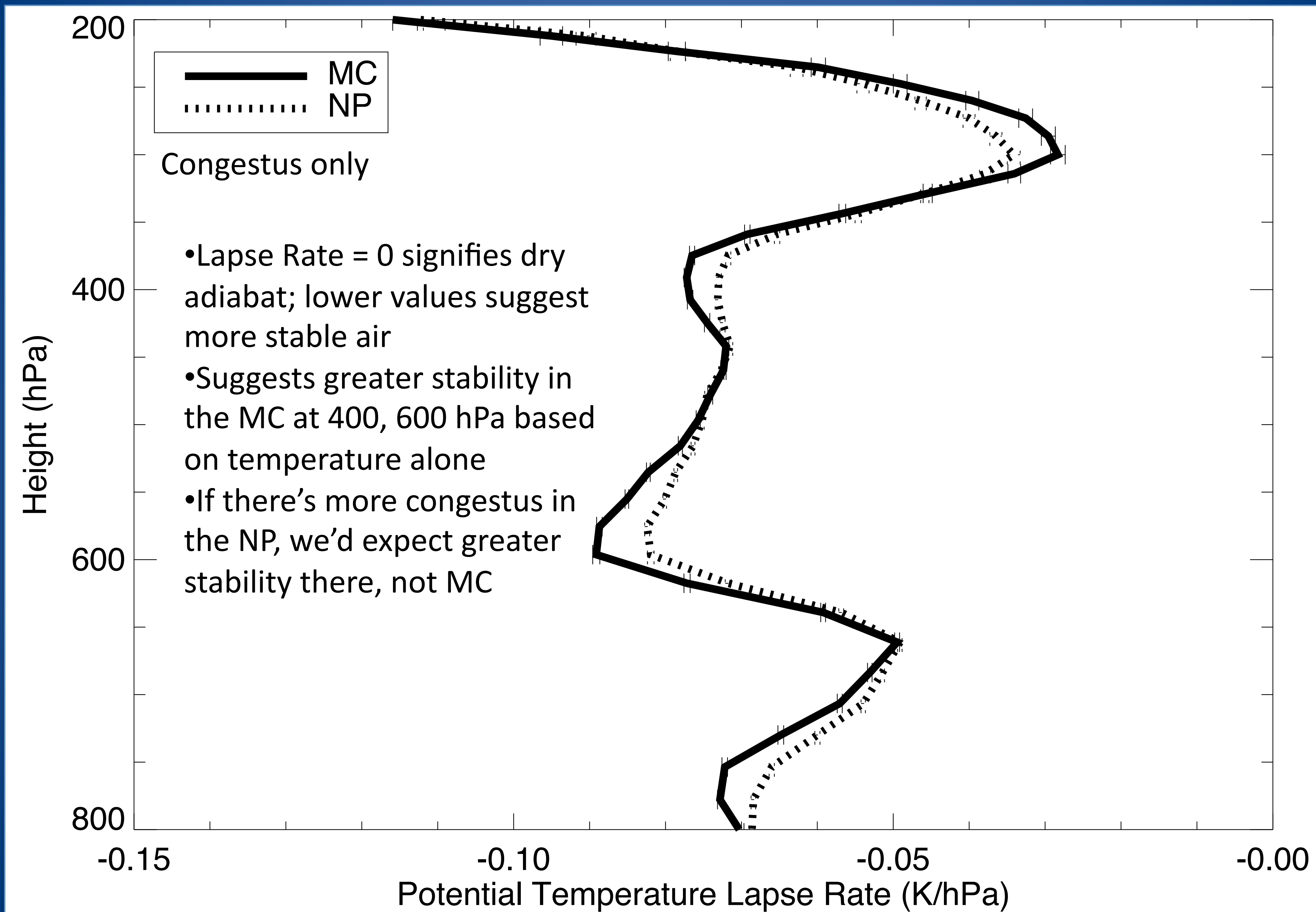
* Medians differ by 1.37720 hPa/day (also not significant)

2. Changes in Vertical Temperature Gradient from AIRS?

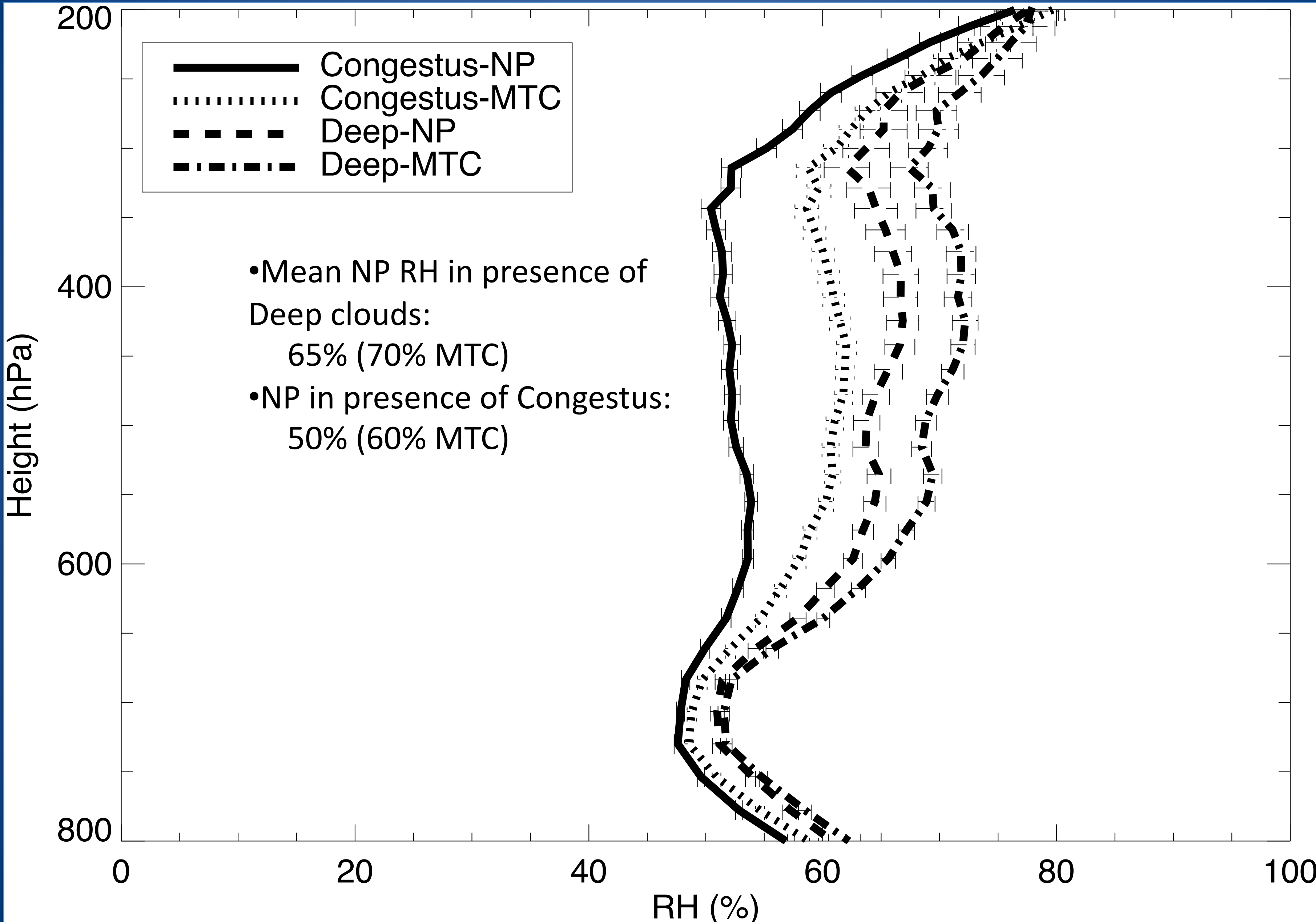


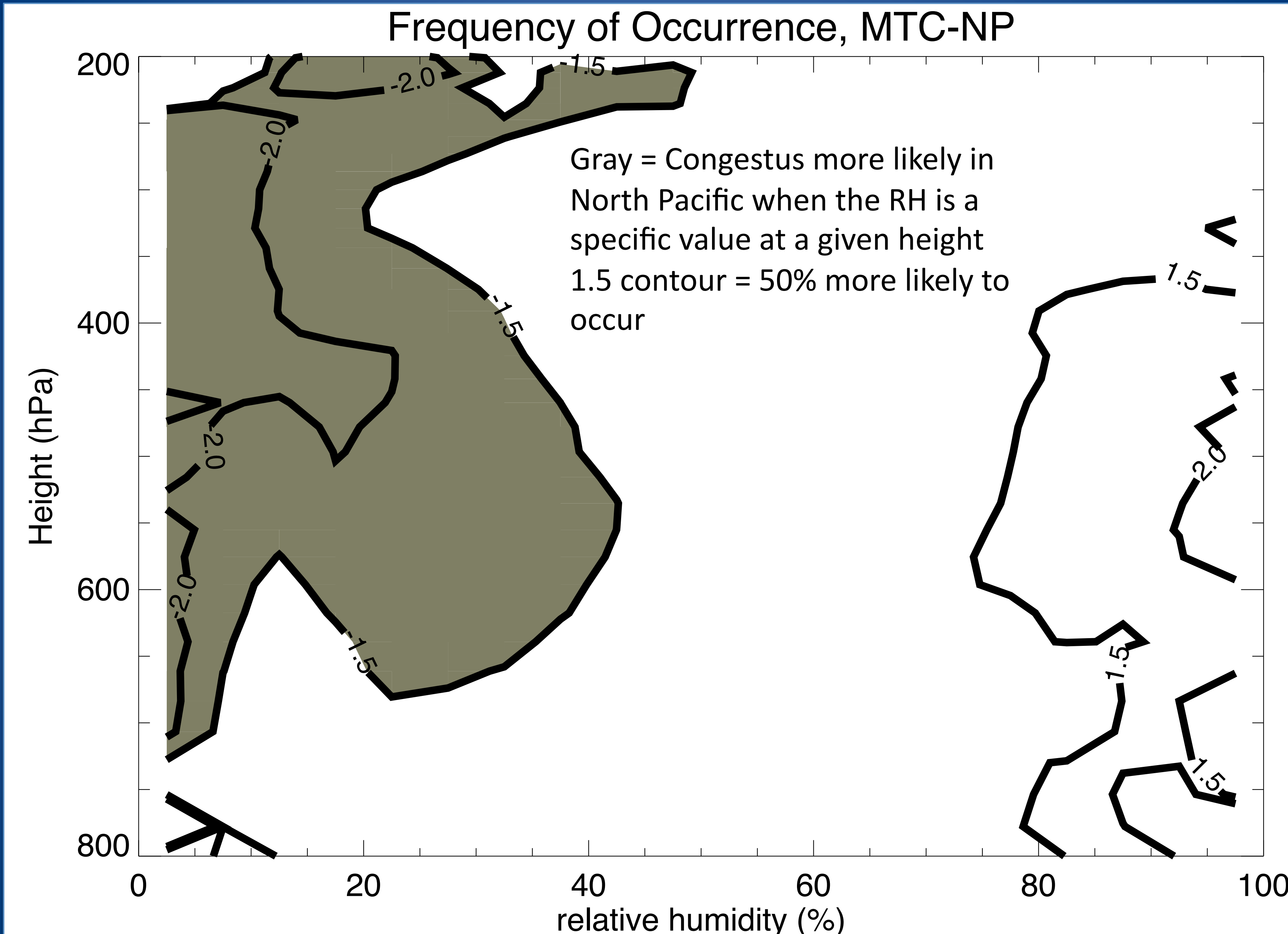
- Little difference in mean θ profile
- 1 K difference near 350 hPa

dθ/dp-congestus only



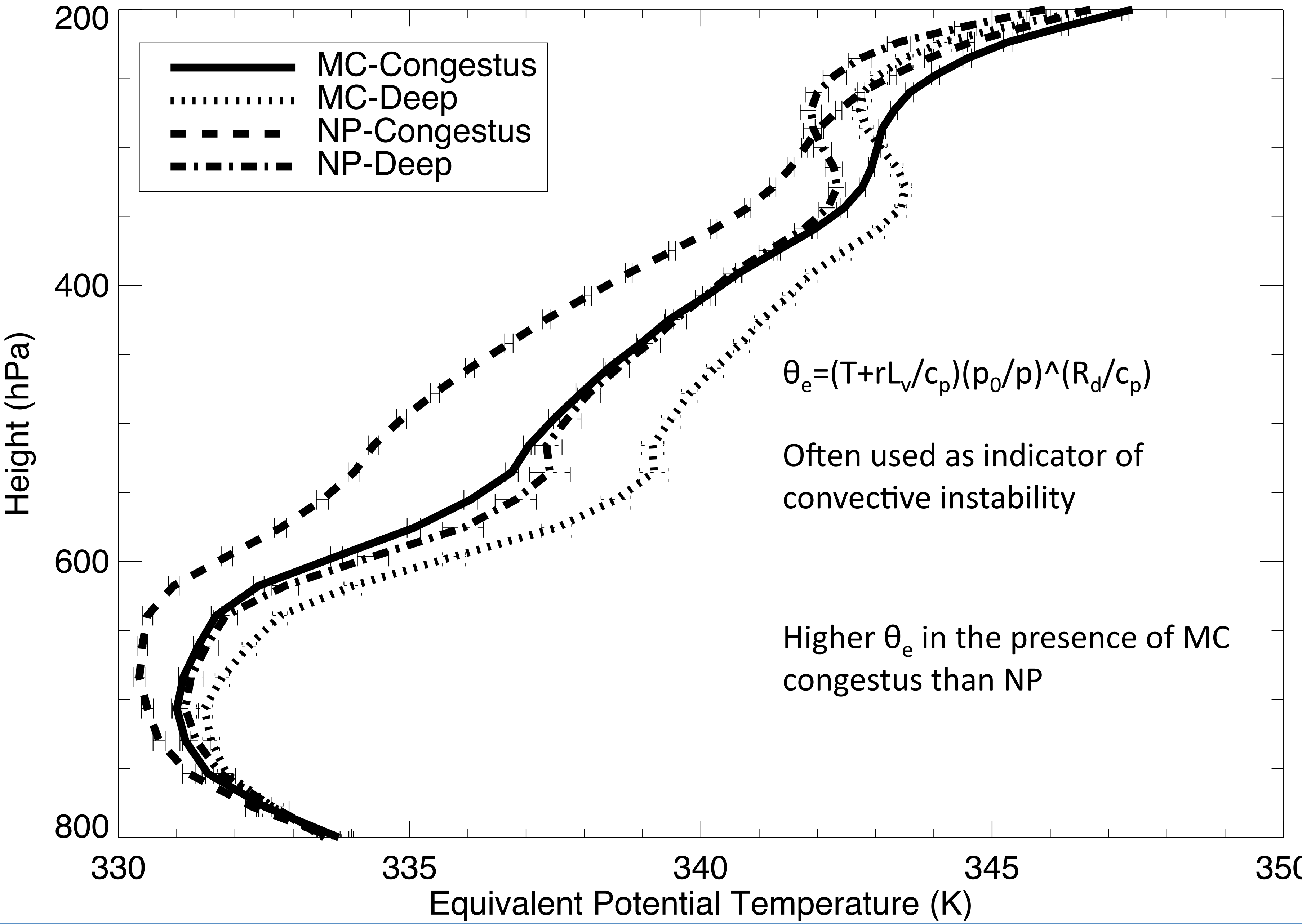
3. Differences in Midtropospheric Moisture from AIRS





Frequency of Occurrence, MTC-NP
Gray = Congestus more likely in North Pacific when the RH is a specific value at a given height
1.5 contour = 50% more likely to occur
Height (hPa)
200
400
600
800
relative humidity (%)
0
20
40
60
80
100
-2.0
-1.5
1.5
2.0

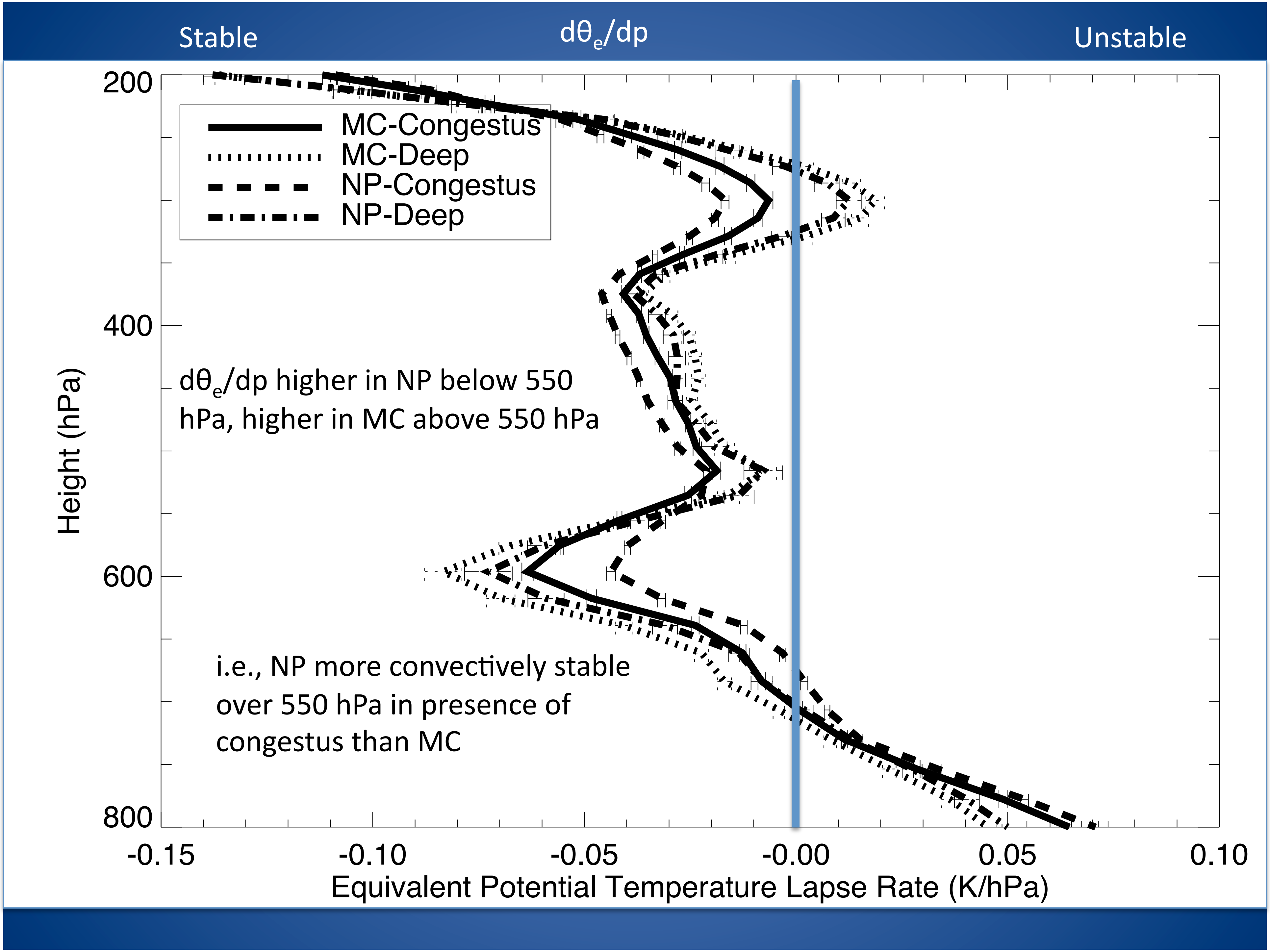
Equivalent Potential Temperature from AIRS



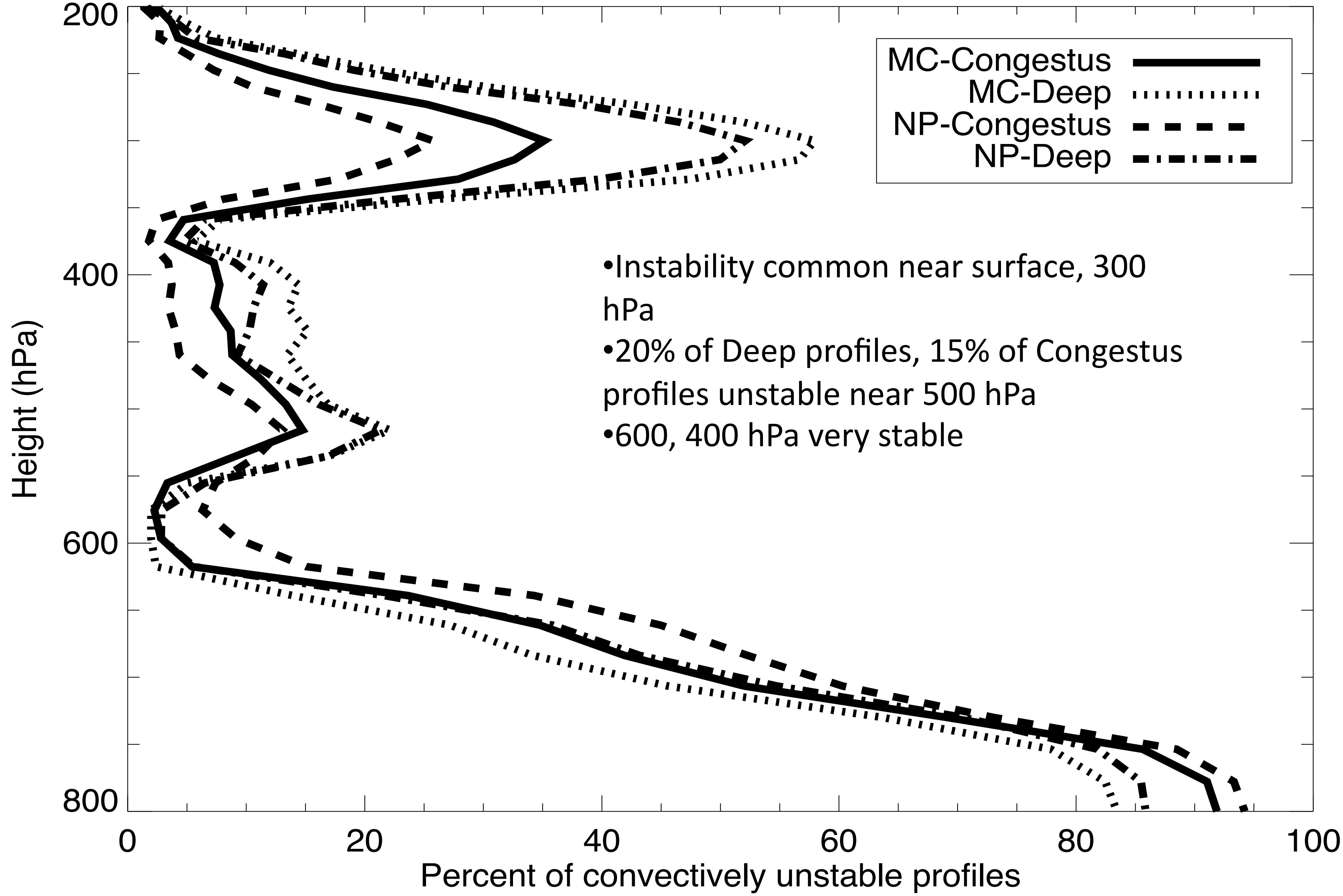
$\theta_e=(T+rL_v/c_p)(p_0/p)^\wedge(R_d/c_p)$

Often used as indicator of convective instability

Higher θ_e in the presence of MC congestus than NP

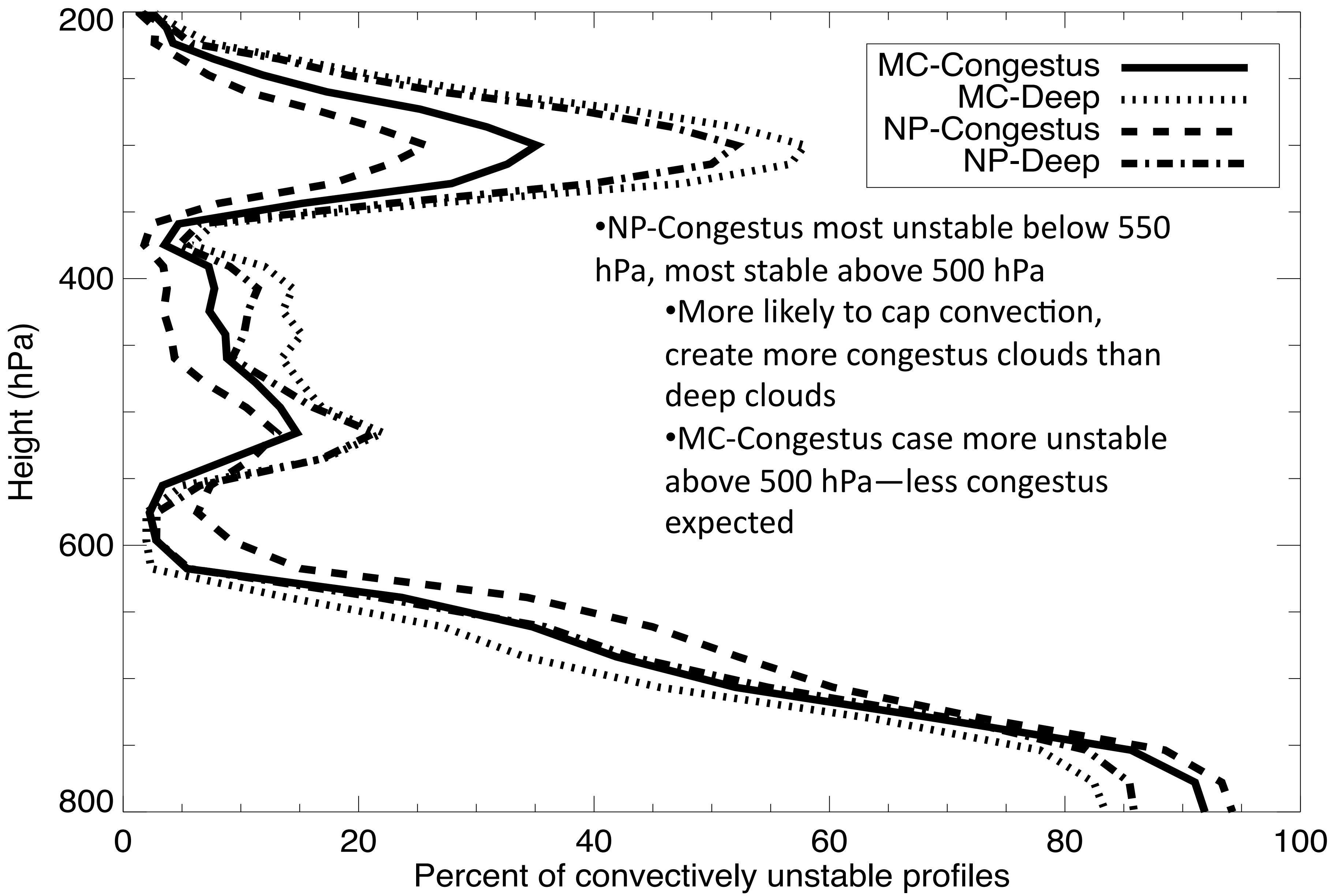

Stable
dθe/dp
Unstable
MC-Congestus
MC-Deep
NP-Congestus
NP-Deep
dθe/dp higher in NP below 550 hPa, higher in MC above 550 hPa
i.e., NP more convectively stable over 550 hPa in presence of congestus than MC
Height (hPa)
200
400
600
800
-0.15
-0.10
-0.05
-0.00
0.05
0.10
Equivalent Potential Temperature Lapse Rate (K/hPa)

How many convectively unstable profiles?



- Instability common near surface, 300 hPa
- 20% of Deep profiles, 15% of Congestus profiles unstable near 500 hPa
- 600, 400 hPa very stable

How many convectively unstable profiles?



- NP-Congestus most unstable below 550 hPa, most stable above 500 hPa
  - More likely to cap convection, create more congestus clouds than deep clouds
  - MC-Congestus case more unstable above 500 hPa—less congestus expected

Conclusions

- One years' worth of coincident CloudSat/AIRS profiles were analyzed over the tropical Oceans, looking at midtropospheric congestus and upper-tropospheric deep convective clouds.

- Regional differences were noted in the ratio of congestus/deep cloud observations
  - Congestus more than twice as common over the NP than MTC

- Lower water vapor amounts in the NP noted in coincident AIRS data; dry air entrainment from rising convection encountering drier air could stop development

- Changes in equivalent potential temperature (measure of convective instability) resulted from differences in water vapor, temperature
  - Greater stability above 550 hPa in environment surrounding congestus clouds than deep clouds
    - acts as cap to convection
  - Cap stronger over the NP than MTC, which could lead to more congestus in the NP