Quantifying the Deep Convective Temperature Signal within the Tropical Tropopause Layer (TTL)

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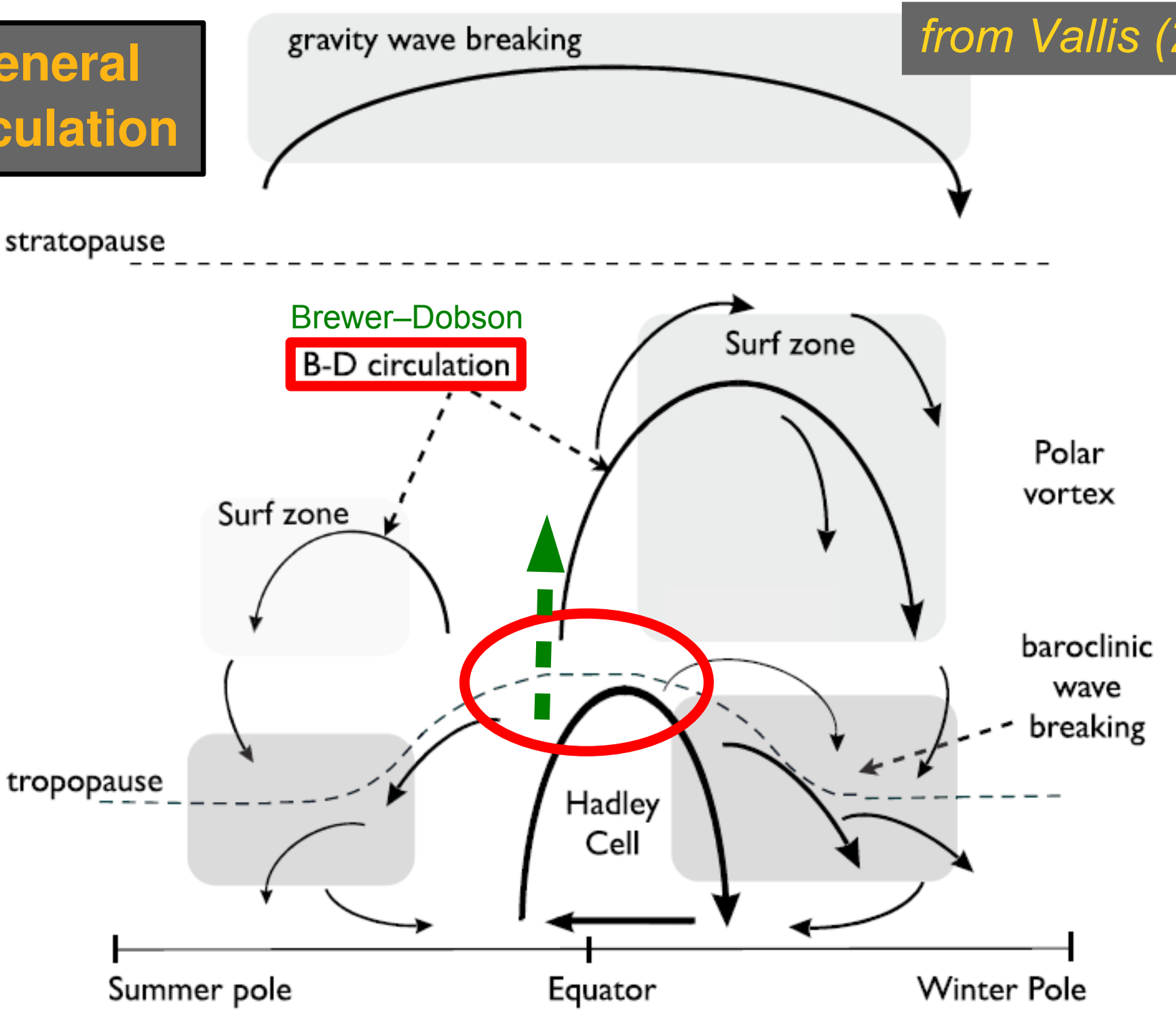
Dynamical Controls on TTL Temperatures

- Planetary-scale circulations (e.g. adiabatic cooling by Brewer-Dobson upwelling)
- Convectively coupled equatorial waves (broad spectrum!)
- Convection (large-scale indirect & small-scale direct)

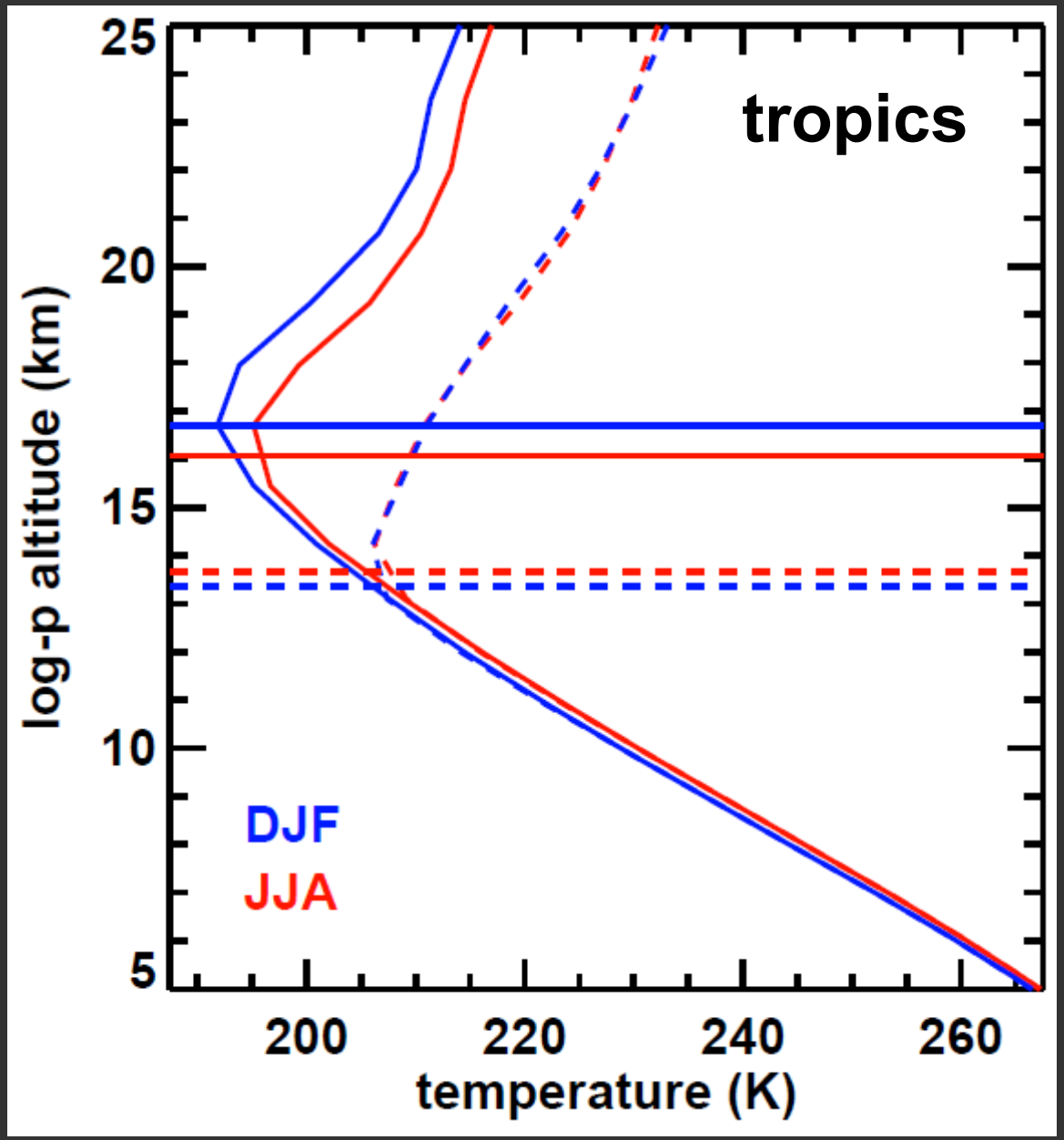
- Here: large-scale (hydrostatic) response to tropospheric deep convective diabatic heating – TTL cooling (Johnson & Kriete 1982; Highwood & Hoskins 1998; Holloway & Neelin 2007; Gettelman & Birner 2007)

General Circulation

from Vallis (2006)



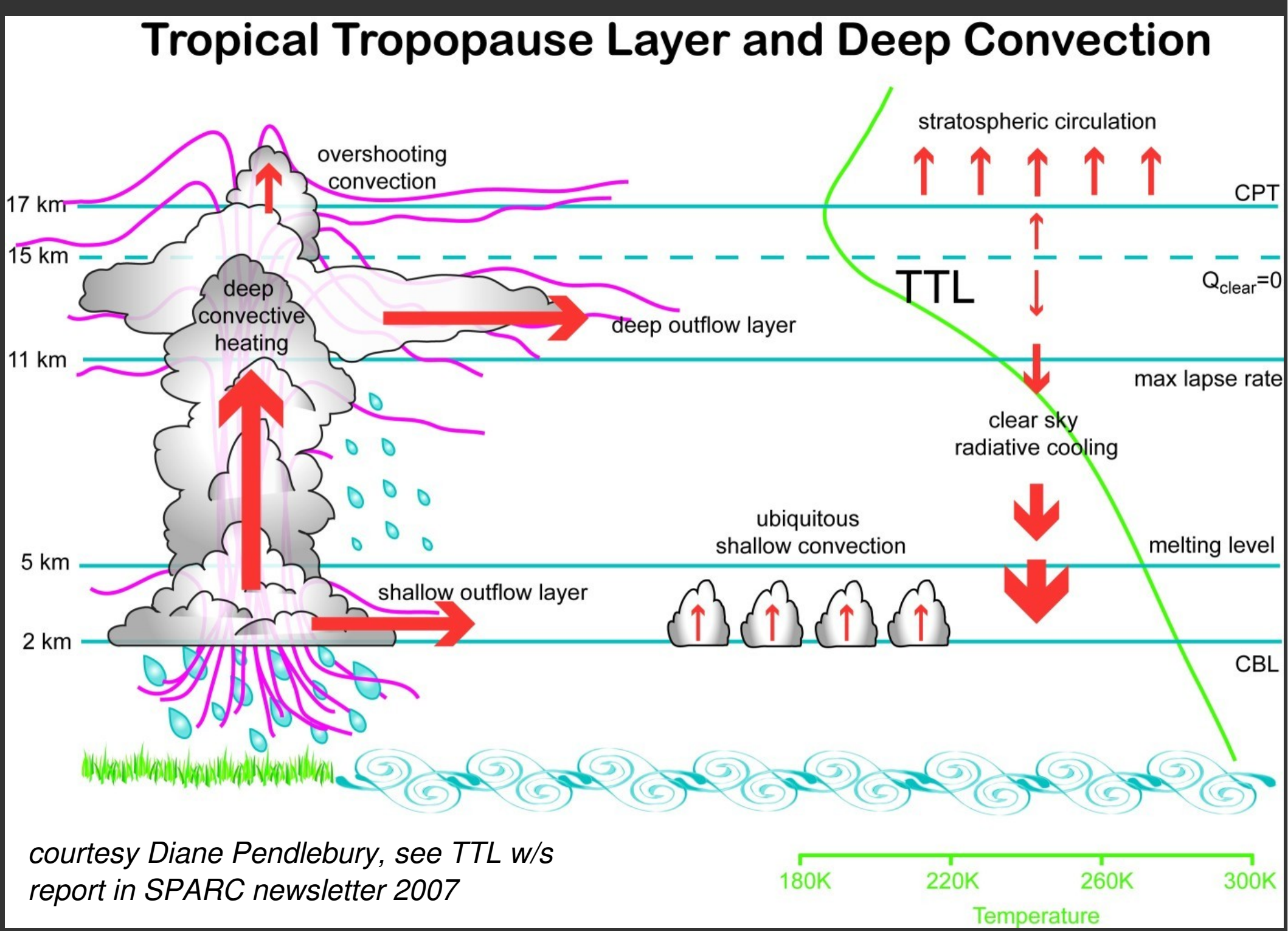
Temperature Profiles (Tropics): Stratospheric Dynamics removed (dashed) vs. CCM (full)



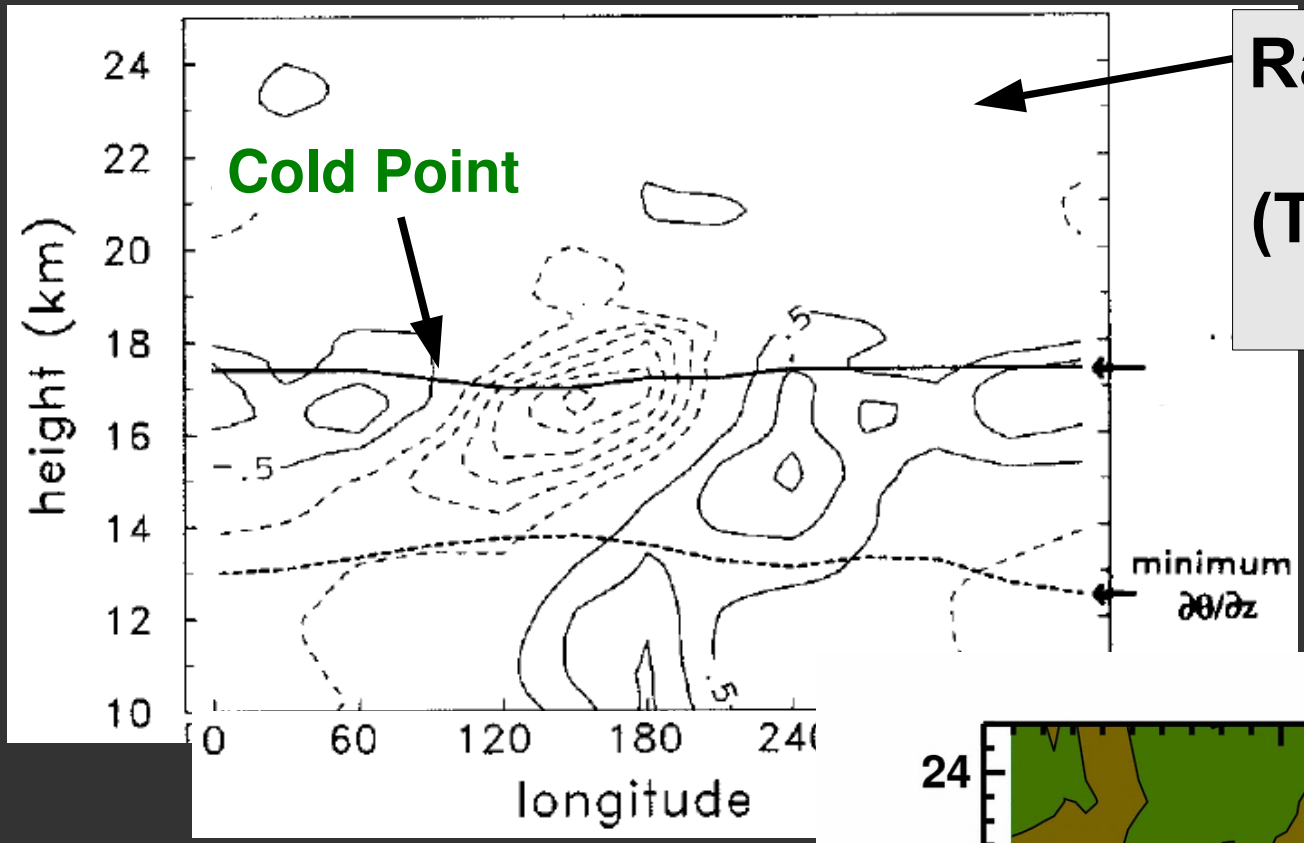
→ Virtually no Tropical Tropopause Layer (TTL) without stratospheric dynamics (in SRE)

Birner (2010)

Tropical Tropopause Layer and Deep Convection

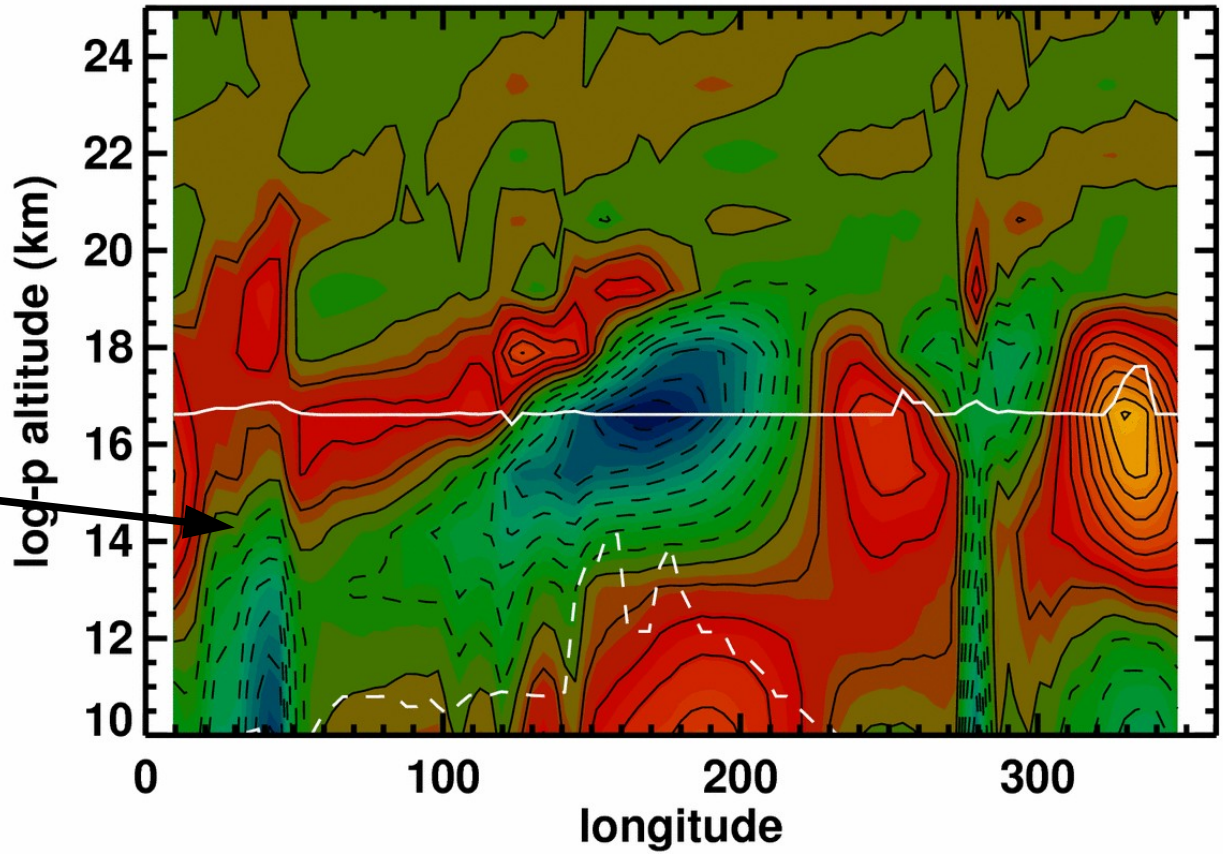


courtesy Diane Pendlebury, see TTL w/s report in SPARC newsletter 2007

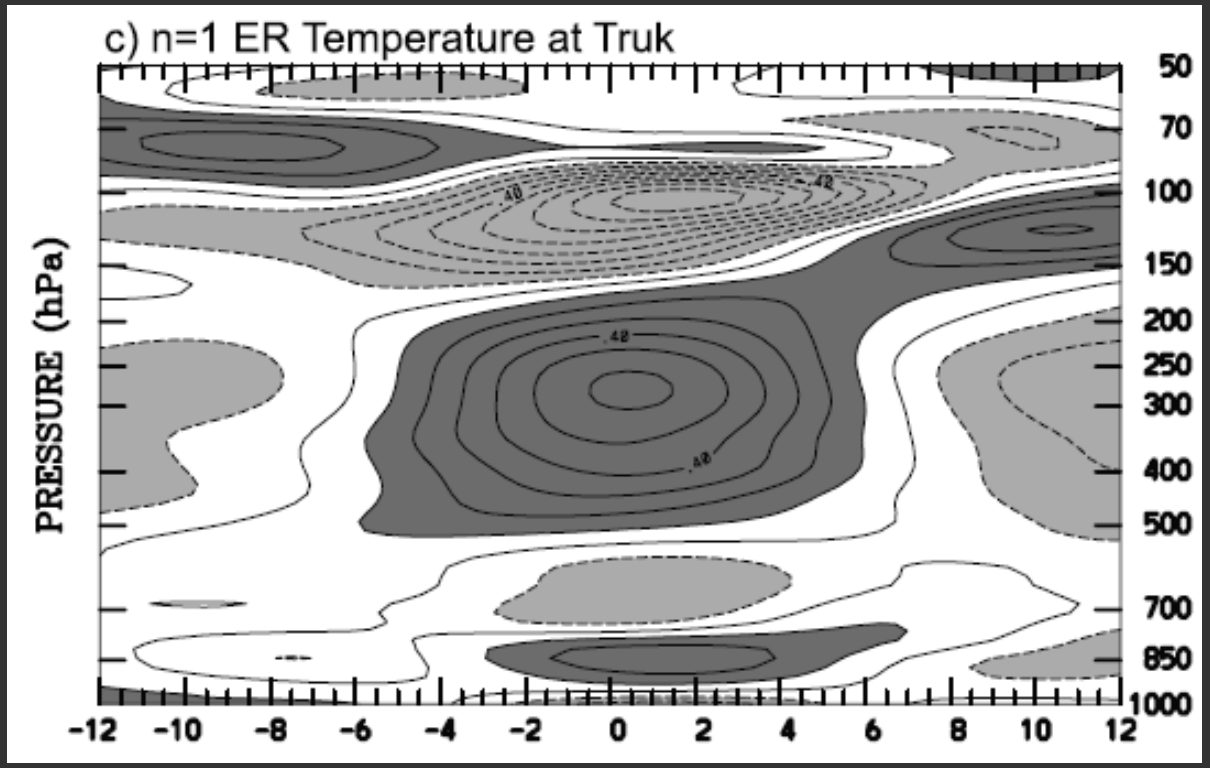


Randel et al. (2003): GPS/ MET Observations (Temperature Anomalies, 10S-10N, DJF)

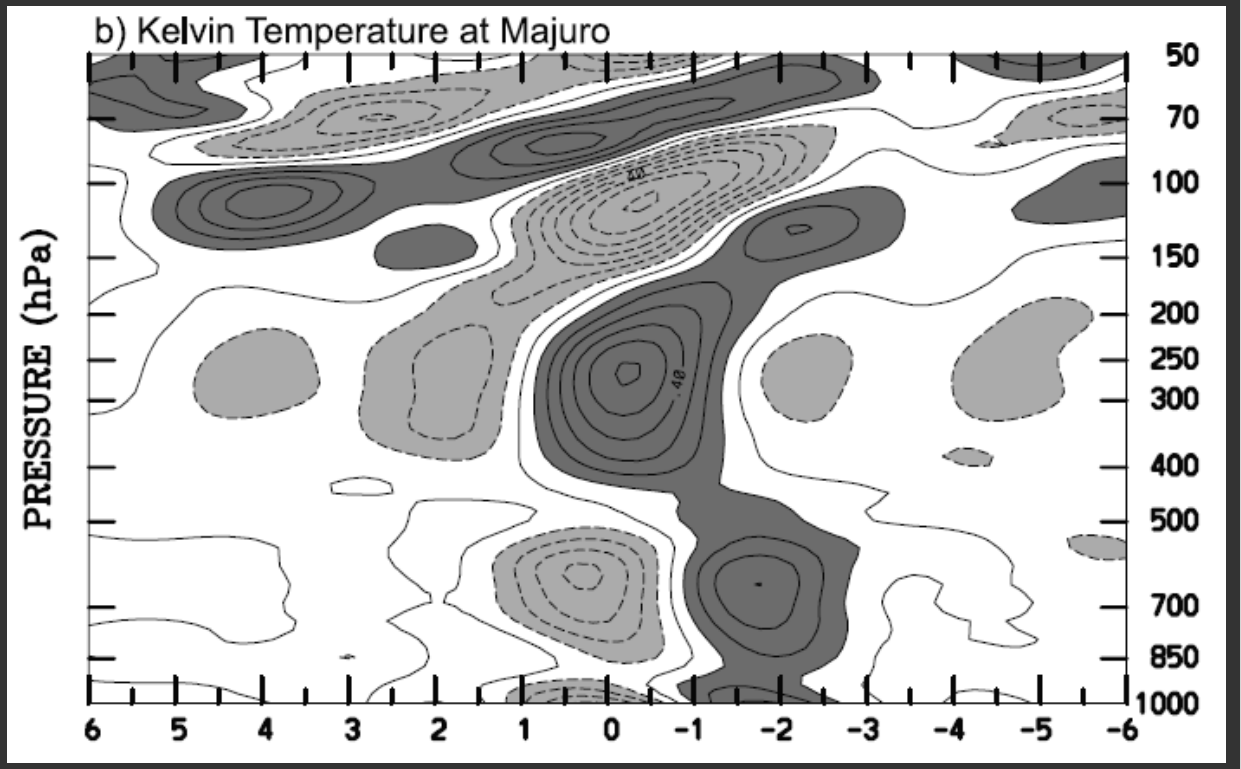
CMAM (DJF)



Gettelman & Birner (2007)



Kiladis et al. (2009)



TTL Cooling by Overshooting Convection (from CRM run into Radiative-Convective Equilibrium)

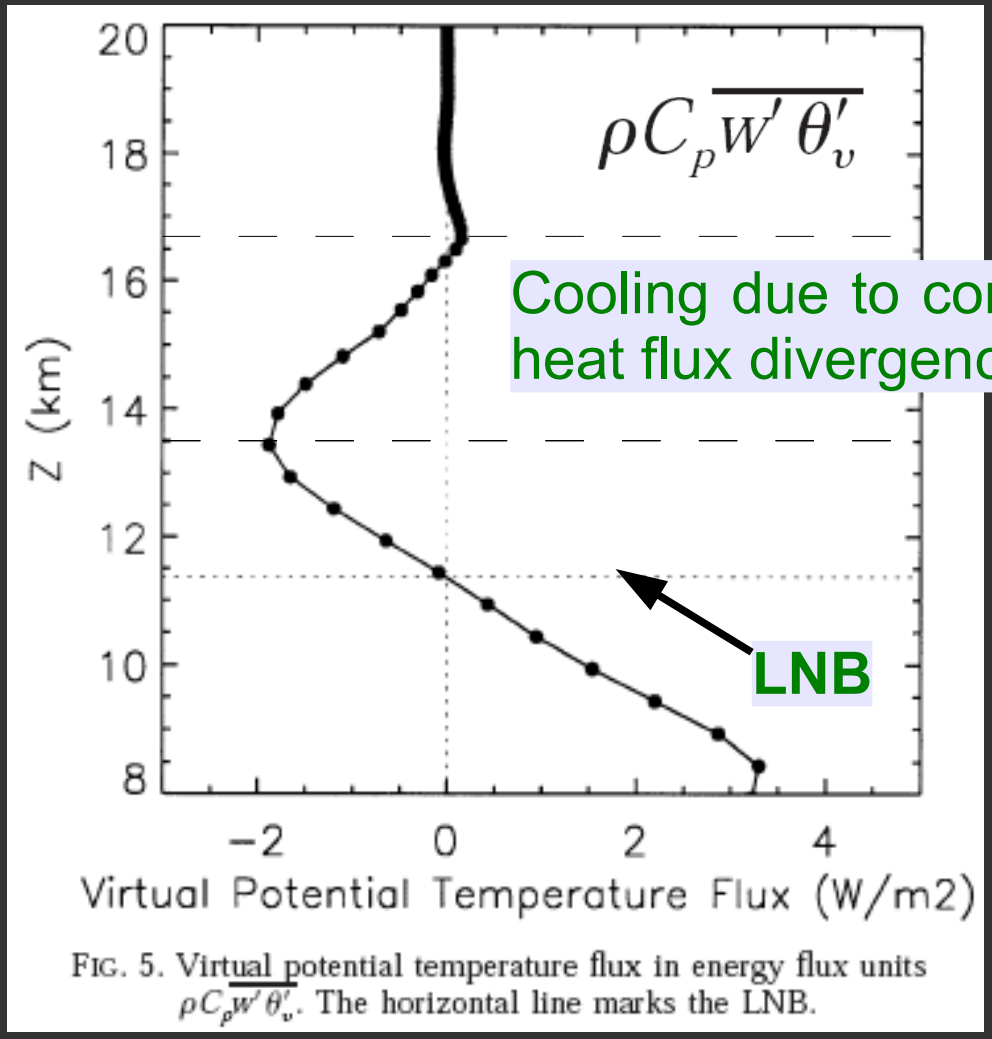
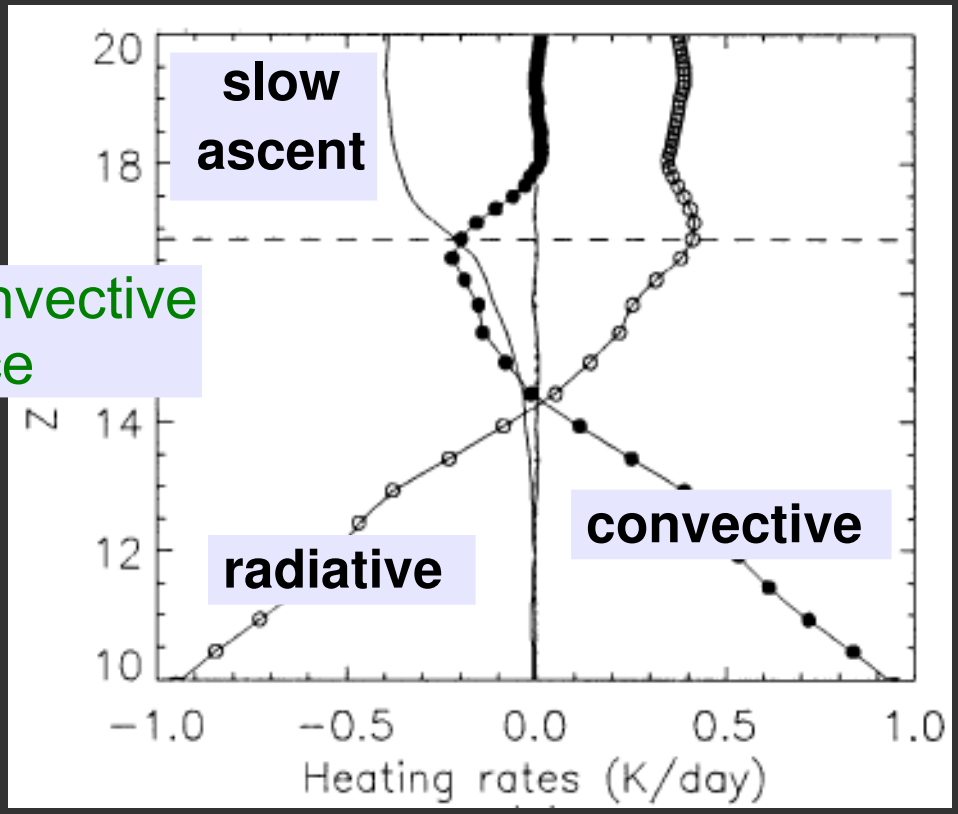


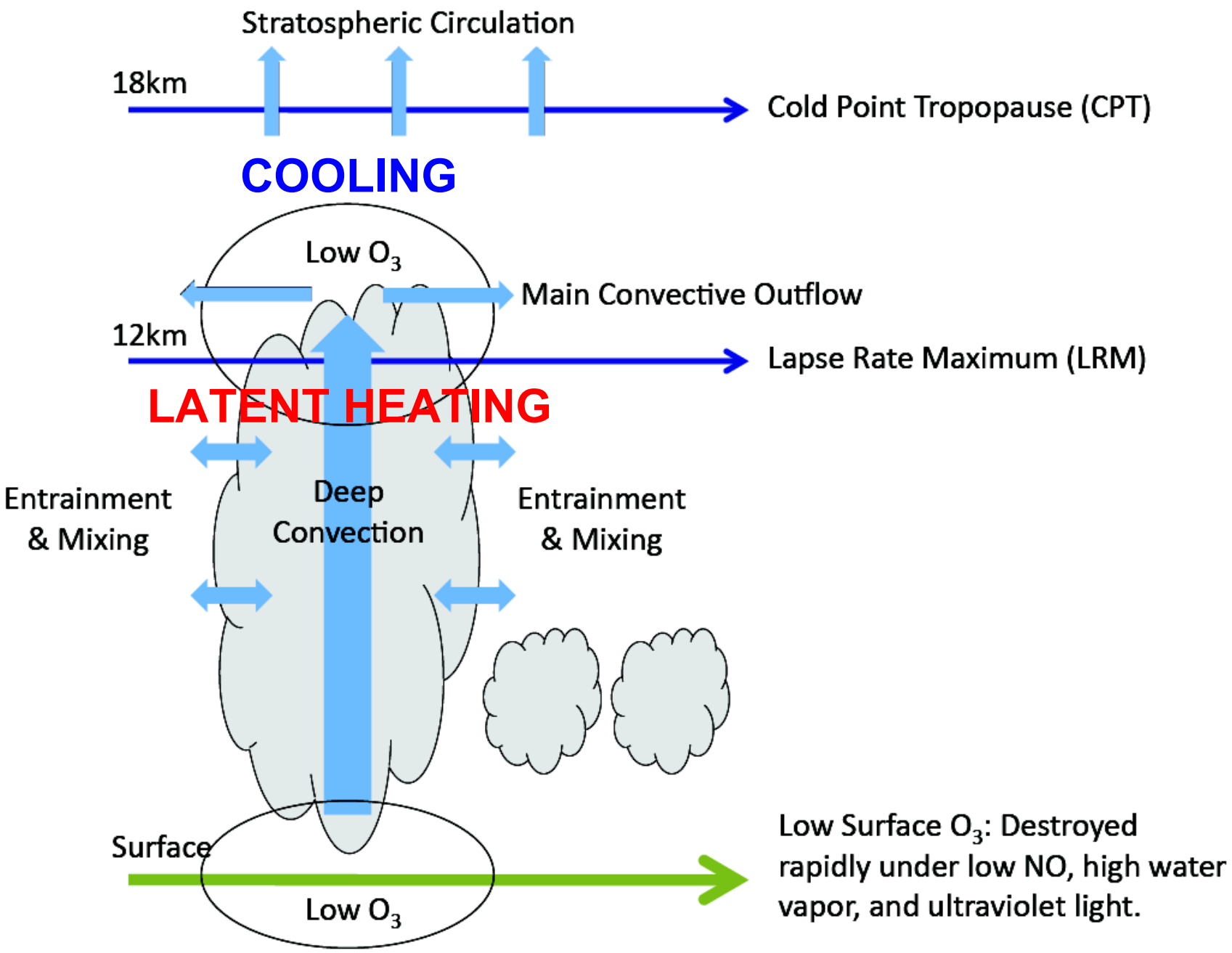
FIG. 5. Virtual potential temperature flux in energy flux units $\rho C_p \overline{w' \theta_v'}$. The horizontal line marks the LNB.



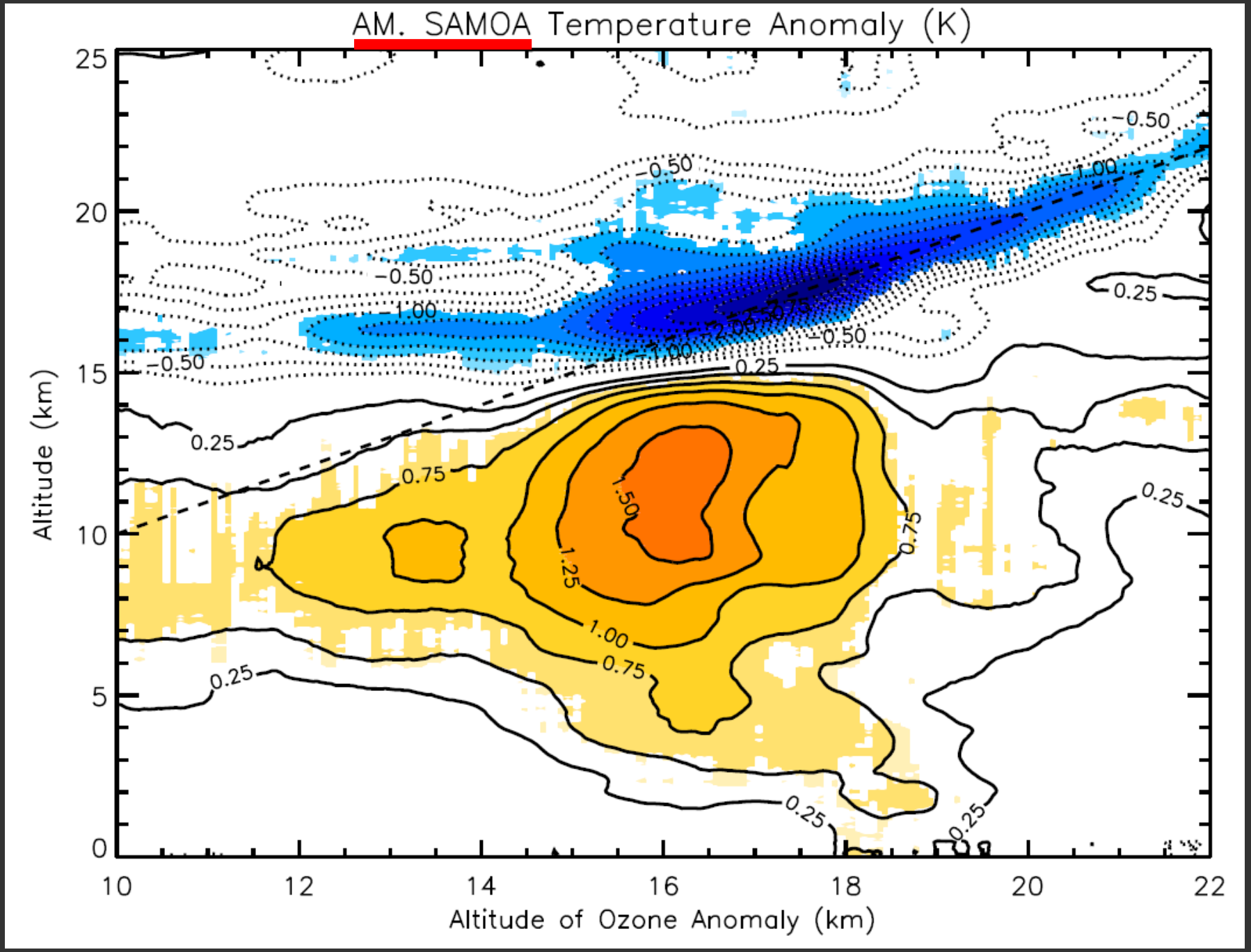
Kuang & Bretherton et al. (2004)

But: conflicting results from other CRM studies (Küpper et al. 2004)

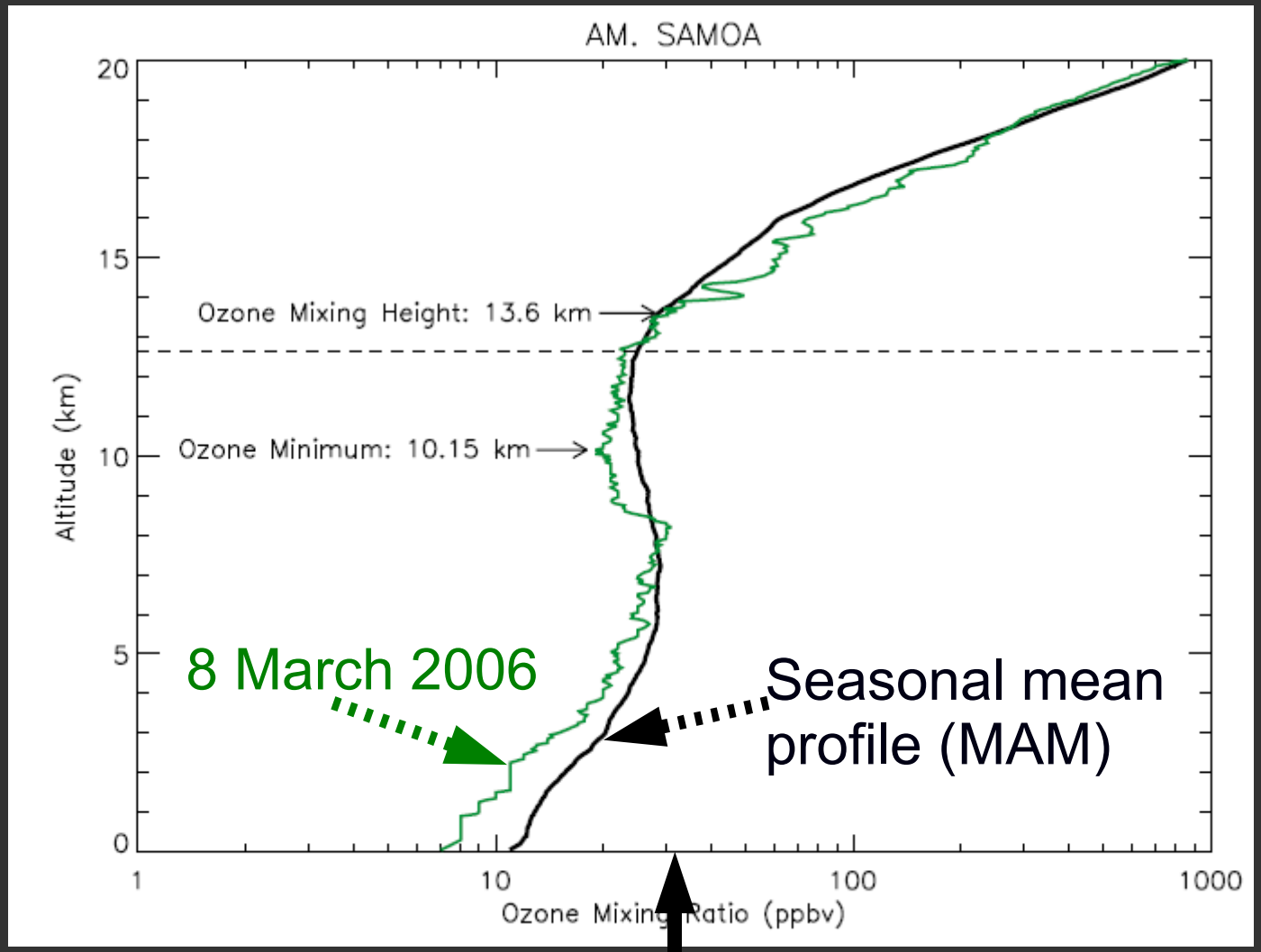
Ozone as a Tracer of Deep Convection



Temperature anomalies corresponding to reduced ozone events at various altitudes



Ozone Minimum Height vs. Ozone Mixing Height



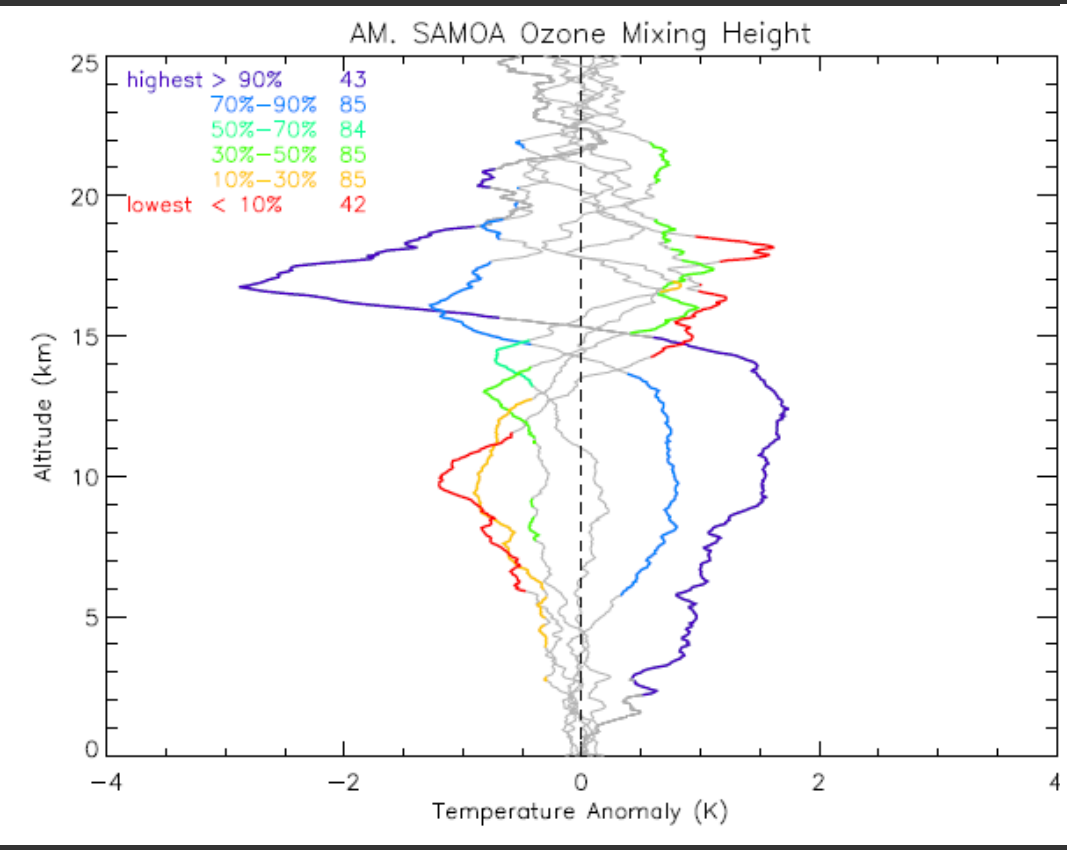
Defined as the maximum height the ozone mixing ratio is less than some threshold

Threshold here defined as average ozone mixing ratio at level of neutral buoyancy (LNB)

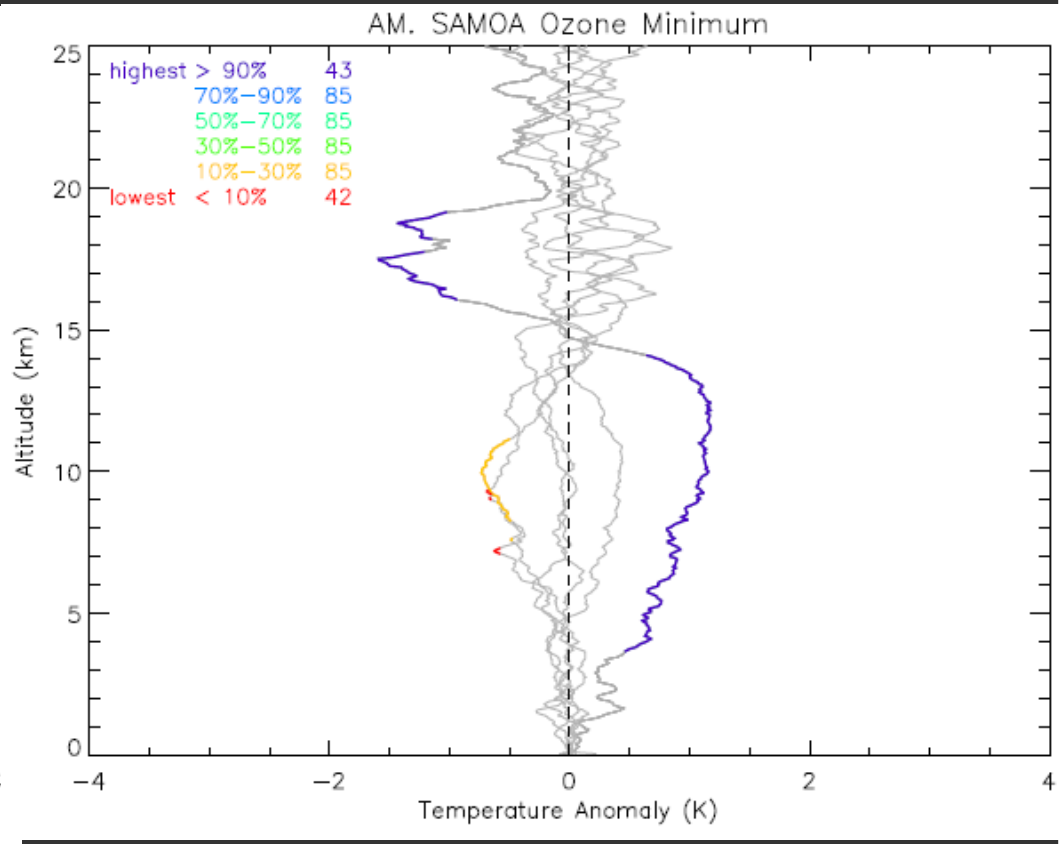
O_3 @ LNB (MAM) = 33 ppbv

Temperature Anomaly Profiles as a Function of:

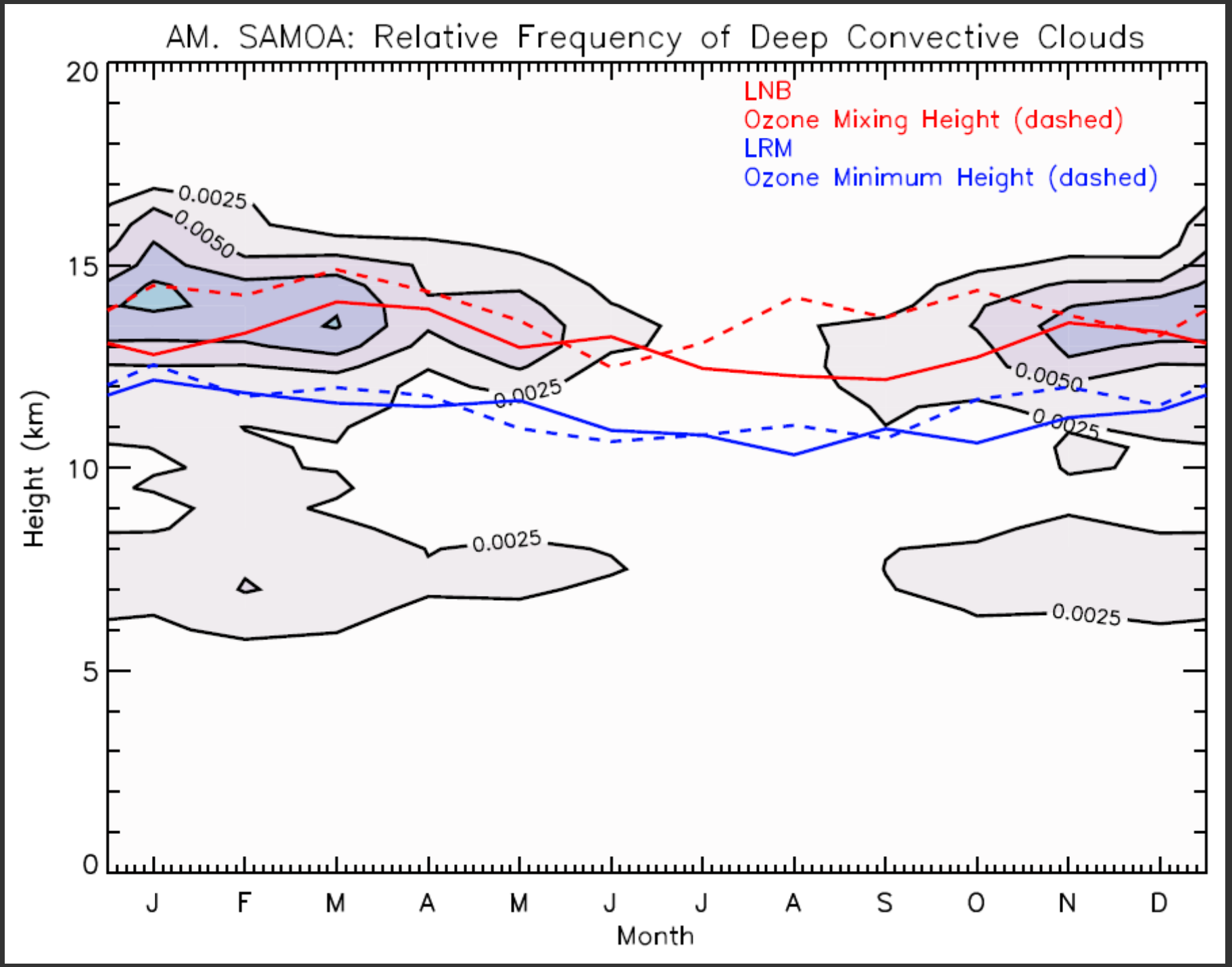
Ozone Mixing Height



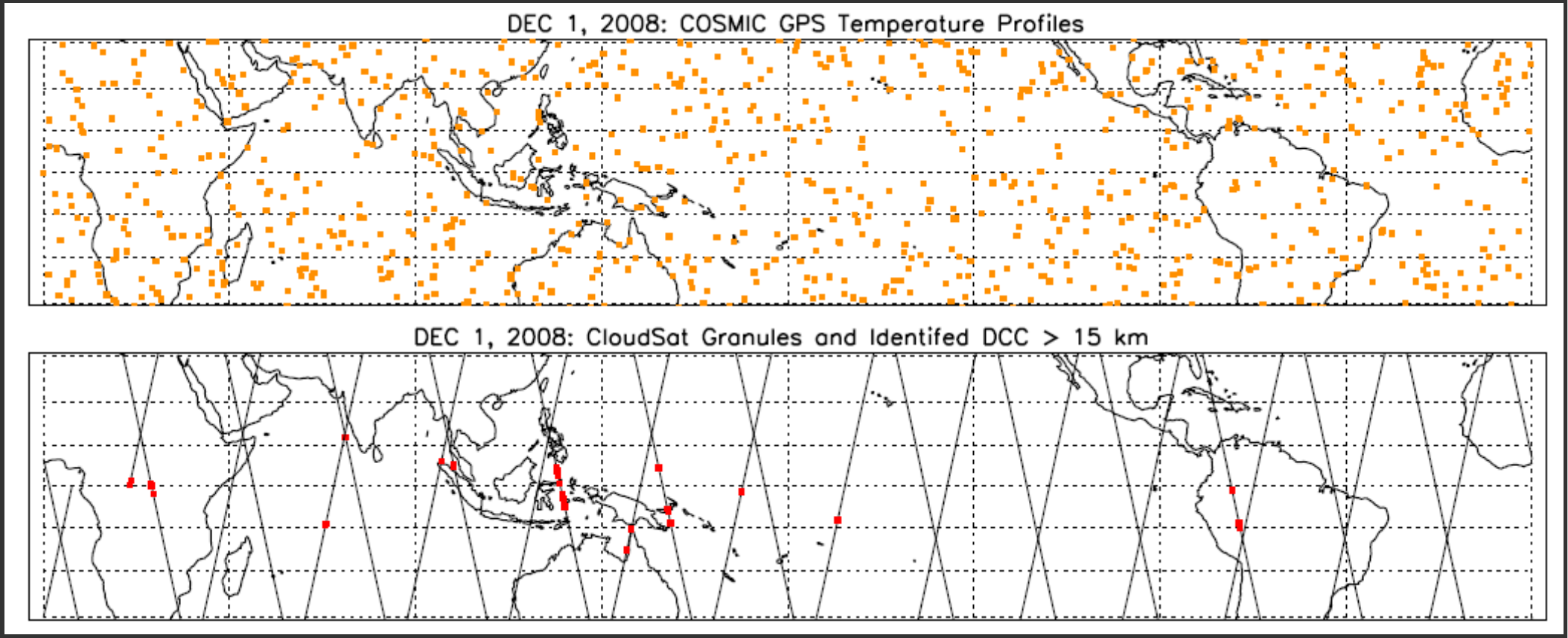
Ozone Minimum Height



→ More distinct convective signal when using ozone mixing height


AM. SAMOA: Relative Frequency of Deep Convective Clouds
LNB
Ozone Mixing Height (dashed)
LRM
Ozone Minimum Height (dashed)
0.0025
0.0050
0.0025
0.0050
0.0025
0.0025
Height (km)
20
15
10
5
0
J
F
M
A
M
J
J
A
S
O
N
D
Month

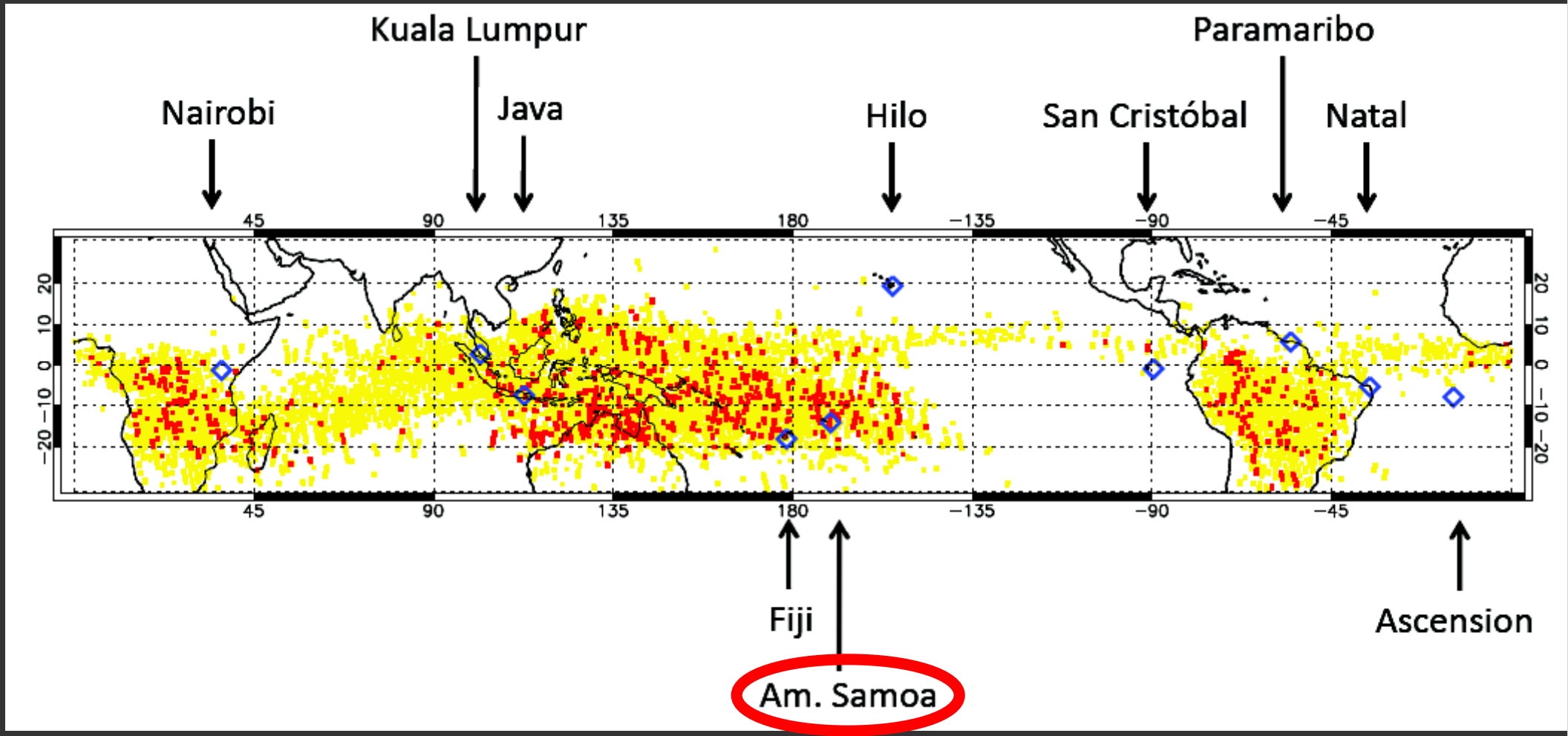
COSMIC GPS Radio Occultation Temperature Profiles & CloudSat Deep Convective Cloud Top Pixels



→ Create temperature anomaly profiles by subtracting monthly means interpolated to position of profile

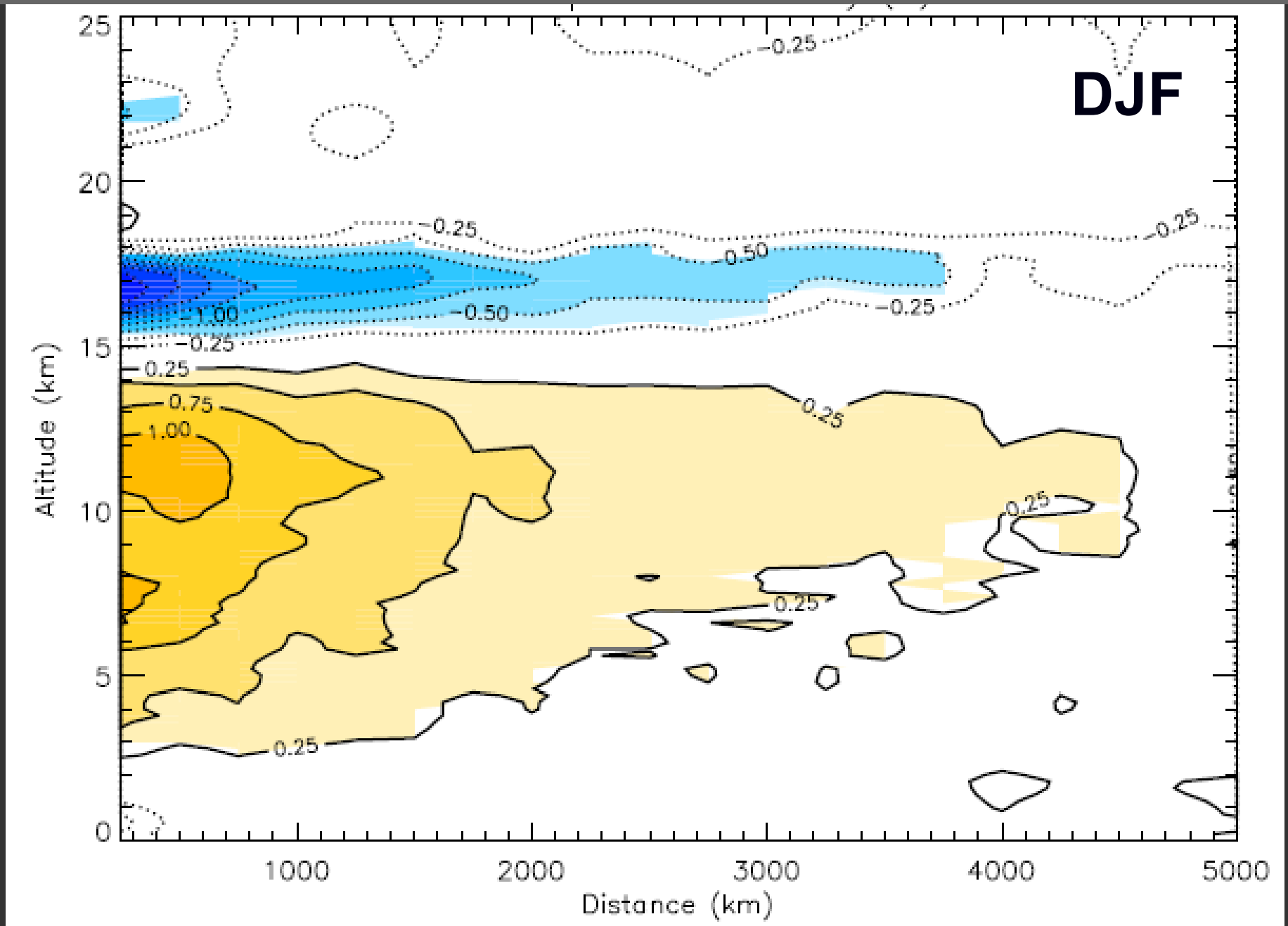
→ Study temperature associated with deep convective cloud top events

Deep convective cloud top pixels as identified by CloudSat (Stephens et al. 2002, Sassen & Wang 2008), DJF

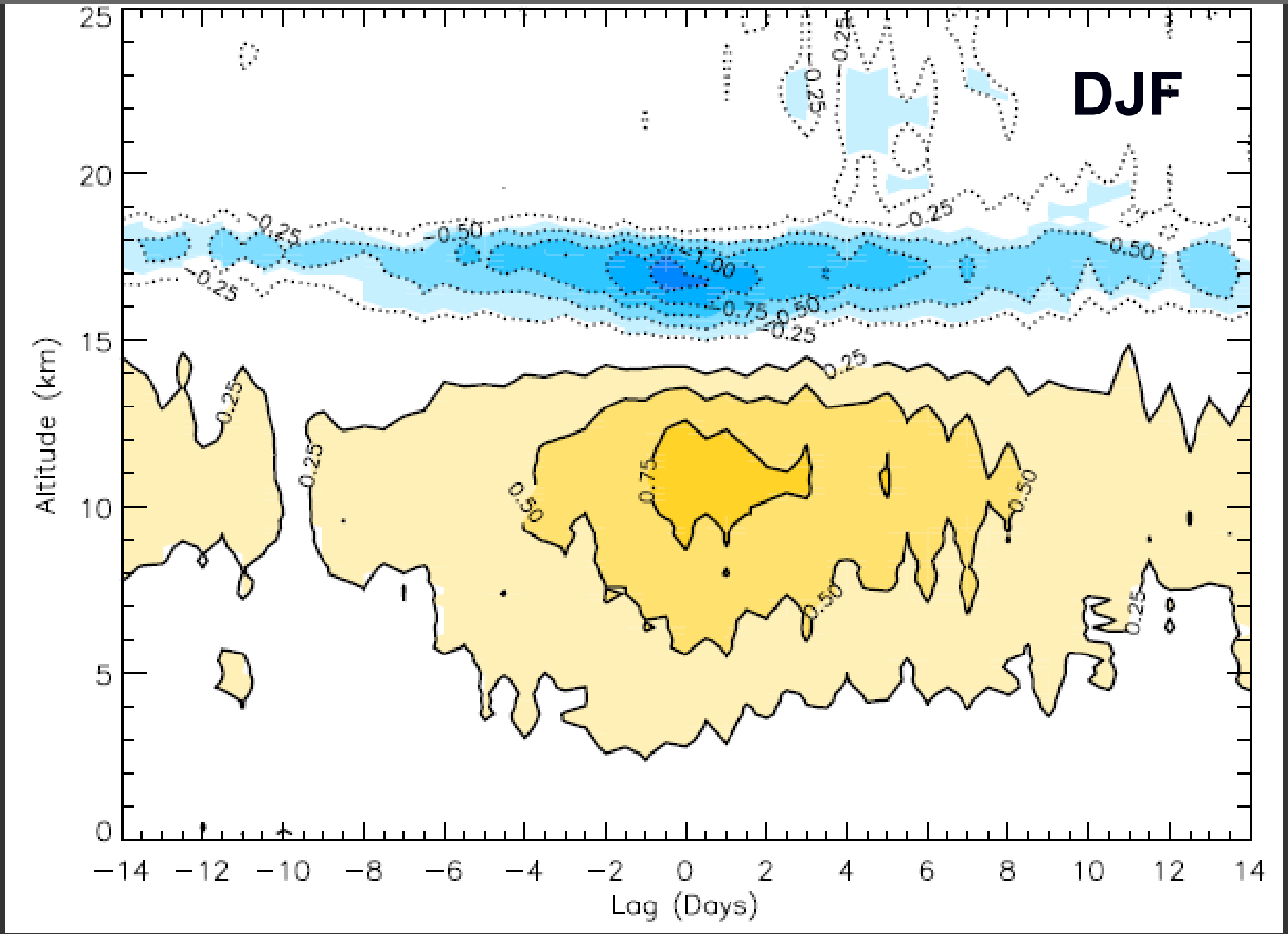


Diamonds: SHADOZ stations

Temperature Anomalies as a Function of Distance from Deep Convective Cloud > 17km (within +/- 6h)



Temperature Anomalies as a Function of Time Lag from Deep Convective Cloud > 17km (within +/- 1000km)



Summary & Conclusions

- Large-scale deep convective temperature signal: warming due to latent-heating in mid to upper troposphere, cooling in TTL
- Usefulness of ozone as a tracer for deep convection confirmed
- Ozone mixing height appears more useful for determining deep convective signal compared to ozone minimum height
- Convective temperature signal from COSMIC / CloudSat for cloud tops > 15 km
- Signal is large-scale (~1000km) & long-lived (1-2 weeks)
- Big(!) differences between DJF and JJA (not shown)