Fine-scale thermal structure of the tropical Cold-Point Tropopause derived from the COSMIC GPS/RO measurements

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Introduction

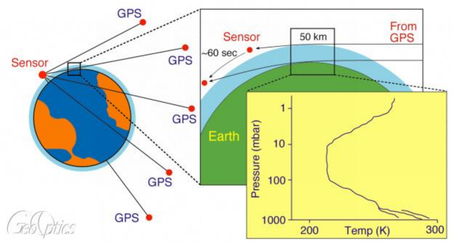
Thermal characteristics of the tropical cold-point tropopause (CPT) play a crucial role in stratosphere-troposphere coupling and exchange (Holton et al. 1995). For example, temperature of the CPT controls transport of water vapor from the troposphere to the stratosphere (Brewer 1949; Mote et al. 1996) and affects global radiation budget (Holton et al. 1995; Forster and Shine 1999). Thus, the thermal variabilities are of importance in climate studies.

In this study, we examine the thermal variabilities of the CPT in seasonal and intraseasonal time scales using high-resolution global temperature profiles from COSMIC GPS RO measurements.

Data

COSMIC GPS RO mission was jointly launched by Taiwan and US for weather, climate, space weather and geodetic studies. It provides a large number of high-resolution temperature profiles over the globe (~2000 profiles/day) since its operation at April 2006.

This study uses recent 4 years of COSMIC data (Sep. 2006 – Aug. 2010)



Schematic of GPS RO (image from GeoOptics.com)

1. Climatology ① ②

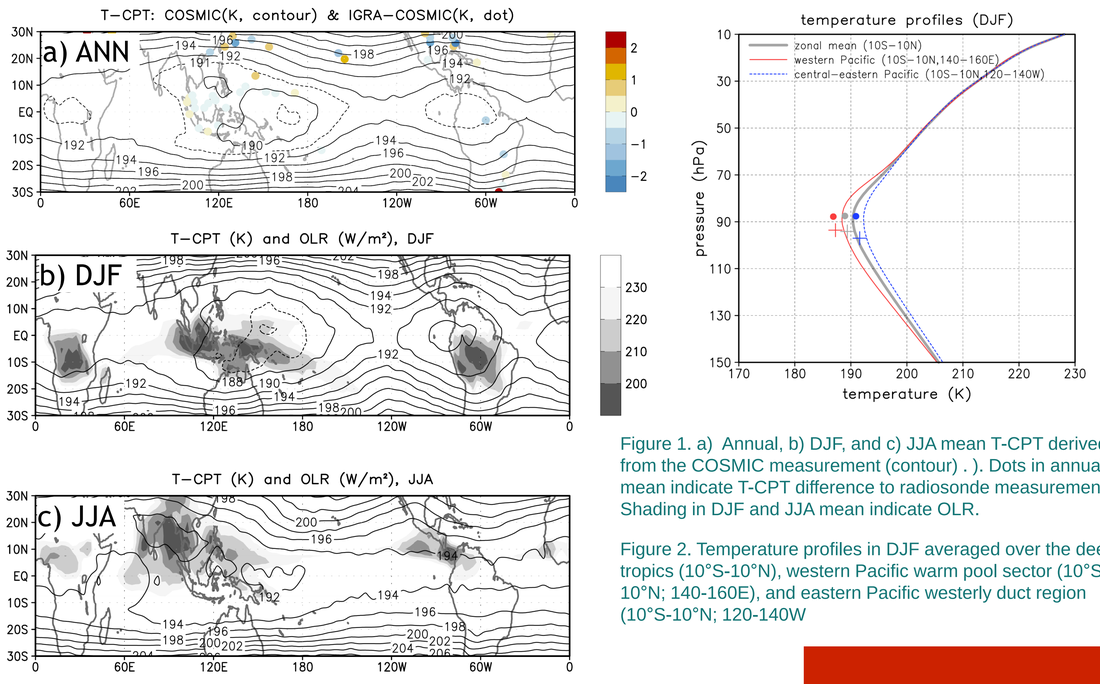


Figure 1. a) Annual, b) DJF, and c) JJA mean T-CPT derived from the COSMIC measurement (contour) .). Dots in annual mean indicate T-CPT difference to radiosonde measurement. Shading in DJF and JJA mean indicate OLR.

Figure 2. Temperature profiles in DJF averaged over the deep tropics (10°S-10°N), western Pacific warm pool sector (10°S-10°N; 140-160E), and eastern Pacific westerly duct region (10°S-10°N; 120-140W

Coincidence with OLR minima
→ Influence of deep convection
Longitudinal structure in DJF
→ Influence of tropospheric circulation

2. Seasonal cycle ③ ④

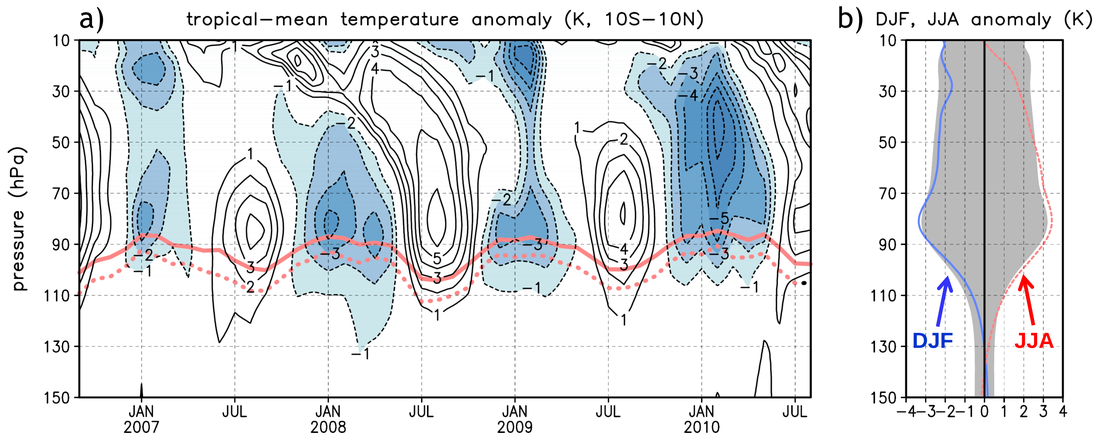


Figure 3. Monthly mean zonal-mean a) temperature anomalies averaged over 10°S-10°N. Thick solid and dotted lines denote cold point tropopause and lapse rate tropopause, respectively. b) Seasonal mean of the temperature anomalies during DJF and JJA. Shading shows one-standard deviation of the monthly mean data.

Anomalies in the stratosphere → Effect of stratospheric processes (e.g., Brewer-Dobson circulation, QBO)

Strong anomalies just above the CPT
→ Upwelling in the tropical tropopause layer (TTL) due to tropospheric eddy momentum flux.

What drive the thermal variability of the CPT?

① Convection
② Tropospheric circulation
③ Stratospheric processes
④ TTL upwelling
⑤ Equatorial waves

3. Intraseasonal variability ① ⑤

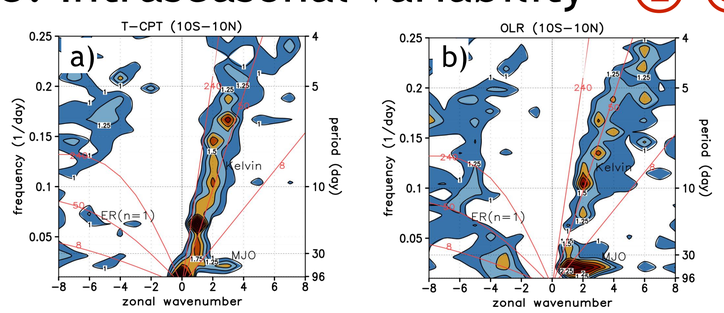
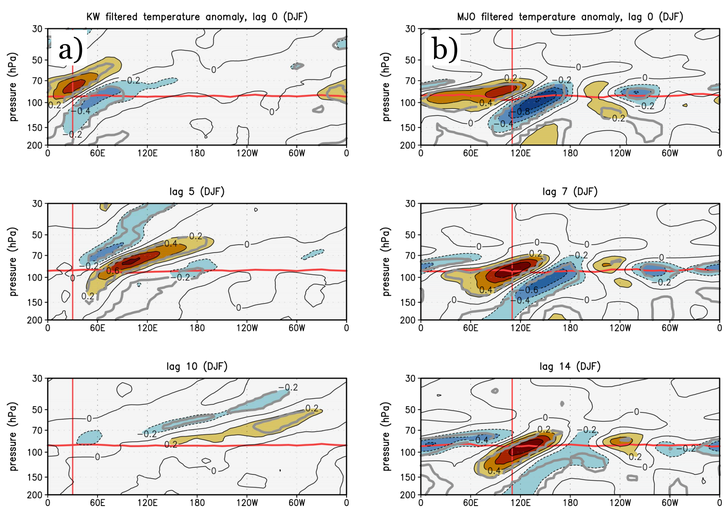


Figure. 4 Wavenumber-frequency power spectra of (a) T-CPT and (b) OLR averaged over 10°S-10°N.

Strong variabilities in the Kelvin wave and MJO bands
→ influence of convection and tropical waves.



Temperature anomalies associated with Kelvin wave and MJO convection show similar vertical structure (eastward titled)

But, they show different behaviors
MJO : move slowly eastward
KW : propagate eastward and upward

Figure. 5 Composite temperature anomalies averaged over 10°S-10°N for (a) Kelvin wave and (b) MJO bands during extended winter (October-March). Thick grey contour denotes 99 % confidence level. Vertical lines indicate reference longitudes where minimum OLR anomaly appears. Thick horizontal lines denote the location of the CPT.

Conclusion

- Geographical distribution of T-CPT minima and maxima is controlled by localized deep convection and large-scale circulation in the tropical troposphere.
- However, its seasonal cycle is largely driven by stratospheric circulation and upwelling in the TTL.
- Intraseasonal variability of T-CPT is dominated by Kelvin waves (free and convectively-coupled waves) with non-negligible contribution by MJO convection.

Further work

1. Seasonal cycle of T-CPT : Compare the contribution of ③ and ④ using idealized GCM
   ③ Brewer-Dobson circulation
   ④ Eddy driven upwelling in the TTL
2. Locality of T-CPT, Water vapor transport in the TTL

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