The Effects of Deep Convection on Regional Temperature Structure in the Tropical Upper Troposphere/Lower Stratosphere

Benjamin Johnston (bjohnston1@tamucc.edu), Feiqin Xie, and Chuntao Liu
Department of Physical and Environmental Sciences, Texas A&M University - Corpus Christi

INTRODUCTION

Developing a better understanding of the impact convection has on heat budget of the tropical upper troposphere/lower stratosphere (UTLS) region is important because tropical deep convection plays a significant role in regulating stratospheric water vapor through direct convective injection and also by enhancing thin cirrus cloud presence, both of which play a significant role in the climate.

Main Research Goals

1) **To better understand tropical deep convection by identifying its impact on the thermodynamic structure in the UTLS region on a diurnal scale.**
2) **To quantify the impact of convection height and intensity on UTLS temperature anomaly magnitude and the role land-ocean contrast plays in determining anomaly structure.**
3) **To evaluate the difference in UTLS temperatures between GPS RO and global reanalysis inside and surrounding convection.**

DATA

COSMIC GPS Radio Occultation – dry temperature & refractivity profiles

- Roughly 2000 atmospheric profiles daily with relatively uniform distribution around the globe
- High vertical resolution (~500 meters in UTLS)
- All weather (insensitive to clouds and precip)
- High accuracy (0.1-0.15 K) and precision (0.1-0.2%)

Tropical Rainfall Measuring Mission – deep convection locations and properties

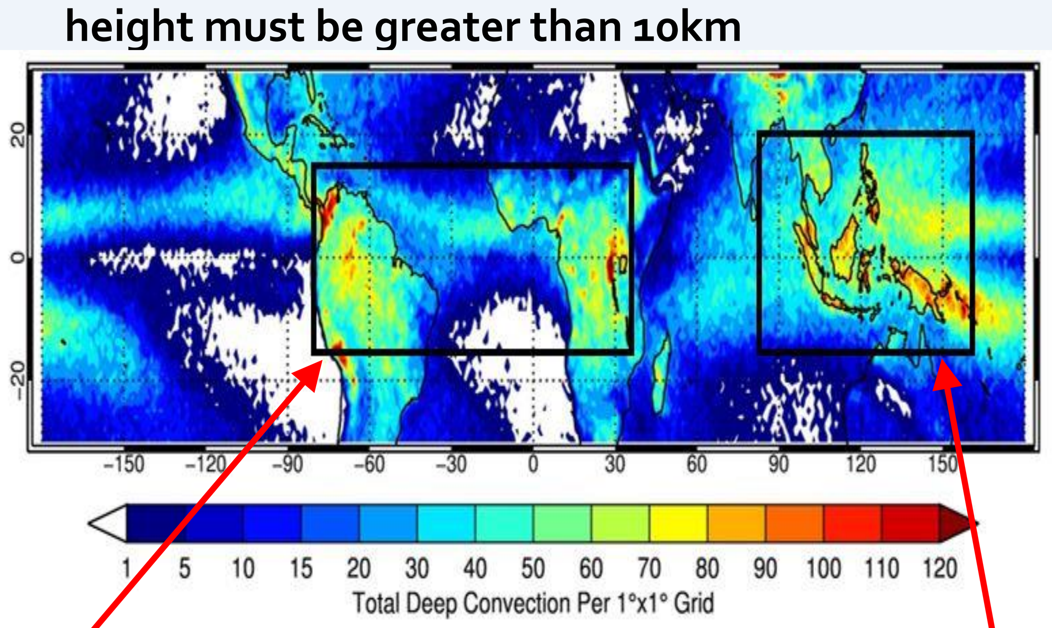
- First comprehensive dataset of precip distribution over the under-sampled tropics (35°N-35°S)
- Four main instruments – **Precipitation Radar**, **Visible and Infrared Scanner**, Microwave Imager, Lightning Imaging Sensor

ERA-Interim reanalysis – temp & humidity profiles

- Atmospheric variables derived 4 times daily
- Uses assimilated meteorological observations
- Horizontal resolution: 0.75 x 0.75 degrees; Vertical resolution: 60 levels (surface to 0.1hPa)

STUDY REGIONS

- Deep convection is determined using the TRMM PR
- **The convection's maximum 20 dBZ echo-top height must be greater than 10km**



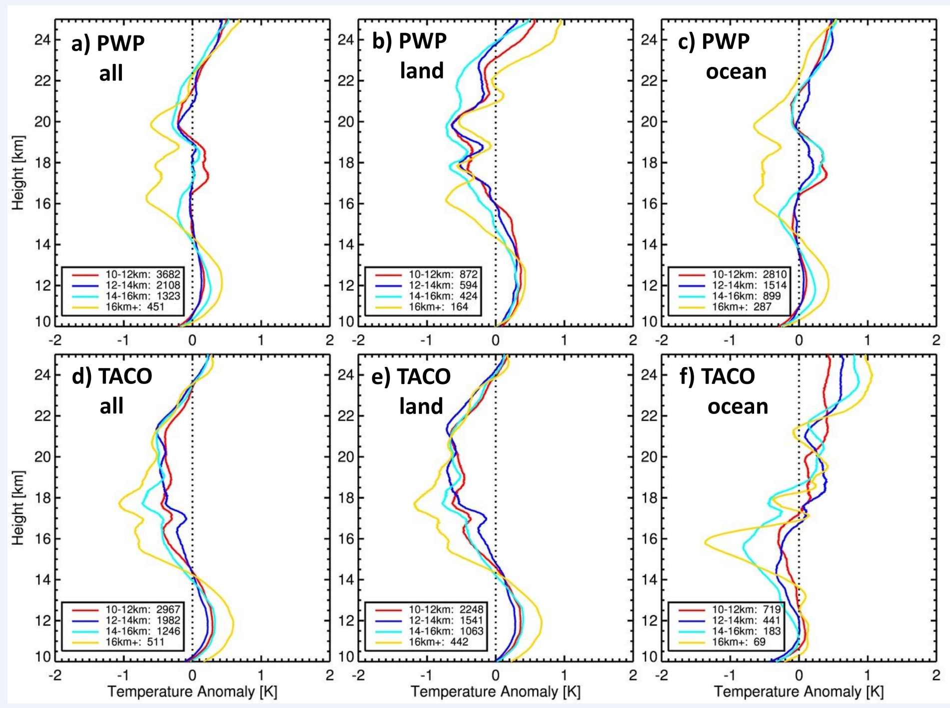
Tropical Atlantic Continental and Oceanic **(TACO)** Region – 15°N-15°S, 65°W-35°E

Pacific Warm Pool **(PWP)** – 20°N-15°S, 80°E-160°E

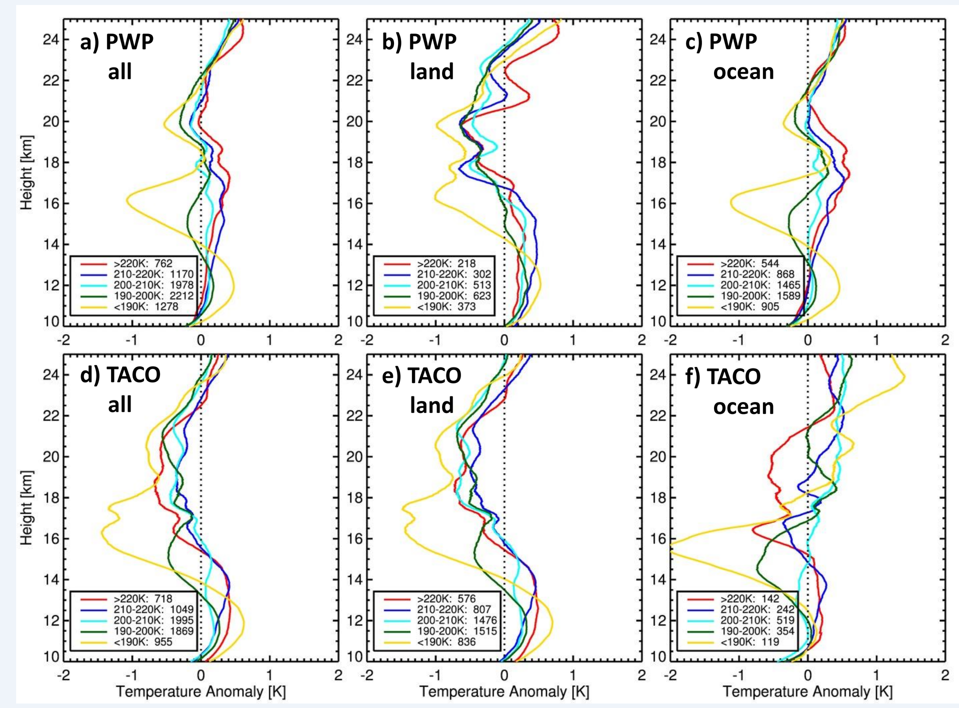
METHODOLOGY

- COSMIC and ERA-I atmospheric profiles along with TRMM convection locations and characteristics were obtained from 2007-2011.
- Profiles were collocated after convection occurred using a 3 hour/300km collocation threshold.
- Profiles were interpolated using polynomial interpolation to a 10m uniform vertical grid and smoothed to 500m (roughly the native COSMIC resolution in the UTLS).
- Diurnal temperature anomalies are generated by subtracting the mean regional diurnal background profile (all profiles from 2007-2011) in each 1-hour local time bin.
- A harmonic analysis is applied to the diurnal anomalies to compute their diurnal & semi-diurnal amplitudes and their phases at selected heights (11 & 17 km).
- Profiles are also classified by various convective characteristics (maximum 20 & 40 dBZ height, minimum IR temp) to analyze anomalies for different convection intensities.
- Anomalies are generated by subtracting mean gridded background temperatures (5° x 5°).
- Classified profiles based on if they occurred over land or ocean to determine any significant warming/cooling anomaly differences based on surface type.

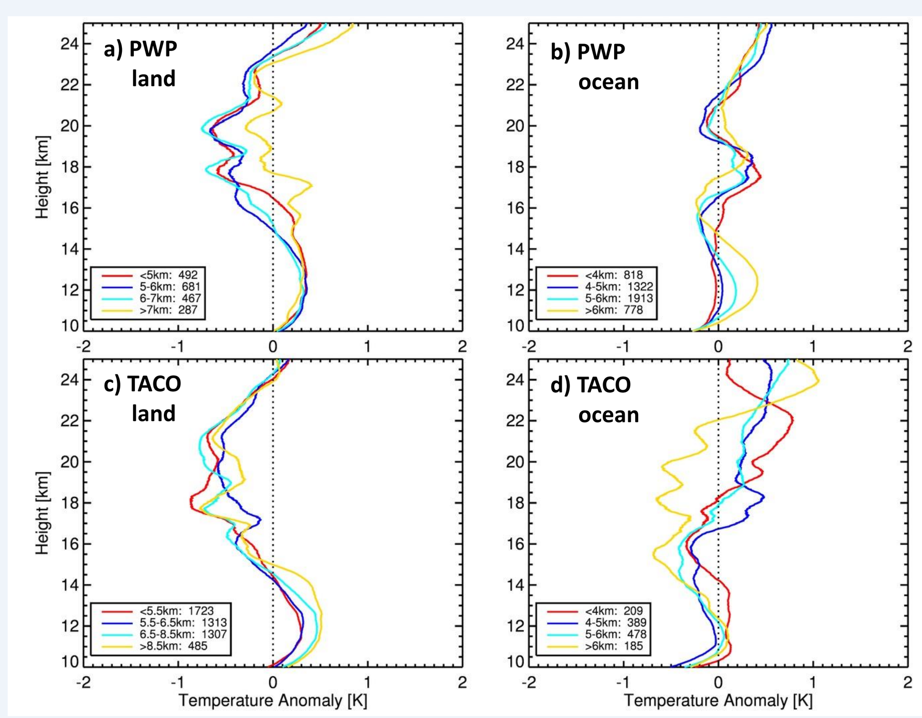
CONVECTION INTENSITY IMPACT



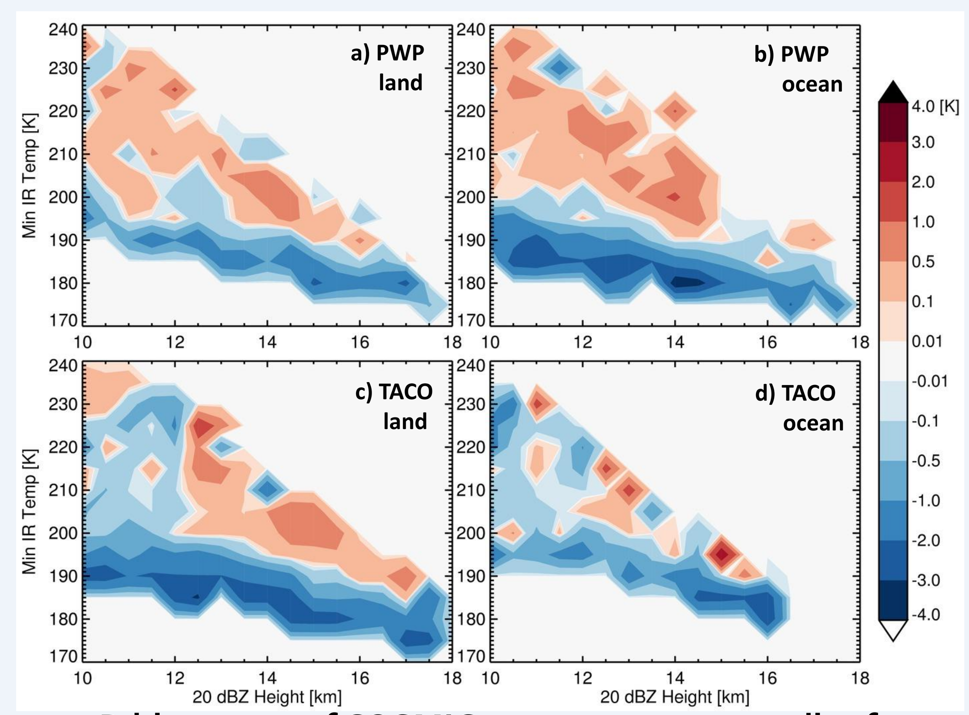
COSMIC temperature anomalies for varying 20 dBZ heights with convection separated by land and ocean.



COSMIC temperature anomalies for varying minimum IR temperatures with convection separated by land and ocean.

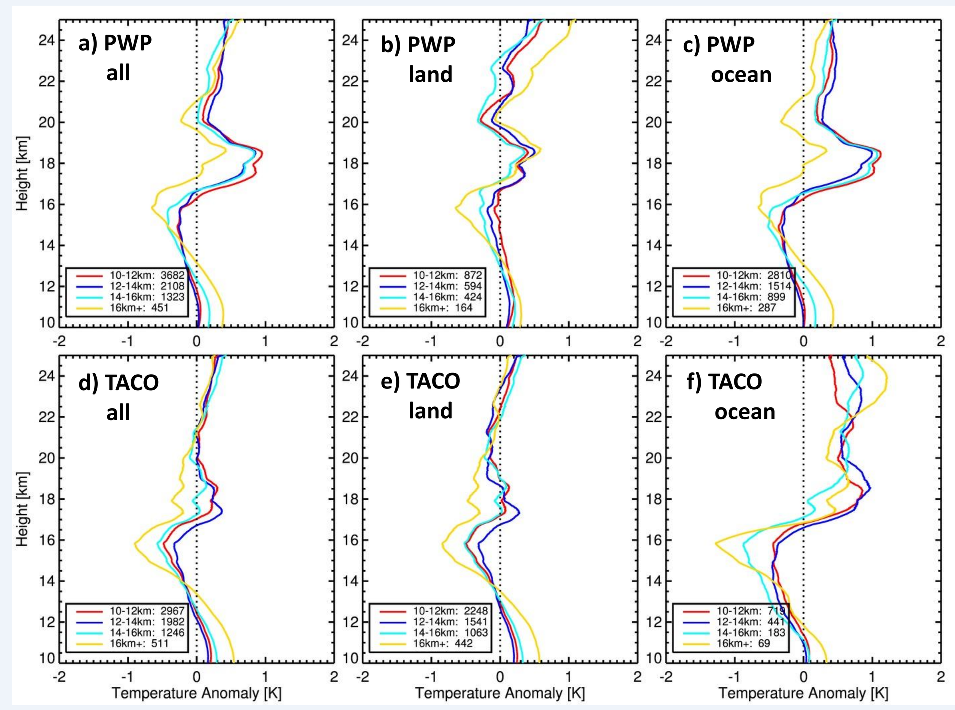


COSMIC temperature anomalies for varying 40 dBZ heights with convection separated by land and ocean.

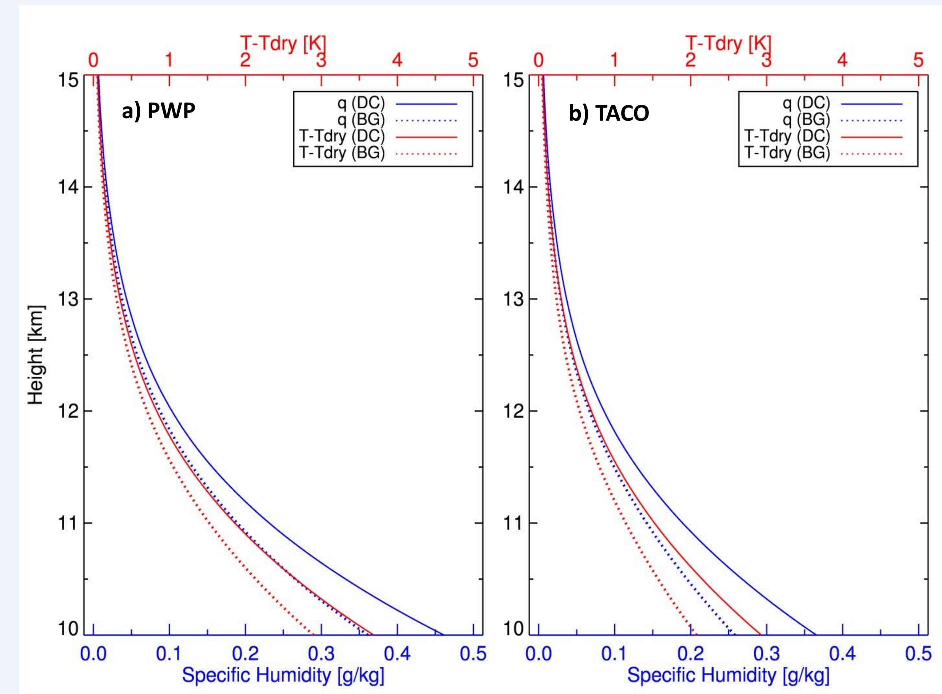


2D histogram of COSMIC temperature anomalies for varying 20 dBZ heights vs. minimum IR temperatures with convection separated by land and ocean.

ERA-I COMPARISON

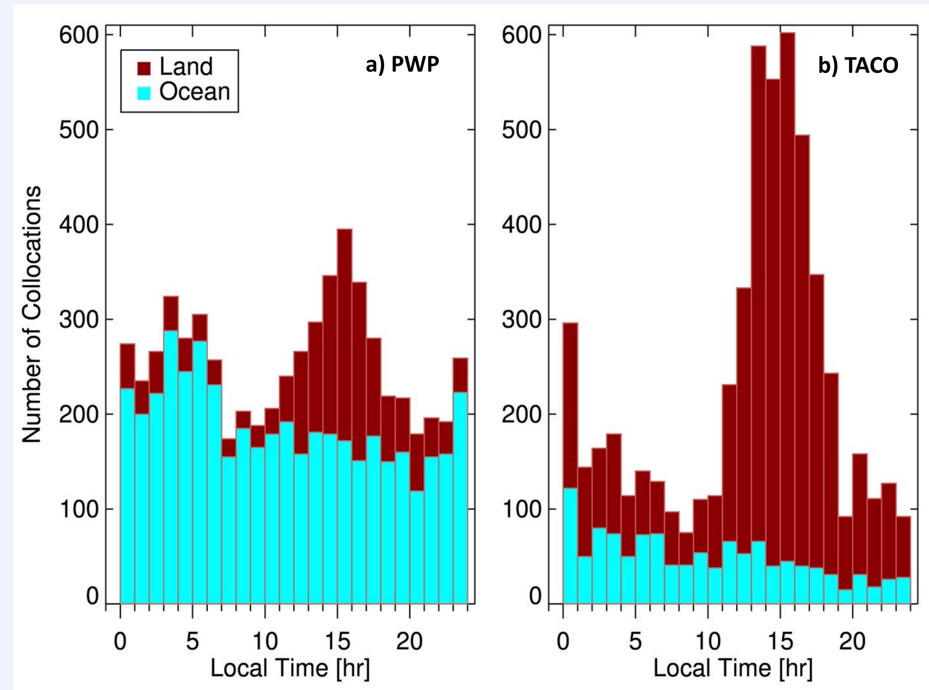


ERA-I temperature anomalies for varying 20 dBZ heights with convection separated by land and ocean.

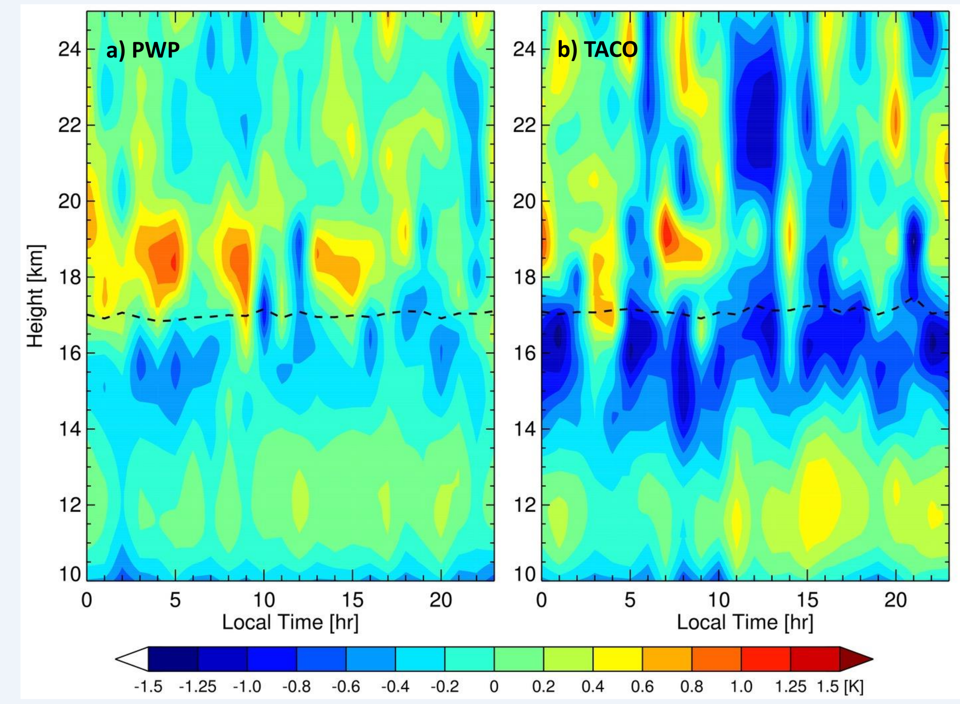


ERA-I specific humidity (g/kg) (blue) along with temperature/dry-temperature differences (red) for background (dotted) vs. after deep convection (solid).

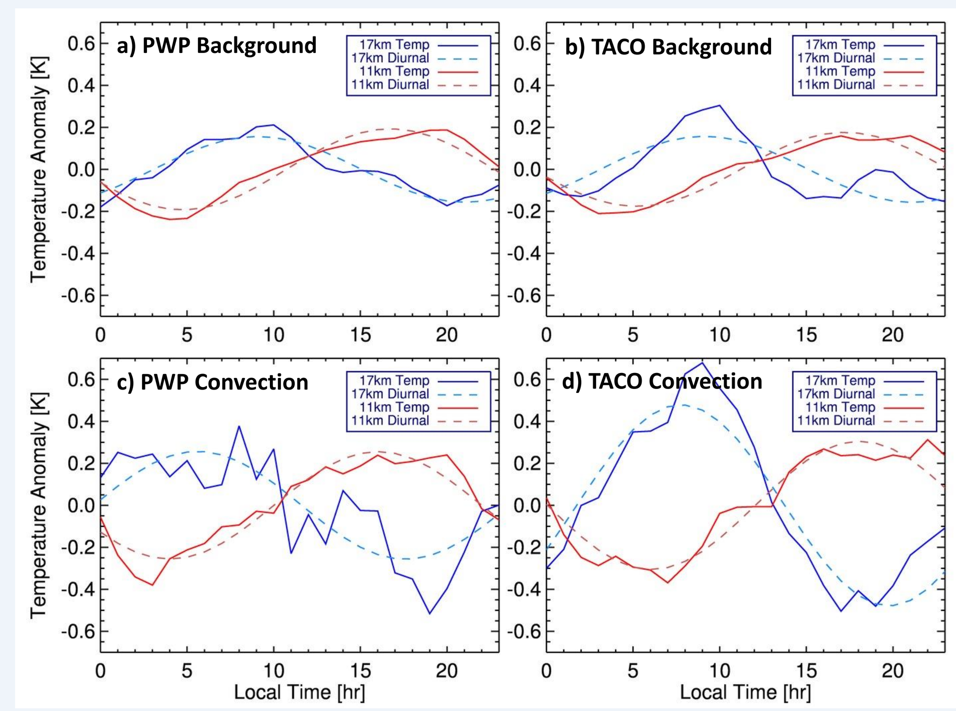
DIURNAL ANOMALIES



Diurnal distribution of TRMM deep convection that have collocated COSMIC profiles within 300 km and 3 hours after convection occurrence (land=red, ocean=cyan).



Diurnal distribution of COSMIC vertical dry-temperature anomalies (K) after deep convection. Dashed lines represent cold-point tropopause height.



COSMIC diurnal temperature anomalies (K) for background conditions and after deep convection. Anomalies (solid lines) are shown along with their diurnal components from harmonic analysis (dashed lines) at 11km (red) and 17km (blue).

CONCLUSIONS

- Diurnal warm anomalies ranging from 0.2 K to 0.8 K are observed within 10-14 km, transitioning to a stronger layer of cool anomalies ranging from -0.4 to -1.5 K within 14-17 km, and finally back to a disjointed layer of warm anomalies ranging up to 1 K within 17-20 km (PWP) or a mix of warm and cool anomalies (TACO).
- TACO deep convection displays stronger anomalies compared to the PWP.
- Amplitude of diurnal variation increases by 0.2-0.3 K in both regions after deep convection occurs (confirms deep convection enhances the UTLS diurnal variation).
- Distinct increase in temperature anomaly magnitude is observed near the deepest convection (strongest anomalies have the highest 20 dBZ heights).
- Land-ocean contrast plays a significant role above the tropopause (within 17-20 km) - cool anomalies are observed for land convection while warm anomalies are generally displayed for oceanic convection.
- COSMIC and ERA-I generally have decent agreement except just above the tropopause, where ERA-I warming is much stronger.
- Higher 40 dBZ heights do not lead to stronger cool anomalies near the tropopause (since higher 40 dBZ heights do not necessarily reach overall higher altitudes).
- Combination of IR CTT and 20 dBZ heights is needed to obtain the full picture of convective effects to the UTLS temperature environment.

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