Poster # T66B

Constraining Climate Trends at the Tropical Tropopause

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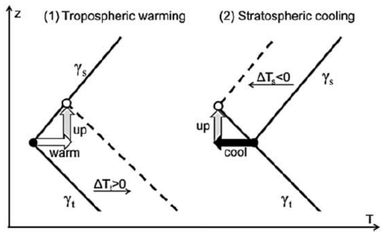
1. Background

- The cold temperatures at the tropical tropopause, a transition layer between the troposphere and the stratosphere, restrict transport of radiatively and chemically active water vapor to the stratosphere.
- Cold-point tropopause (CPT) is defined as the point of minimum temperature in a vertical profile up to stratosphere.
- Cooling at tropical CPT over past 2-3 decades, and since 2000 especially, has been reported [*Randel et al.*, 2006; *Rosenlof and Reid*, 2008; *Zhou et al.*, 2001], also correlation with stratospheric water vapor. The water vapor changes have been linked to changes in surface warming rates [*Solomon et al.*, 2010].
- However, existing long-term climate records contain time-varying biases, or inhomogeneities.
- Adjusted radiosonde data sets deal only with fixed pressure levels, not the CPT.
- Most coupled chemistry and climate models (CCMs) do not reproduce the strong cooling trend seen in some reanalysis data sets: mean trend over 18 CCMs was not significantly different from zero in the CCMVal-2 model intercomparison [*Gettelman et al.*, 2010].

Conceptual Model of Tropopause

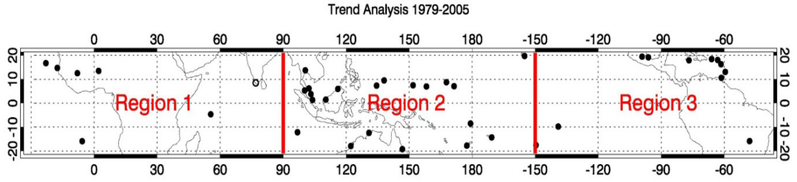
- Tropospheric warming and stratospheric cooling have competing effects on tropopause *temperature*.
- In contrast, tropospheric warming and stratospheric cooling both drive an increase in tropopause *height*.

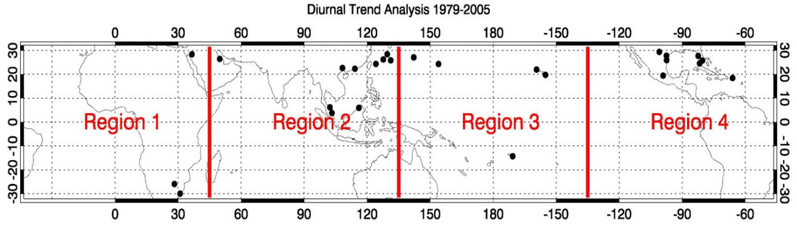


From Austin and Reichler [2008]

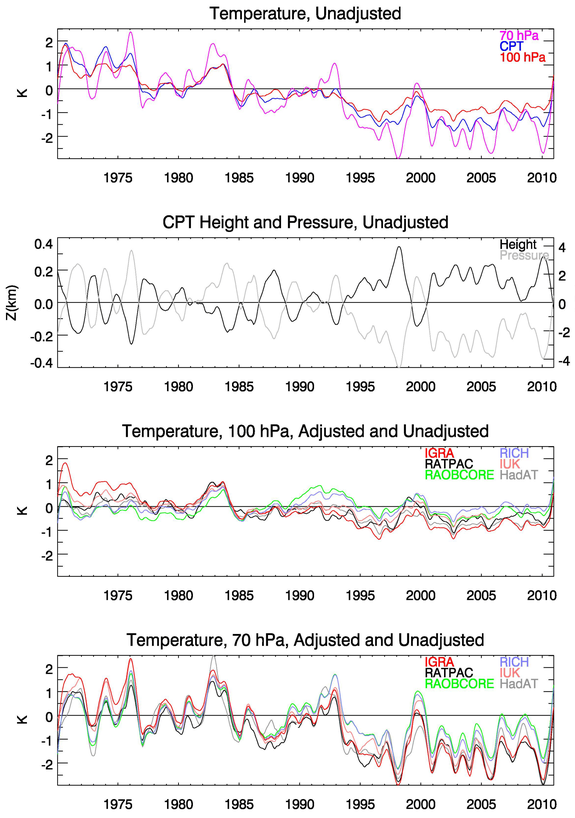
2. Methods

- IGRA unadjusted radiosonde data [Durre et al., 2006]
- Adjusted radiosonde data sets: RATPAC-B [Free et al., 2005], HadAT2 [Thorne et al., 2005], RAOBCORE [Haimberger, 2007], RICH [Haimberger et al., 2008], and IUK [Sherwood et al., 2008].
- Cold-point tropopause quantities extracted from daily soundings that meet completeness criteria.
- Monthly anomalies calculated; omitted time series with more than one third of data missing.
- Given uneven distribution of stations, we computed the tropical average after first averaging within three regions, shown in first map below.
- Trends calculated using least-squares linear regression; standard errors account for autocorrelation.
- **Two approaches to adjusting CPT trends:**
  1. **"Nearby Level" approach**: Add together the temperature trend at a fixed level (100 hPa or 70 hPa) from an adjusted data set and the trend in the difference between temperatures at the CPT and the fixed level in the unadjusted data set.
  2. **"Diurnal Difference" approach**: Subtract trend in difference between midday and midnight observation (temperature, height or pressure) from midday trend to remove solar heating bias.





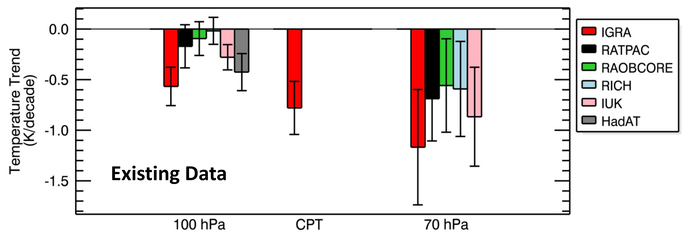
3. Tropical Average Monthly Anomaly Time Series



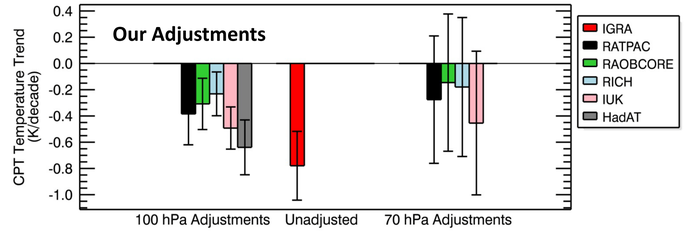
- Long-term cooling around tropopause, increasing with altitude (from 100 hPa to CPT to 70 hPa).
- CPT height and pressure anti-correlated; height exhibits positive trend, pressure exhibits negative trend.
- Adjusted data sets exhibit less cooling than the unadjusted IGRA data set at 100 hPa and 70 hPa.
- Temperature drops, height increases, and pressure drops at end of 2000; these were described in previous studies and attributed to strengthening stratospheric upwelling. **However, these do not seem unusual in the context of the overall period, at least not when averaged over the entire tropics.**

4. Constraining CPT Trends: Nearby Level Approach

1979-2005 Period



- Again, cooling trend increases with altitude, and adjusted data sets exhibit less cooling than the unadjusted data set.



- **Wide range of estimates for adjusted CPT temperature trend.**
- **All are less negative than unadjusted trend. Some confidence intervals even encompass zero.**

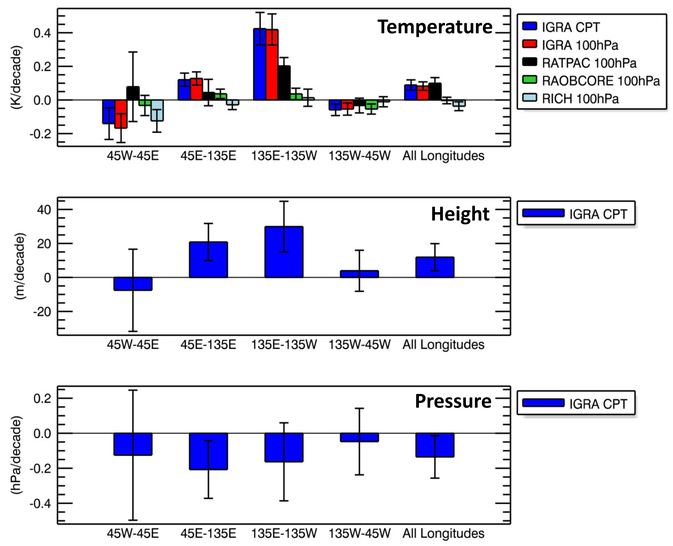
5. Sensitivity Tests

- Multi-decadal trends generally not sensitive to the years considered between 1970 and 2010.
- RAOBCORE-based CPT trends exhibit warming up to 2001 (but not significant); other data sets do not produce positive trends (not shown).

  → Estimated CPT temperature trends still seem inconsistent with apparent positive trend in stratospheric water vapor up to 2000, as in previous studies [*Fueglistaler and Haynes*, 2005; *Zhou et al.*, 2001].
- Trends sensitive to inclusion of outlier station Thiruvananthapuram (Trivandrum) in India.
  - Inclusion of this and other problematic stations in previous studies (e.g. *Zhou et al.*, 2001) could have contributed to large cooling trends.

6. Constraining CPT Trends: Diurnal Difference Approach

Regional Average Trends in 12Z - 00Z Differences (1979-2005)



- Regions surrounding the 0° and 180° meridians exhibit largest trends in 12Z-00Z temperature in the unadjusted data set → Largest solar heating effect where 00Z or 12Z corresponds to local midday.
- Similar longitudinal pattern for height → Geopotential height is calculated from temperature. Pressure unaffected by diurnal effects.
- Adjusted CPT temperature trend averaged across longitudes is **-0.59 ± 0.12 K/decade**; cf. unadjusted trend of -0.75 ± 0.11 K/decade.
- Adjusted height trend is **109 ± 18 m/decade**, **10% more** than unadjusted trend of 99 ± 17 m/decade.

7. Conclusions

- **Recent tropical CPT trends are less certain than implied previously**, with **temperature possibly not decreasing significantly** and **height increasing more than previously thought**.
- **Wide range of CPT temperature trends encompassing zero is consistent with prediction of conceptual model of tropopause**: Tropospheric warming and stratospheric cooling have competing effects.
- **Increase in CPT height consistent with conceptual model**: Tropospheric warming and stratospheric cooling act in same direction.
- **Smaller or non-significant temperature trend is consistent with CCM predictions**.
- Possible causes of inconsistency between temperature and water vapor trends before 2000 include changes in the location of water vapor transport, changes in small-scale processes, and remaining biases in adjusted temperature data.

Acknowledgments

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