Ticosonde CFH at Costa Rica: A seasonal climatology of tropical UT/LS water vapor and inter-comparisons with MLS and CALIPSO

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Talk topics

A. Seasonal structure at Costa Rica: T, ozone and the water vapor tape recorder
B. Intercomparison to MLS v3.3 WV
C. Relationship between sonde saturation and CALIOP cloud fraction
D. Changes of WV in the tropics UT/LS
   - Comparisons of sondes to MLS at 82 hPa
   - 2-km WV time series at Costa Rica
Science drivers

A. Processes controlling stratospheric water vapor: local freeze-drying, transport from remote tropical regions, in-mixing from higher latitudes

B. Continuing differences among *in situ* water vapor instruments

C. *Jensen et al.* [2013] found differing saturation regimes for low- and hi-particle density cirrus

D. Radiative forcing of UT/LS water vapor and impact in warming climate
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Mean Dry and Rainy Season Profiles
2005-2013
Frostpoint temperature, ambient temperature, and ozone

DJF

T_{fp} \quad T \quad O_3

CPT at base of profile minimum
T_{fp}/water vapor
Ozone gradient change nearly coincident with mean coldpoint
Prominent inflection in O_3 profile @ 20 km

JJA

T_{fp} \quad T \quad O_3

CPT overlain by decreasing T_{fp}/WV
Ozone gradient change well below mean coldpoint
Smooth ozone profile throughout
Tape recorder - I

Second half of year – JJA and SON

- 4 ppmv “hygropause” clearly visible at 468 K in JJA
- 5.5 ppmv maximum rises out of TTL in SON to 415 K
Tape recorder - II
First half of year – DJF and MAM

- Profile minimum near trop in DJF and slow movement upward through MAM
- But SON max near 420 K has moved up to 460 K by DJF and 525 K in MAM
- Weak ascent in LMS during DJF and MAM, but more rapid above 450 K

WV_{\text{min}}: 2.7 \text{ ppmv} 
402 \text{ K}
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Coincidences with MLS v3.3
±3 hours, Δ ≤ 600 km

December – February
65 coincident soundings:
Costa Rica (35), Biak (19), Kototabang (4), Tarawa (4)

June – September
28 coincident soundings:
Costa Rica (22), San Cristobál (6)
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$\text{RH}_{\text{ice}}$: DJF vs. JJA
CALIOP Vertical Feature Mask comparison
15 July 2005

VFM cloud analyzed at San José 10.5 to 14.5 km

CFH saturation layer 11.4 to 15 km

- 28 VFM/CFH coincidences closer than 400 km, 2006-2011
- Preliminary finding is that CALIOP is capturing most of the layers > 1 km deep
- However, VFM is just first step – ultimate goal is to compare to ice water content
CALIOP Mean Cloud Fraction at San Jose, Costa Rica

Peak frequencies of sonde saturation
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Lower stratospheric water vapor
MLS, frostpoint sondes and tropical CPT

Adapted from Fig. 2.43, BAMS 2014: State of the Climate 2013
Time series calculations

- Costa Rica CFH observations, July 2005 – July 2013
- Monthly time series of 2-km thick layers
  - Linear average of 40 values at 50-m grid points
  - Centered at 3, 5, 7..... km
  - Layer average points computed only if 30 or more grid levels present
- Multiple soundings in a month composited to a single value
- Monthly time means at each 1-km level derived for 8-year period
  - Minimum sample size of 4 for each monthly level time mean
  - Exclude levels with 6 or more monthly time means missing
  - However, did allow interpolation of up to 2 consecutive missing months
  - Highest level meeting this criterion was 21 km
- De-seasonalized anomaly time series generated
  - Subtract long-term means for the month from each value at all levels meeting above criteria
- Did linear fits in IGOR Pro to anomaly time series to check for trends
Layer-average WV time series and de-seasonalized anomalies
Layer-average WV time series and de-seasonalized anomalies

Graph showing time series data with trend lines and labels for coefficients.

Title: Layer-average WV time series and de-seasonalized anomalies.

Graphs with data points and trend lines for different layers.

Legend: Coefficients for trend lines.

Graph labels and axes indicated.

Summary

- Tape recorder structure at Costa Rica consistent with zonal mean, including slow uplift in early part of year in lowermost stratosphere
- Intercomparing MLS and CFH:
  - No real change from Vömel et al. [2007]: MLS drier than CFH in UT, wetter in LMS
  - Caveats: UT result swamped by large scatter; difference in LMS within instrumental uncertainties
- Seasonal mean CALIOP cloud fractions consistent with pattern of saturated sondes
  - Preliminary comparisons with coincident CALIOP feature mask data indicate that it can see most saturated sonde layers deeper than about 1 km are
  - However, addressing low- vs. high-density cirrus question will require information on ice water content
- Changes of WV in the tropics UT/LS:
  - Ticosonde CFH following tropical CPT values
  - Weak upward trends over nine years of program not significant – which is not unexpected given dominance of interannual variability