Thermal structure of the TTL and its relation to stratospheric-tropospheric exchange of water

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- We describe the annual cycle of the TTL fine scale thermal structure as captured by GPS radio occultation and the pressure levels of the ECMWF weather analysis.
- We compare this annual cycle to the annual cycle in water concentrations measured by HALOE.
- A comparison between saturation mixing ratios at the temperatures captured by GPS radio occultation and HALOE concentrations of water vapor shows an annual cycle dominated by supersaturation in the boreal winter months, when the upward mass fluxes are larger, and subsaturation in the summer.
- The longitudinal dependence of these cycles is discussed and so is its possible implication for the seasonality of stratospheric-tropospheric exchange of water.

Outline

1. Introduction

2. Validation of GPS occultation temperatures near the tropical tropopause:
   - against radiosondes
   - against the ECMWF analysis

3. Tropical tropopause structure and variability:
   - Interannual.
   - Seasonal.
   - Seasonal.

4. Conclusions.

Introduction

Why is UT/LS water important ?

1. It determines the radiative properties of the upper troposphere and lower stratosphere (UT/LS).
2. It is the major source of OH radicals in the UT/LS.
3. It is a tracer in the UT/LS.

What do we want to understand ?

1. The mechanisms that decide the water budget in the UT/LS: (i.e. dehydration)
2. It has been argued that if the Fixed Anvil Temperature (FAT) hypothesis holds, the impact of SSTs on outgoing radiation could be minimal. (i.e. temperature at the bottom of the TTL)

What do observations suggest ?...

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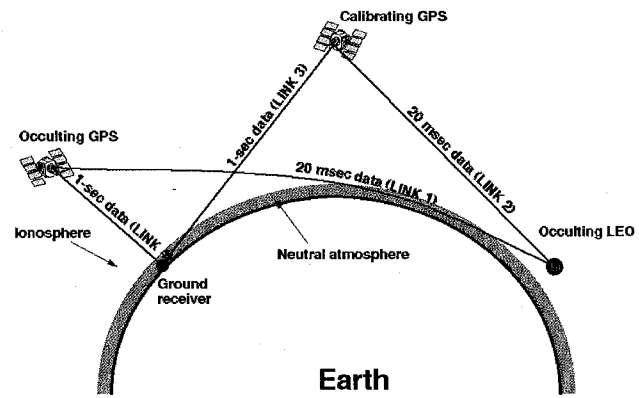
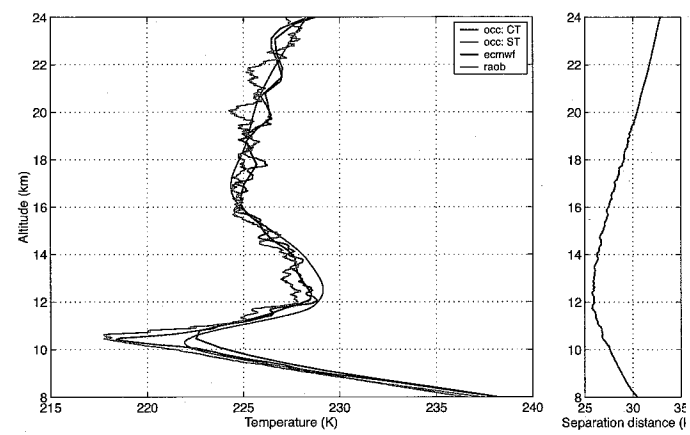


The occultation geometry involving two GPS transmitters, one ground receiver and one space receiver



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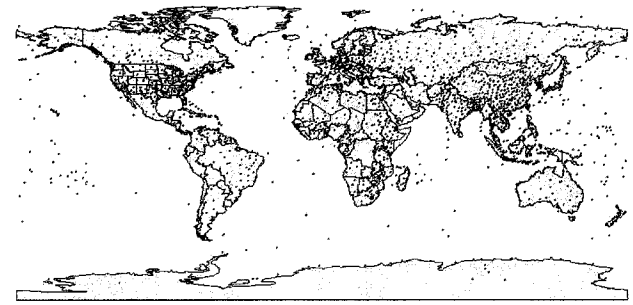
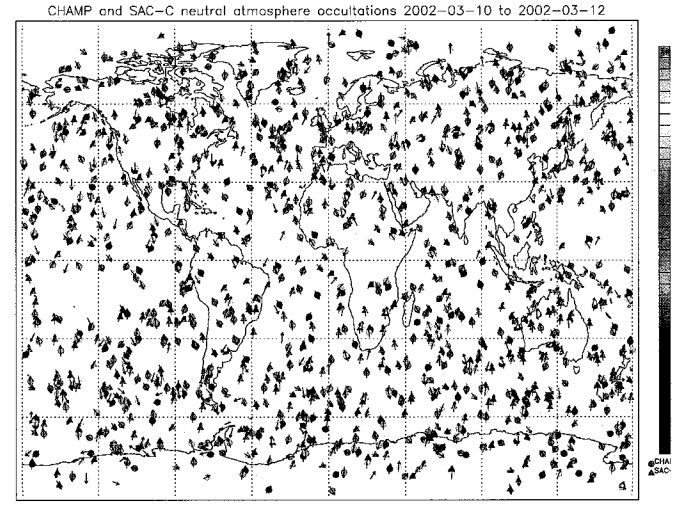
CARDS Global Network

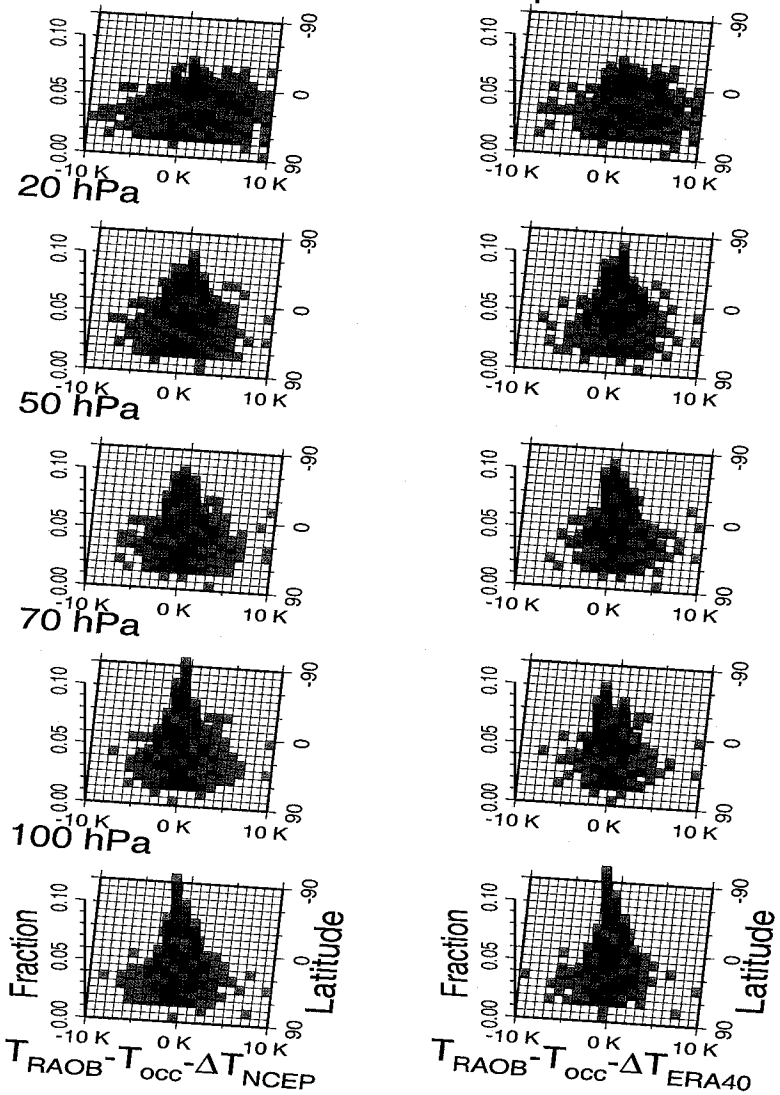


CHAMP and SAC-C neutral atmosphere occultations 2002-03-10 to 2002-03-12

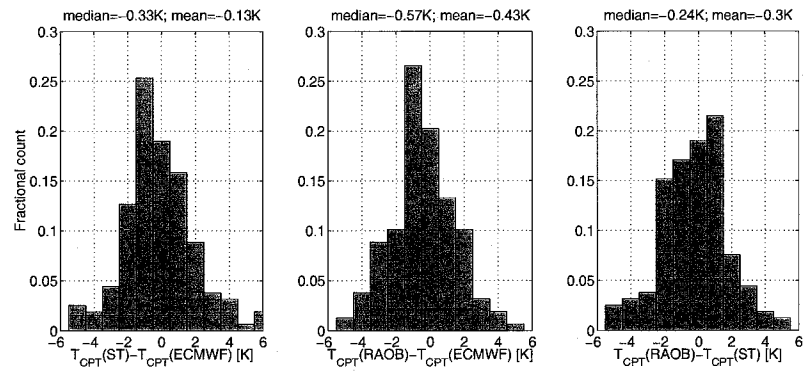


Comparison with radiosondes

Validation of GPS occultation temperatures near the tropics [15°S–15°N]

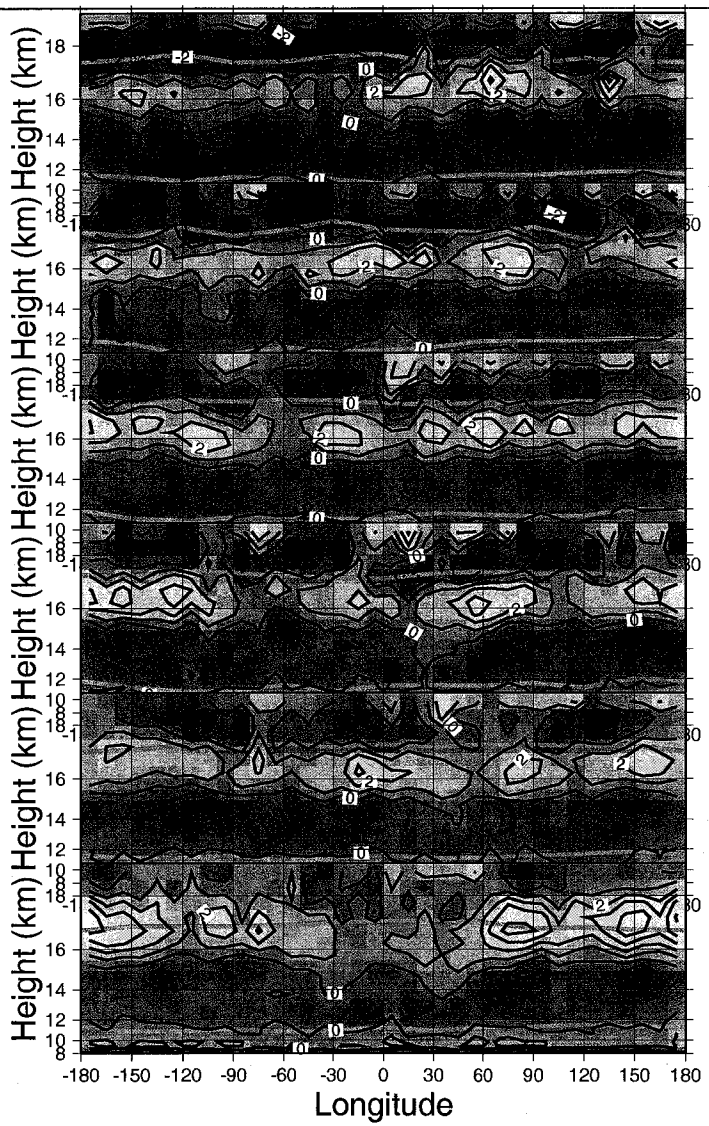


← Differences between GPS RO and coincident radiosondes at 150 hPa, 100 hPa, 70 hPa, 50 hPa, and 20 hPa. **Left:** using NCEP reanalysis to interpolate the Radiosonde temperature to the occultation location and time.**Right:** using ERA-40.

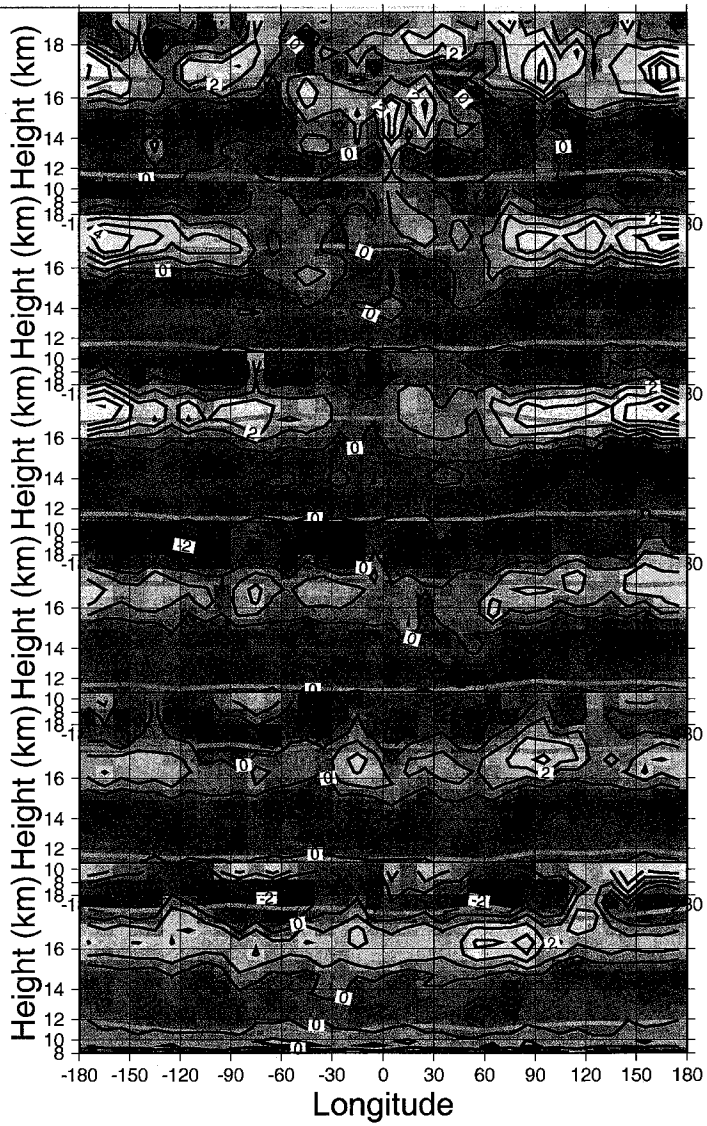


CPT temperature differences for 158 coincident high resolution radiosondes T_{RAOB}, the interpolated ECMWF-TOGA analysis T_{ECMWF}, and occultations T_{ST} within the period 2001-2002. RAOB were "coincident" if they measured within 3 hours and less than 300 km from the occultation times and tangent points. The CPT radiosonde temperatures are closer to occultations than to the interpolated analysis.

Comparison with ECMWF analysis (Pot. Temperature)

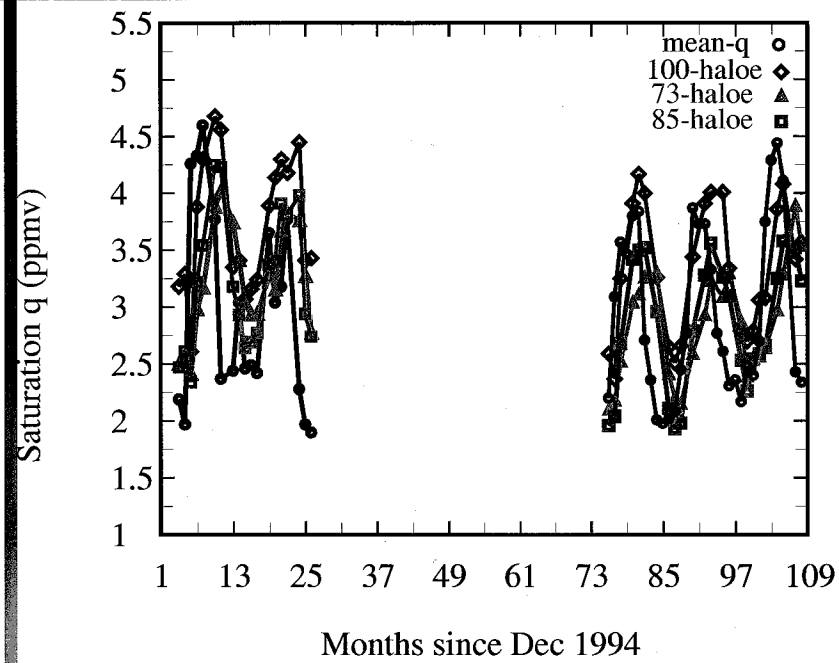


Mean ECMWF-GPSRO January–June.



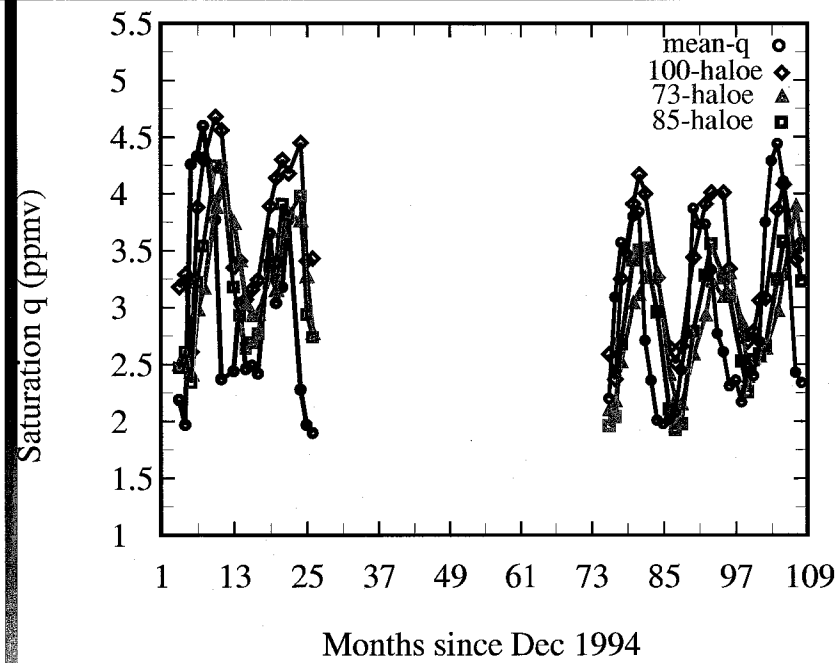
Mean ECMWF-GPSRO July–December.

Is the stratosphere "too" dry ?



Monthly averages of lowest GPS occultation q_s, and HALOE's specific humidities at 100 hPa, 85.8 hPa, and 73.6 hPa. Global means (standard deviation)/median are: q_s = 2.86 (0.78)/2.5 ppmv; HALOE measured q_{h2o} = 3.49 (0.62)/3.41 ppmv at 100 hPa; 3.01 (0.61)/2.96 ppmv at 85.8 hPa; and 3.01 (0.52)/3.03 ppmv at 73.6 hPa. $\longrightarrow$ HALOE values are higher than the GPS saturation values (and HALOE has been reported to have a dry bias).

Is the stratosphere "too" dry ?



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$\longrightarrow$ NOT on the global mean

Interesting because radiosondes, and other in situ measurements, do capture subsaturated air at the UT/LS.

On the other hand, there are in-situ measurements showing supersaturation.

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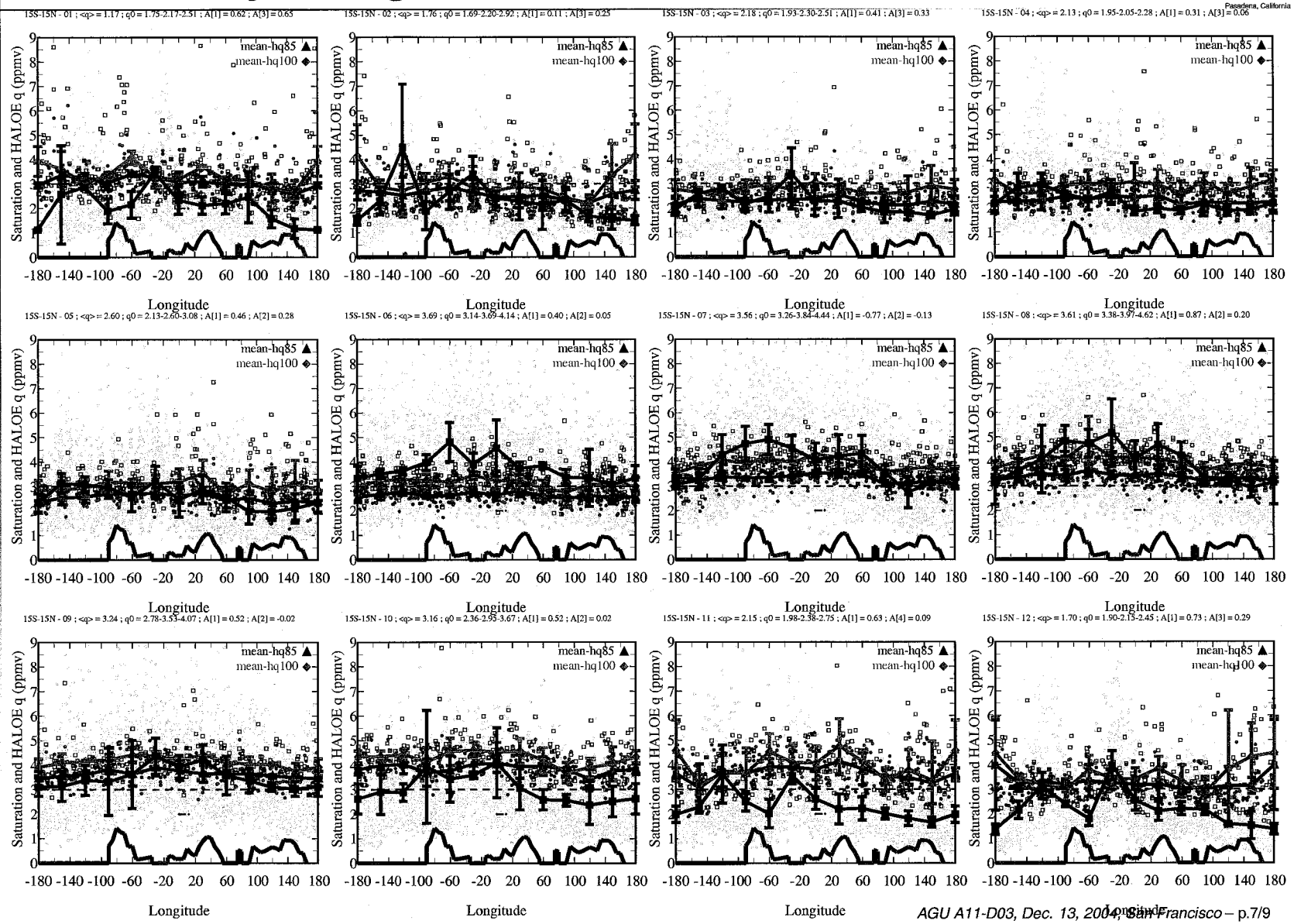
Monthly changes in saturation levels (GPS w. HALOE)

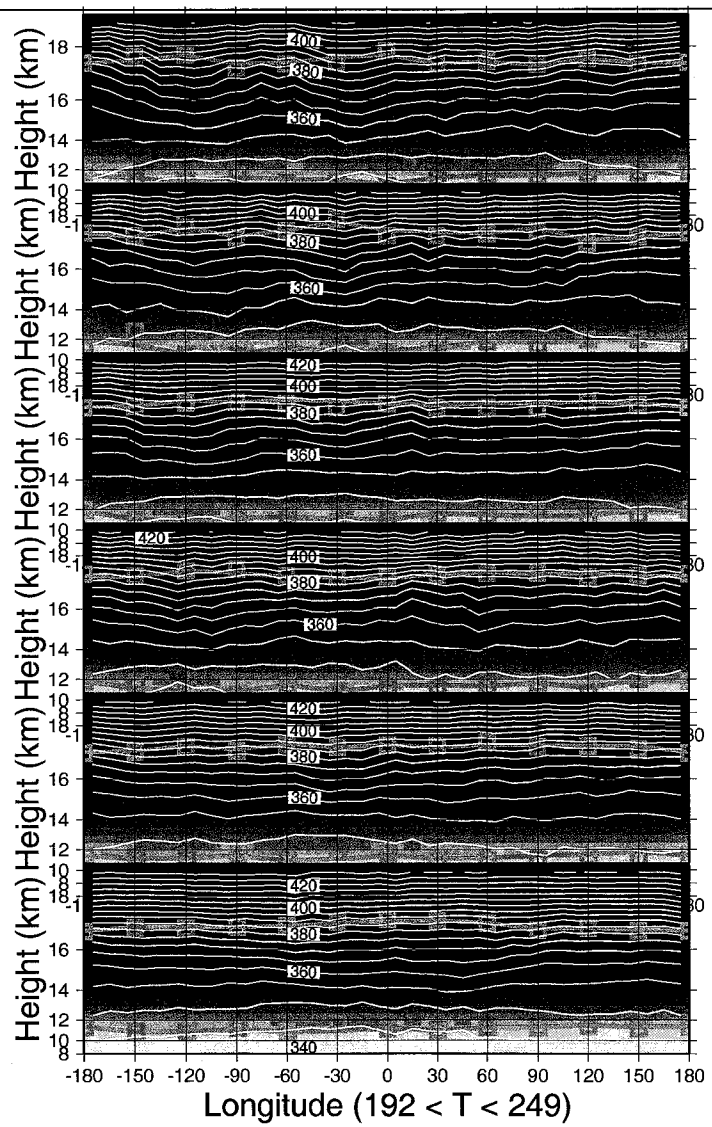
National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California



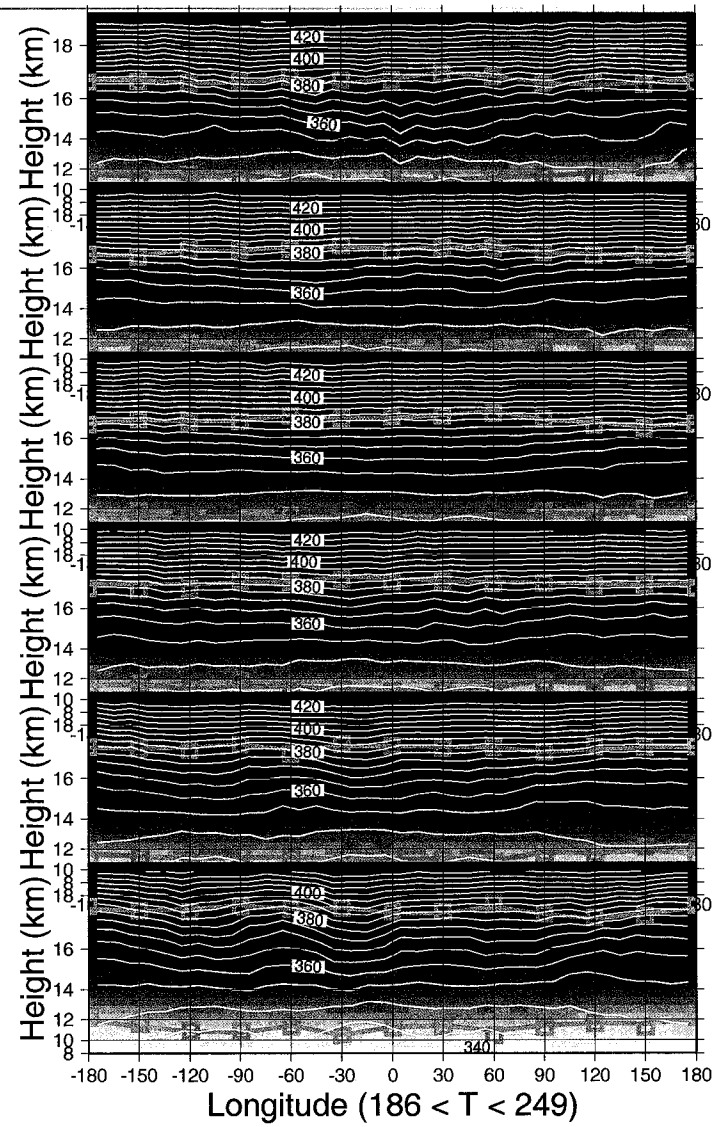
Jet Propulsion Laboratory
California Institute of Technology

Monthly variability in isentropes (Pot. temperature)

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California



Left) January–June.



Right) July–December.

Conclusions

Space based observations with global coverage and high vertical resolution help unveil the detailed thermal structure of the UT/LS. We have used it to infer the saturation/subsaturation cycles and the monthly changes of trajectories followed by isentropic transport accross the tropopause.
Both observations help test our current theoretical understanding of how gases are transported in the tropical troposphere:

1. Dehydration mechanisms, if present, appear either unnecessary or counterbalanced by hydration mechanisms.

2. The geometry of the tropopause layer suggests that air crossing the Eastern Pacific crosses first over other regions that could rehydrate it before entering the stratosphere.

3. Boreal Winter months seem to have abundant instances of supersaturation.

4. Boreal Summer months seem to have abundant instances of undersaturation.

Could this be explained by the Monsoons ? (e.g. Bannister et al. QJRMS, 2004).