Trends in the temperature and water vapor content of the tropical lower stratosphere

Karen Rosenlof and George Reid, NOAA ESRL CSD, Boulder, CO

Introduction

Water vapor in the stratosphere is important both chemically and radiatively. Increasing trends in the historical record have been noted (see Figure 1), however mechanisms for that increase are not well understood, and will likely involve both increases in methane and circulations changes over the time period in question. What is easier to explain is the annual cycle in entry of water into the stratosphere (Figures 2 & 3). The amplitude of the cycle is large (1-2 ppmv peak to peak), and is correlated with the annual cycle in temperatures at the tropical tropopause.

Therefore, to understand changes in water vapor, we also need to understand changes in tropical temperatures. Because of the tight correlations noted between them, and the independence of the measurements, we can also use temperature and water vapor measurements together to show reliably when significant changes occur. Such a change occured at the end of 2000. In this work we will examine that change in greater detail (also see Rosenlof and Reid [2008]).

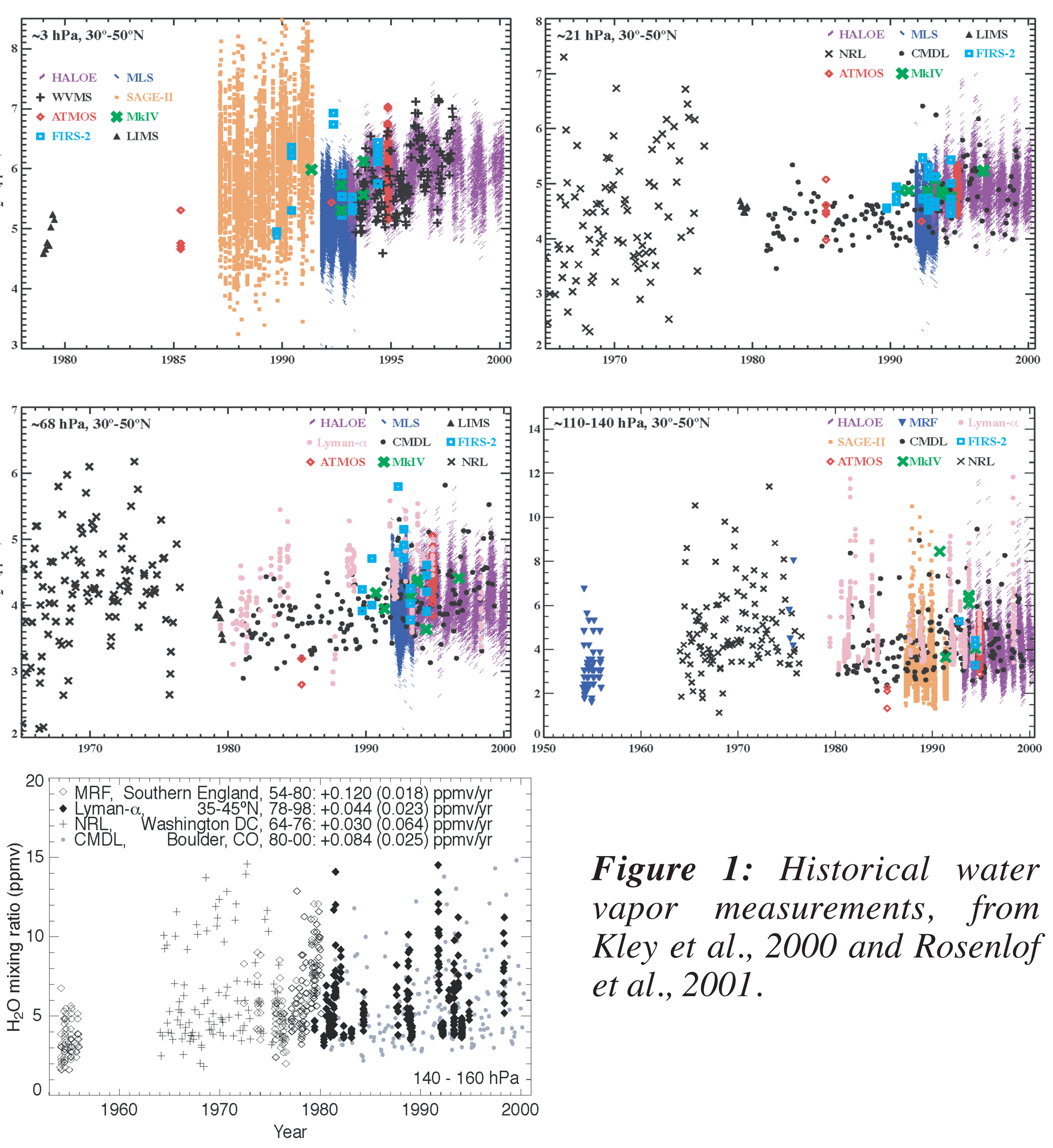

Figure 1: *Historical water vapor measurements, from Kley et al., 2000 and Rosenlof et al., 2001.*

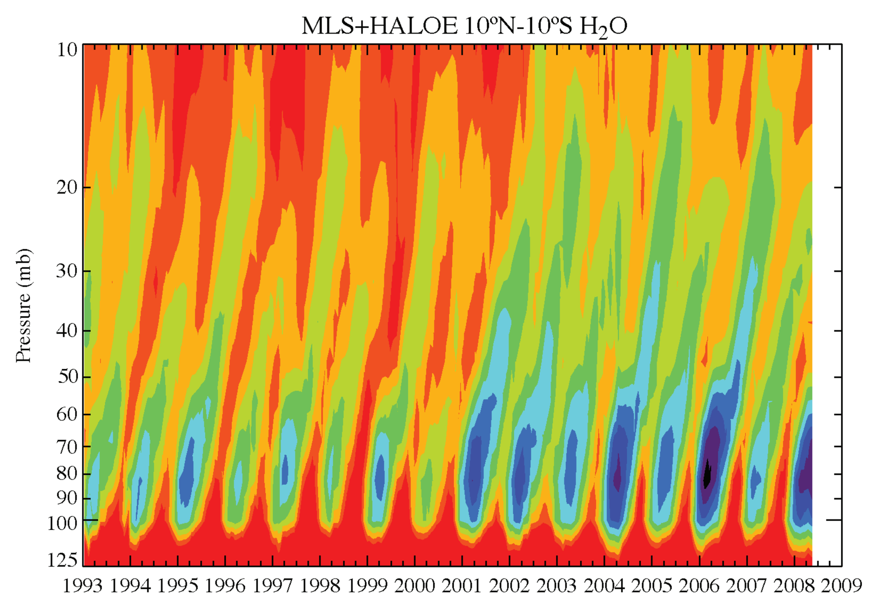

Figure 2: *Tropical water vapor (tape recorder). Note the change to lower values at the hygropause at the end of 2000. The time series was created by combining UARS HALOE and Aura MLS after adjusting HALOE to match MLS on an average basis during the overlap period from September 2004-December 2005.*

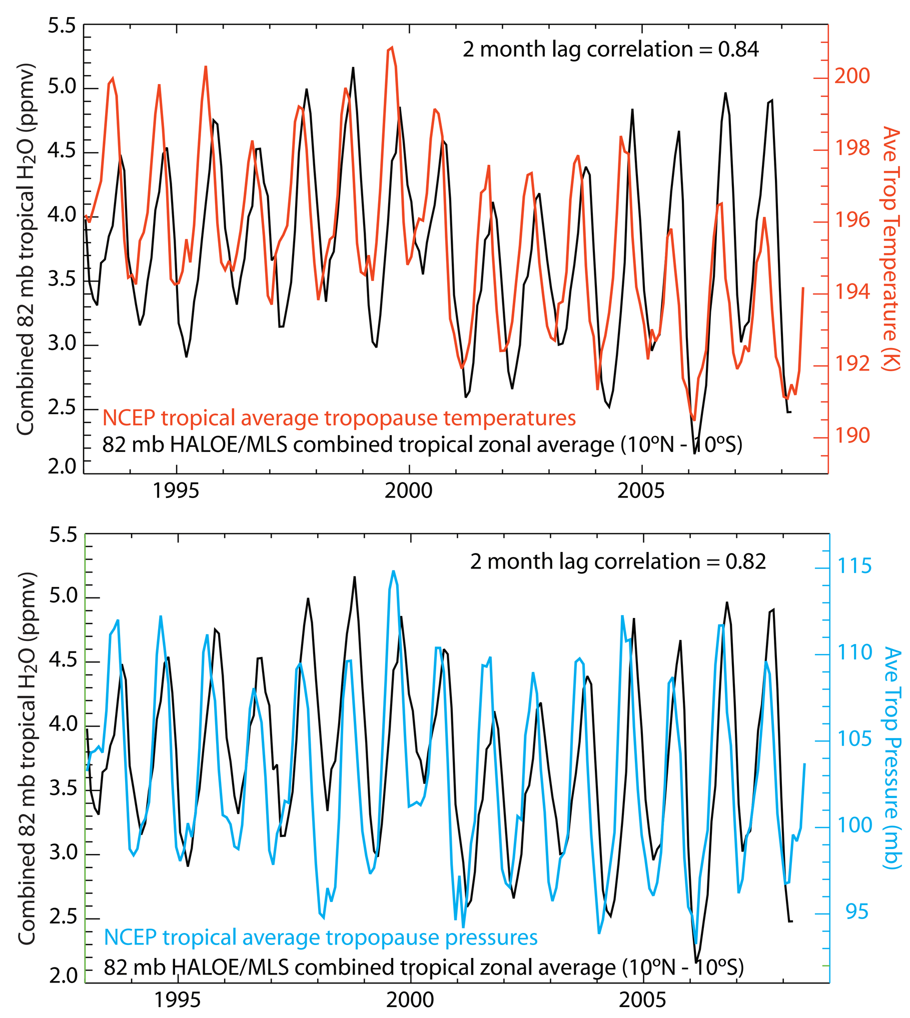

Figure 3: NCAR/NCEP reanalysis 10ºN-10ºS zonally averaged tropopause temperatures (upper panel) and pressures (lower panel). 82-mb water vapor (combined UARS HALOE and Aura MLS time series) averaged between 10ºN and 10ºS is also plotted on each panel. They key feature to note here is that there is a coincident drop in both water vapor entering the stratosphere and tropical tropopause temperatures at the end of 2000. The change in the NH wintertime temperature and water vapor has persisted into 2008. The tropical average tropopause is also higher after 2000 during NH winter. (NCEP data from NOAA ESRL PSD)

What changed?

The drop in water vapor noted in the HALOE/MLS tropical record appears in other measurements and at other latitudes as well. Figure 4 shows the change in POAM III high NH lower stratospheric measurements, in HALOE measurements at 40ºN, and in a long-term frostpoint balloon record taken by NOAA GMD in Boulder, Colorado.

The temperature change is present in the UKMO asimilation (Figure 5), in the radiosonde record as (Figure 6), and in the MSU/AMSU LST temperatures (Figure 7).

The difference in water vapor near the tropical hygropause between the time before 2000 and that after 2001 is ~1 ppmv. The temperature drop is on the order of 1-2º as determined from radiosonde station data. Ice saturation at 191.25º and 100 mb is ~4 ppmv; a drop of 1.75º gives ice saturation of 3 ppmv. Therefore, the magnitude of the tempeature and water vapor decreases are consistent with one another.

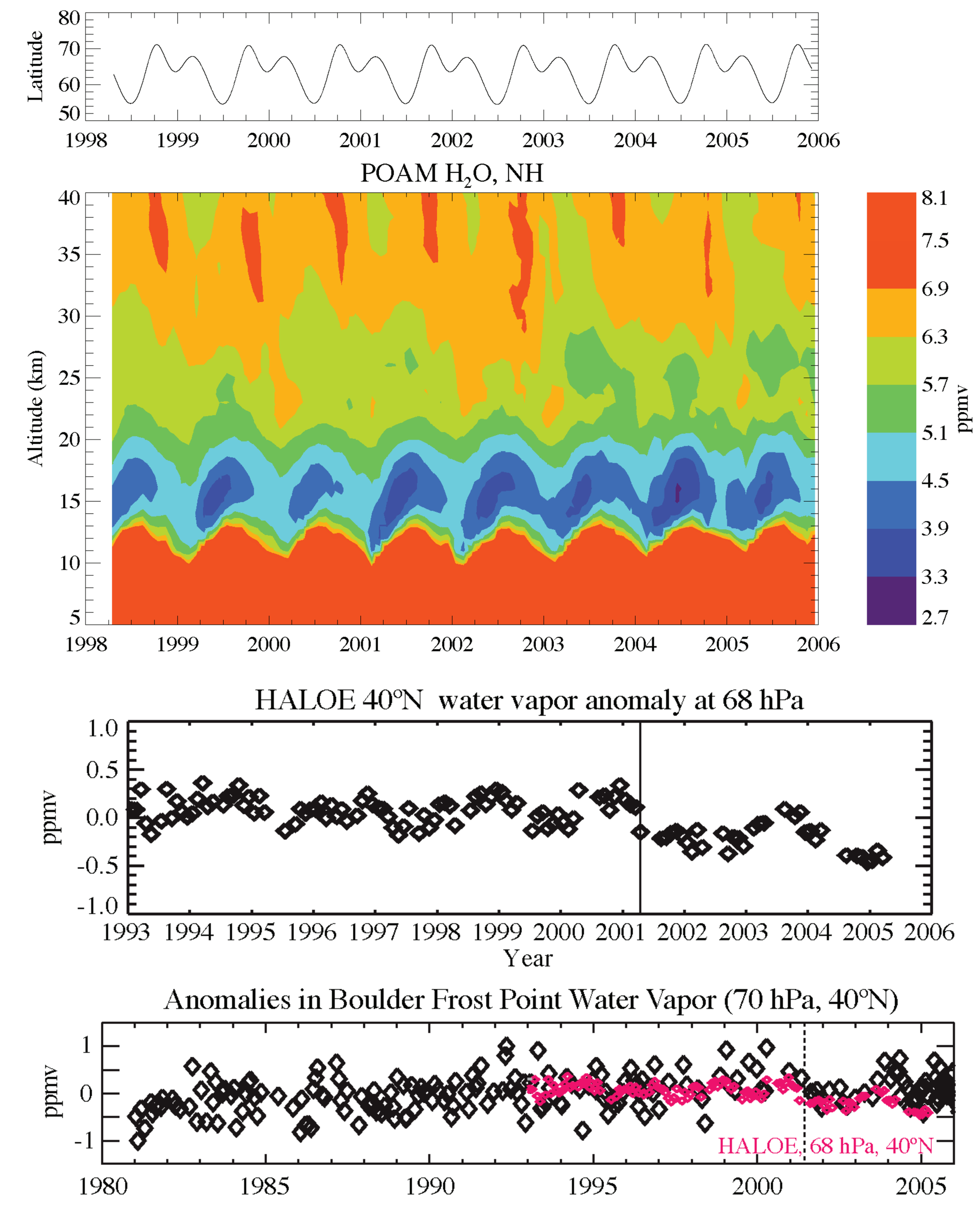

Figure 4: *Time evolution of water vapor in the Northern Hemisphere, from POAM (high latitudes) (top panel), HALOE at 40ºN, (middle panel) and the NOAA GMD frost point hygrometer (bottom panel).*

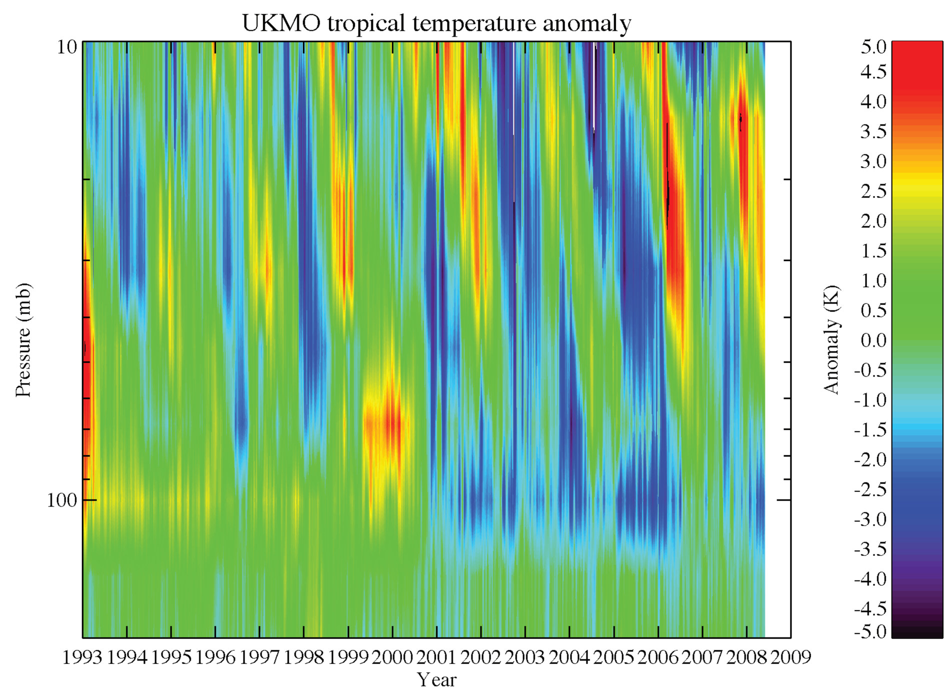

Figure 5: *Tropical (10ºS - 10ºN) temperature anomolies from the UARS UKMO assimiilation product (obtained from BADC).*

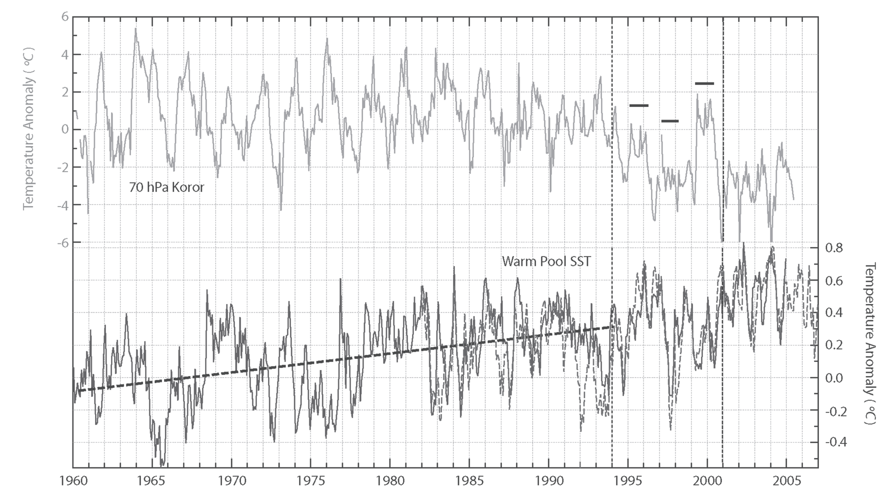

Figure 6: *Monthly mean temperature anomalies at the 70 hPa pressure level over Koror (upper curve), and SST anomalies averaged over the area of the western tropical Pacific between 7.5˚S and 4.5˚N latitude and between 120˚E and 180˚ longitude (lower curves).*

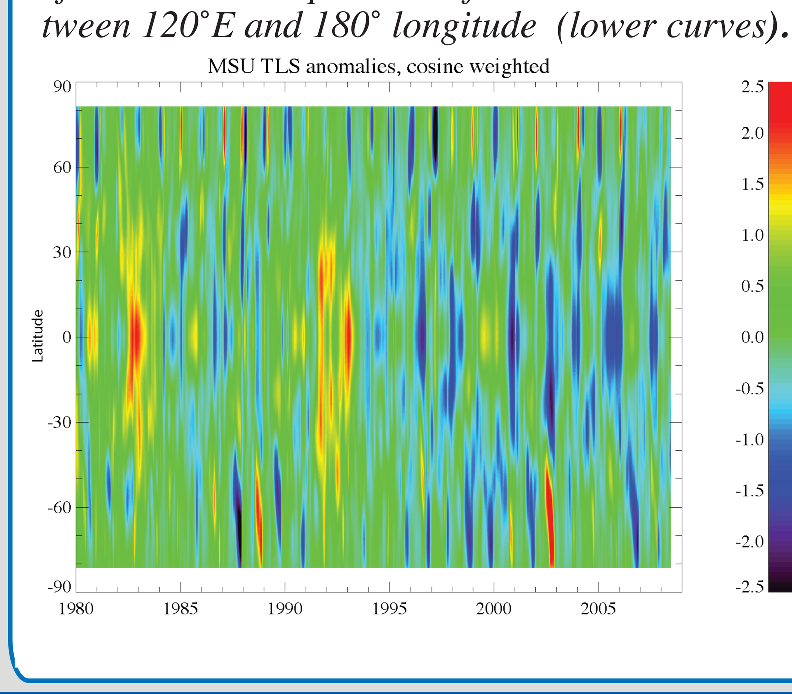

Figure 7: *MSU & AMSU TLS (lower stratosphere) temperature anomalies, weighted by cosine of latitude.*

MSU data are produced by Remote Sensing Systems and sponsored by the NOAA Climate and Global Change Program. Data are available at www.remss.com.

Mechanisms?

The actual temperature drop at the end of 2000 appears to be correlated with an increase in the Brewer Dobson circulation in the lower stratosphere, also noted by Randel et al. (2006). An estimate of the anomalies in the 10ºS-10ºN zonal tropical upwelling is shown in Figure 8. There is a marked increase near the tropopause level at the end of 2000 that is not evident higher up. This is consistent with the observation in Figure 5 that the cooling post-2001 is in a relatively narrow layer near the tropical cold point.

We find that the drop in tropopause temperatures at the end of 2000 correlates well with a change in SSTs at the western edge of the warm pool (Figure 9). There is a corresponding expansion of the near tropopause cold pool, as seen in Figure 10. What remains to be determined is why the atmosphere changed at this time, and what the consequences will be. Figure 11 shows that the anomalies in water have propagated to the upper stratosphere. As seen in Figure 12, there are some unusual relationships between lower troposphere and lower stratosphere temperatures in the 3 years before this apparent regime shift.

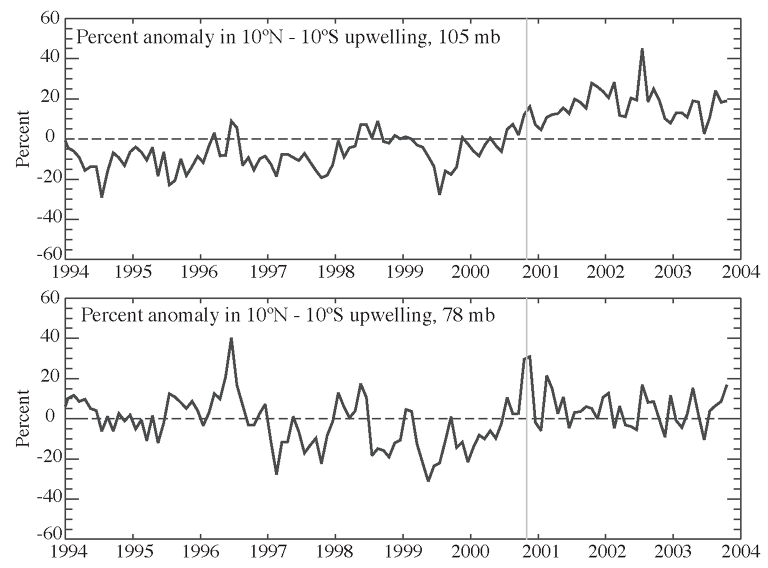

Figure 8: *Radiatively determined upwelling anomalies in the tropics at 105-hPa (top panel), 78-hPa (bottom panel).*

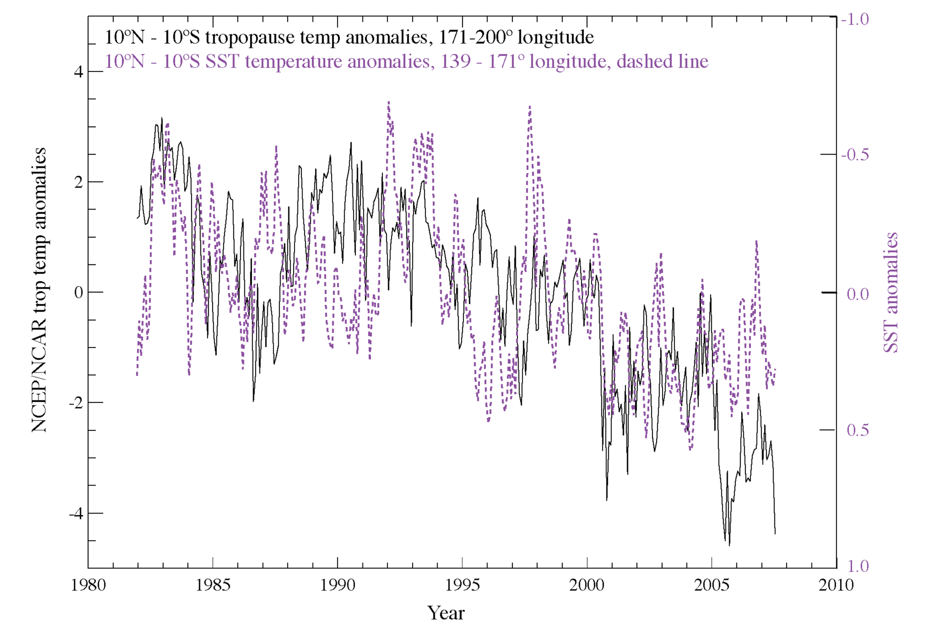

Figure 9: *10ºN-10ºS tropopause temperature anomalies and SST anomalies from the Optimal Interpolation V2 data obtained from NOAA ESRL PSD. These are for longitudinal regions in the Pacific; 139º-171º for the SSTs, and 171º-200º for the tropopause temperatures. The left axis is for the tropopause temperature anomalies, while the right axis is for the SST anomalies.*

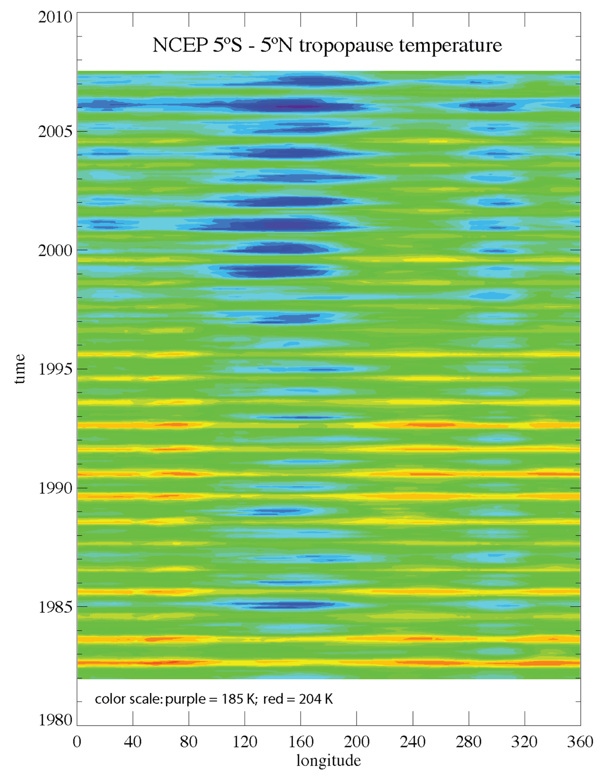

Figure 10: *NCEP/NCAR reanalysis tropical tropopause temperatures; longitude versus time. Blue values are low, red values are high. Note the growth of the blue (cold) area at Pacific longitudes with time.*

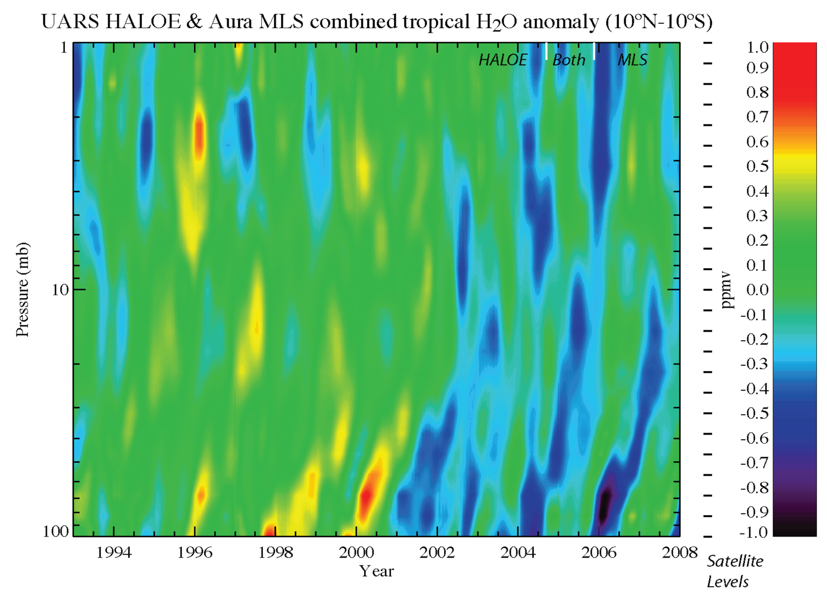

Figure 11: *Tropical water vapor anomaly, from UARS HALOE and Aura MLS through the depth of the stratosphere.*

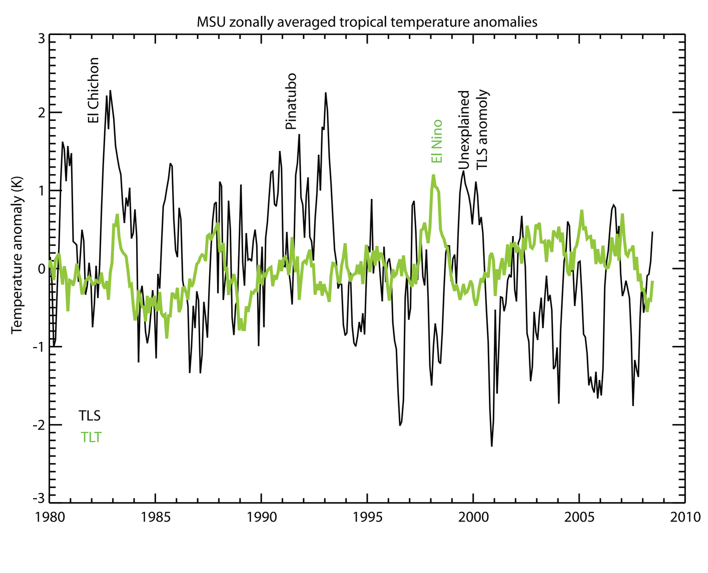

Figure 12: *MSU/AMSU zonally averaged tropical temperature anomalies, for the lower stratosphere (black) and the lower troposphere (green). Of interest is the 97/98 El Nino, showing a zonally averaged and rather large positive anomaly, and the 1999 warm period in the lower stratosphere, unprecedented in the record in the absence of a large volcanic eruption. The period folloing 2000 is cold on average in the lower stratosphere, and warm in the lower troposphere.*