SPARC Water Vapor Assessment: Establishing steps for producing a climate data record for upper tropospheric and stratospheric water vapor

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Key Point: UTLS water vapor is significant both for climate and for ozone chemistry

1) It is a radiatively active gas, impacting temperatures in the stratosphere and also at the surface.
2) It impacts ozone chemistry in the stratosphere (via influence on OH chemistry, PSC formation)
3) Long term measurements can also give some information on variations and trends in tropical tropopause temperature and stratospheric circulation strength.

Why do we need a UTLS CDR and what are the difficulties in producing one?

We want to be able to assess past trends in stratospheric water vapor and make predictions as to possible future changes and feedbacks.

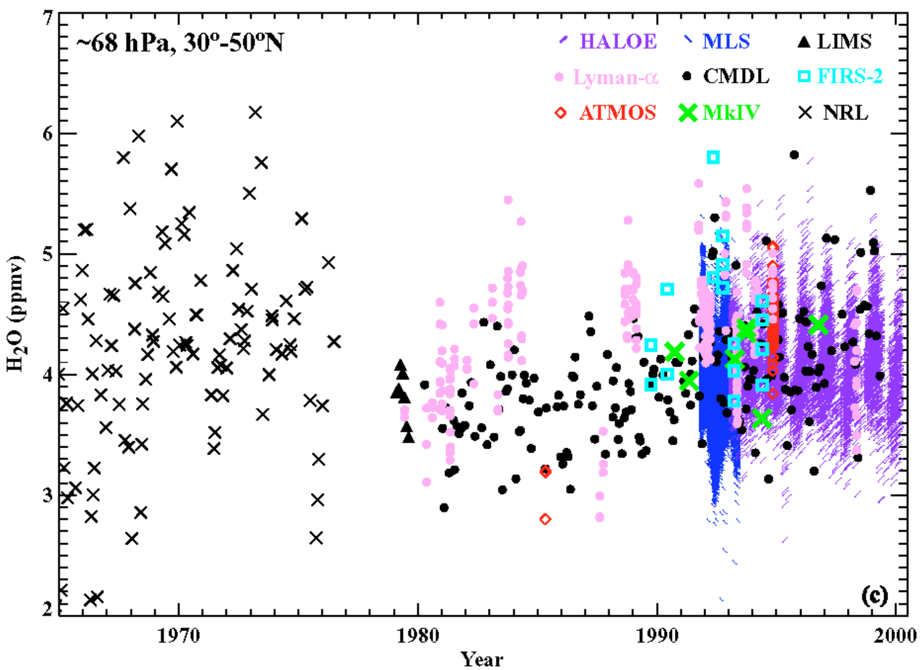
We'd like: Global measurements over a long time period.

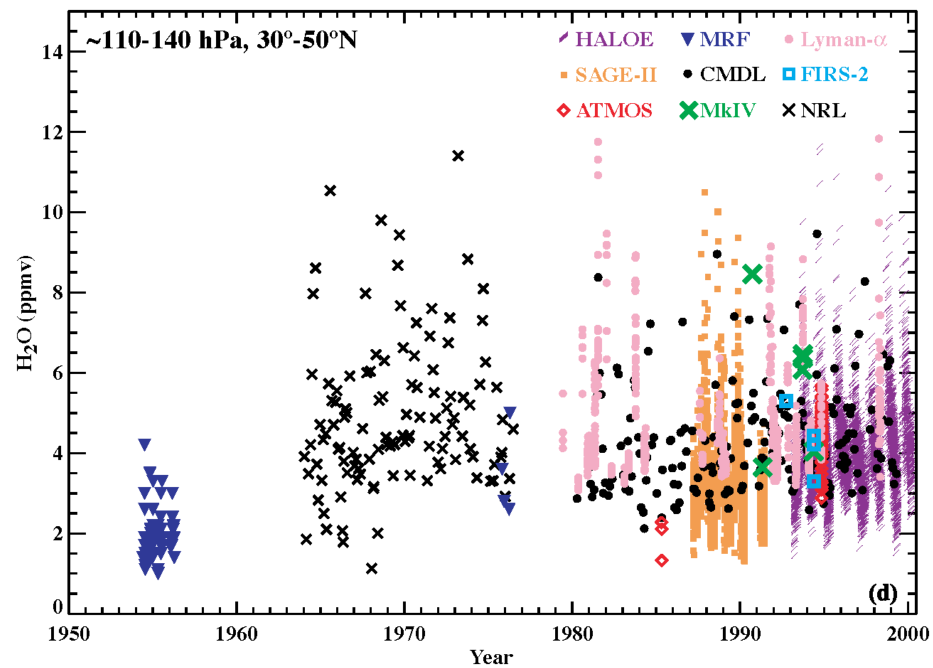
We have: *Over a long period*: local balloon sondes and solar occultation satellite measurements.
More recently: satellite measurements with better spatial coverage.

Problem: There are long-standing differences between various data sets; so we do not have a great handle on measurement uncertainties, which hinders trend estimation.

Problem: Stratospheric water vapor observations are not consistent in time

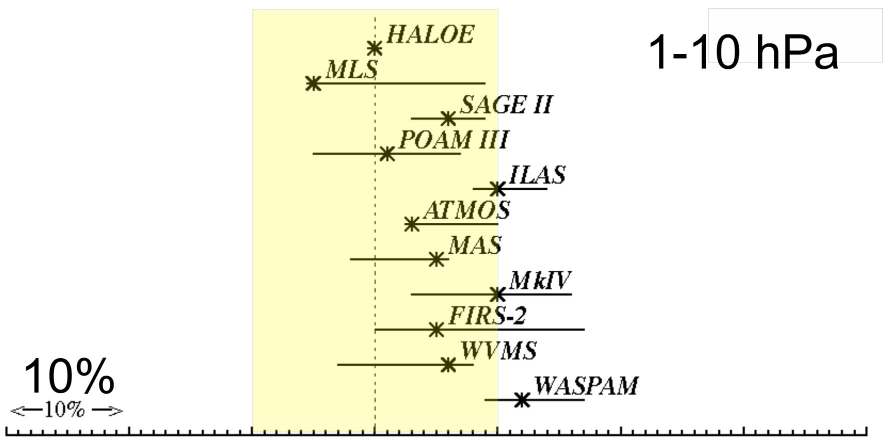
Stratospheric water vapor measurements have not been taken continuously at any one location or with any one technique for an extended period of time.





Ideally, we would like to be able to combine data sets to get an extended record, but first we need to assess whether different measurement systems are retrieving the same values at the same time/location.

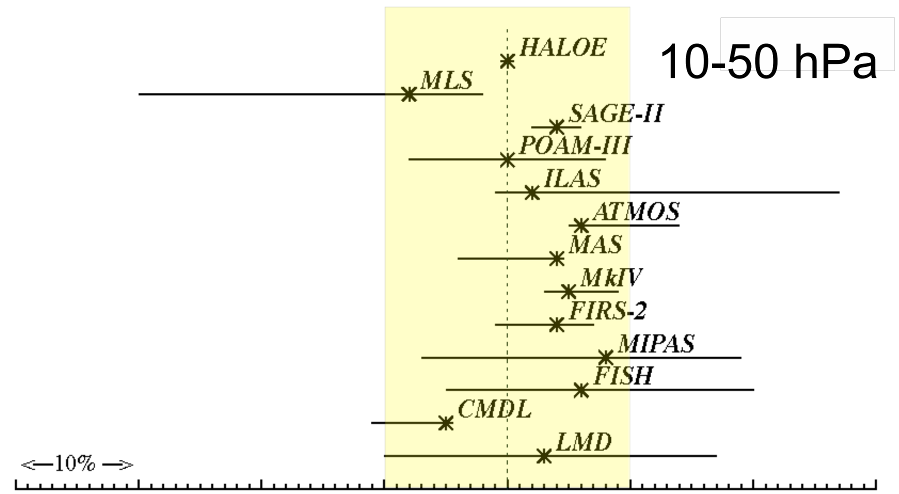
Overall comparisons from SPARC 2000 water vapor assessment

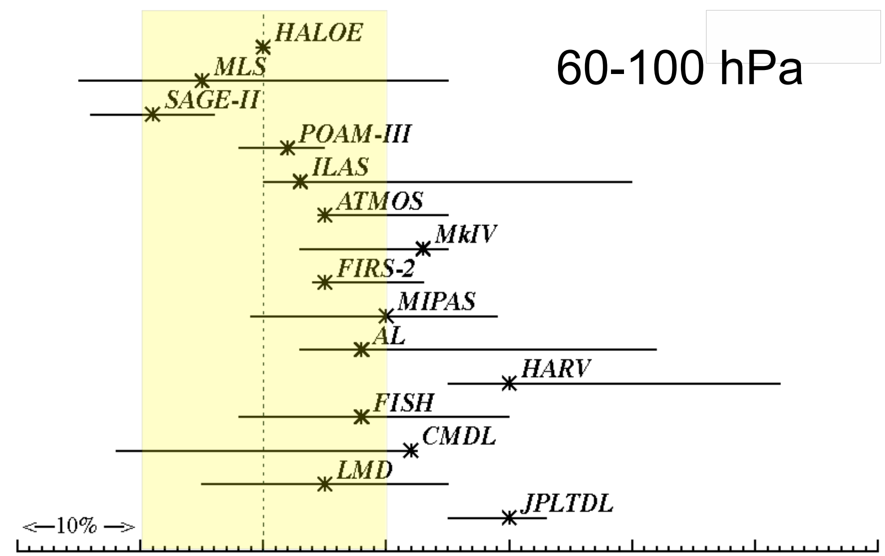


All comparisons were done relative to HALOE, which at the time overlapped with the greatest number of other instruments.

Direct comparisons cluster mainly within a 10% range, with a somewhat larger spread in the lower stratosphere.

In general, HALOE is biased low by ~5% relative to the other measurements considered.

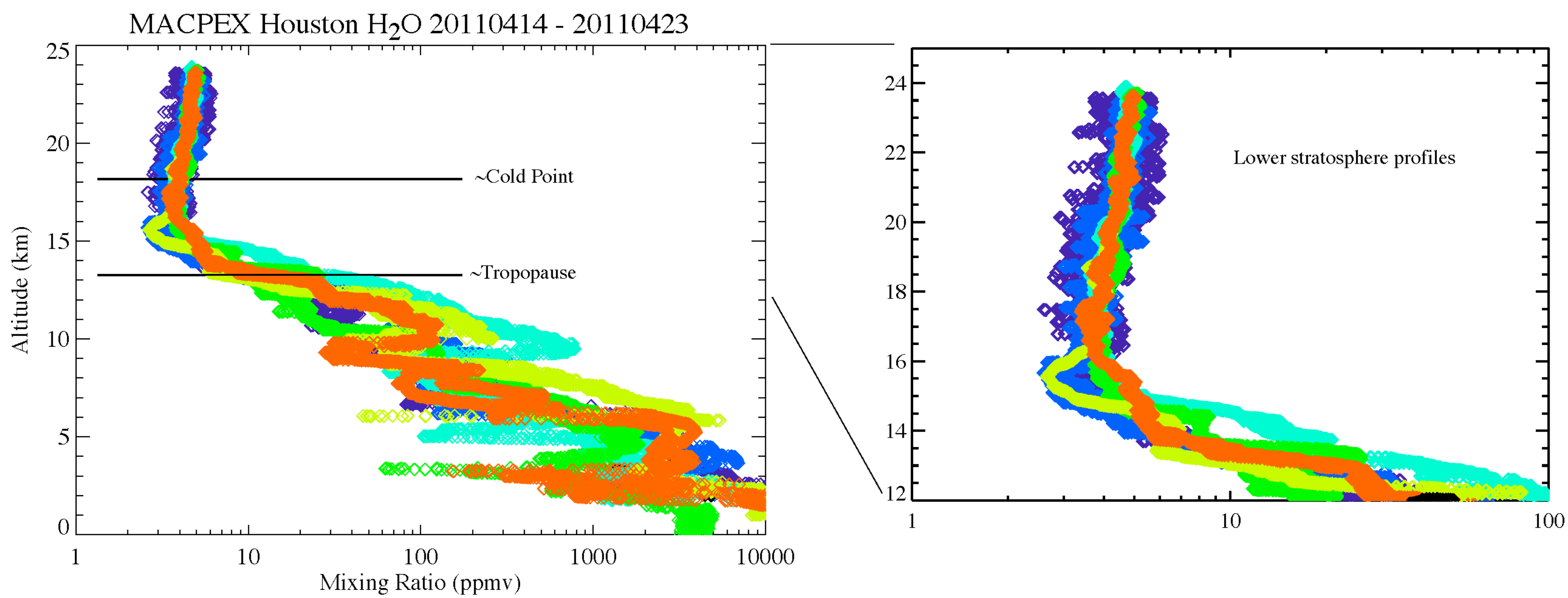




Important Point

There are large vertical gradients in water vapor in the UTLS. In the upper troposphere, there is also large spatial and temporal variability.

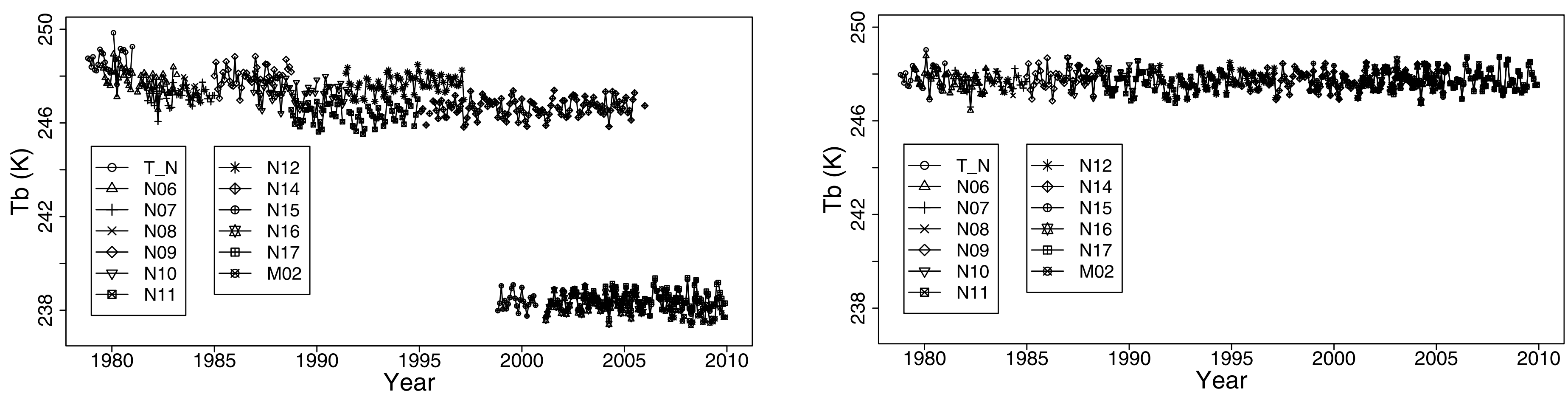
Bottom line: not all measurement techniques are adequate for covering the entire range. As noted below, in mixing ratio space, measurements cover 4 orders of magnitude between the surface and the lower stratosphere.



Upper Troposphere

Producing a consistent upper troposphere data set has been undertaken at NCDC (see Shi and Bates, JGR, 2011).

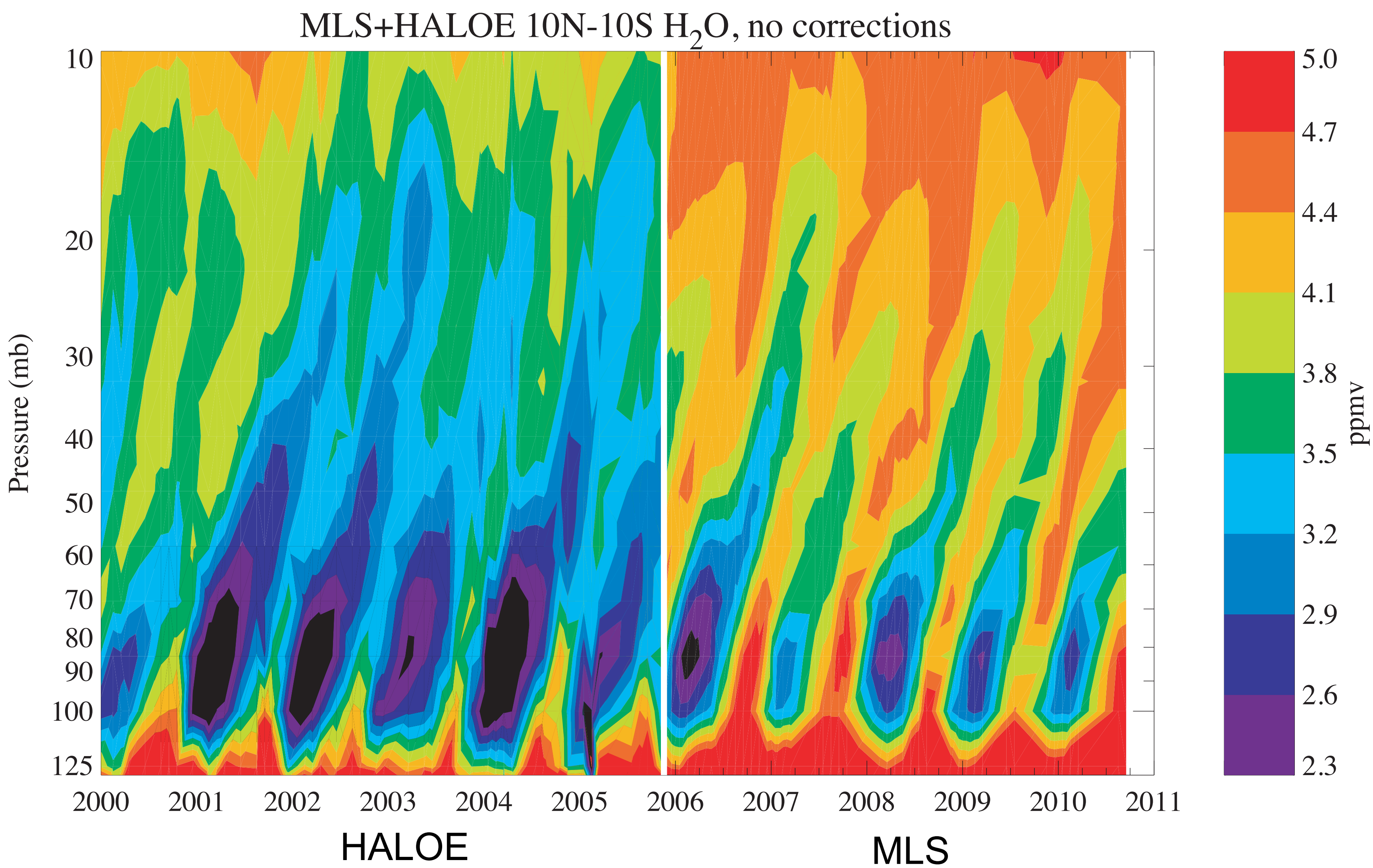
They used a data set of UTWV brightness temperatures from the HIRS instrument covering the time period from 1978 to the present; adjusted biases between satellites from HIRS channel 12 clear-sky data.



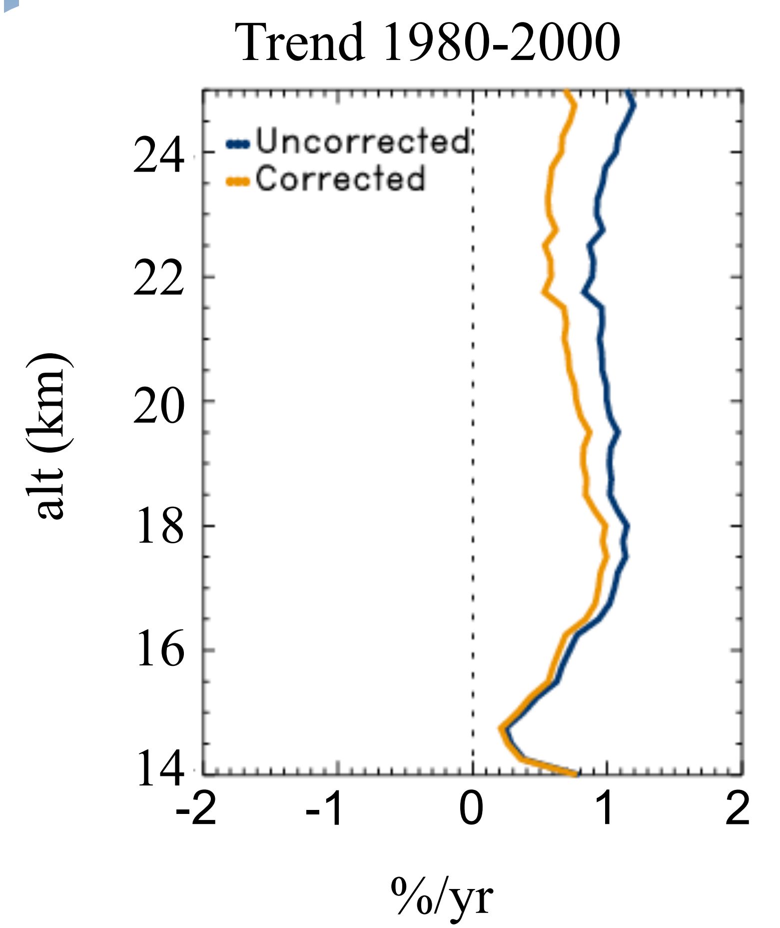
30N-30S brightness temperatures before and after intersatellite calibration

Demonstration of stratospheric satellite measurement offsets

Tropical tape recorder plot: This shows the temporal evolution of tropical stratospheric water vapor over the past decade.



What sort of trends exist for stratospheric water vapor?



From Scherer et al, ACP 2008

Note: trends are 0.5-1%/year, instruments differences are 5-10% or larger, so a simple combination will produce spurious trends.

Note: a trend of 10%/decade is equivalent to a 0.5 ppmv change over 10 years.

A Proposed Method

1) Choose data sets with long continuous records, preferably global coverage, and some overlap in time/space.
2) Determine which data set to which to adjust.
3) Analyze the overlap period to determine adjustments that need to be made before combining data sets.
4) Establish the uncertainties for each part of the combined time series.
5) Determine some means of filling missing data (for cases where a complete data set is needed for model input.

Approach

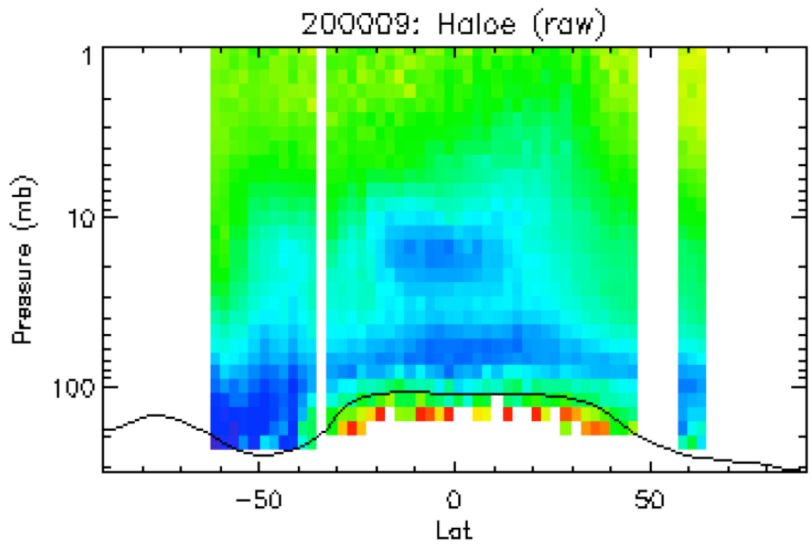
Satellite data sets to consider:

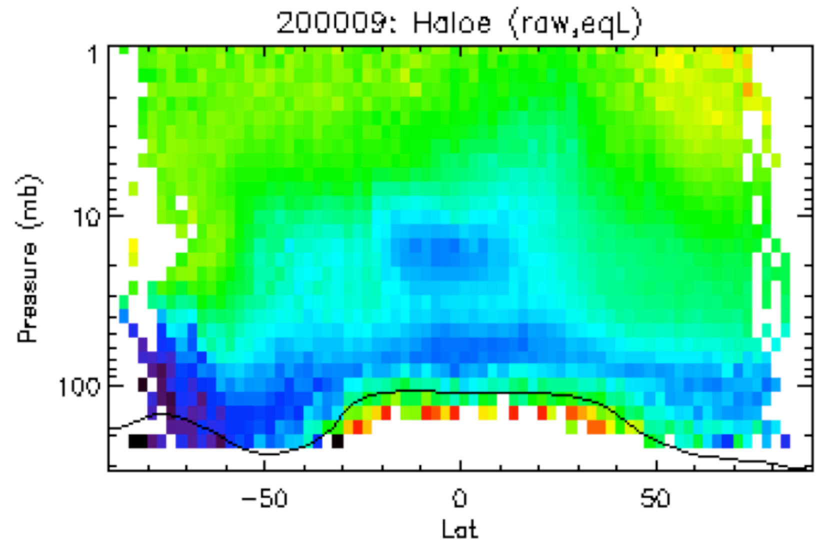
1) SAGE II: 1985-2005
2) HALOE: 1991-2005
3) Aura MLS: 2004-present

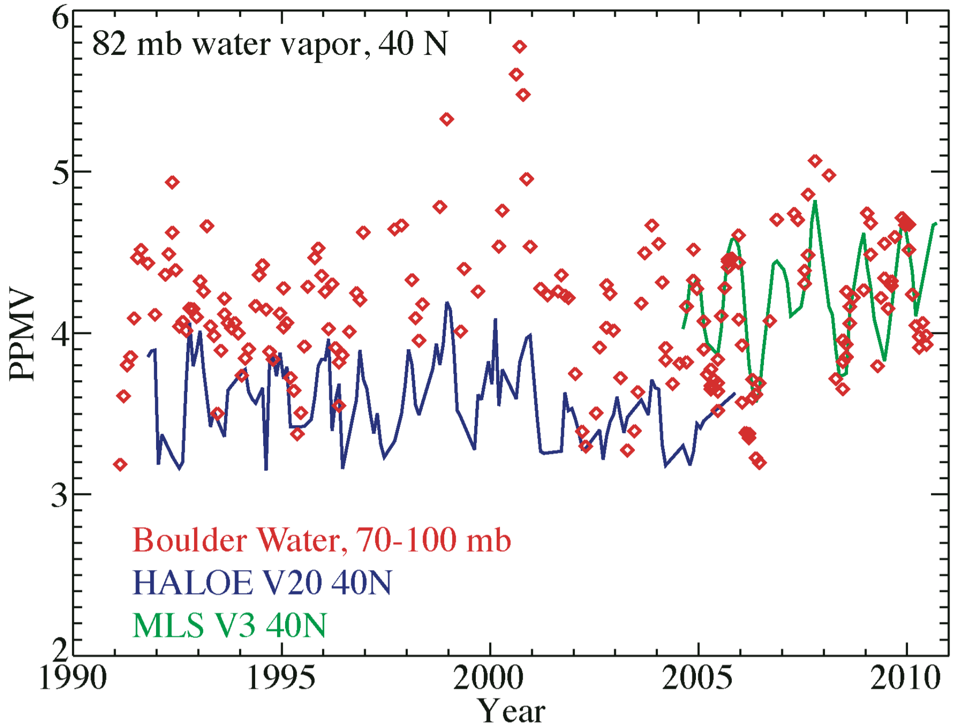
To fill in gaps in polar regions; ACE (2004-present) can be used. Additionally, there are other shorter period satellite records.

Zonal average time series gridded with respect to equivalent latitude

Use of equivalent latitude allows greater latitudinal coverage.

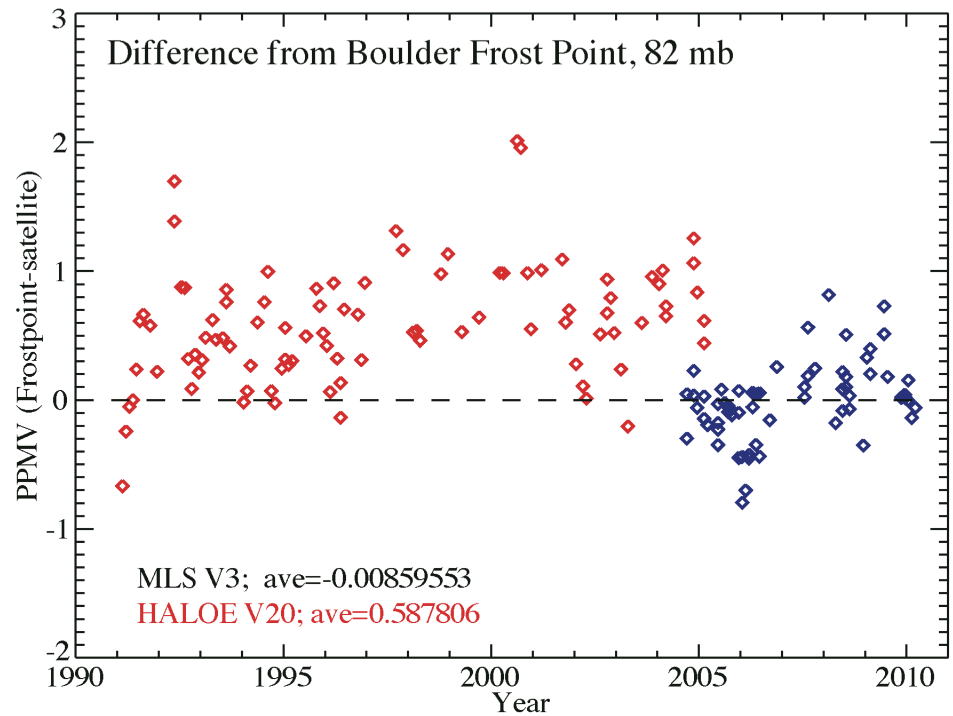




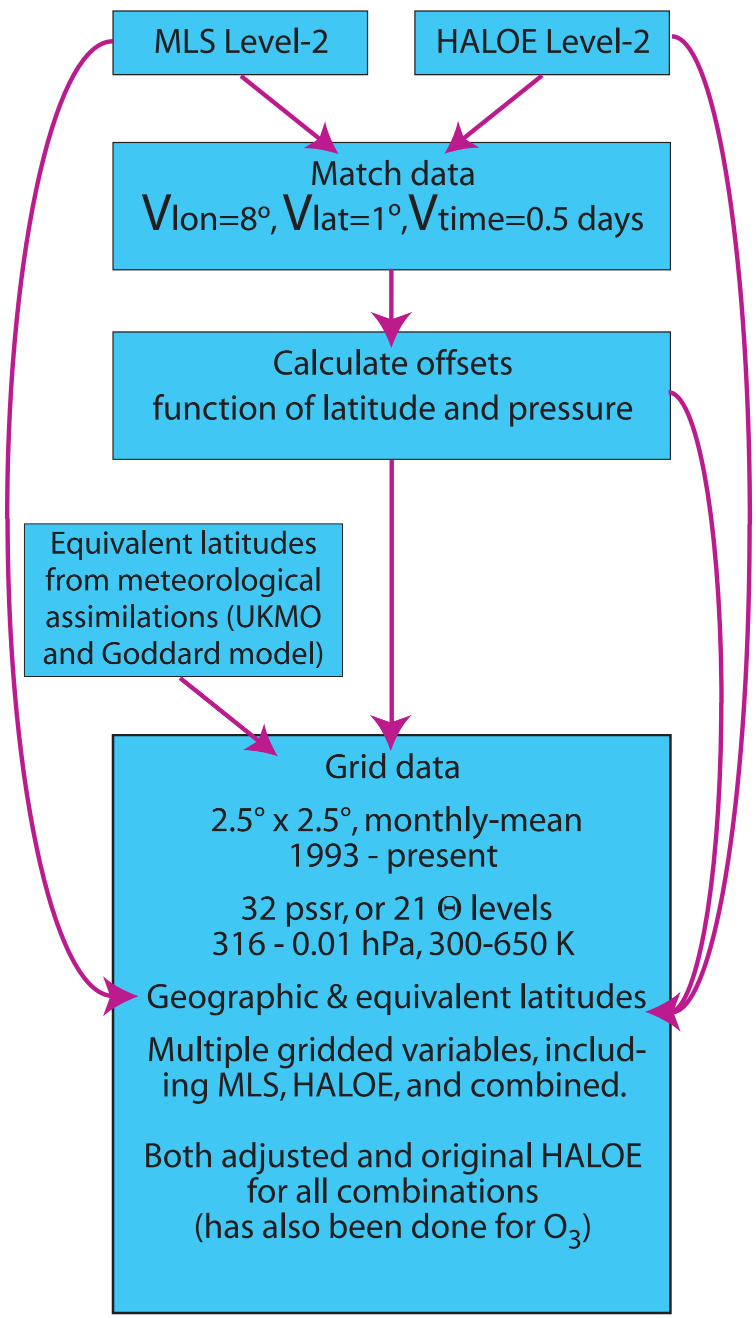


We used comparisons with *in situ* measurements to choose a primary data set.

MLS differences from Boulder frost point are smaller (by ~.5 ppmv) than HALOE differences. We have therefore decided to compute the adjustment to MLS for the overlap period (2004 & 2005), and use those adjustments for the entire HALOE data set and SAGE-II. This makes the assumption that there has been no drift in the HALOE or SAGE-II measurements over time.

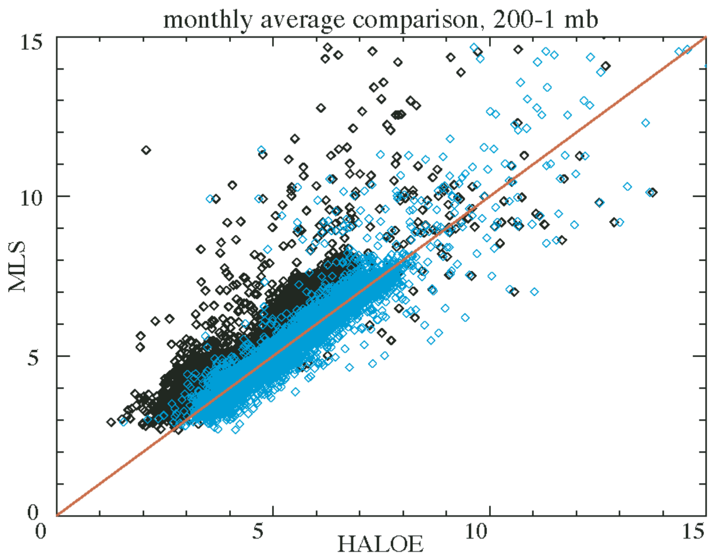


Methodology for H_2O climatology



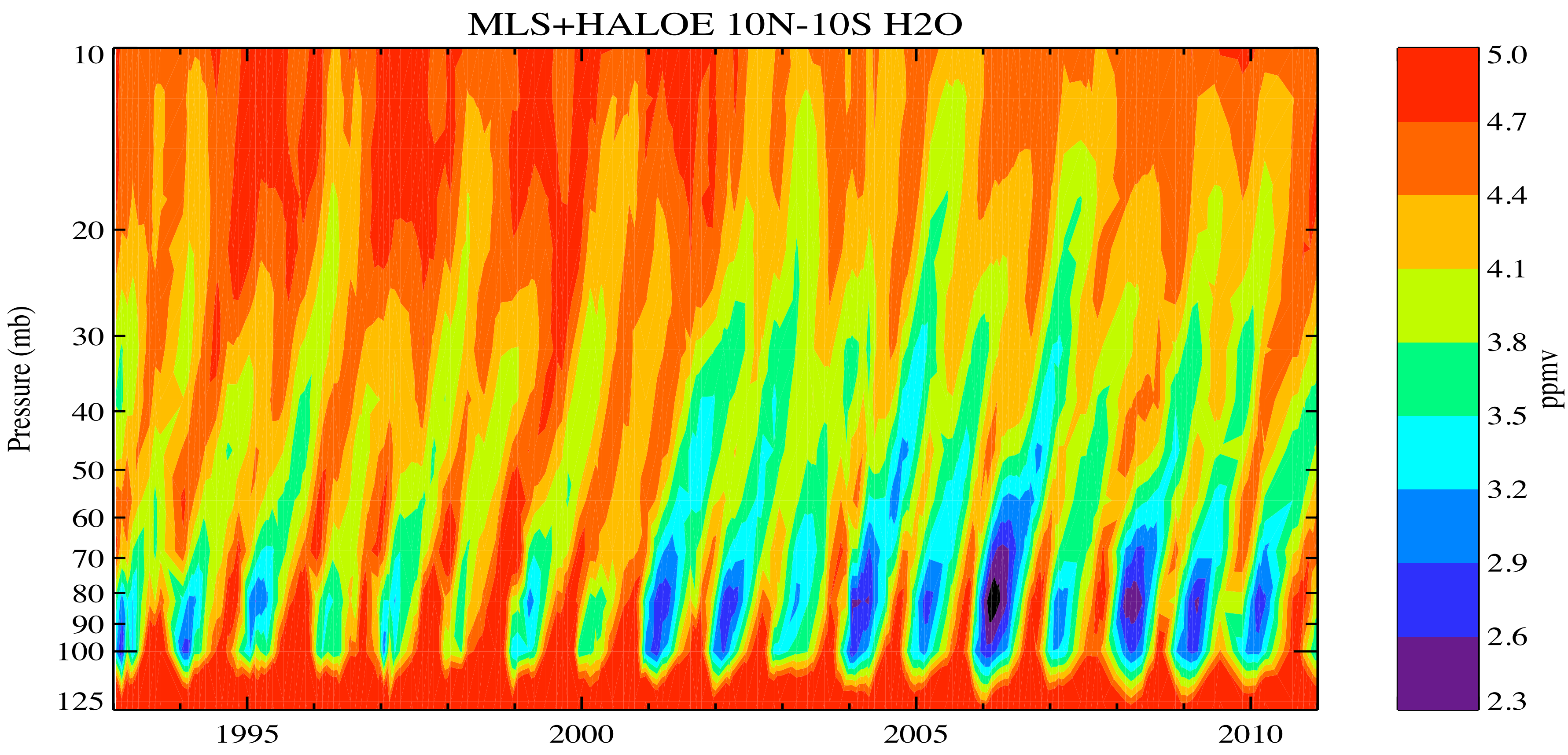
The same procedure will is followed with SAGE-II measurements, which overlap with HALOE from 1991-2005, and with MLS from 2004-2005. The resultant data set will extends from 1985-present.

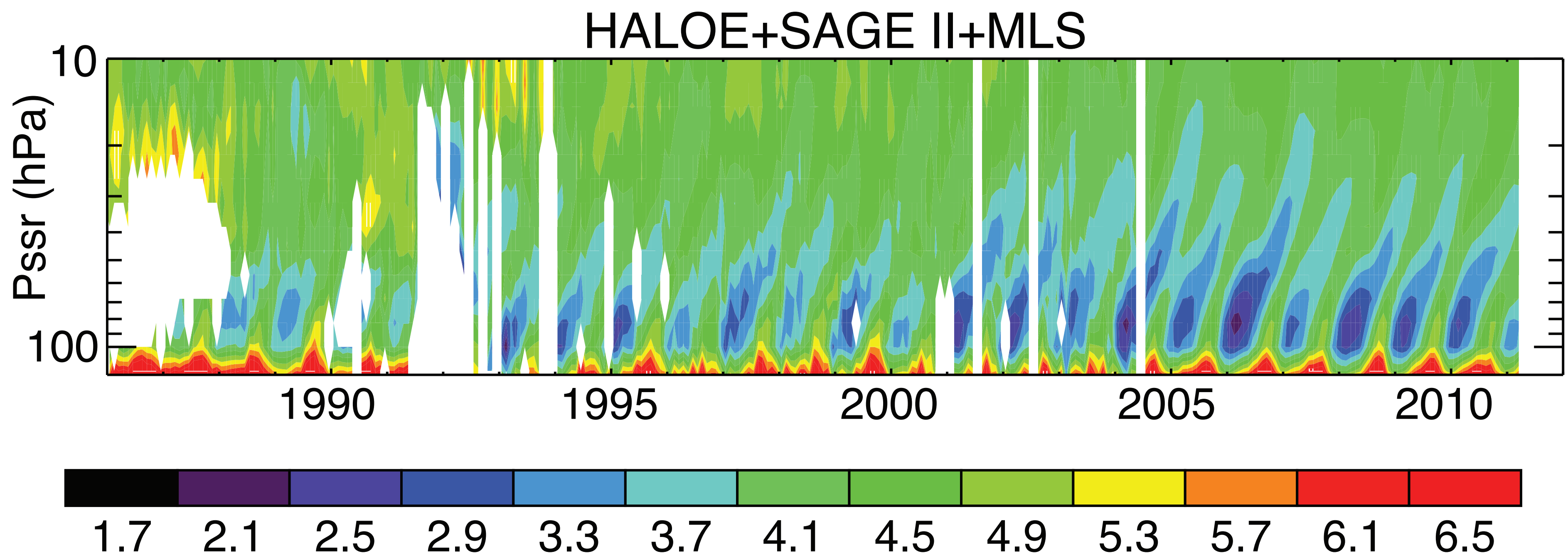
Because agreement with the frost point record is better with MLS than HALOE or SAGE-II, we chose to shift data to match MLS.



Correlation without correction: 0.79
Correlation with correction: 0.91

After merging HALOE and MLS, this is the tropical tape recorder plot; note the discontinuity we saw in the unadjusted data set is gone.





Preliminary version including SAGE II in the tropics. (presented in poster by Sean Davis today). Additional work will include validation via comparison both with *in situ* data sets and other satellite water measurements. Ultimately we want to perform trend and variability analysis and an assessment of uncertainties.

Next steps

Compare what we have with available *in situ* measurements from balloon and aircraft, and from other satellites not incorporated into this data set.

Establish uncertainty estimates for this data set.

Produce a filled data set for use in model runs and comparisons.

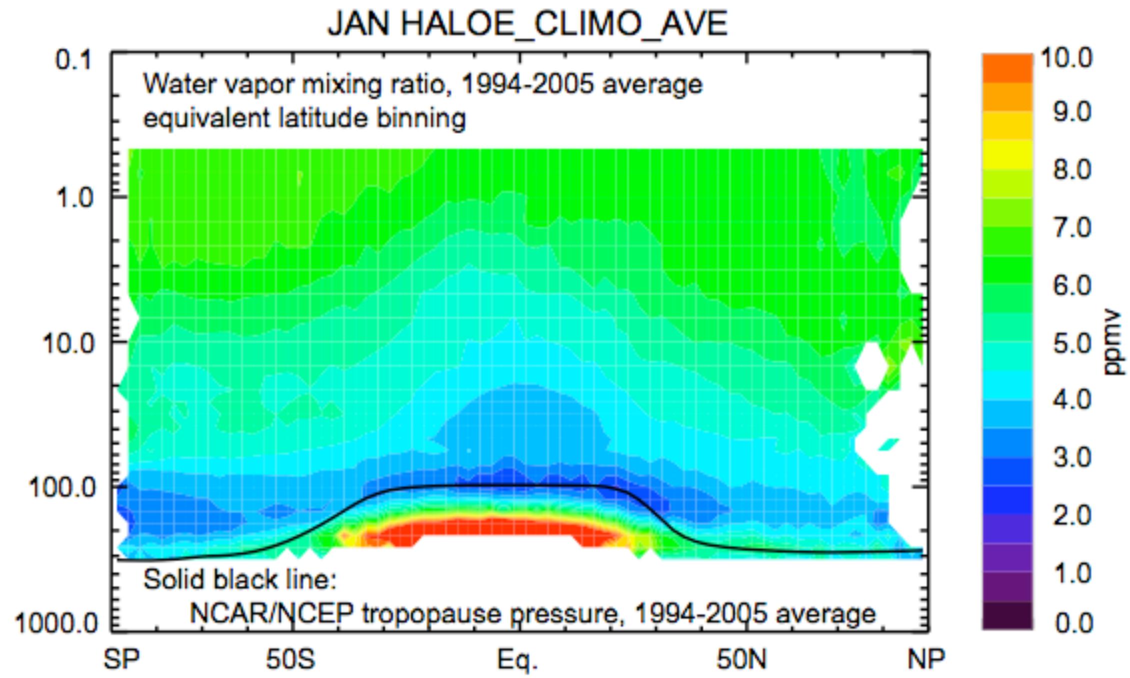
Analyze data set for trends and variability.

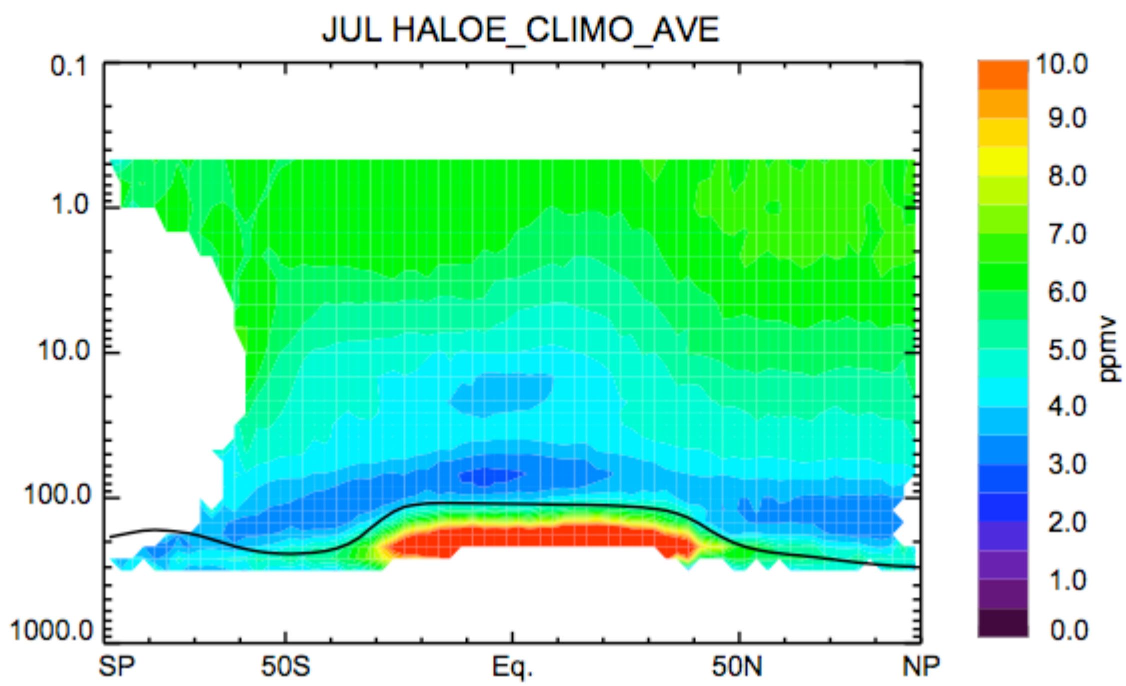
The End

Thanks for your attention!

Extra slides follow

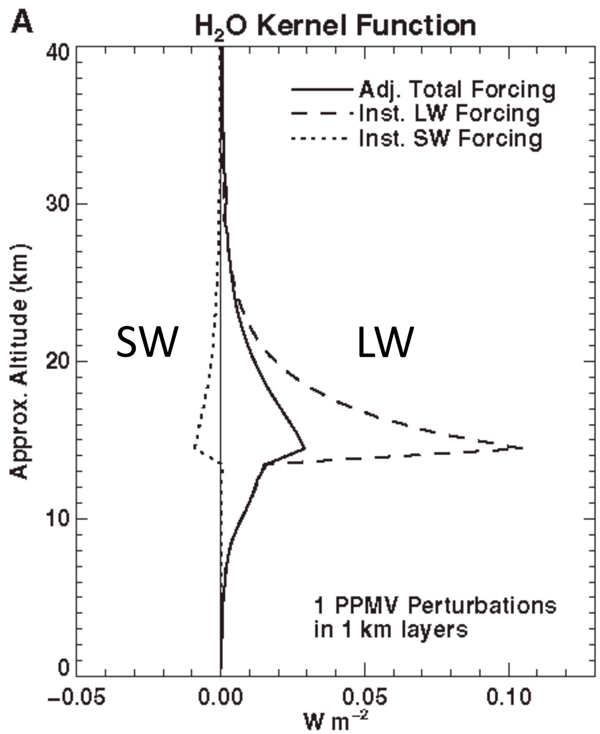
Sample latitudinal distributions of UT and stratospheric water vapor



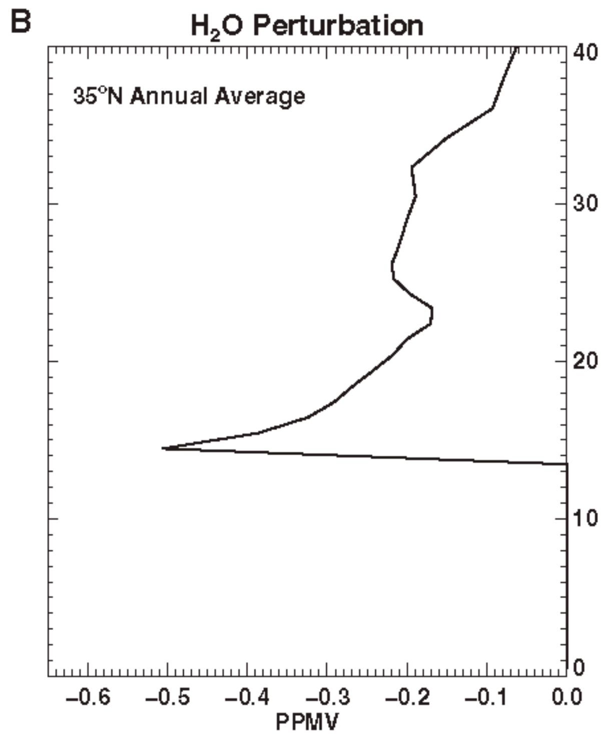


Radiative effects

A high spectral resolution model including stratospheric adjustment (FDH) was used to calculate the radiative forcing due the change in water vapor. The RF is ~-0.1 W/m^2. In comparison, a 1 ppmv increase uniformly throughout the stratosphere gives RF of +.24 W/m^2 (representative of the 1980-2000 H_2O trends discussed in SPARC 2000). RF increase due to 1996-2005 growth in CO_2 is +0.36 W/m^2….decadal changes in water have the potential to affect recent climate.

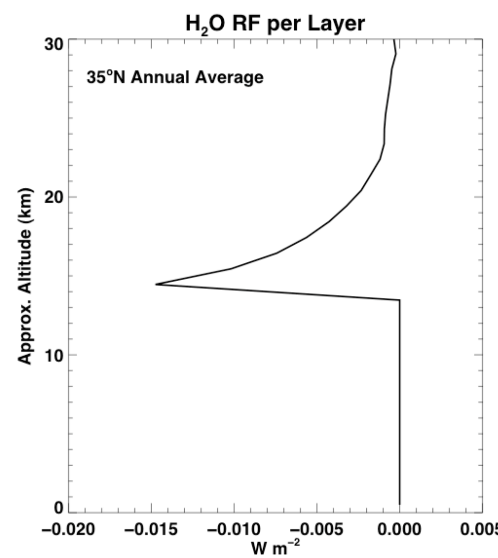


Contributions to radiative forcing per 1 ppmv decrease in 1 km layers-> strongly peaked very near tropopause



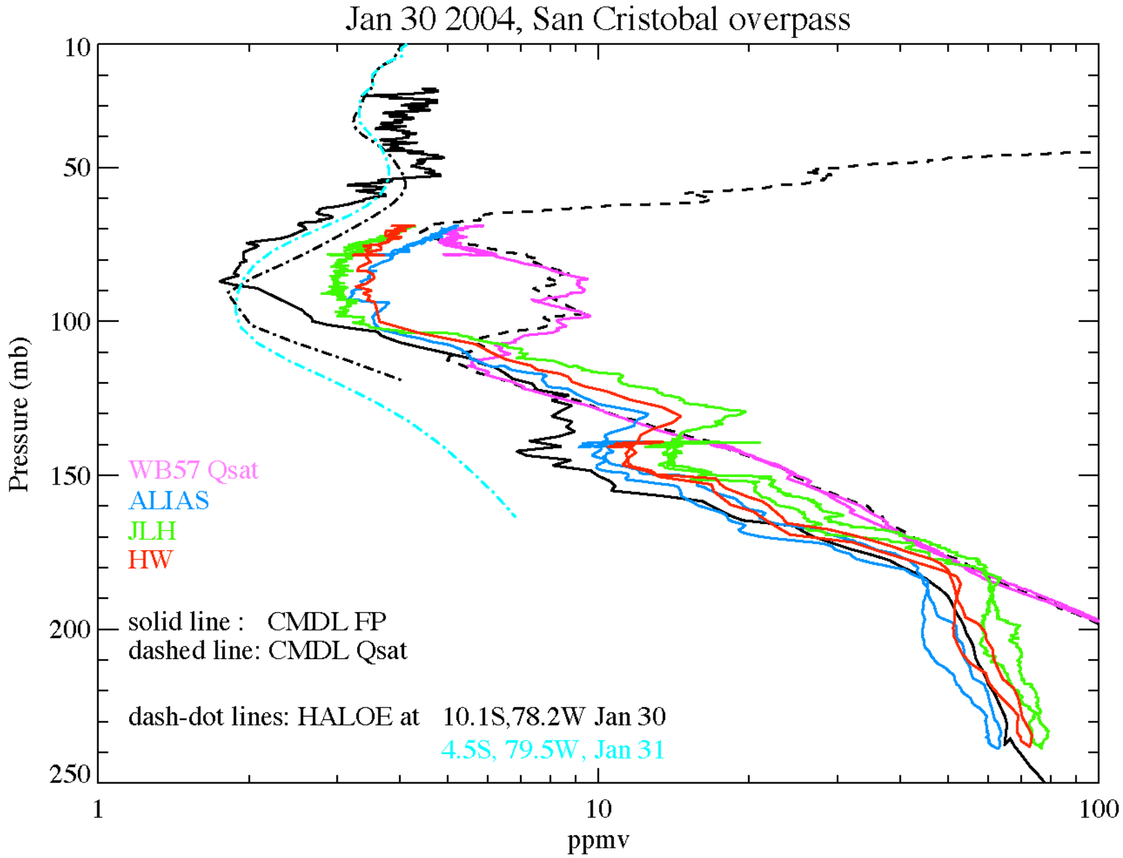
Change in H_2O near 35°N, Post-2000 minus pre-2000

Narrow region is important!



Convolving kernel function with the H_2O perturbation

Differences between *in situ* measurements made at the same time



Example of MLS/HALOE Comparisons