Variability and trends in stratospheric water vapor

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NCAR, Boulder, CO

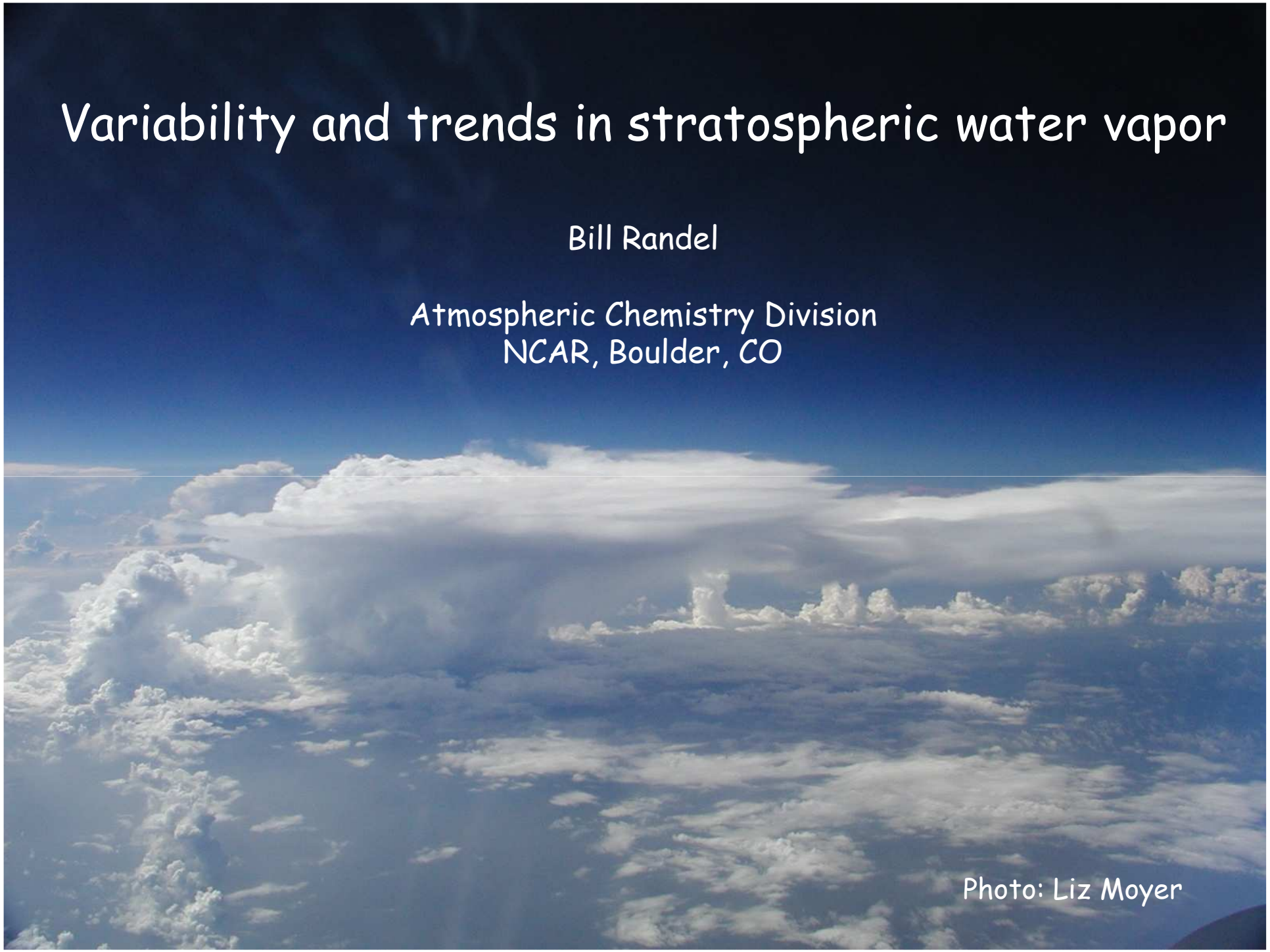


Photo: Liz Moyer

Climatology

- Seasonal cycle (by far the largest variability)
- summer monsoon circulations

Interannual variability

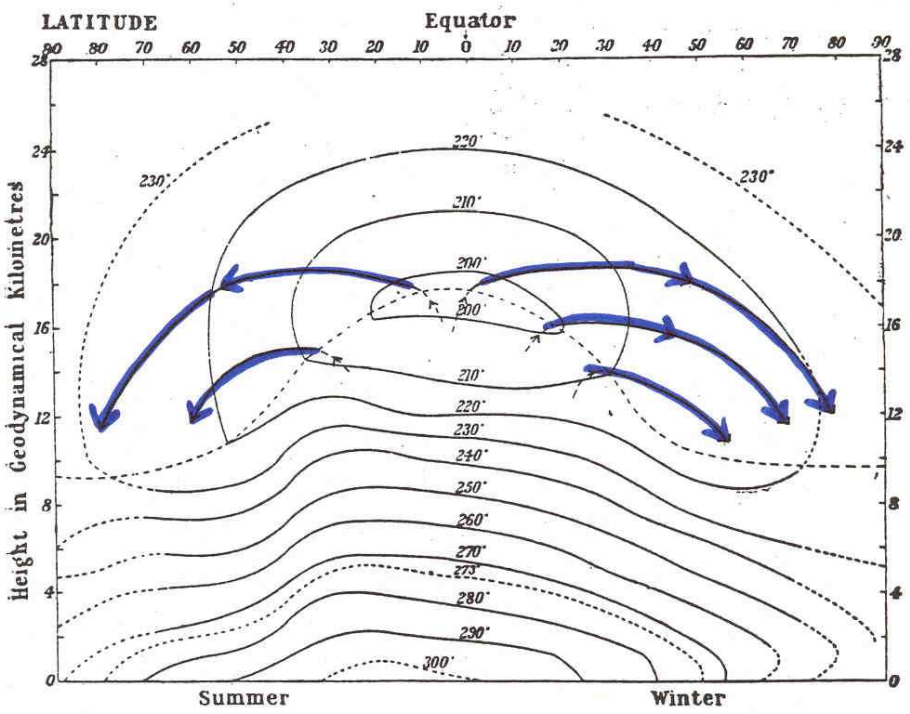
- HALOE + MLS satellite record
- correlations with tropical cold point temperatures
- brief comparisons with Boulder sonde record

Some Chemistry Climate Model results for comparison

EVIDENCE FOR A WORLD CIRCULATION PROVIDED BY MEASUREMENTS OF HELIUM AND WATER VAPOUR DISTRIBUTION IN THE STRATOSPHERE

By A. W. BREWER, M.Sc., A.Inst.P.

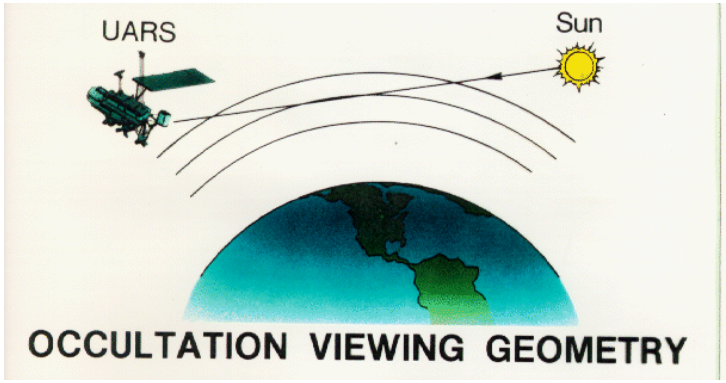
QJRMS, 1949



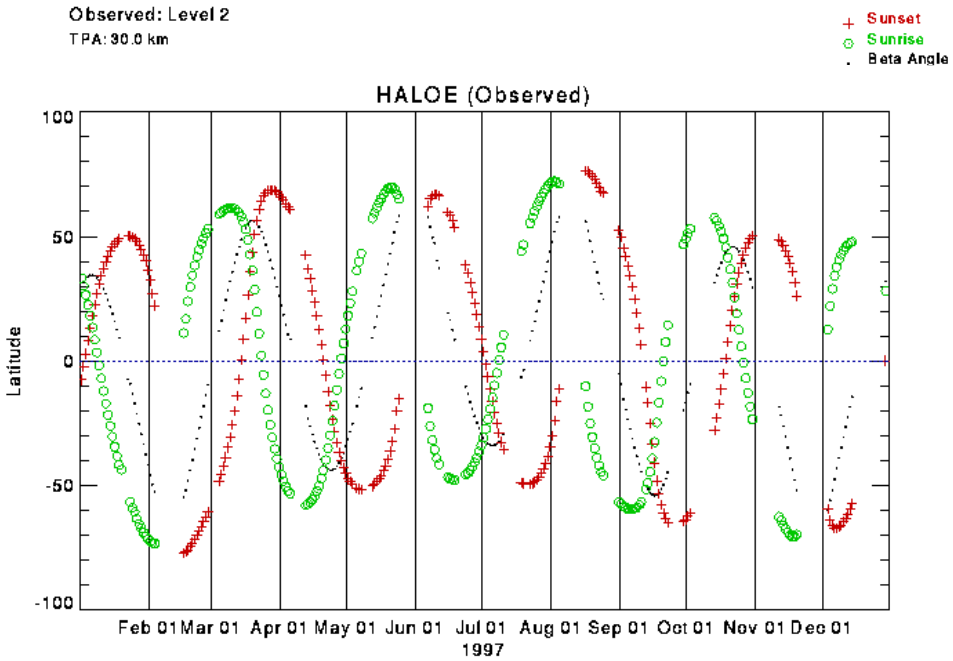
Isotherms over the Globe

FIG. 5. A supply of dry air is maintained by a slow mean circulation from the equatorial tropopause.

HALOE solar occultation measurements

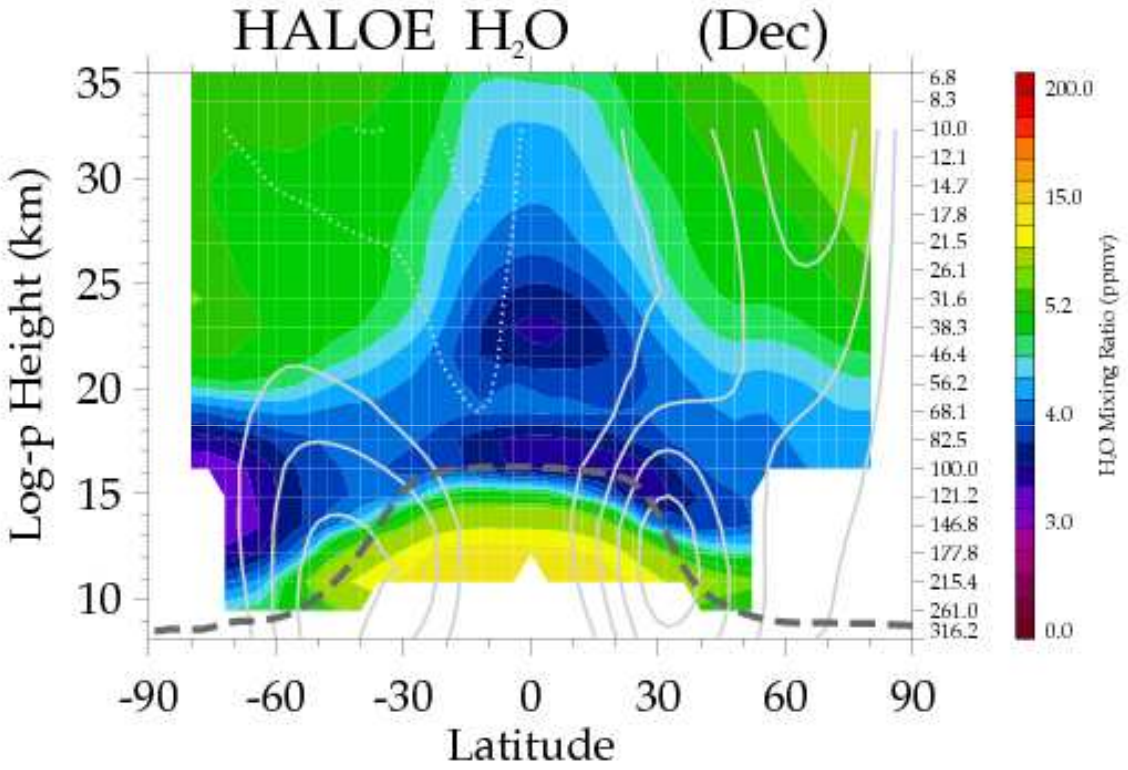


HALOE sampling for one year

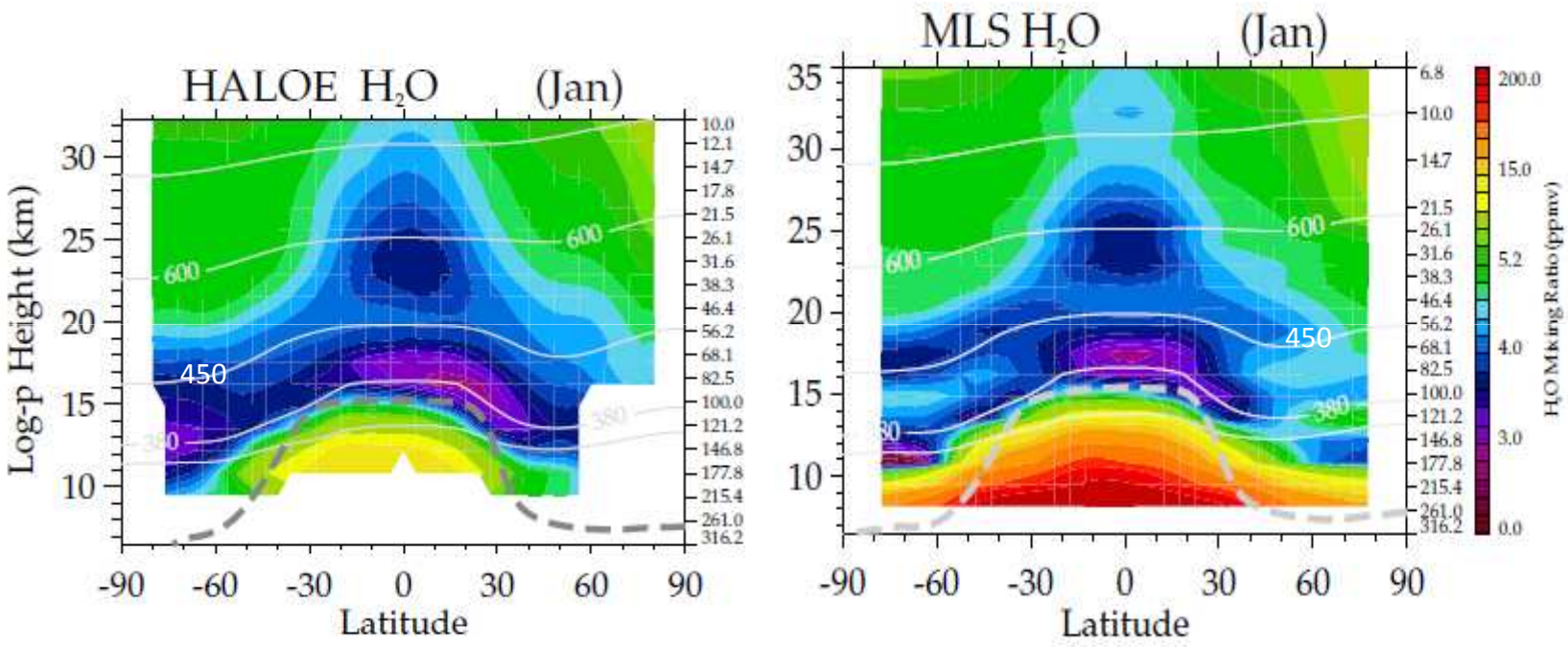


Latitude Progression

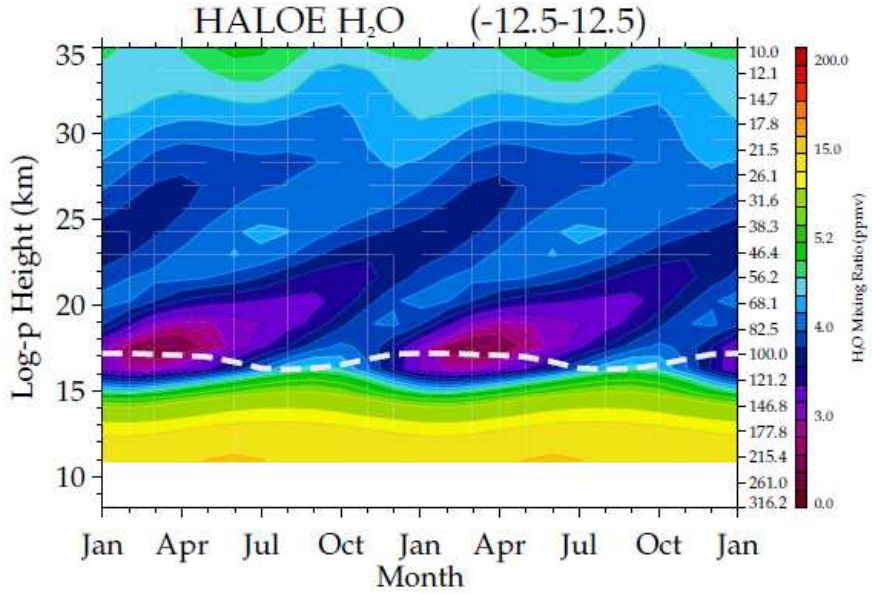
HALOE climatology



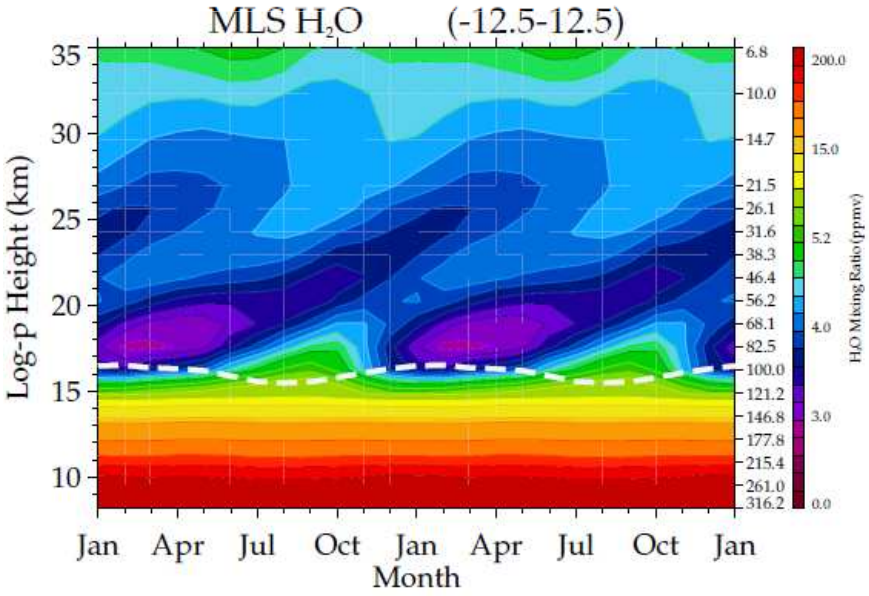
HALOE vs. Aura MLS climatology



Climatological tape recorder

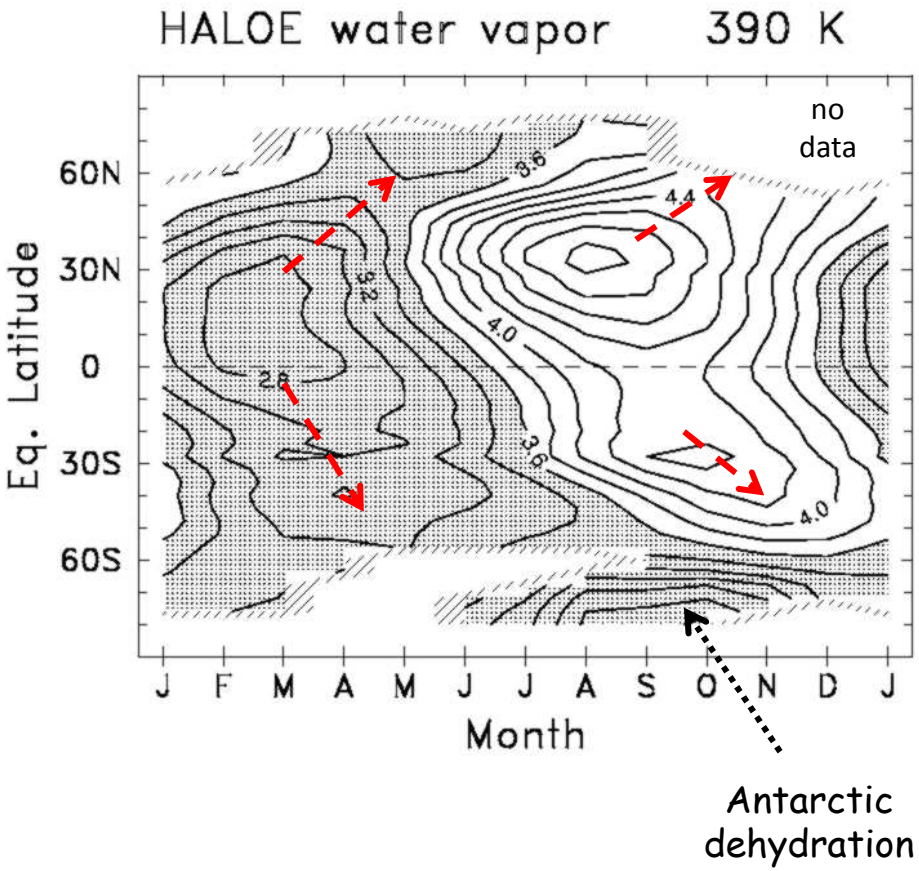


HALOE



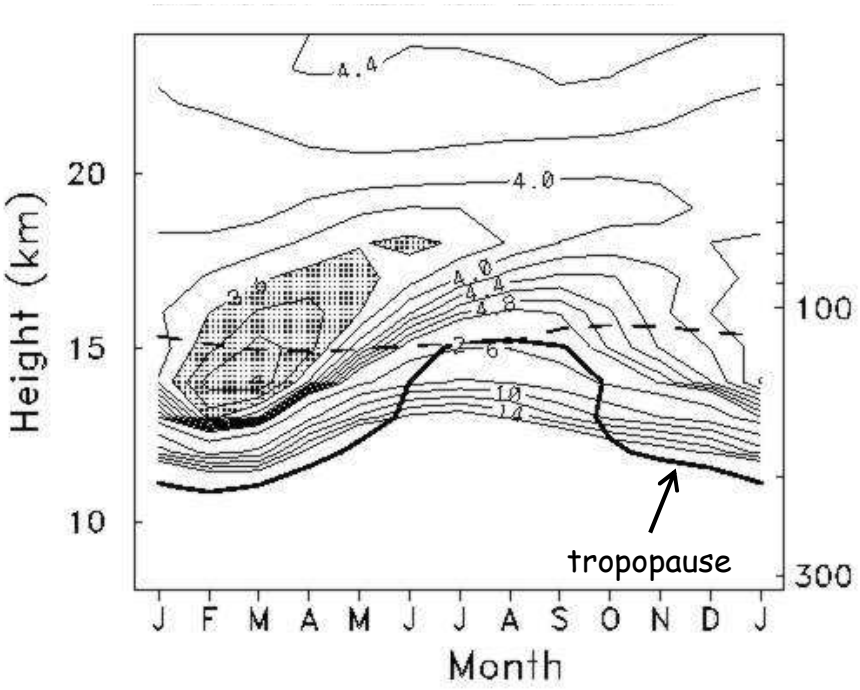
MLS

Latitudinal structure at 390 K (~18 km)

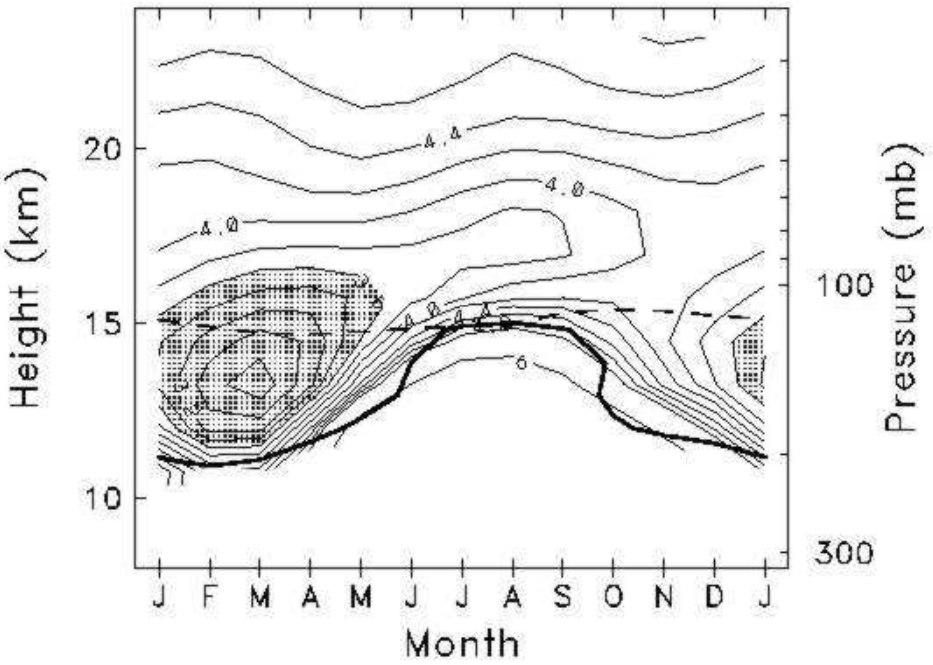


Climatology at Boulder (40° N)

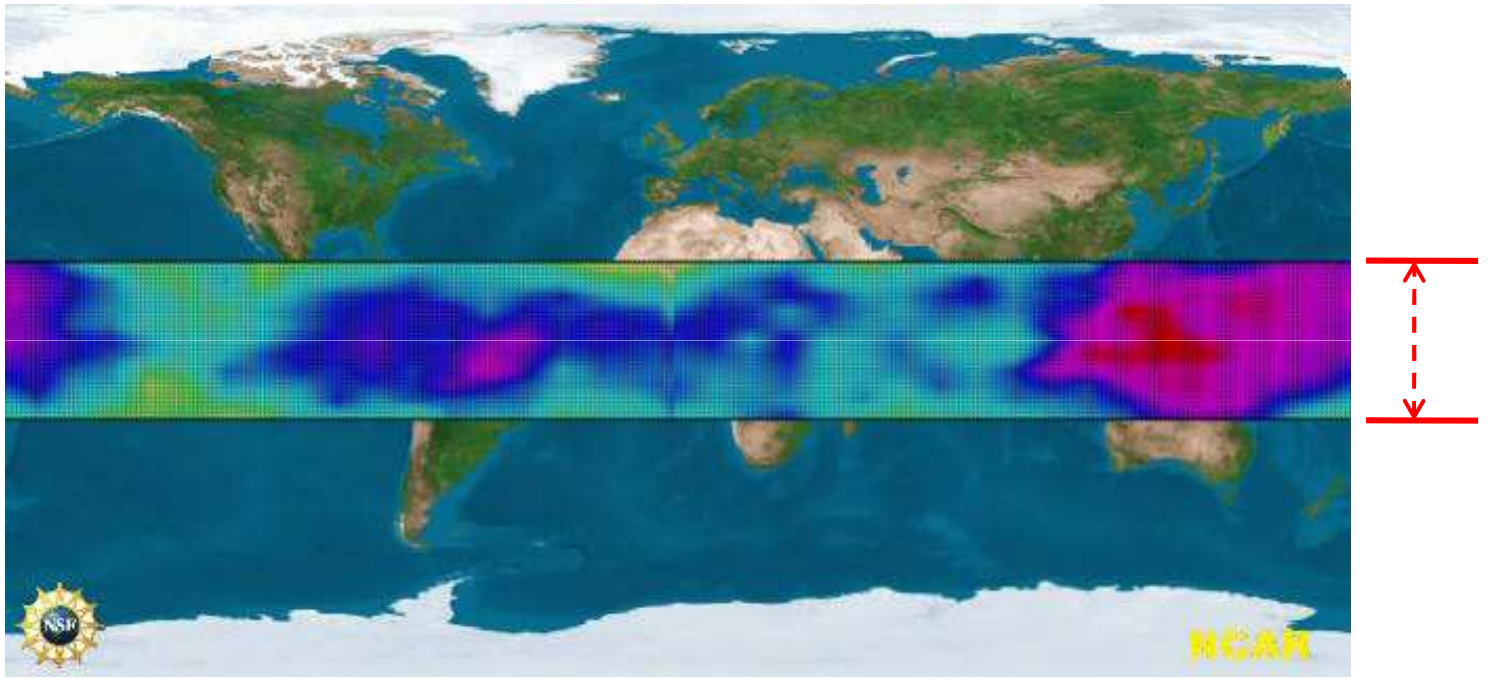
Balloon



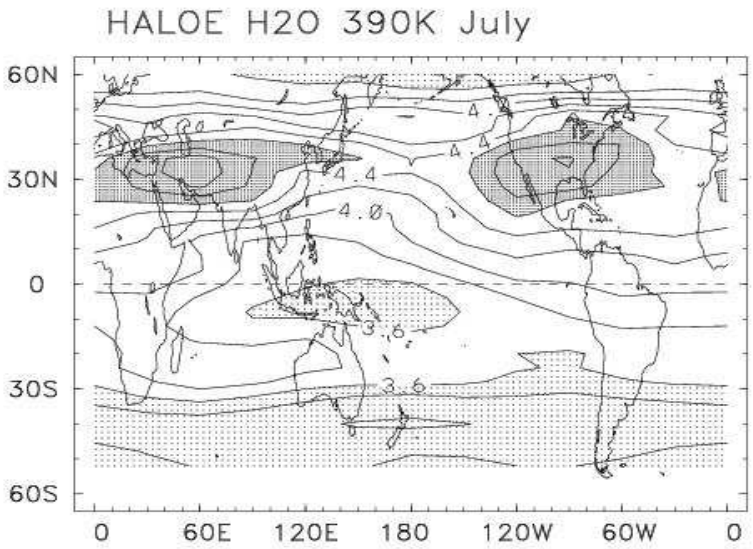
HALOE

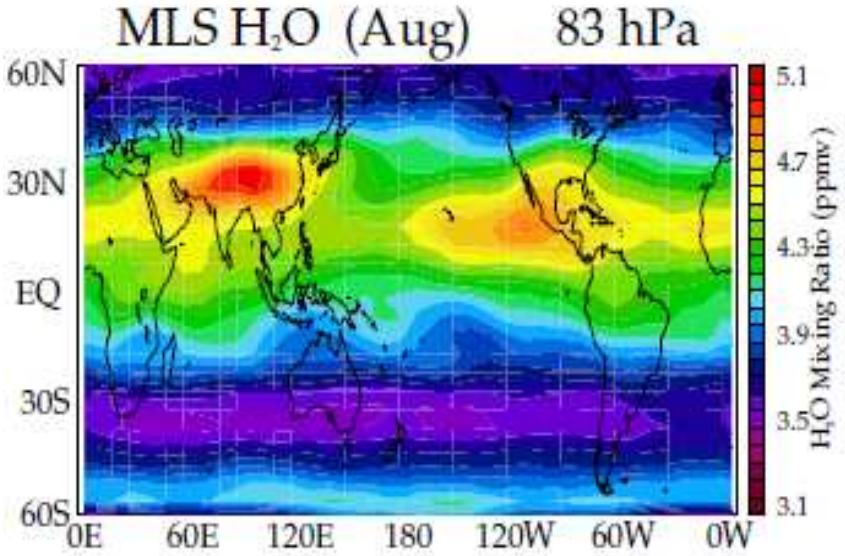


Trajectory simulation of transport on 400 K isentrope

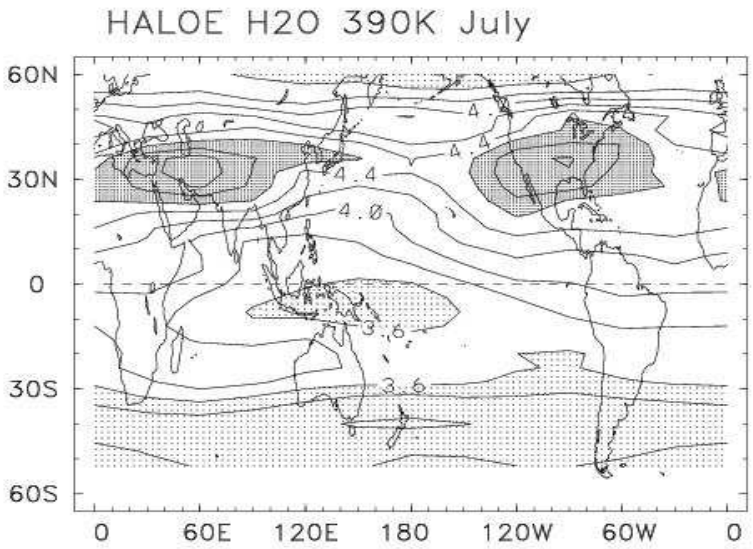


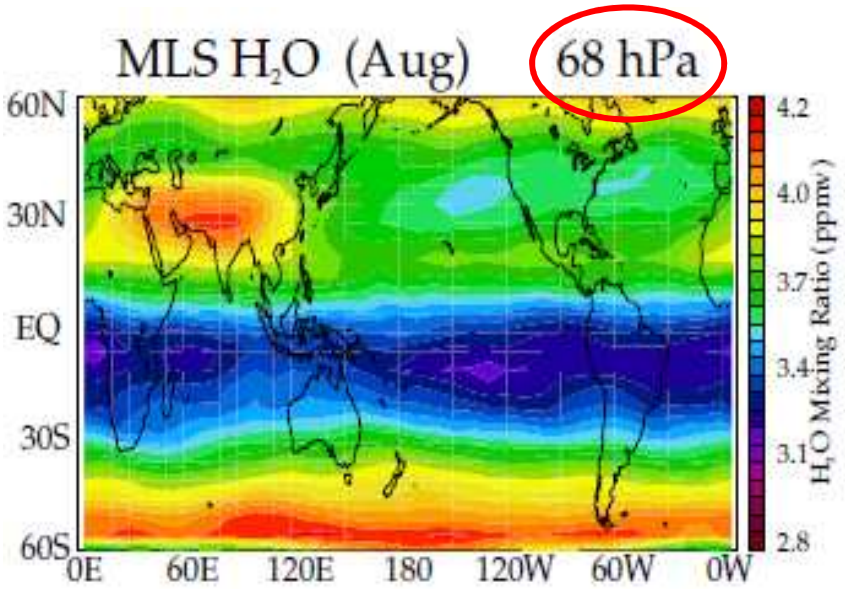
summertime
lower stratosphere
maxima linked to
monsoons

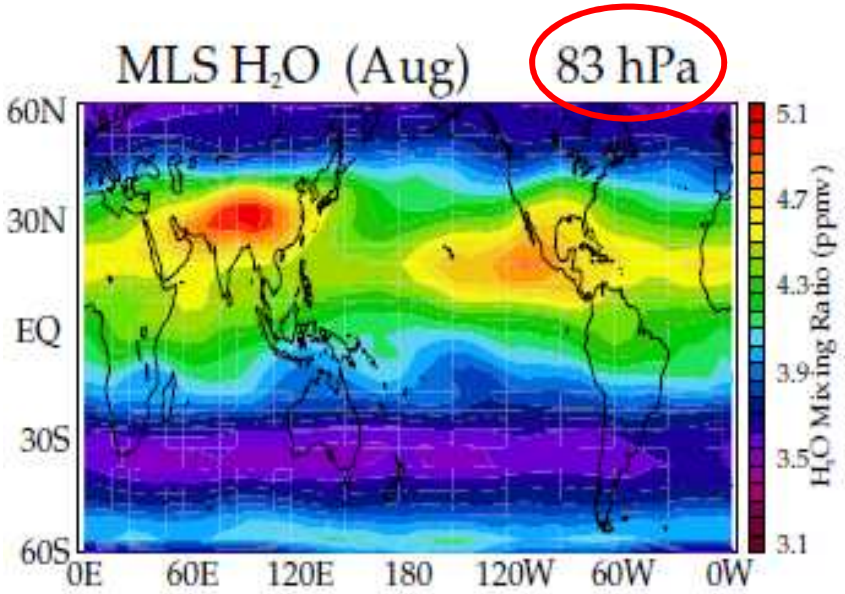




summertime
lower stratosphere
maxima linked to
monsoons



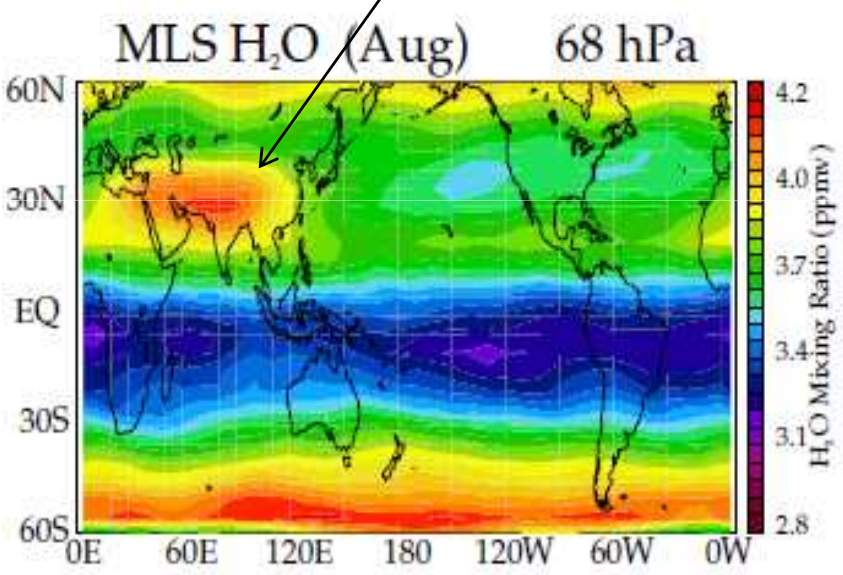


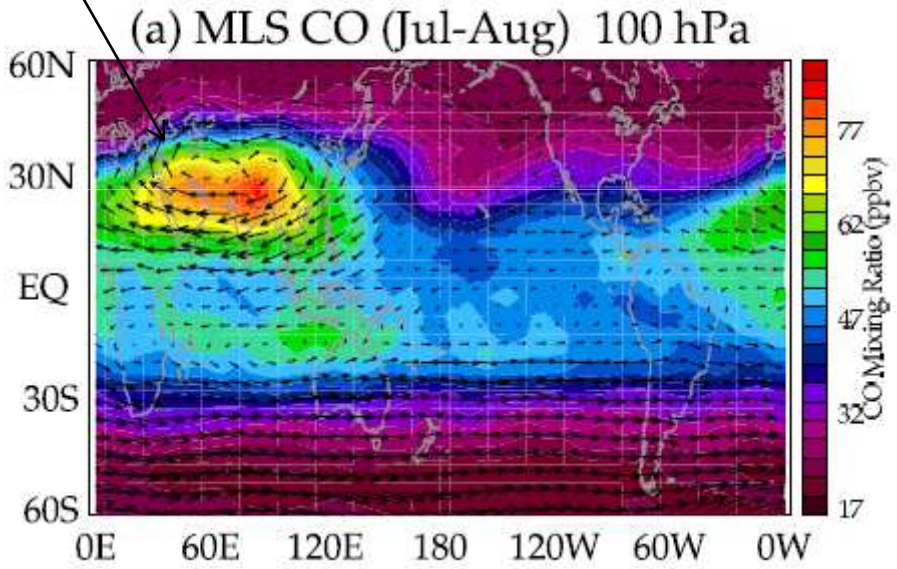


maxima tied to confinement
in Asian monsoon anticyclone

water
vapor

carbon monoxide

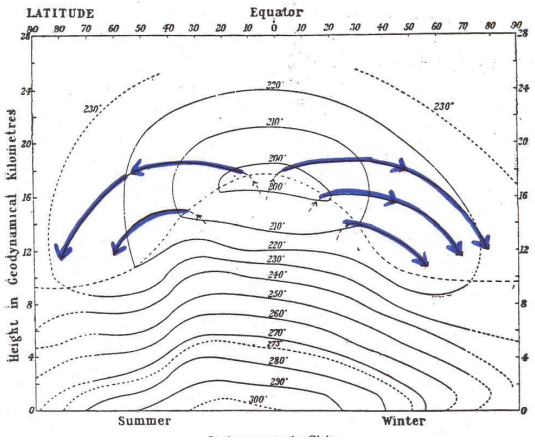




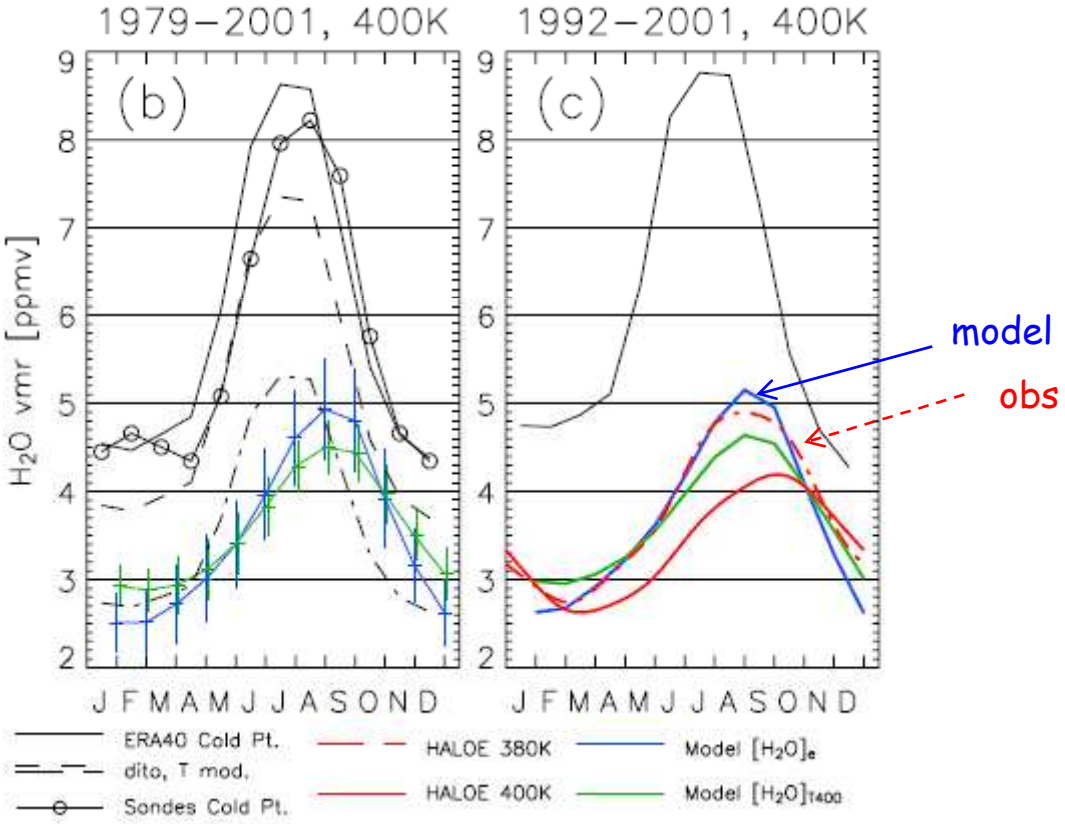
Park et al, JGR, 2006

Seasonal cycle reasonably well understood based on trajectory calculations

* dehydration at cold point *



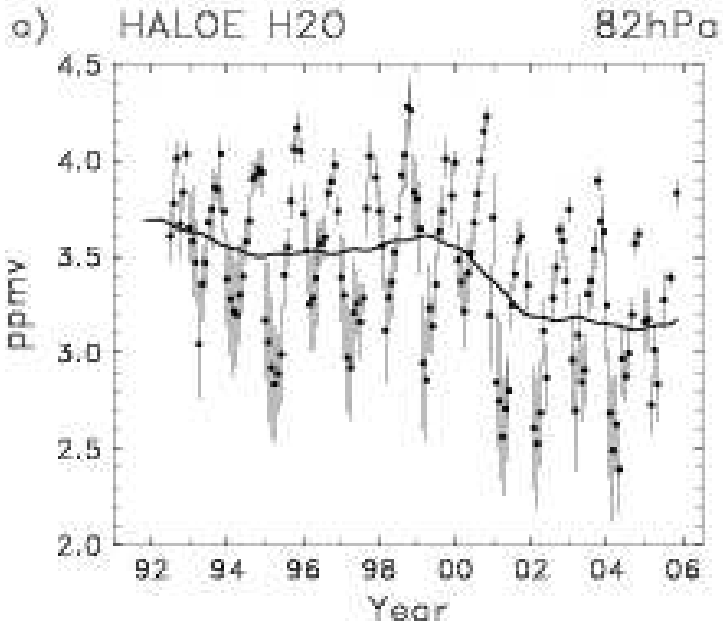
Brewer, 1949



Fueglistaler et al 2005

Interannual variability from HALOE

global mean, 82 hPa



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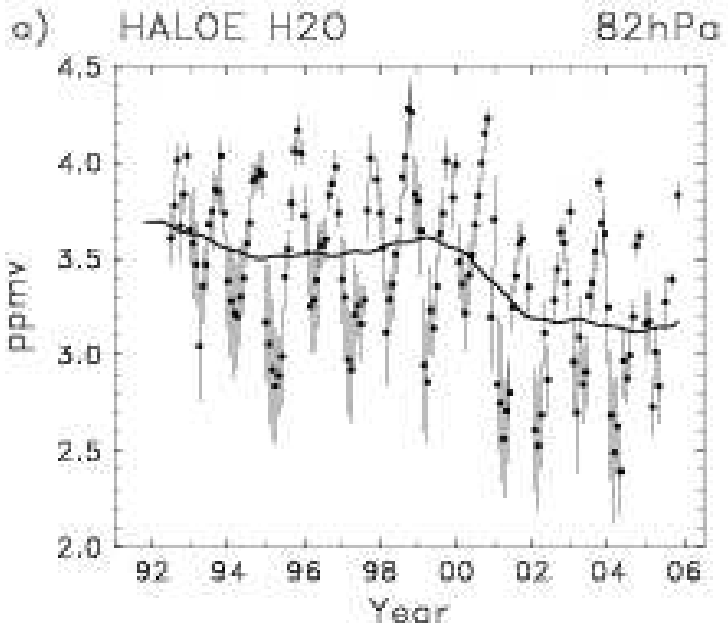
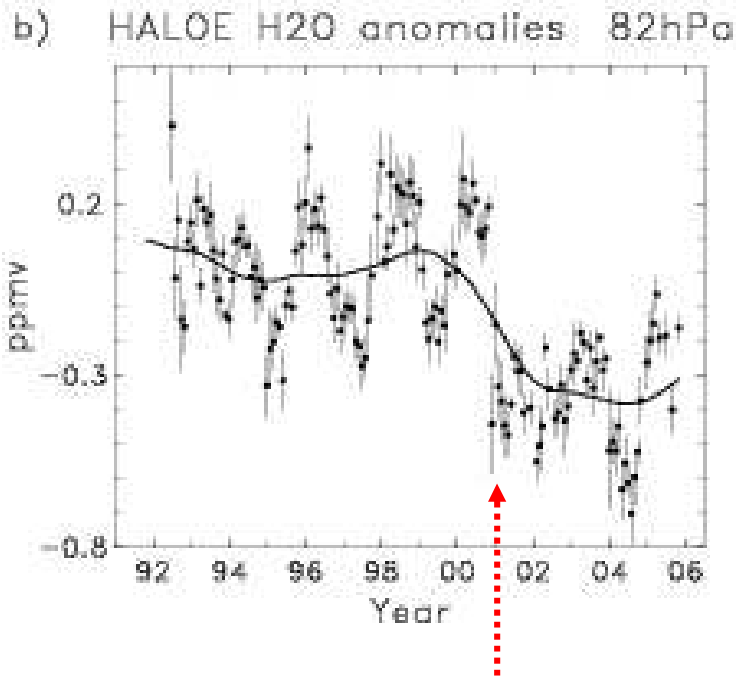
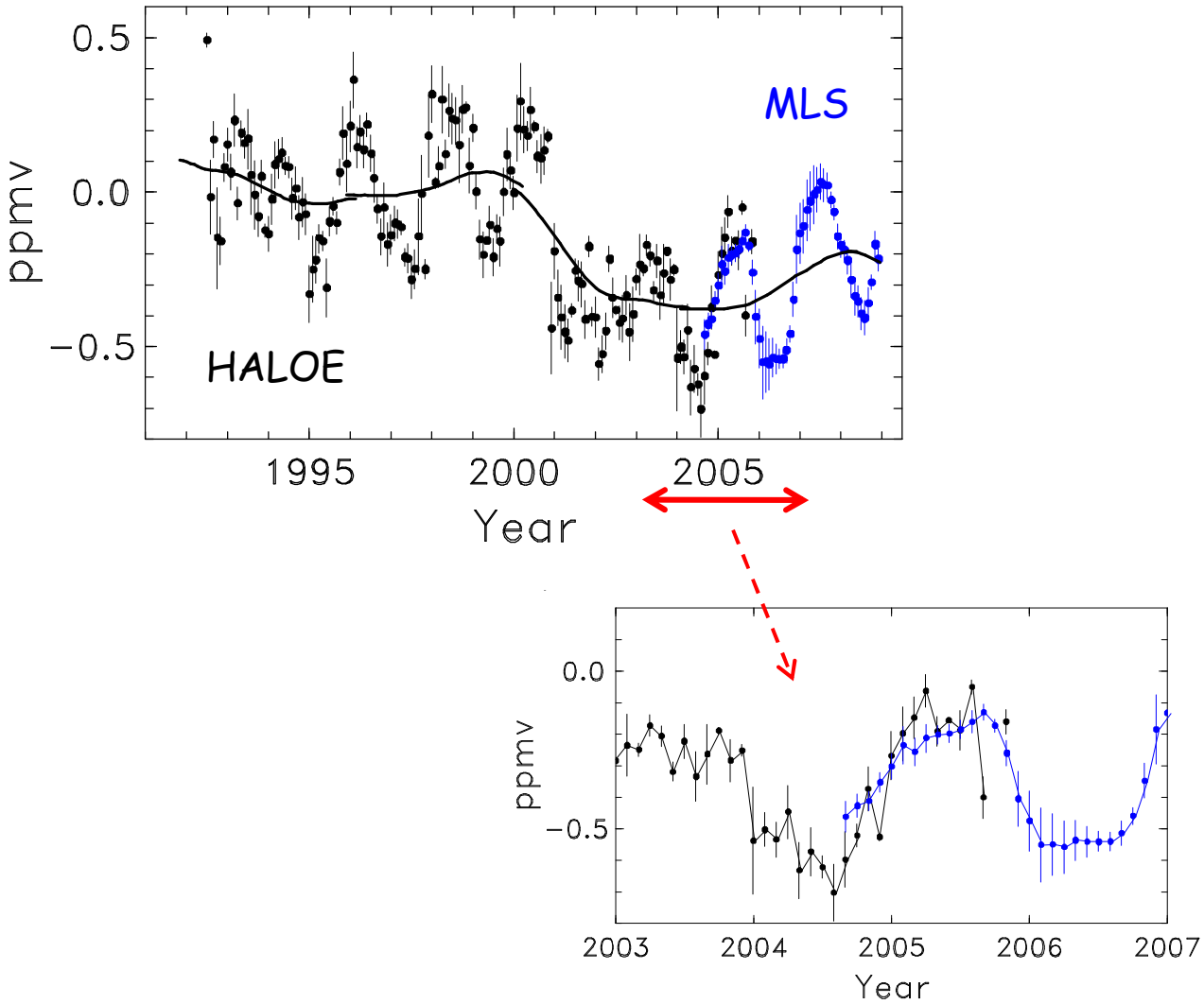


deseasonalized



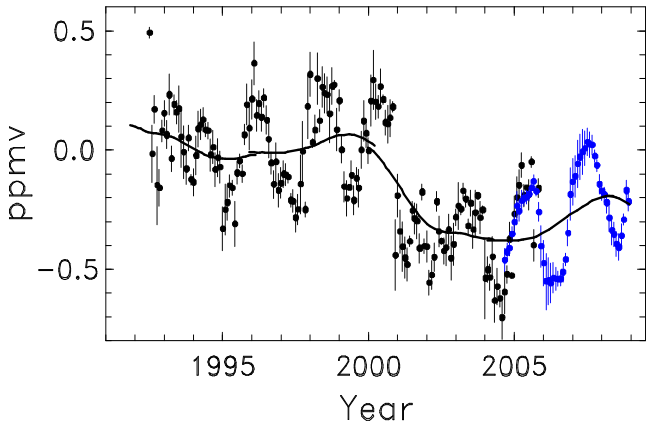
decrease after 2001

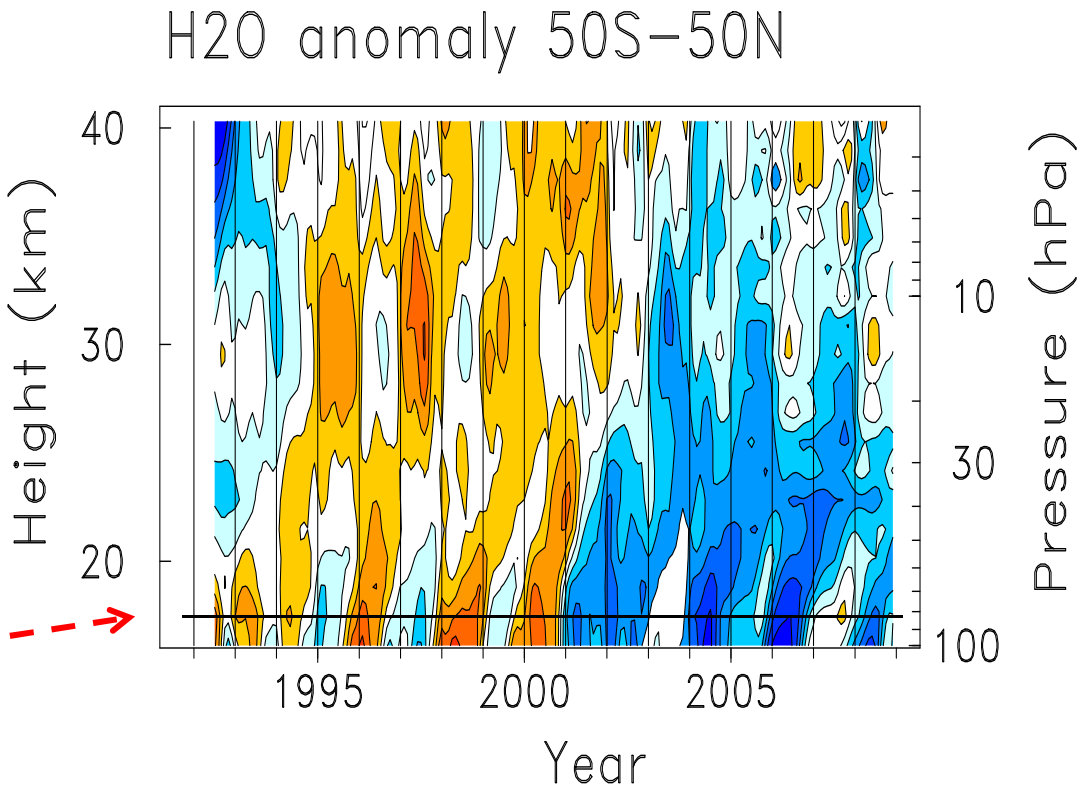
Extending the satellite record: HALOE + Aura MLS data



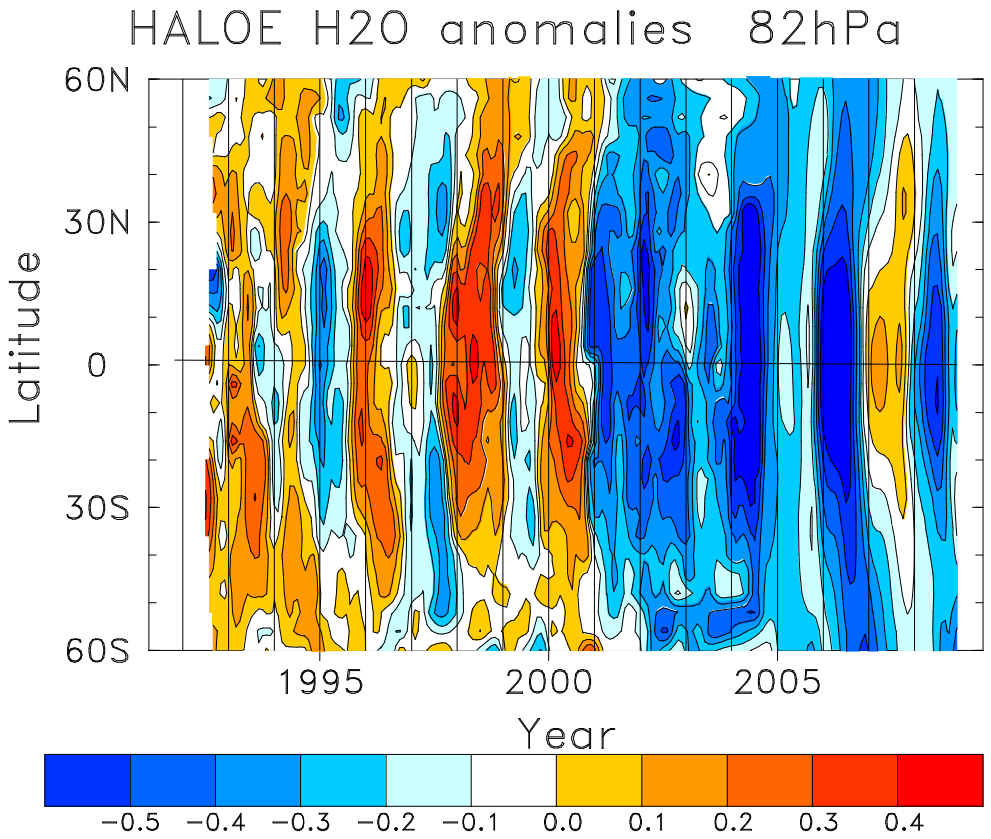
Anomalies originate near the tropical tropopause, and propagate coherently with time

Deseasonalized anomalies

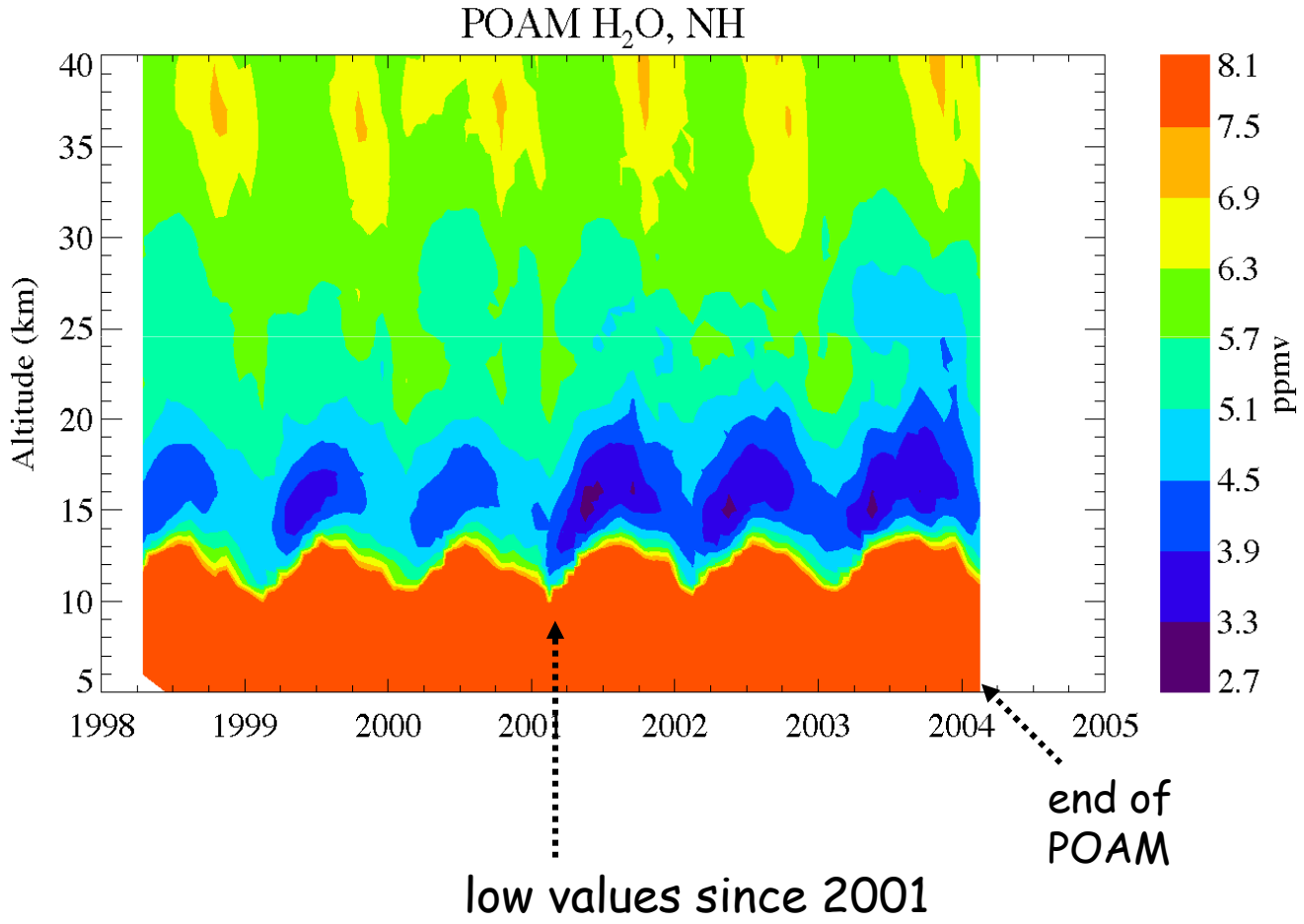




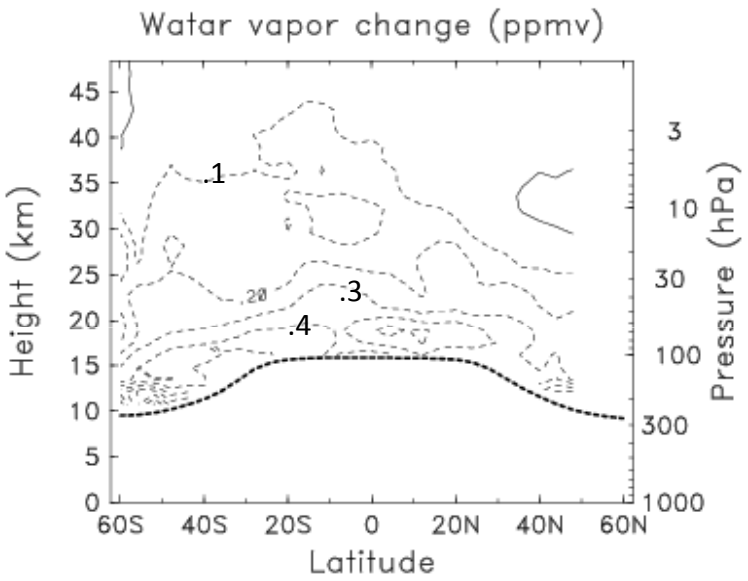
Rapid latitudinal propagation in lower stratosphere



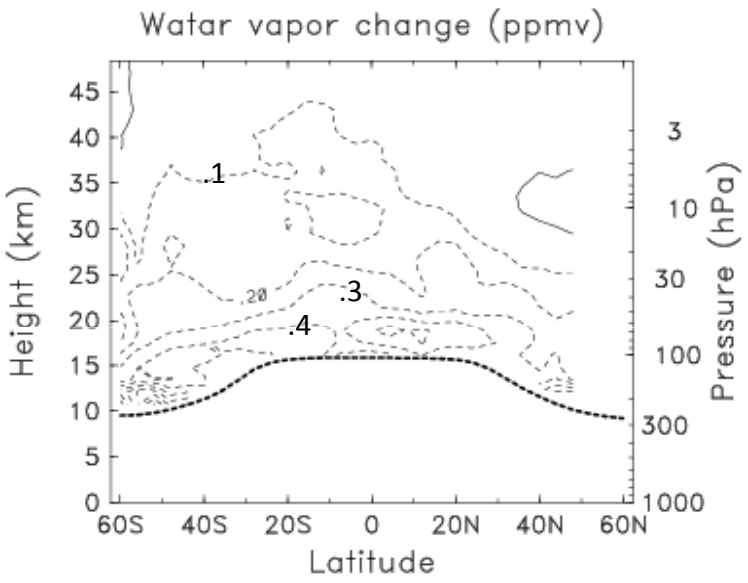
POAM Arctic water vapor (lats 55-70 N)



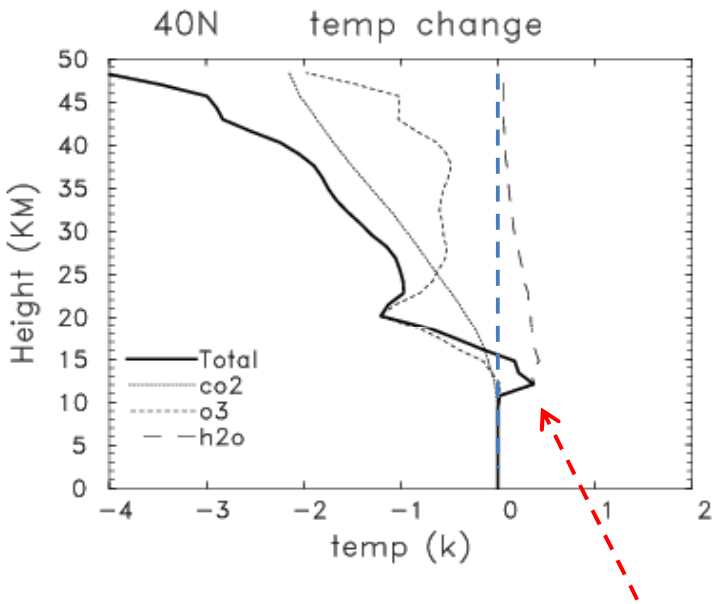
Water vapor differences
Pre- vs. post 2001



Water vapor differences
Pre- vs. post 2001

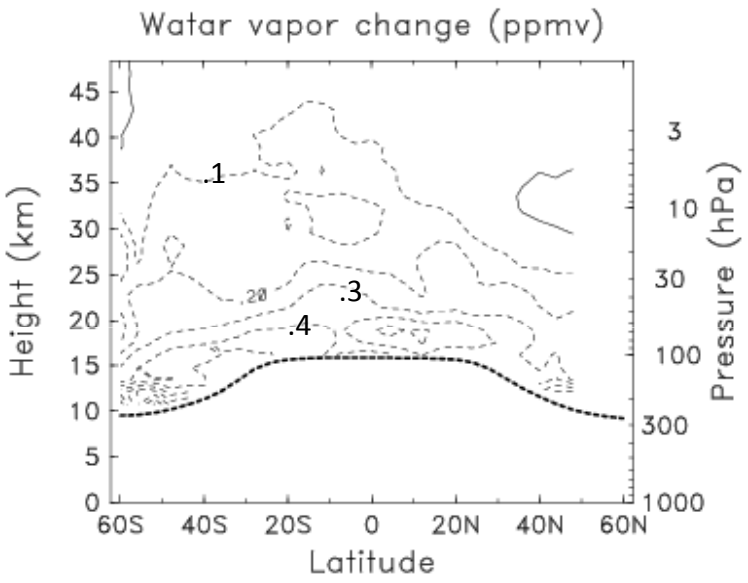


Radiative influence on temperature
(Fixed Dynamical Heating calculations)



Water vapor decreases
associated with warming

Water vapor differences
Pre- vs. post 2001



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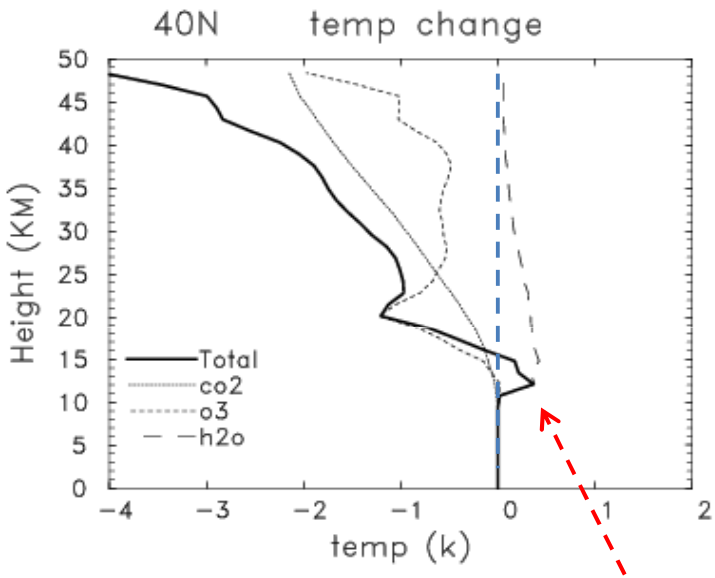
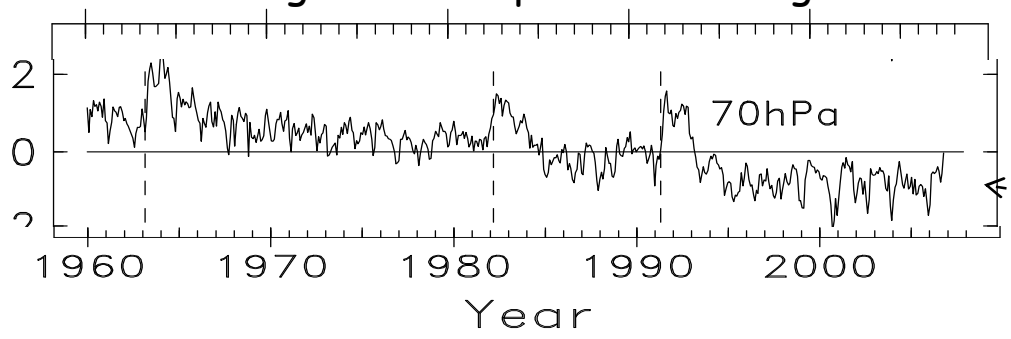


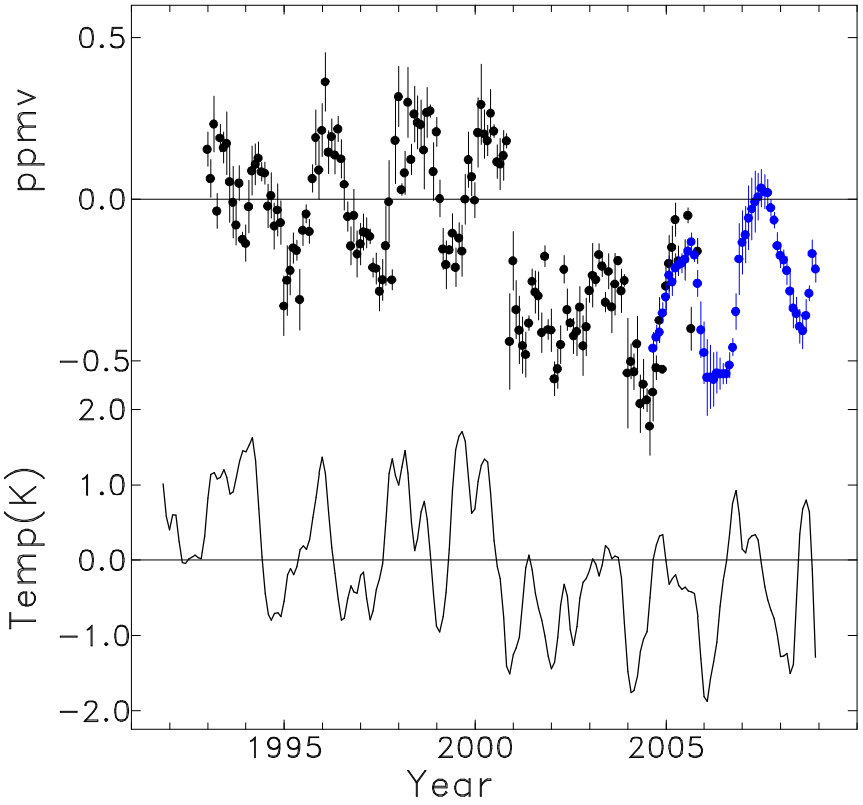
Water vapor decreases associated with warming

Long-term temperature changes



flat since ~1995

Correlations with tropical tropopause temperatures

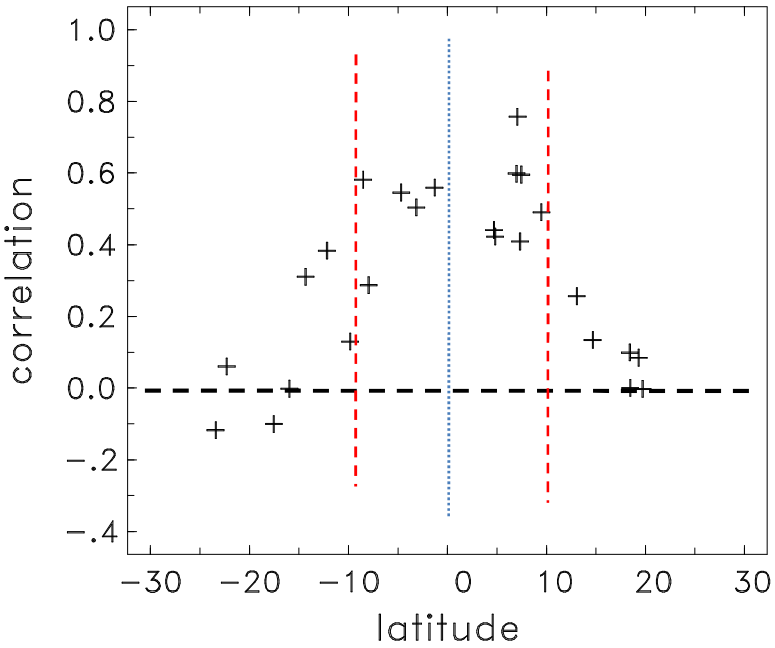


82 hPa water vapor

cold point temperature anomalies

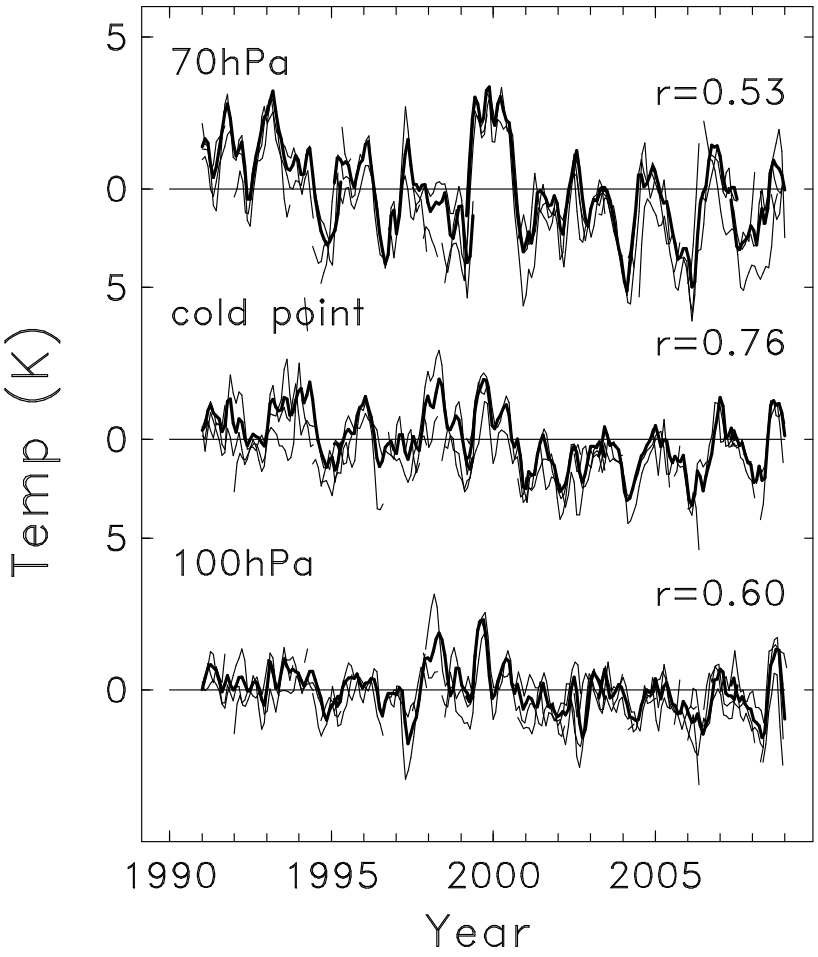
r=0.76 lag=2 months

Correlation between water vapor and cold point temperature anomalies for individual radiosonde stations 1993-2008



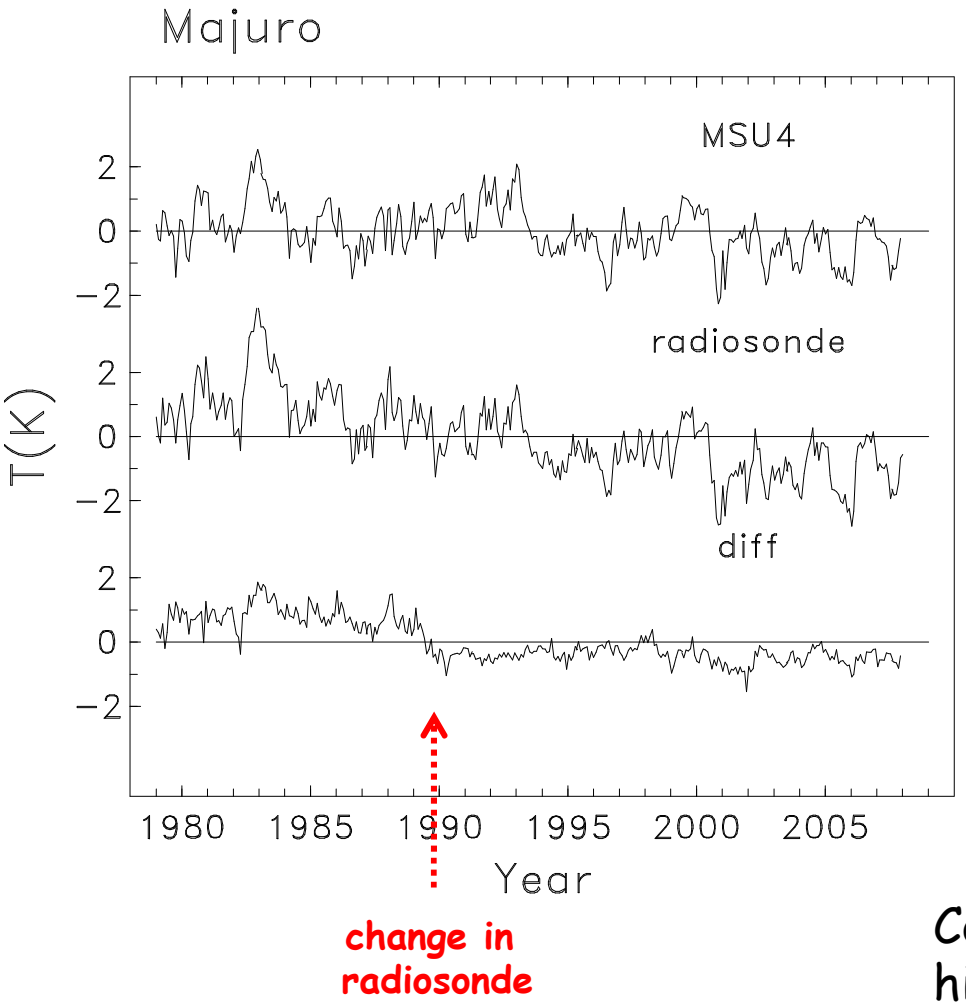
Strongest correlations for stations 10 N-S, linked to the QBO

Tropical radiosondes: Nairobi, Majuro, Manaus



← Best correlations using cold point

Beware problems with historical radiosonde data



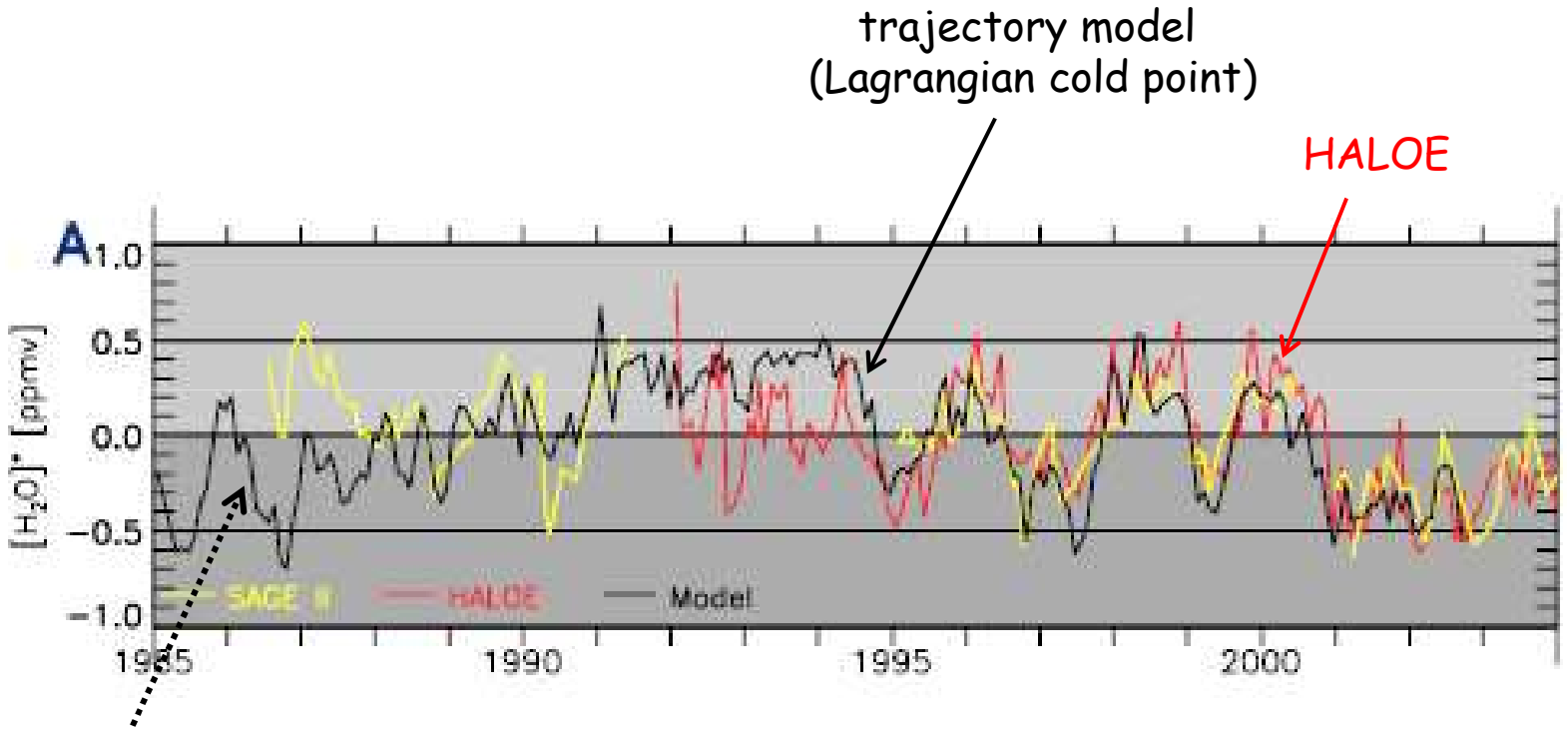
satellite

radiosonde

difference

Common problem; many historical radiosonde data have similar jumps

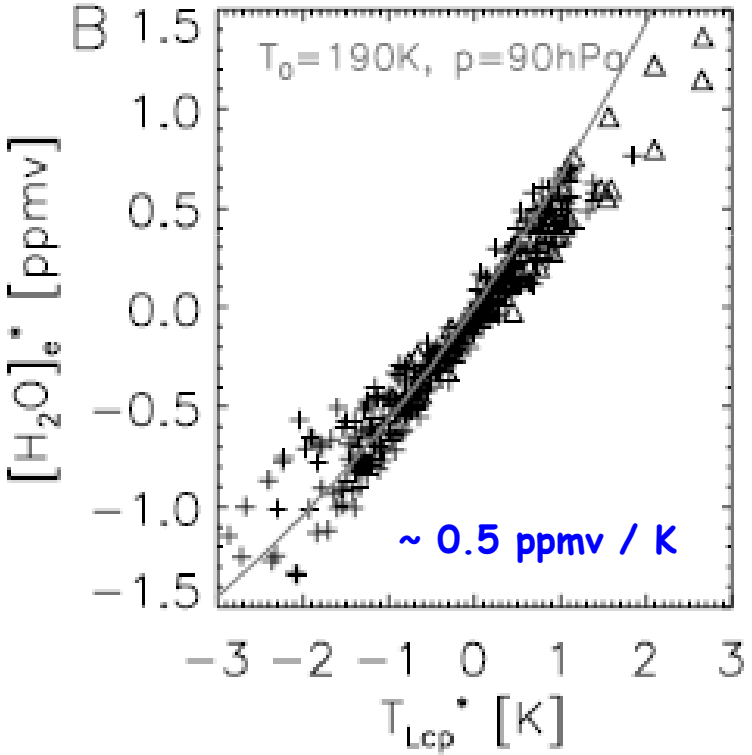
Observed vs. calculated interannual changes



Fueglistaler and Haynes, 2005

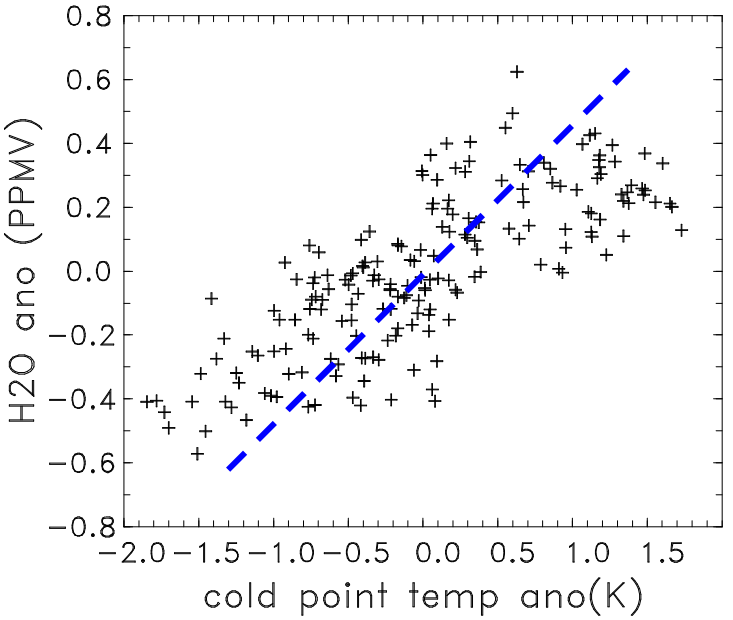
Water vapor – temperature sensitivity

Lagrangian trajectory model



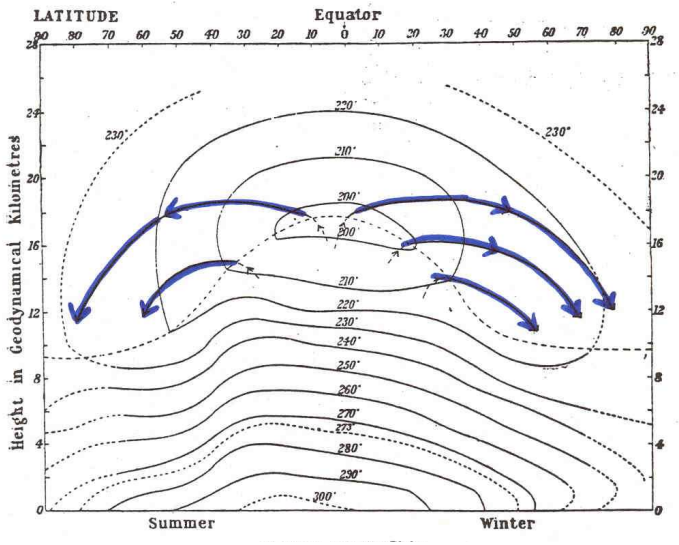
Fueglistaler and Haynes, 2005

observations with cold point temps



Summary:

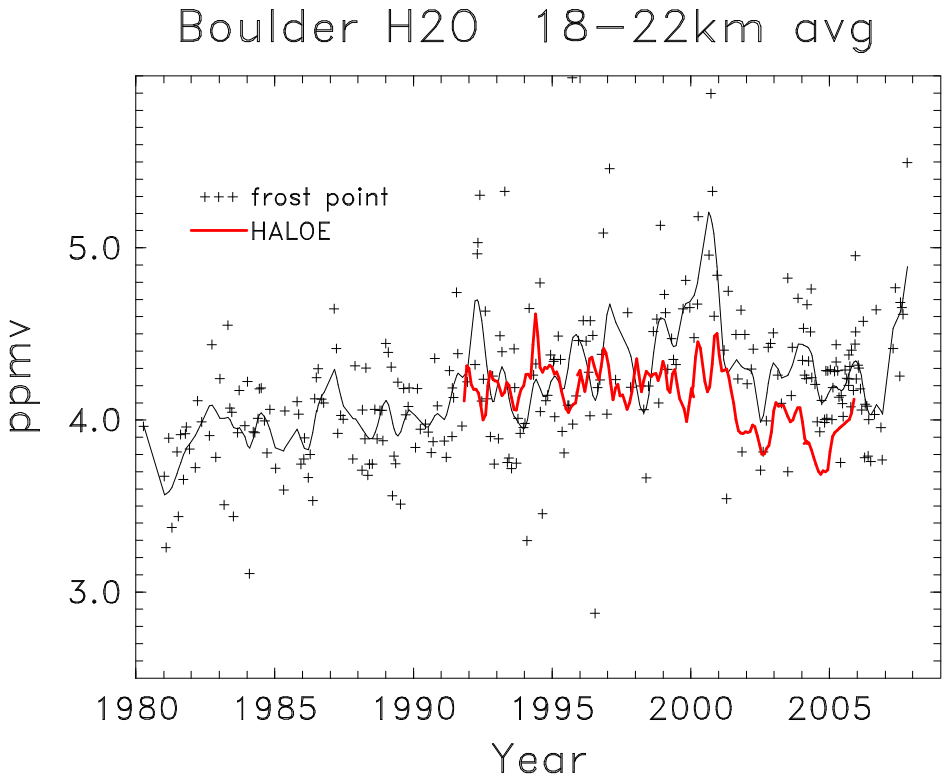
For satellite record (1993-2008), interannual variability
in good agreement with temperature near tropical cold point



Brewer, 1949

What caused the drop after 2001 ?

Comparison between Boulder sondes and HALOE



see Scherer et al, 2008, ACP

The only two continuous data sets for stratospheric water vapor disagree in 'trends' for 1992-2005.

Frost-point balloon data:

*calibrated, trusted technique

* ~once-month 'snapshot' sampling

HALOE:

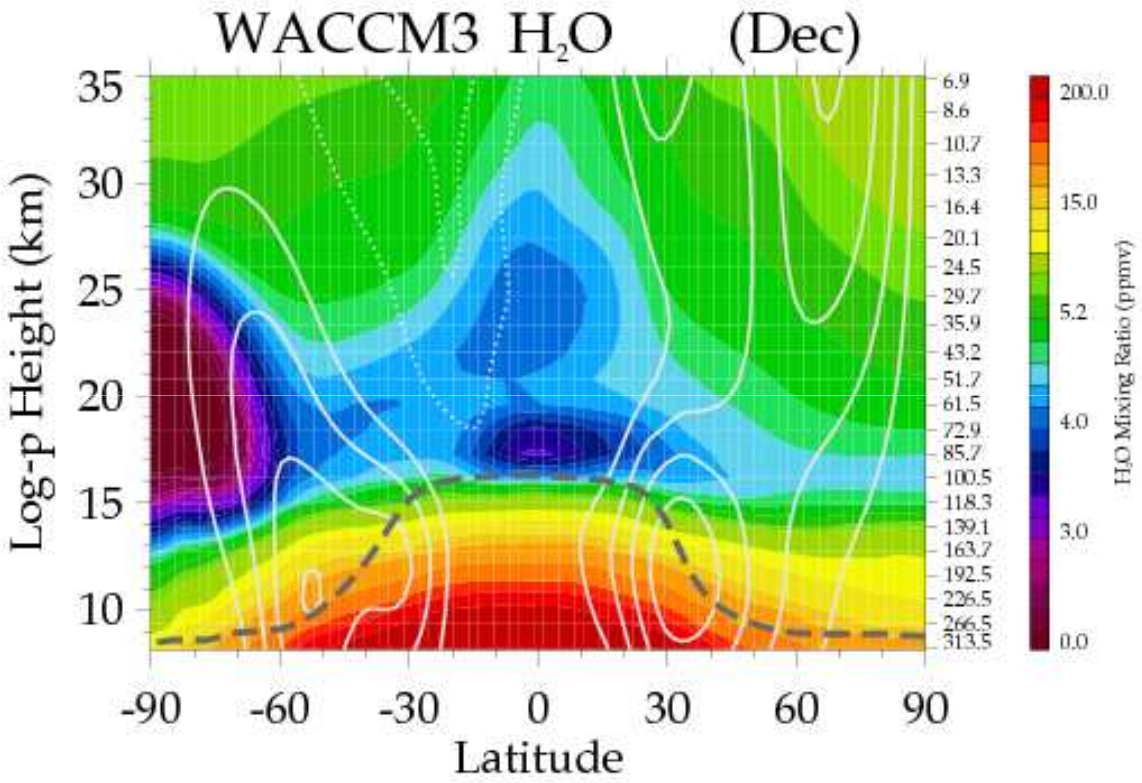
*calibrated, trusted technique

*global sampling

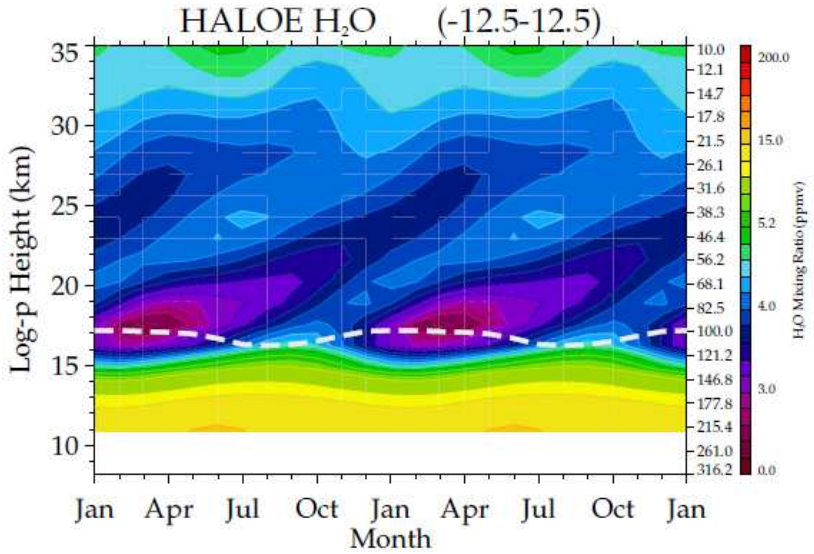
*internal geophysical coherence:

- anomalies propagate in latitude/height
- variations strongly correlated with tropical tropopause temperatures

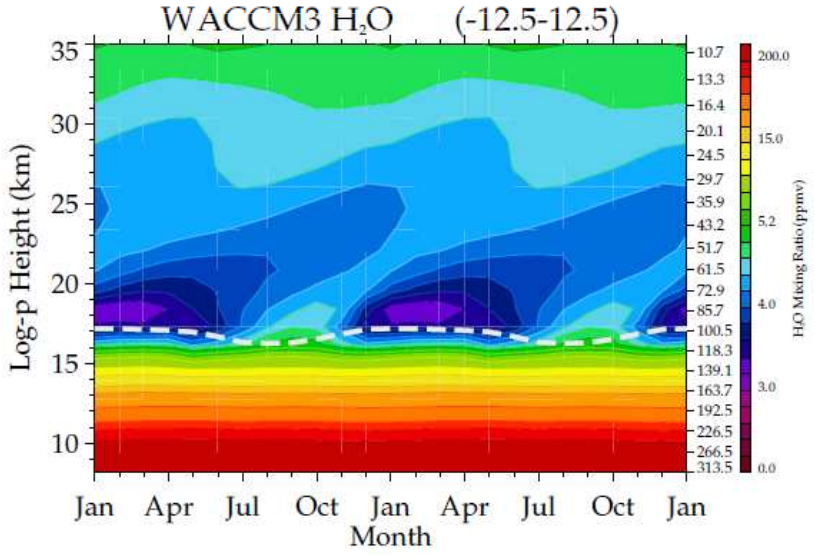
WACCM model climatology



HALOE vs. WACCM

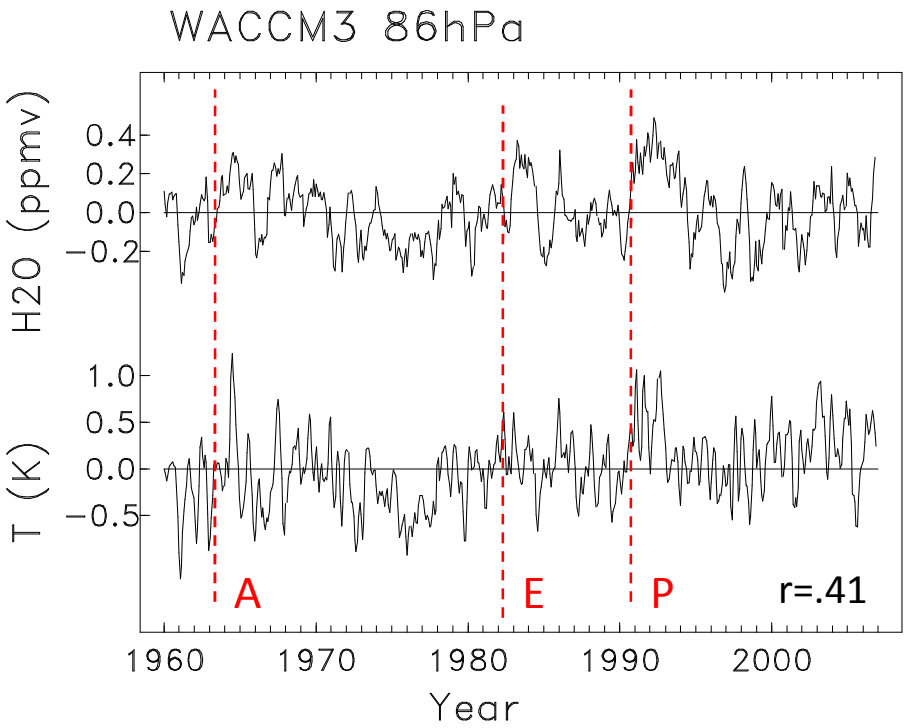


HALOE



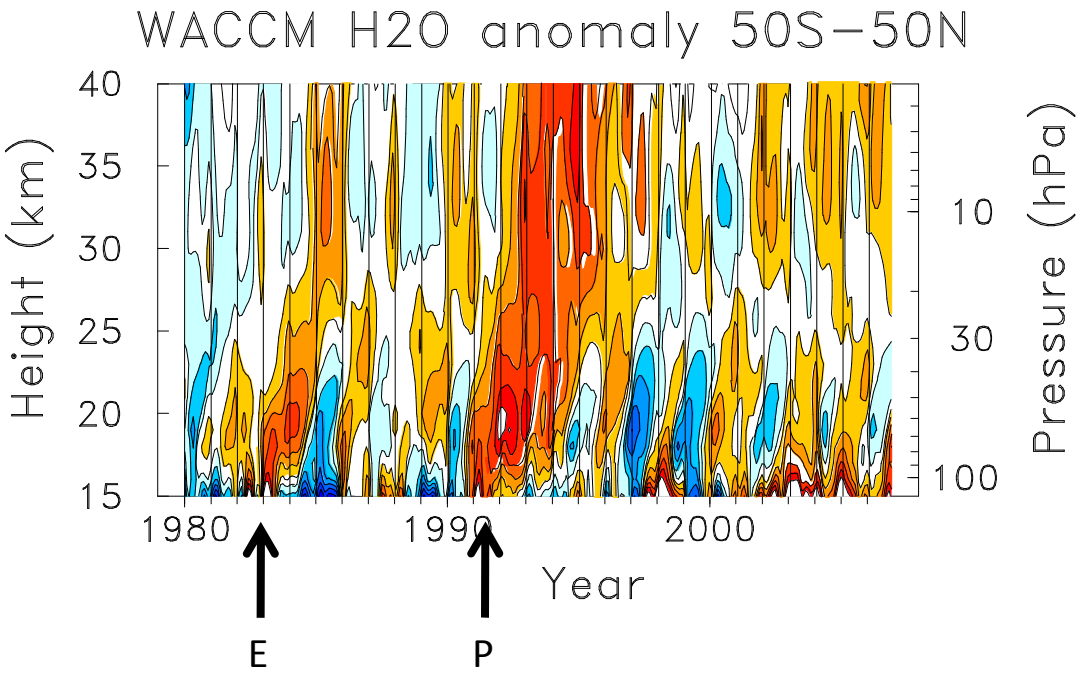
WACCM

Water vapor in a climate model (WACCM REF1)



86 hPa water vapor

cold point temperature anomalies



In the model, volcanoes dominate interannual variability

Key points:

- Stratospheric seasonal cycle is well understood. Tropical tape recorder, rapid global transport in lower stratosphere, Antarctic dehydration, monsoons in UTLS during NH summer.

- Interannual changes for satellite record (1992-2008) in good (quantitative) agreement with tropical cold point. Remaining differences between Boulder sondes and HALOE.

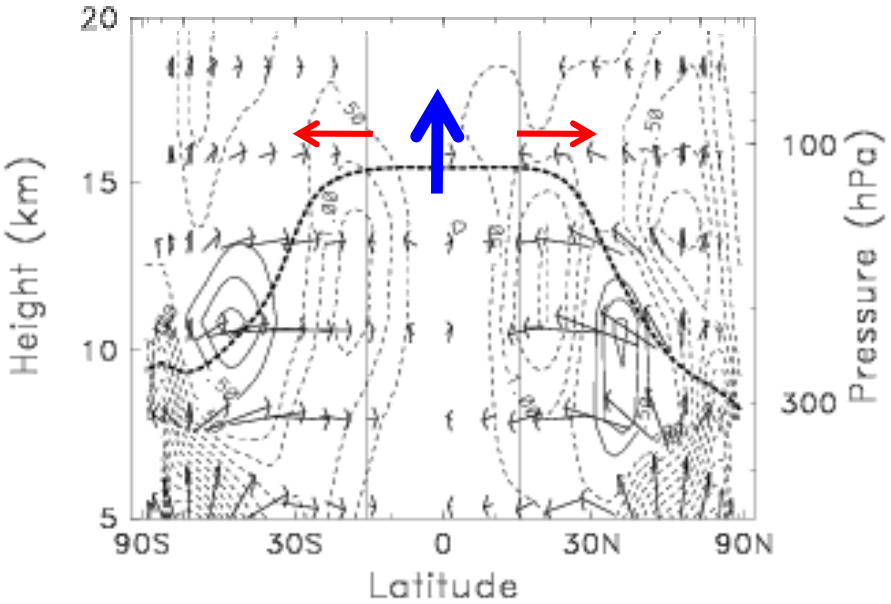
- Overall similar variability in current chemistry-climate models.

Estimates of tropical upwelling from 'downward control' (momentum balance plus continuity)

$$\langle \overline{w}^*_m \rangle(z) = \frac{e^{z/H}}{\int_{-\phi_0}^{\phi_0} a\cos\phi\, d\phi} \left\{ \frac{-\cos\phi}{\hat{f}(z,\phi)} \int_z^{\infty} [\mathrm{DF}(\phi, z') - \overline{u}_1(\phi, z')]_{\overline{m}}\, e^{-z'/H}\, dz' \right\}_{-\phi_0}^{+\phi_0},$$

EP flux divergence

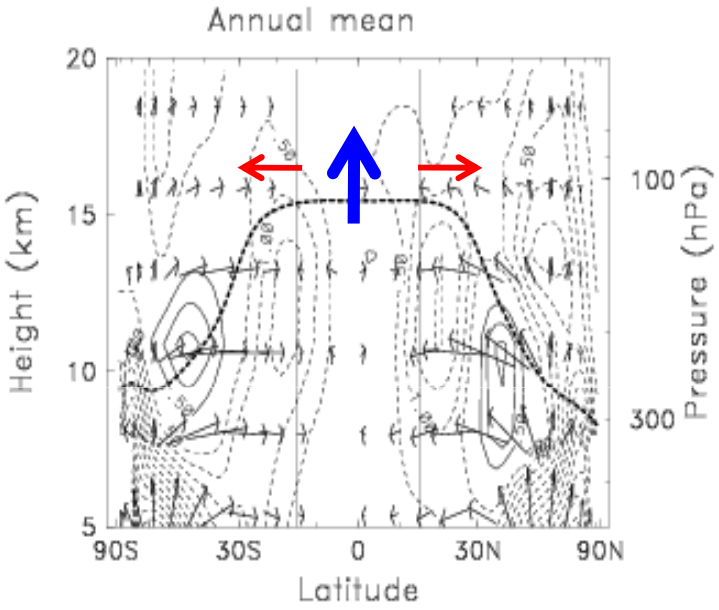
Climatological EP flux structure



sensitive calculation:

- dependent on EP fluxes in subtropics
- proportional to 1/f

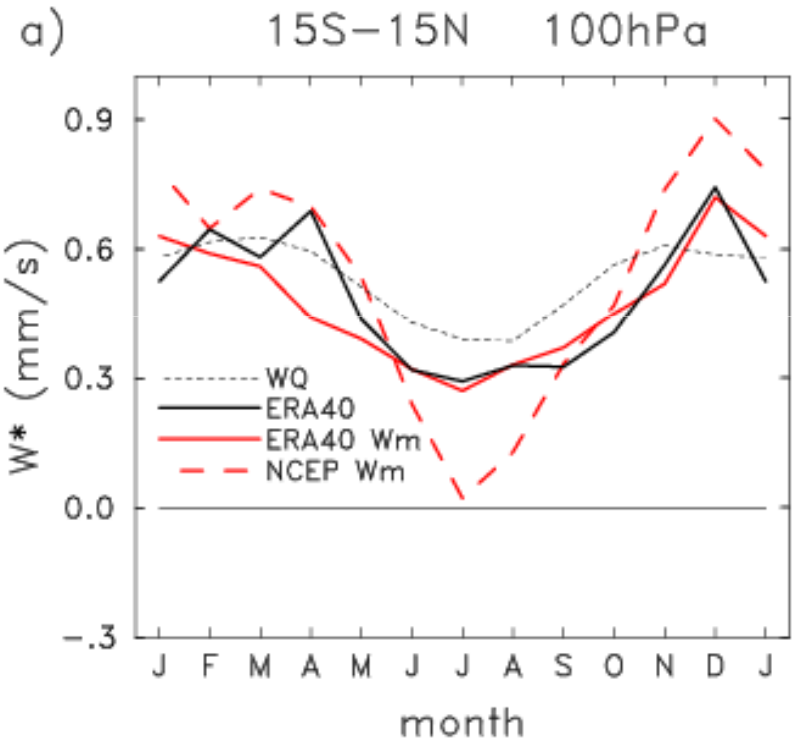
Calculated upwelling from mass balance seems reasonable



Tropical upwelling is primarily due to EP flux convergence in subtropics

(subtropical Fy, not high latitude Fz)

Upwelling at 100 hPa



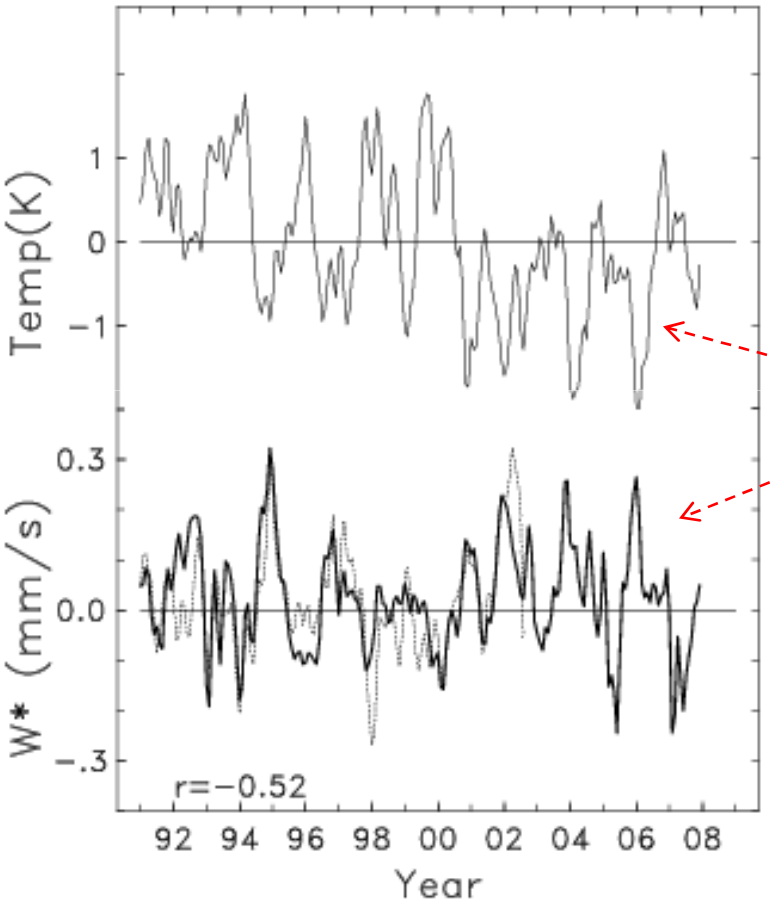
Comparison of upwelling calculated from momentum balance, reanalysis, and thermodynamic balance

Interannual anomalies in temperatures and upwelling

temps from radiosondes

upwelling from momentum balance

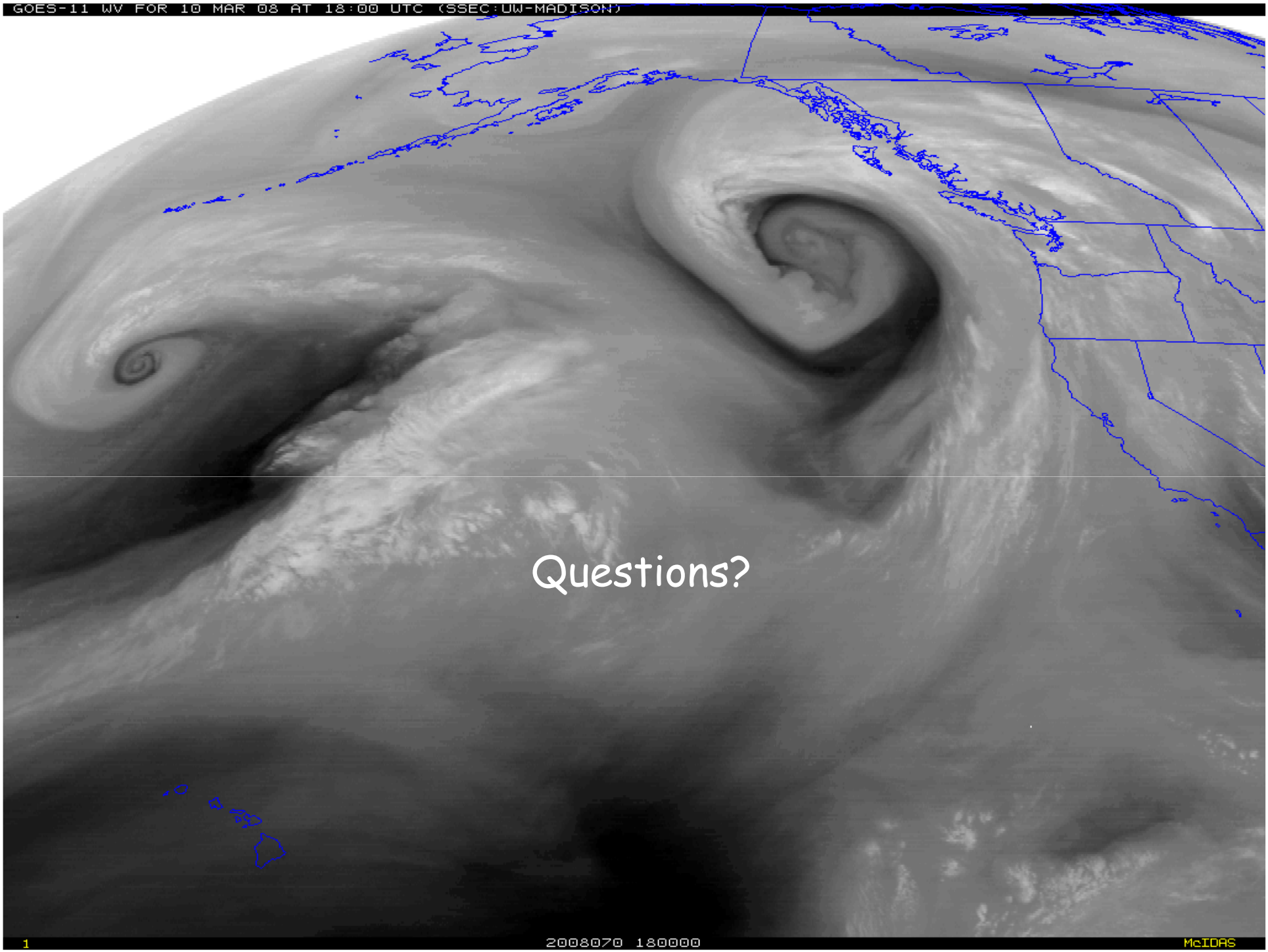
----- ERA40
—— NCEP



note these are completely independent quantities

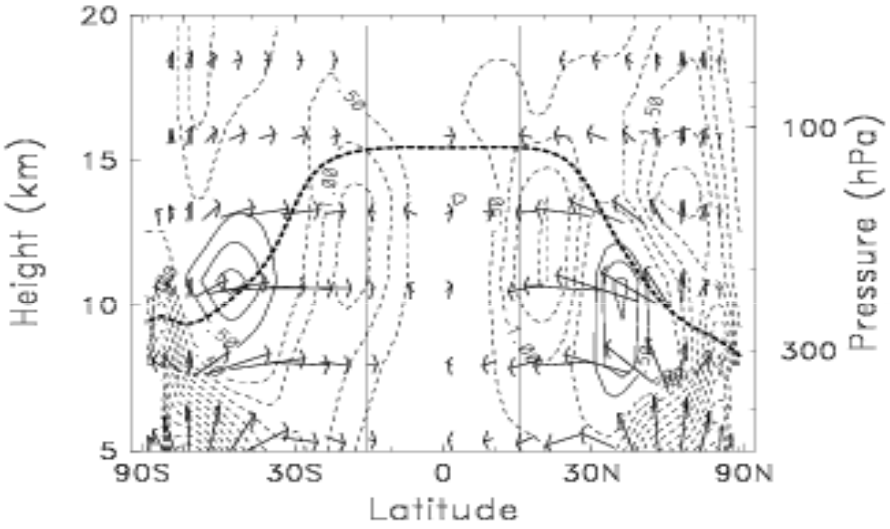
colder temps and stronger upwelling

r=-0.52 **(I am surprised)**

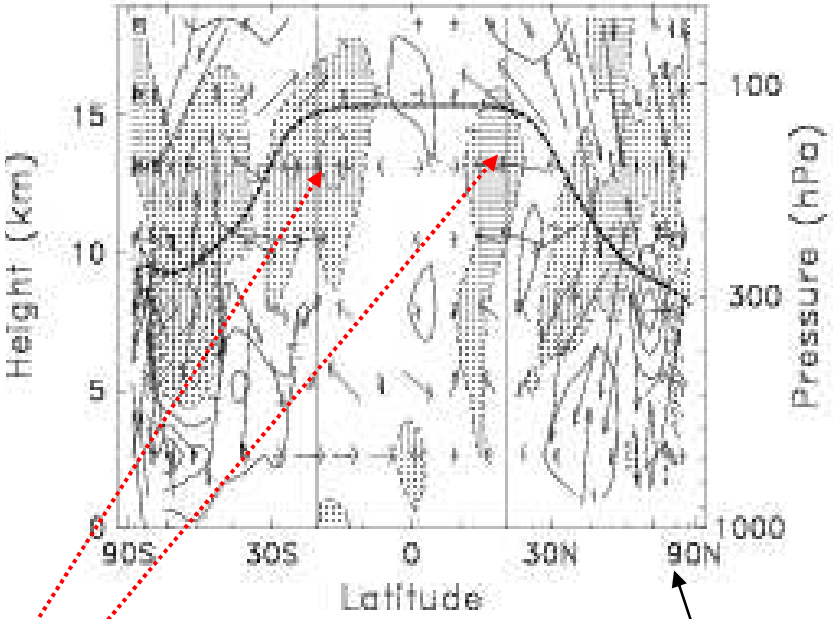

GOES-11 WV FOR 10 MAR 08 AT 18:00 UTC (SSEC:UW-MADISON)
Questions?
1
2008070 180000
McIDAS

Where do the changes in EP flux come from?

EP flux Climatology



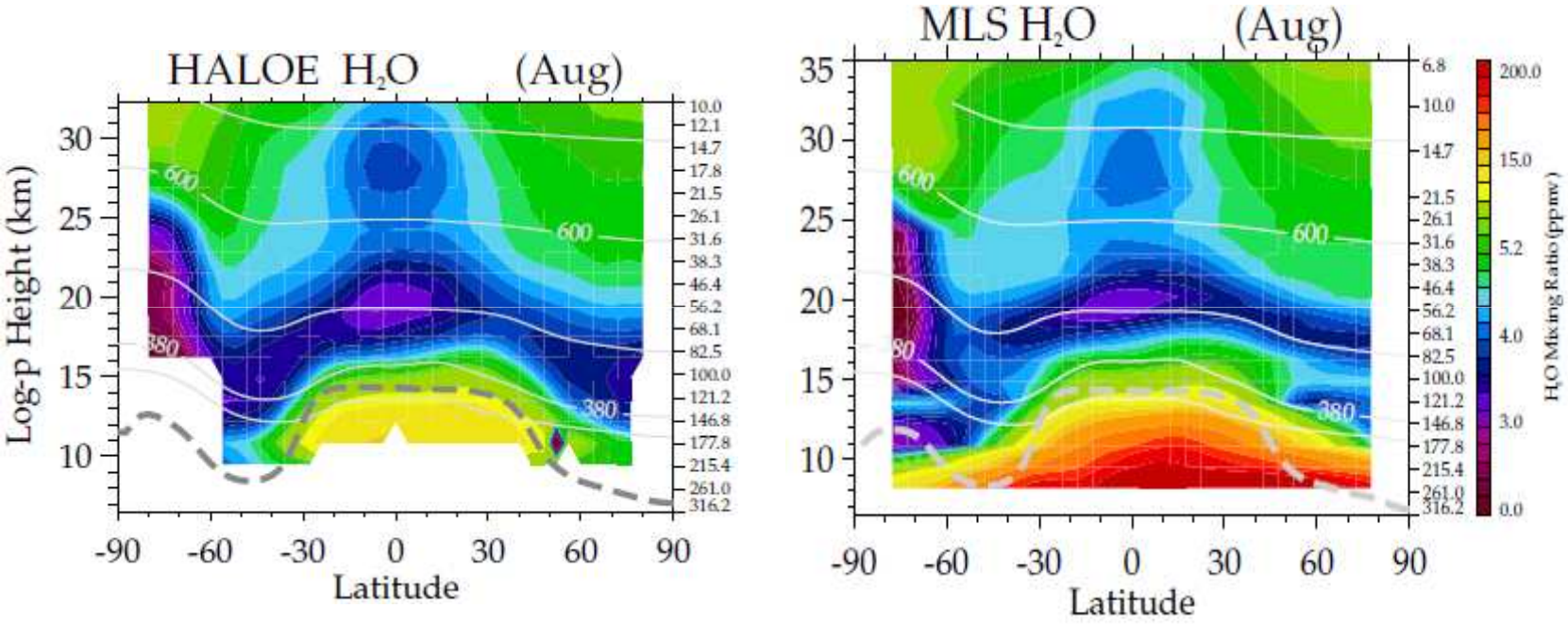
Anomaly for 2001-2004



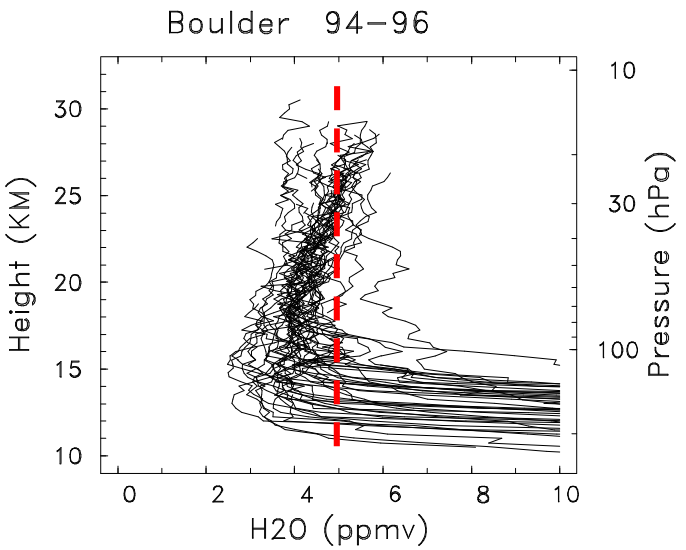
stronger subtropical convergence

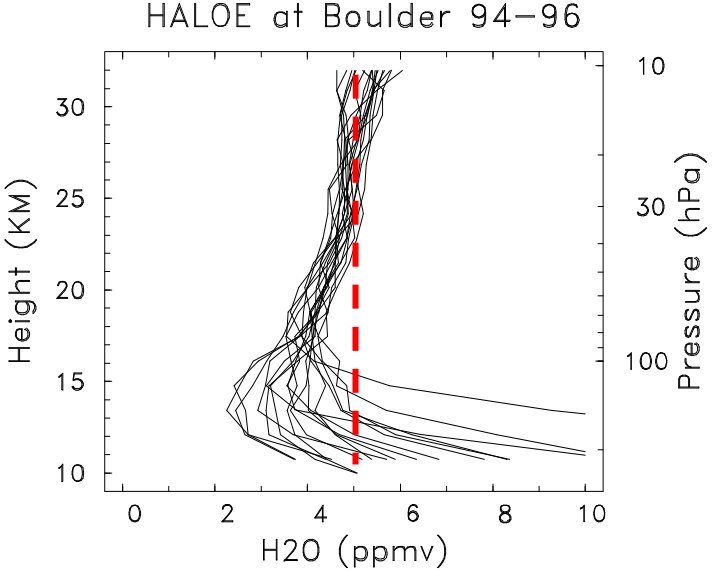
contours scaled by a factor of 10

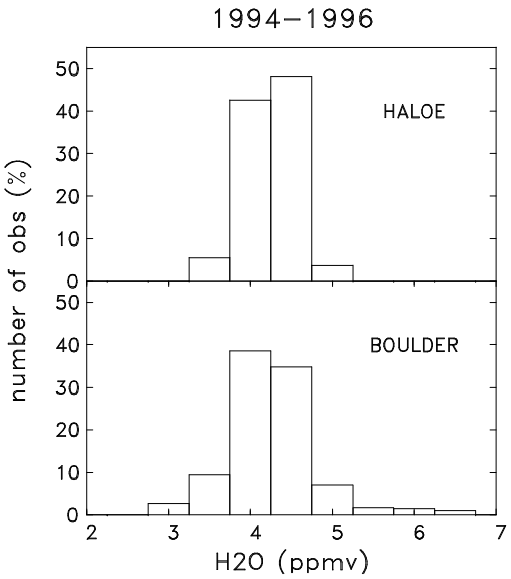
HALOE vs. Aura MLS climatology



1994-1996

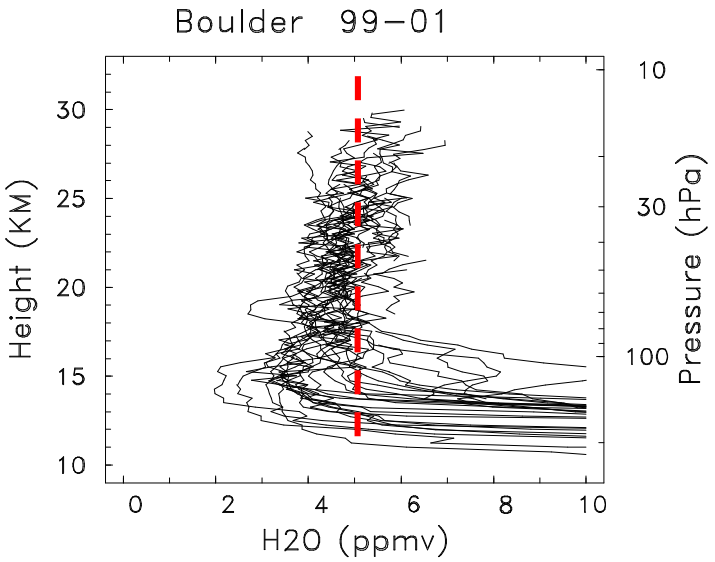


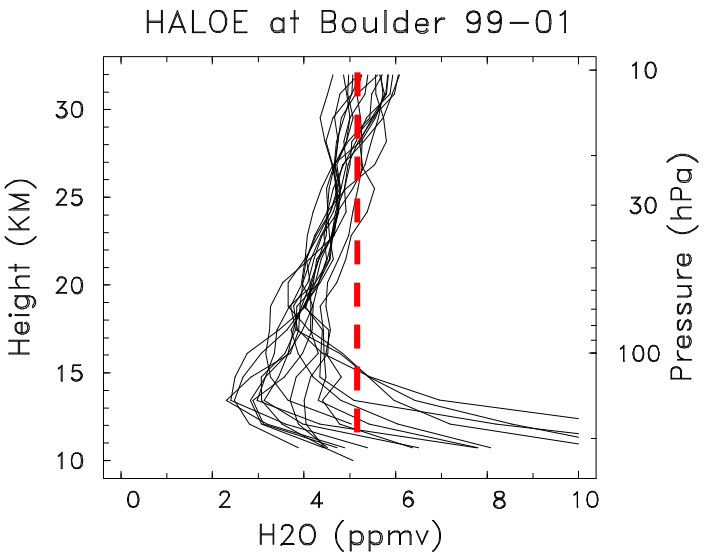


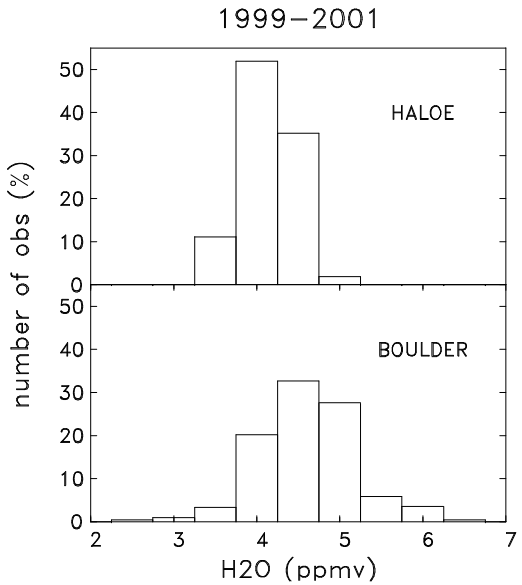


18-22 km

1999-2001







18-22 km