

# Evidence for Recent Stratospheric Circulation Changes From Multiple Measurement Sources

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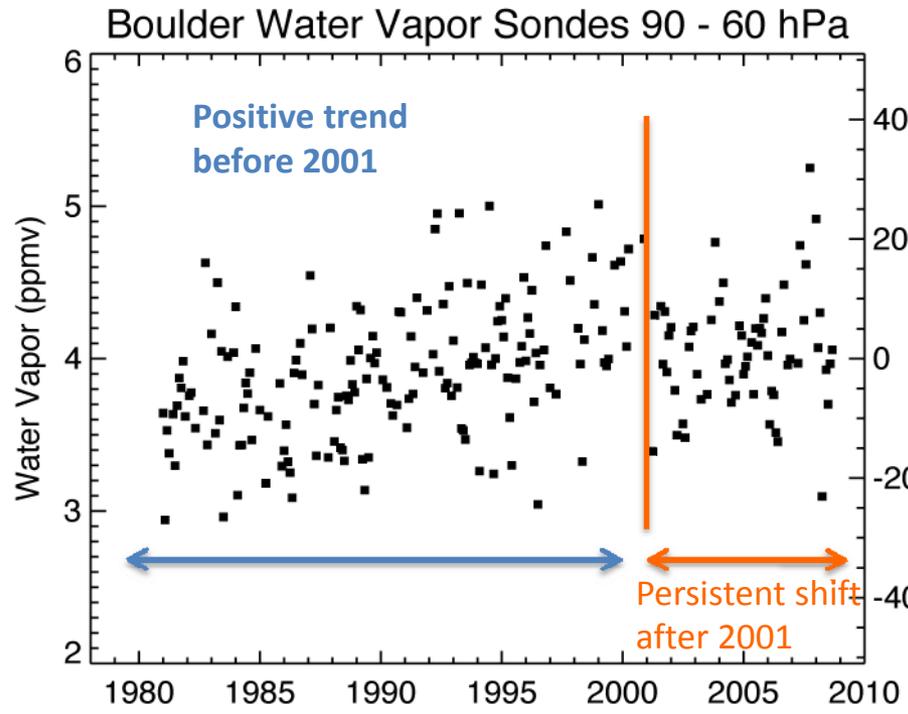
# Goals

Show consistent trends and shifts in several unique, long term stratospheric observations.

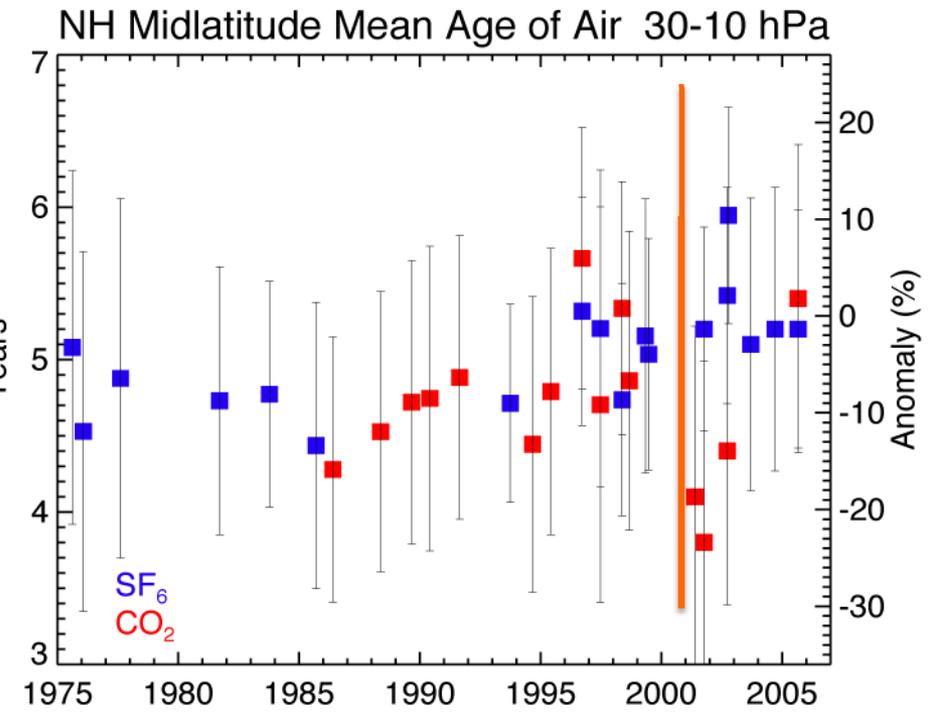
Infer changes in the stratospheric circulation from these observations.

Compare the inferred circulation changes to climate model predictions.

# Stratospheric Water Vapor and Mean Age of Air



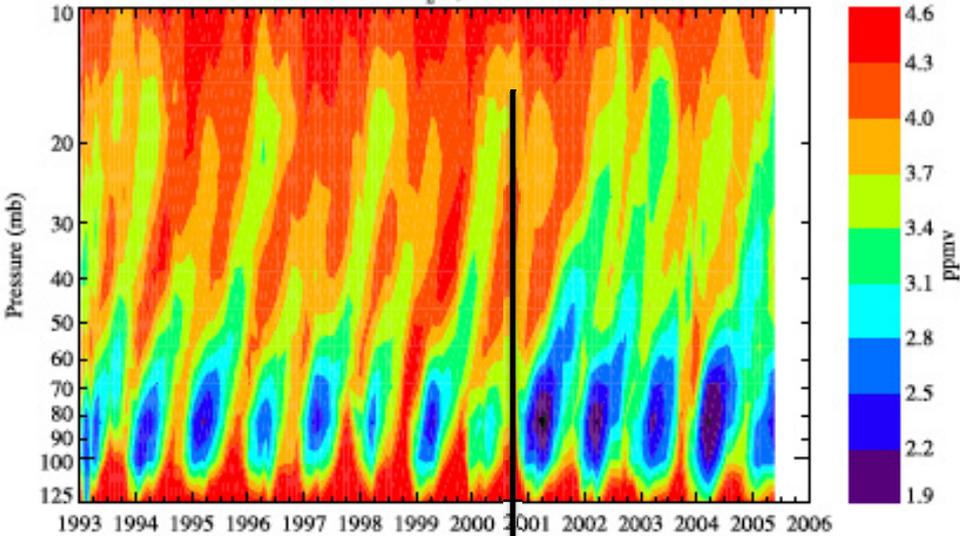
NOAA GMD frostpoint measurements (Oltmans et al., 2000; Scherer et al., 2008)



Mean stratospheric ages calculated from stratospheric SF<sub>6</sub> and CO<sub>2</sub> balloon measurements taken by NOAA GMD, Harvard Univ., NCAR, European and Japanese groups (Engel et al., 2009).

# Evidence for Large Changes in 2000-01

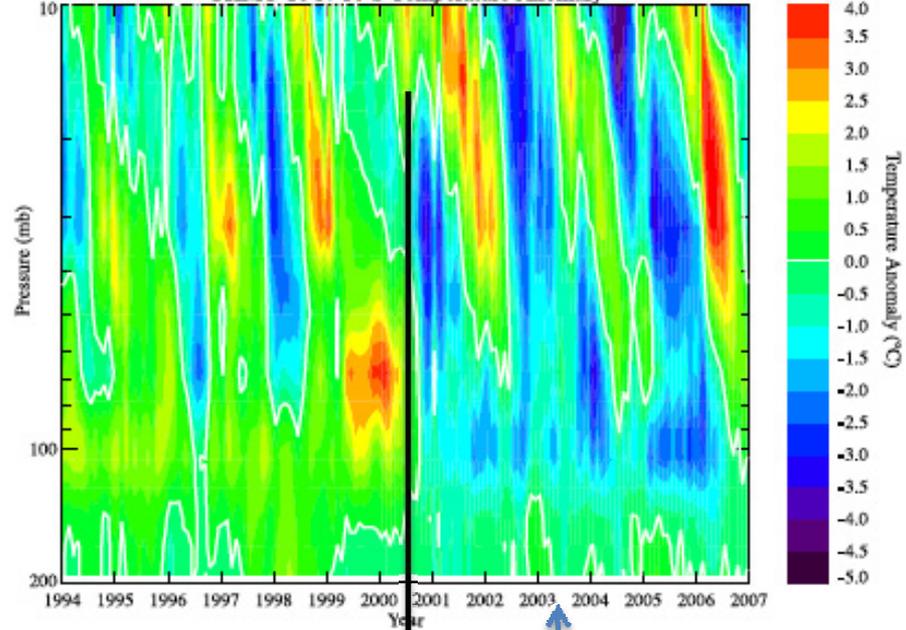
HALOE H<sub>2</sub>O, 5°S - 5°N



Rosenlof and Reid, 2008

Lower tropical water vapor since 2001 from satellite measurements.

UKMO 10°N-10°S Temperature Anomaly



Colder tropical temperatures, especially near the tropopause, since 2001 from assimilated model data.

↑ Tropical upwelling

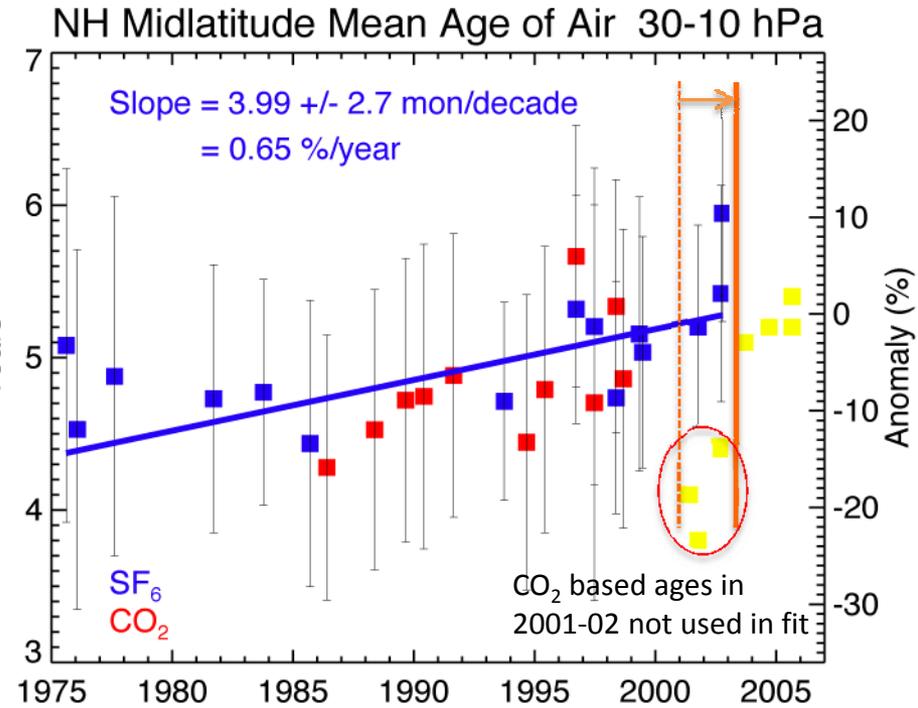
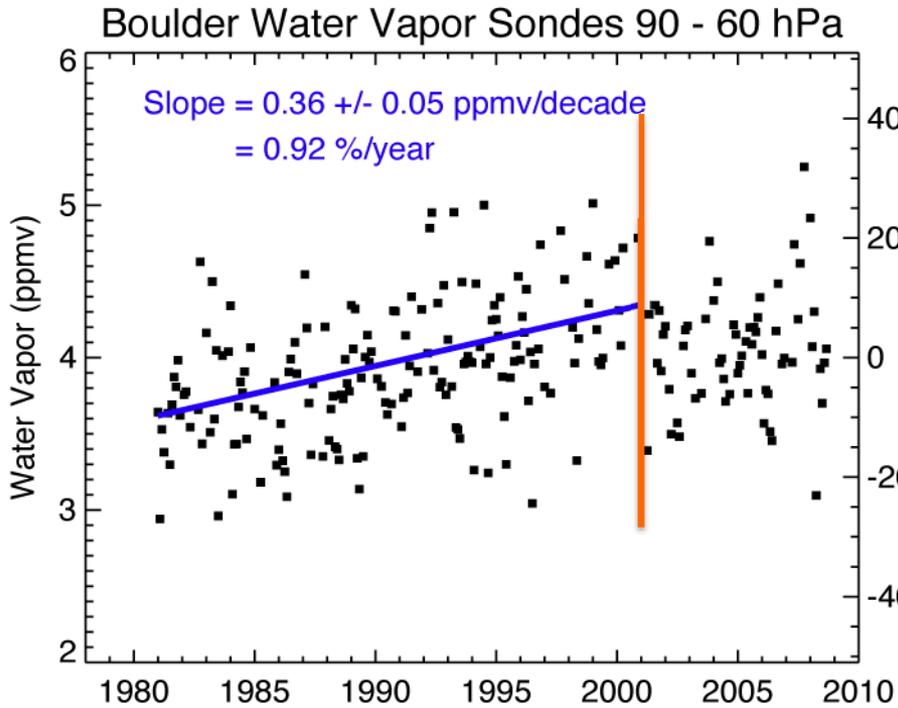


↓ Tropical tropopause temperatures



↓ Stratospheric water vapor

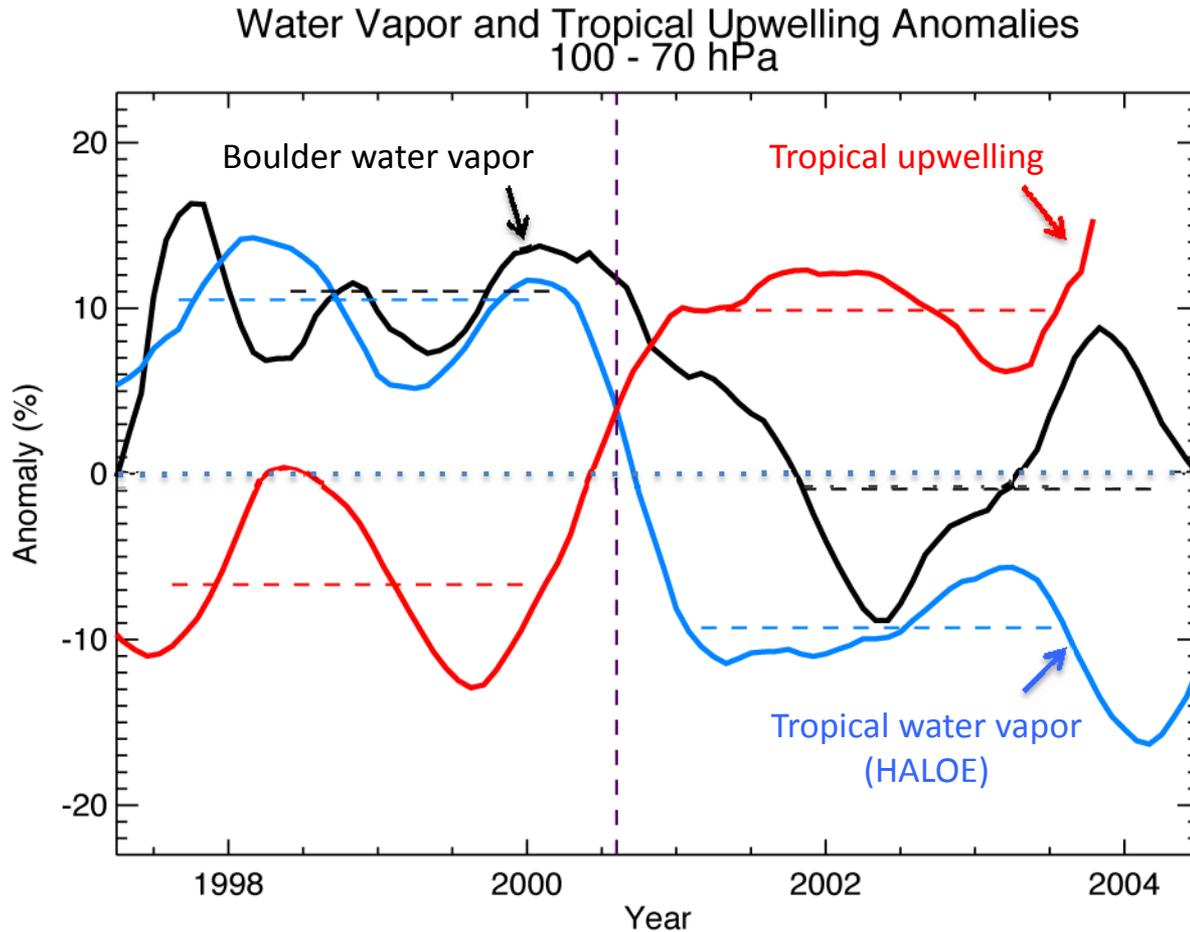
# Stratospheric Water Vapor and Mean Age of Air Trends



Significant, positive slopes before 2001(03) in both stratospheric water vapor and mean age of air.

Is the trend in tropical upwelling consistent?

# Stratospheric Water Vapor and Tropical Upwelling Changes After 2001



Shift in 2000-01

+16.6%



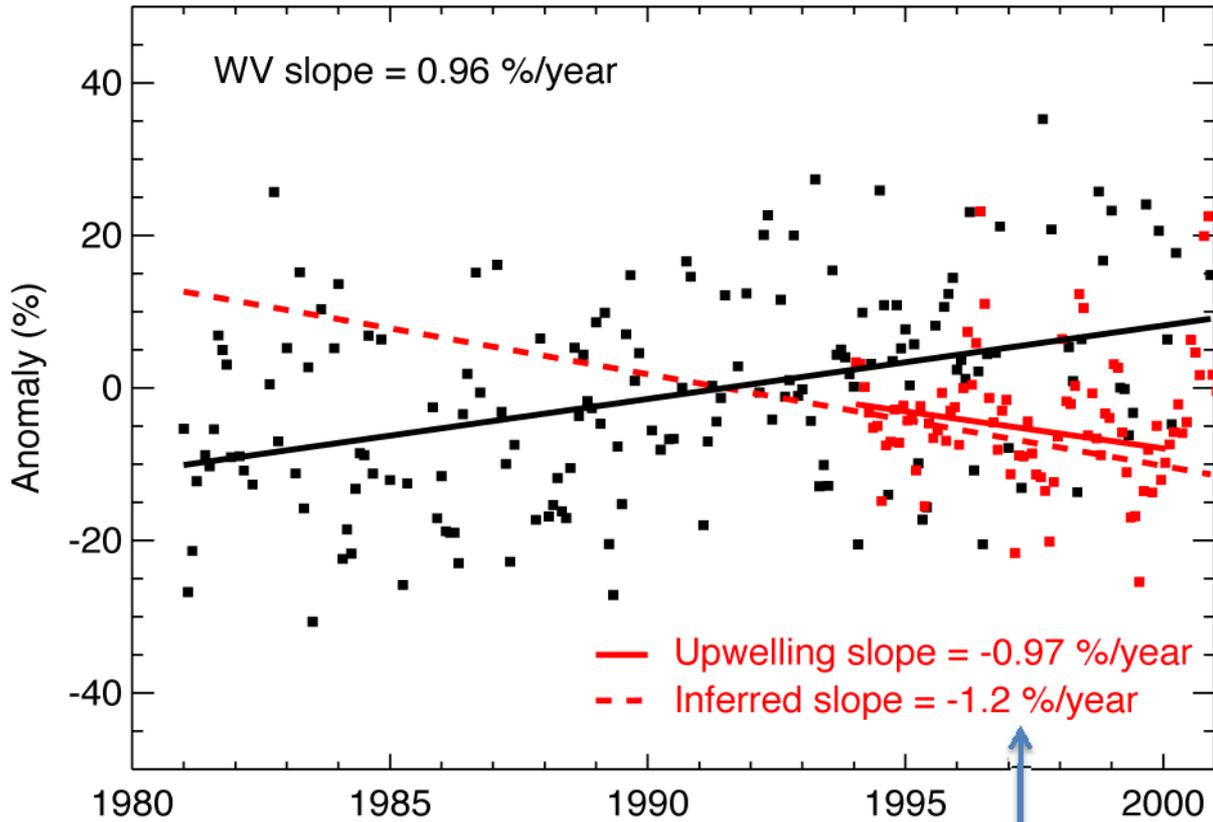
-11.9%

-19.8%

Ratio of tropical upwelling and Boulder water vapor changes can be used to derive the tropical upwelling trend prior to 2001.

Tropical upwelling anomalies are from a residual circulation calculation with the seasonal cycle removed and averaged from 10°S-10°N.

# Boulder Water Vapor and Tropical Upwelling 100 - 70 hPa



Negative tropical upwelling trend implies slowing mean circulation and is consistent with positive mean age trend.

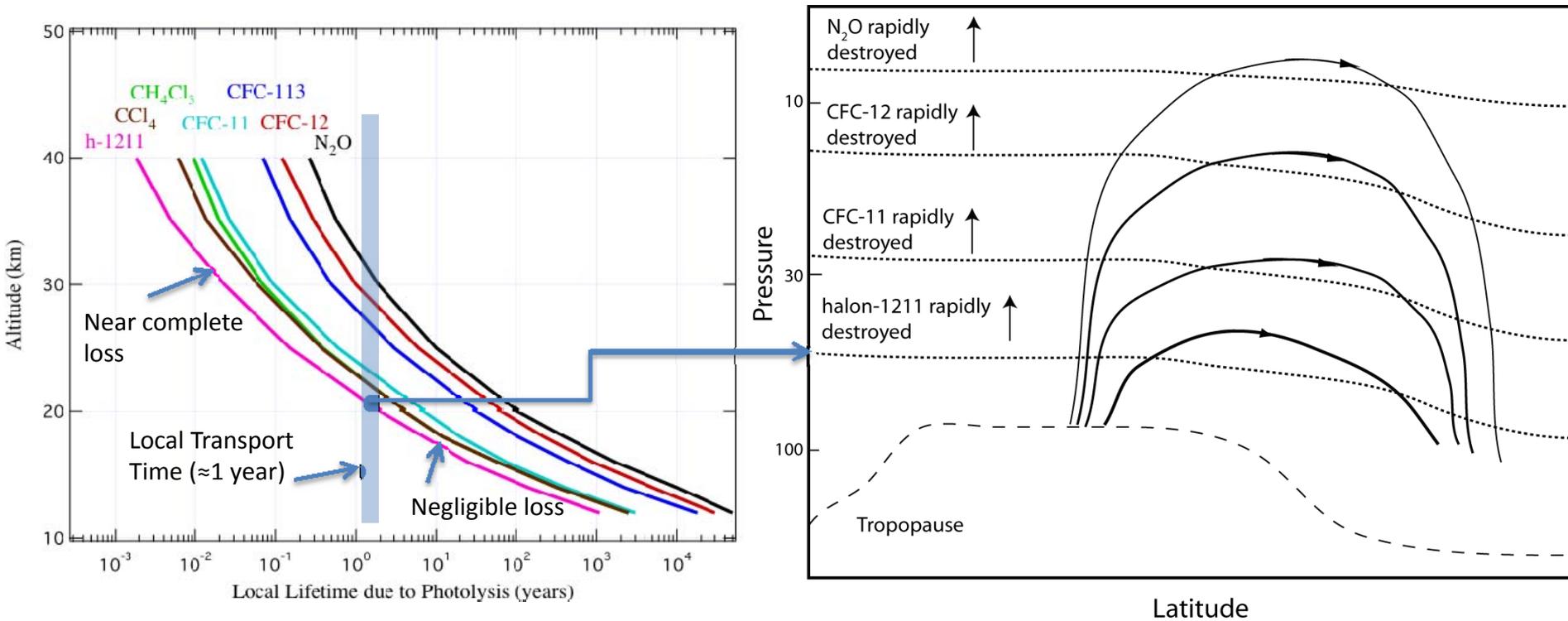
We can look for further details of the circulation changes after 2000 from photolytic tracer measurements...

Inferred tropical upwelling slope =  $-1.39 * 0.9 * \text{WV slope}$

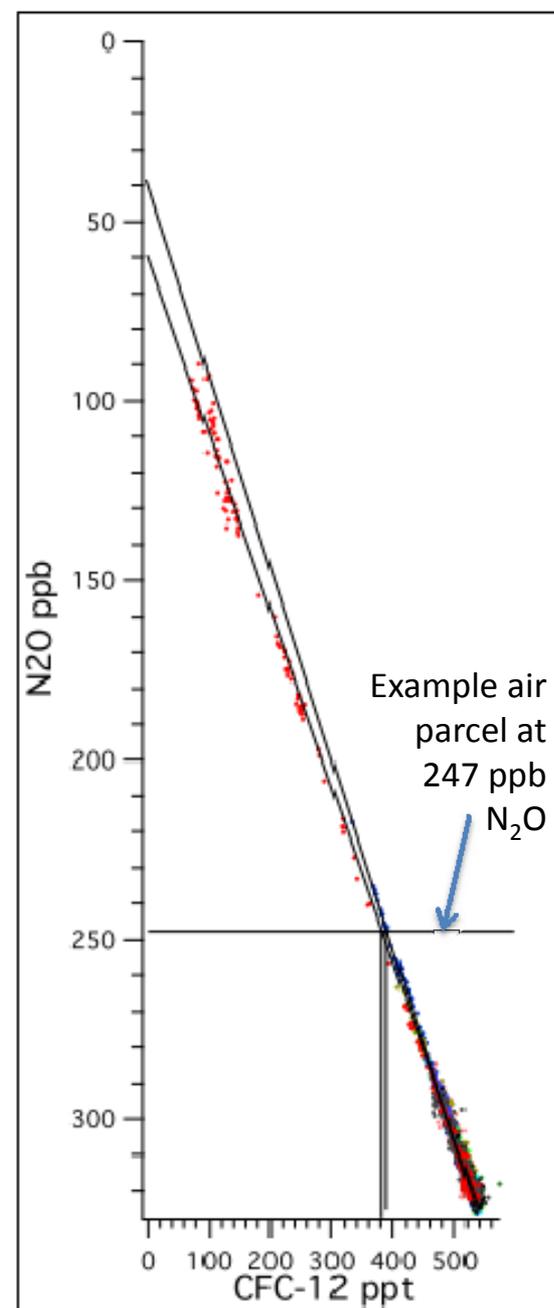
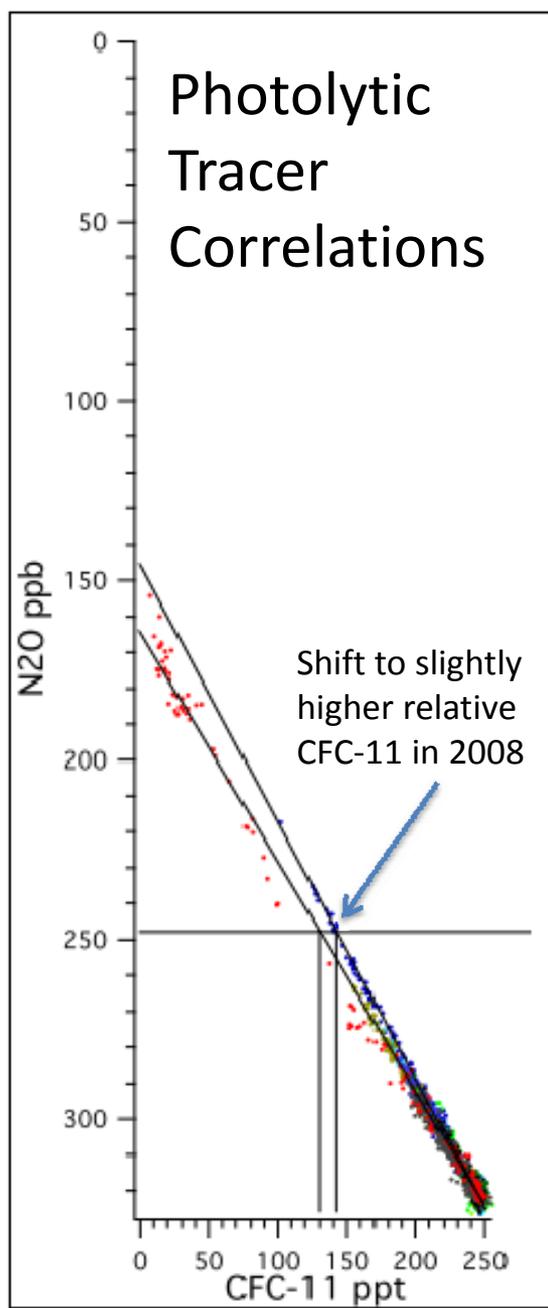
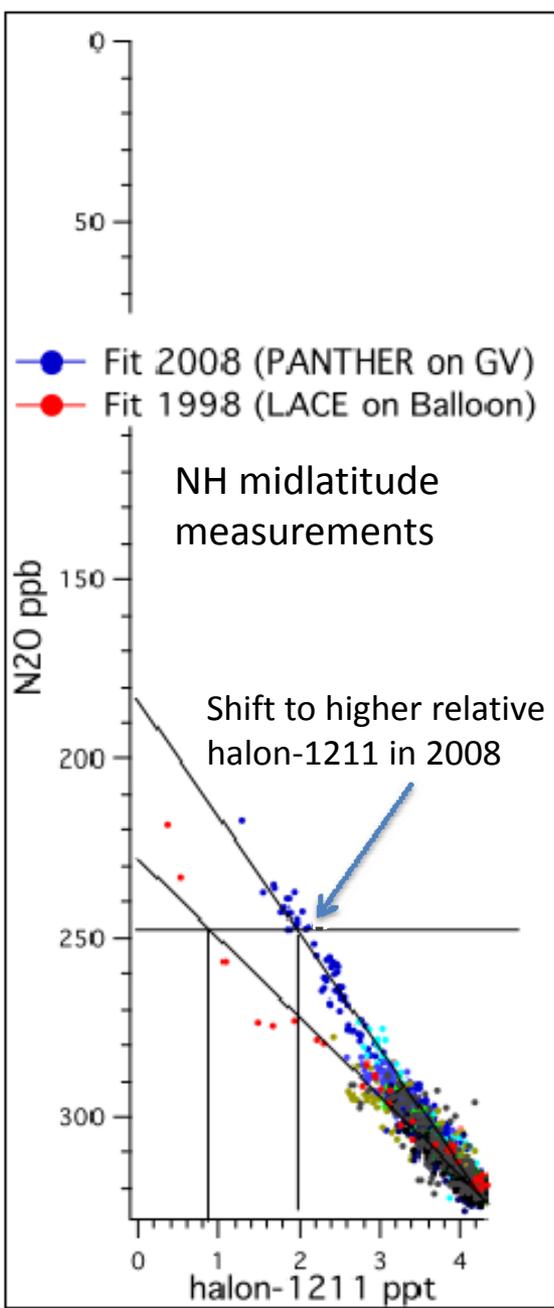
2001 change ratio  $\begin{pmatrix} 16.6\% \\ -11.9\% \end{pmatrix}$

Assume 10% of WV trend is due to CH<sub>4</sub> (Rohs et al., 2006).

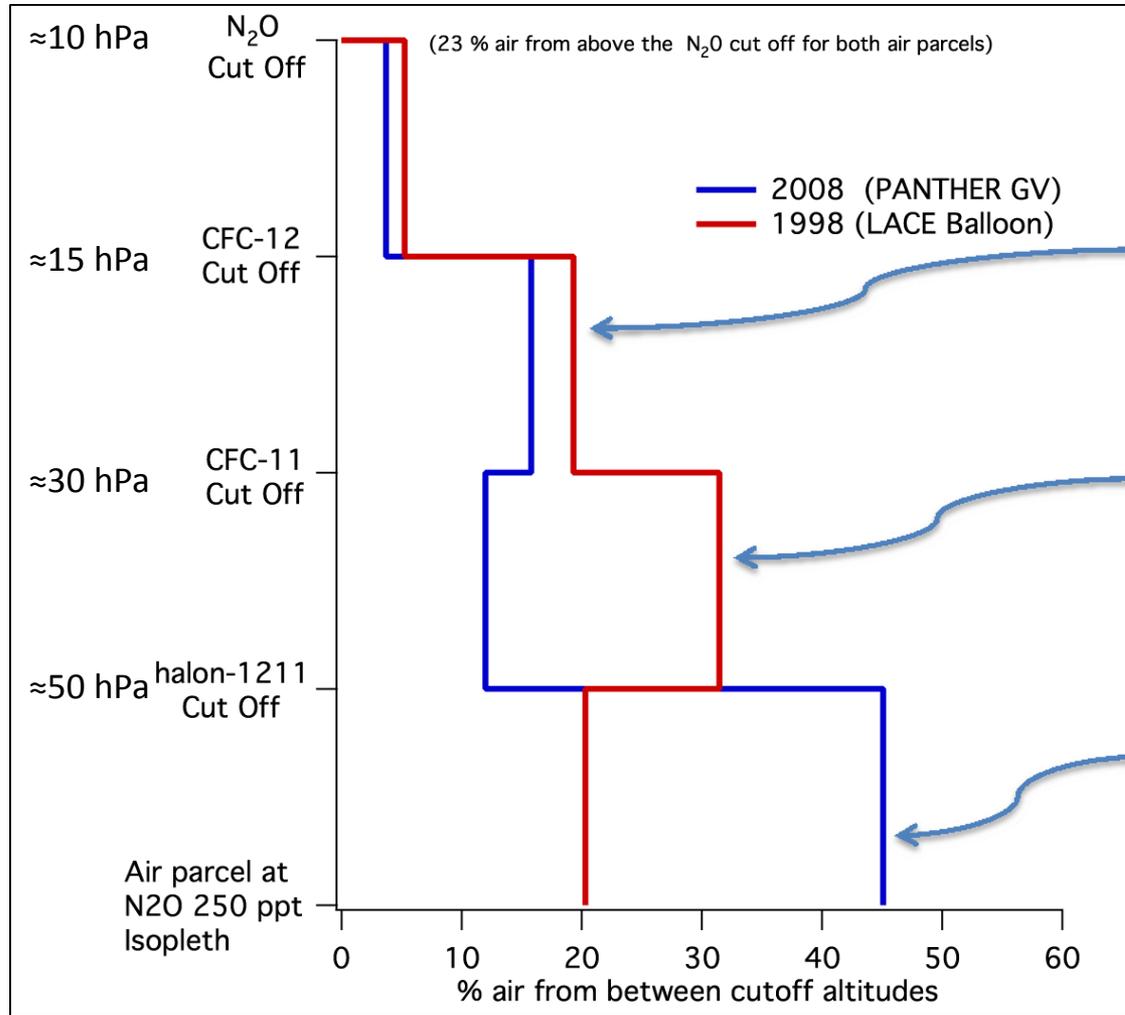
# Photolytic Tracers and the Stratospheric Circulation



The photolytic tracers are sensitive to changes in the maximum path height of an air parcel and each tracer is sensitive to a different height.



# Profile of Circulation Changes Implied by Photolytic Tracer Correlation Changes



Small changes above 30 hPa consistent with observed small mean age changes at this level.

20% less air from between the halon-1211 and CFC-11 cut off altitudes in 2008.

25% more air from below the halon-1211 cut off altitude in 2008.

# Summary of Observed Stratospheric Changes

Dataset	Pressure (hPa)	Trend Pre-2001(03) (%/year)	Shift Post-2001 (%)
Boulder water vapor	90-60	0.80 - 1.05	-11.9
NH midlatitude mean age	30-10	0.22 - 1.09	Small?
Tropical upwelling (inferred from 2001 change)	100-70	-1.00 - -1.32	
Tropical upwelling (residual calculation)	100-70	-0.45 - -1.49	16.6
Meridional mass flux from photolytic tracer correlations	100-50		25

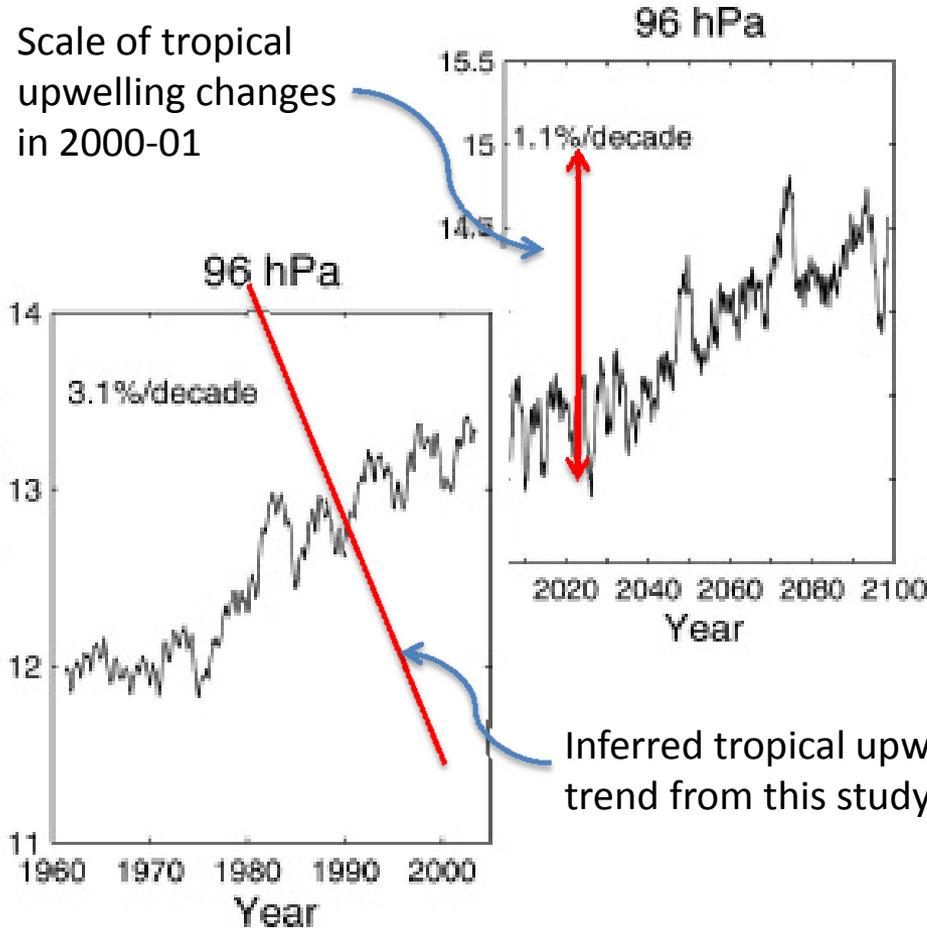
# Significance of the Stratospheric Trends and Shifts

- Consistency among the different long term stratospheric measurements gives confidence in the implied circulation changes.
- **NOT** consistent with climate model simulations of the stratosphere.
- The stratospheric circulation is driven by weather and other tropospheric processes.
- The inability of climate models to accurately simulate observed stratospheric changes implies that the **models are unable to accurately simulate important tropospheric processes.**

# Comparison to Climate Models

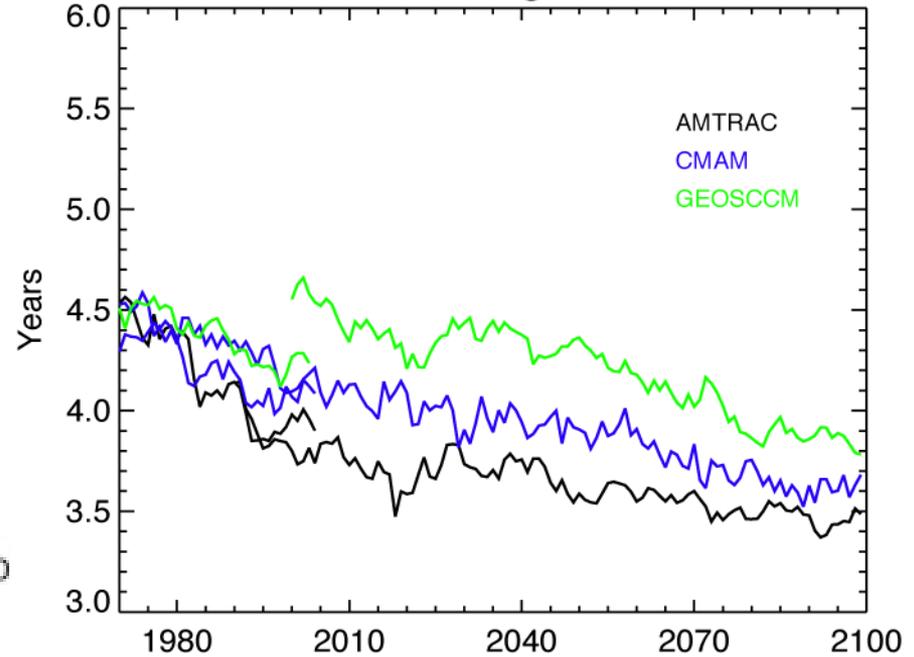
## Tropical Upwelling

Scale of tropical upwelling changes in 2000-01



Inferred tropical upwelling trend from this study

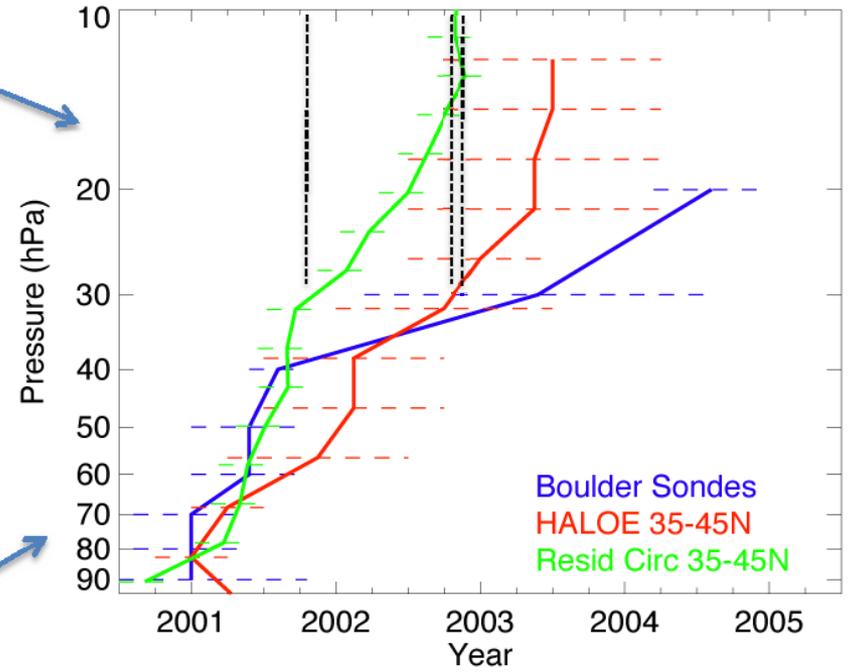
## NH Midlatitude Mean Age of Air 30-10 hPa



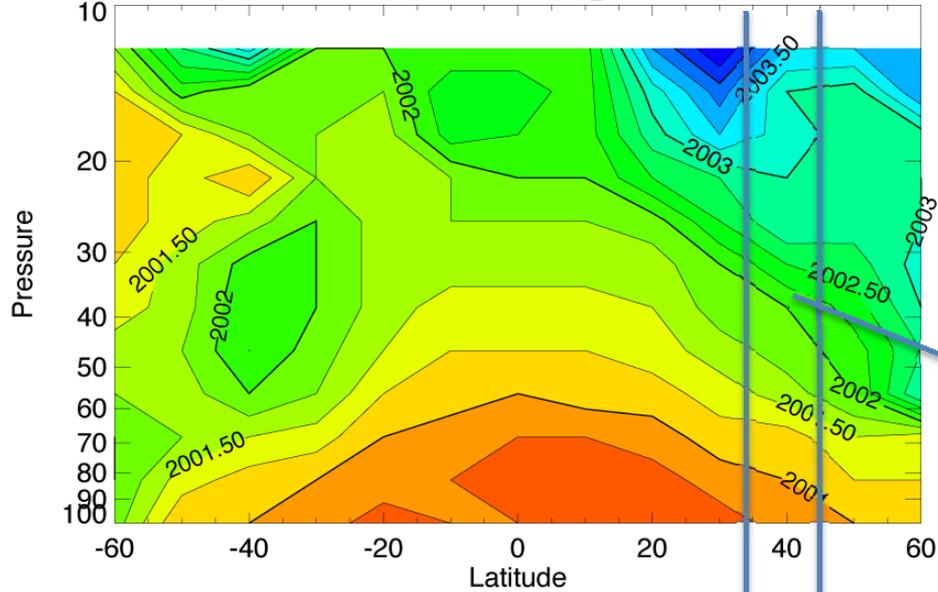
The model data are from the Chemistry Climate Model Validation (CCMVal) activity. The models use IPCC future greenhouse gas scenarios.

# Justification for Calculating Mean Age Slope Through 2002

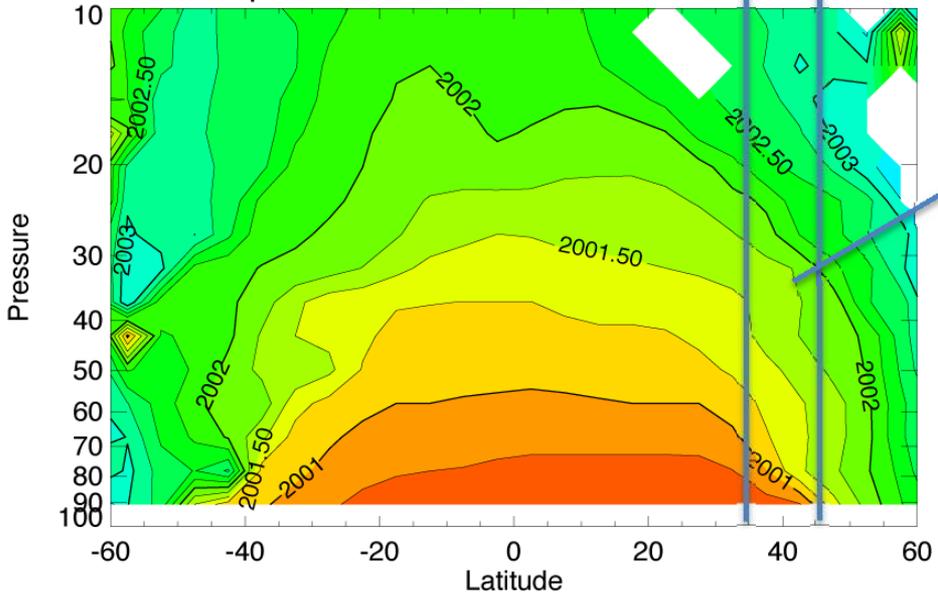
## Detection of Maximum Midlatitude Water Vapor Decrease post-2000



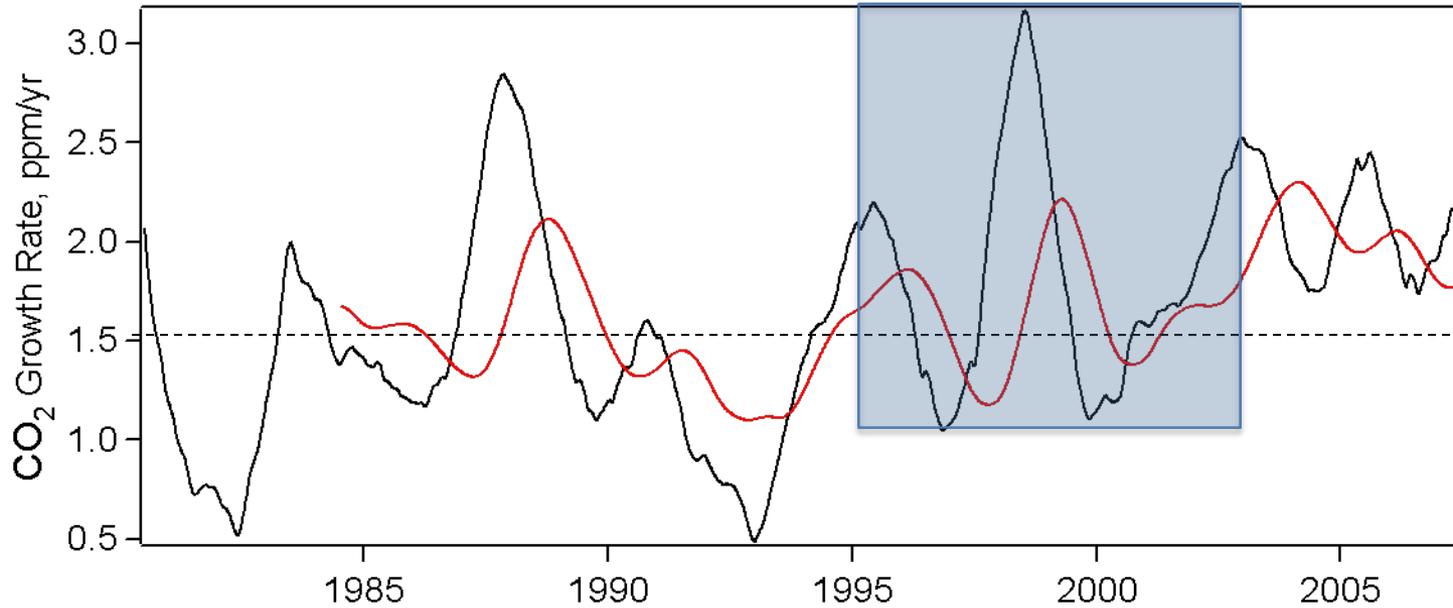
## Detection of Maximum HALOE H<sub>2</sub>O Decrease post-2000



## Transport Time Based on Residual Circulation



# Impact of Recent CO<sub>2</sub> Growth Rates on Mean Age Estimates



CO<sub>2</sub> growth rate has increased substantially since 1998. Mean age estimates in 2001-02 depend on the previous 5+ years of tropospheric CO<sub>2</sub> mixing ratios. Relatively high growth rates translate to relatively young mean age estimates.

SF<sub>6</sub> growth rates haven't changed over this time period, therefore the much lower mean ages derived from CO<sub>2</sub> in 2001-02 are suspect.