Bob Hudson and The Ozone Layer:
What You Might Not Have Known About Their Connection

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What You Might Not Have Known About Their Connection

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Brief Outline

- **Bob Hudson's early career as an ultraviolet spectroscopist in the laboratory**
- **Some of my work on tropical lower stratospheric ozone**
- **Bob Hudson and ozone assessments**

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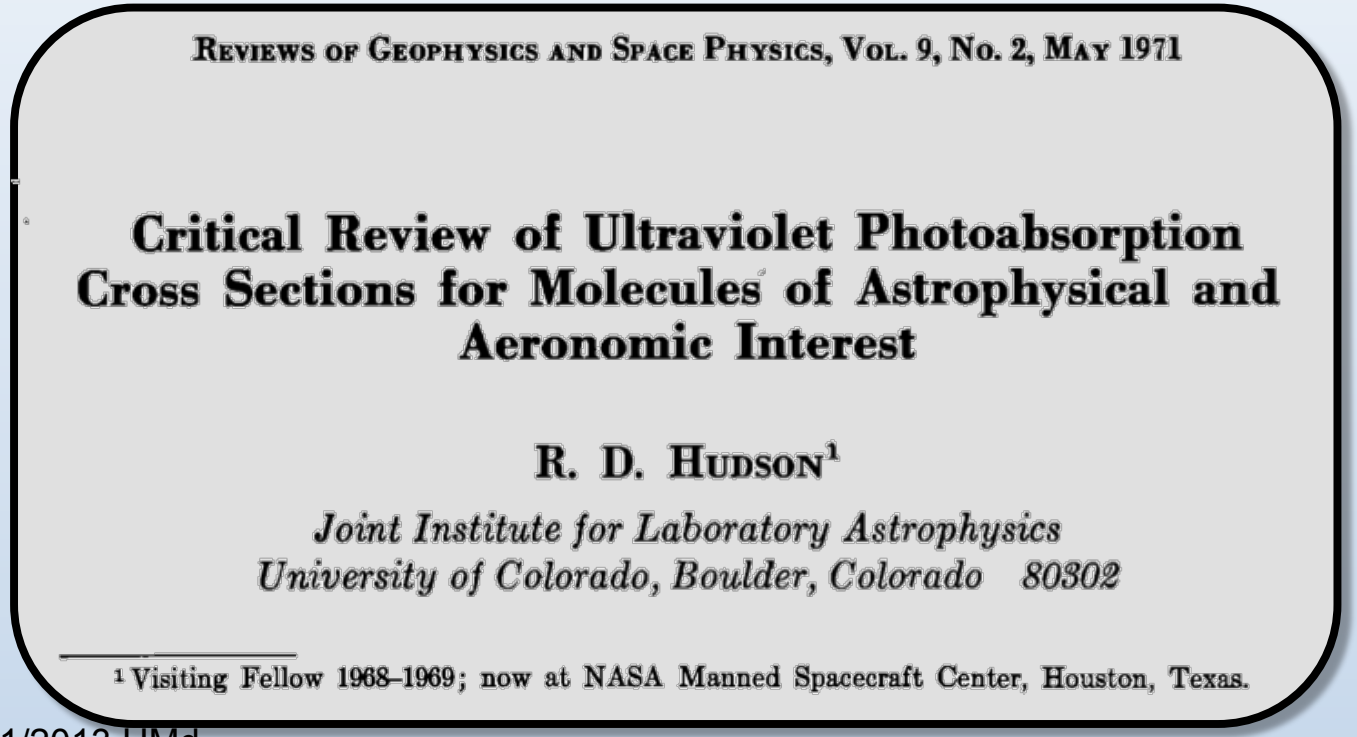
I come not to bury Bob Hudson, but to praise him

Hudson: Early career as a laboratory experimental scientist

- Mid 1960s to early 1970s: 26 papers on laboratory spectroscopy of N_2, O_2, Ca, Sr, Ba, K, Na, Li, Kr, Xe
- Culminated in extensive, highly-cited, review in 1971



REVIEWS OF GEOPHYSICS AND SPACE PHYSICS, VOL. 9, NO. 2, MAY 1971

Critical Review of Ultraviolet Photoabsorption Cross Sections for Molecules of Astrophysical and Aeronomic Interest

R. D. HUDSON[1]

Joint Institute for Laboratory Astrophysics
University of Colorado, Boulder, Colorado 80302

[1] Visiting Fellow 1968–1969; now at NASA Manned Spacecraft Center, Houston, Texas.

Quotes from Hudson (1971)
Review Paper on Cross Sections

"To the reviewer it seems clear that the terms 'atomic cross section' and 'molecular cross section', from their definitions, should apply to cross sections that are characteristic of the atom or molecule only, and that cross sections that are also characteristic of the measuring instrument should not be referred to as atomic or molecular. The reviewer feels that both editors and referees should insist in the future that experimenters demonstrate that the cross sections in their papers do indeed have physical significance."

Quotes from Hudson (1971) Review Paper on Cross Sections

"In general, the discussions of errors in the papers that describe measurements of ultraviolet cross sections are scanty. One can even find some papers where no estimate of errors is given. But even where errors are given, how does one interpret them?

Quotes from Hudson (1971)
Review Paper on Cross Sections

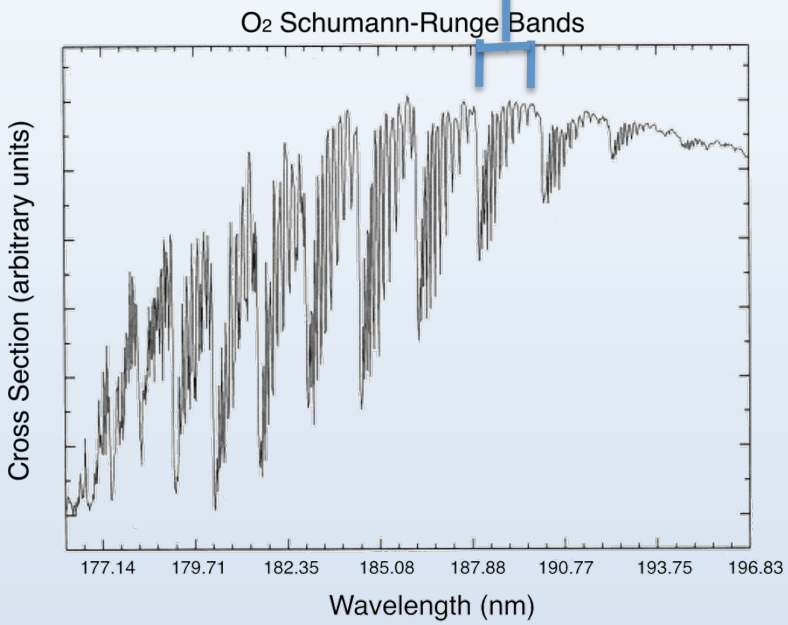
"In general, the discussions of errors in the papers that describe measurements of ultraviolet cross sections are scanty. One can even find some papers where no estimate of errors is given. But even where errors are given, how does one interpret them? **If a paper shows a continuous curve of cross section versus wavelength and ascribes an error of 5% to the cross section, does this error refer to (1) the error on each point used to draw the curve, (2) the spread of these points about the curve shown, or (3) the systematic error on the measurement, i.e., the fact that the whole curve could be raised or lowered by a factor of 1.05.**

Quotes from Hudson (1971)
Review Paper on Cross Sections

"In general, the discussions of errors in the papers that describe measurements of ultraviolet cross sections are scanty. One can even find some papers where no estimate of errors is given. But even where errors are given, how does one interpret them? If a paper shows a continuous curve of cross section versus wavelength and ascribes an error of 5% to the cross section, does this error refer to (1) the error on each point used to draw the curve, (2) the spread of these points about the curve shown, or (3) the systematic error on the measurement, i.e., the fact that the whole curve could be raised or lowered by a factor of 1.05. **These questions cannot be answered by reference to the papers alone**, **and this makes the task of the reviewer that much more difficult."**

The Importance of Oxygen Cross Sections

- Primary source of ozone
- Schumann-Runge bands
  - Highly variable cross section
  - Hard to measure
  - Hard to incorporate into models
  - Crucial for NO photolysis
  - Also crucial for determination of lifetime of CFCs



O_2 Schumann-Runge Bands

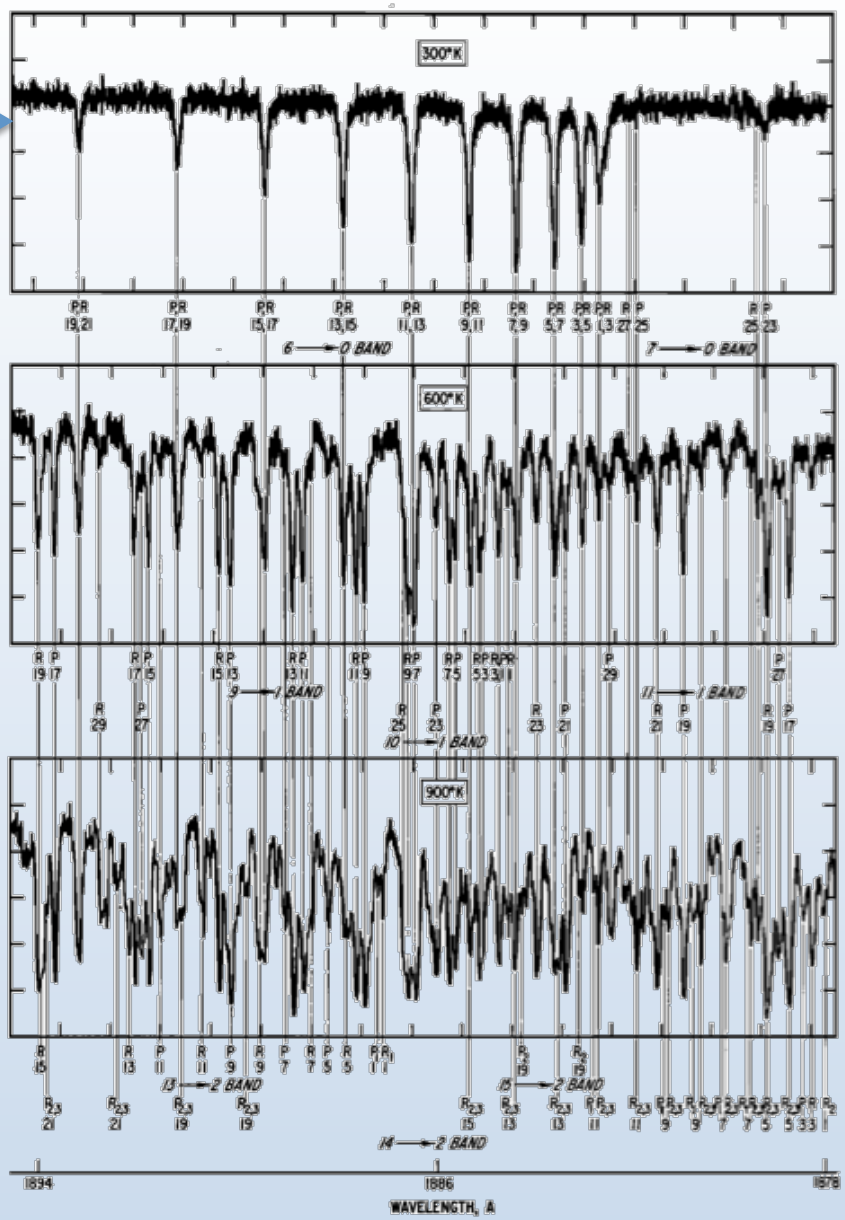


Fig. 10. Absorption by molecular oxygen between 1878 and 1894 A at 300, 600, and 900°K. Taken from *Hudson and Carter* [1968b].

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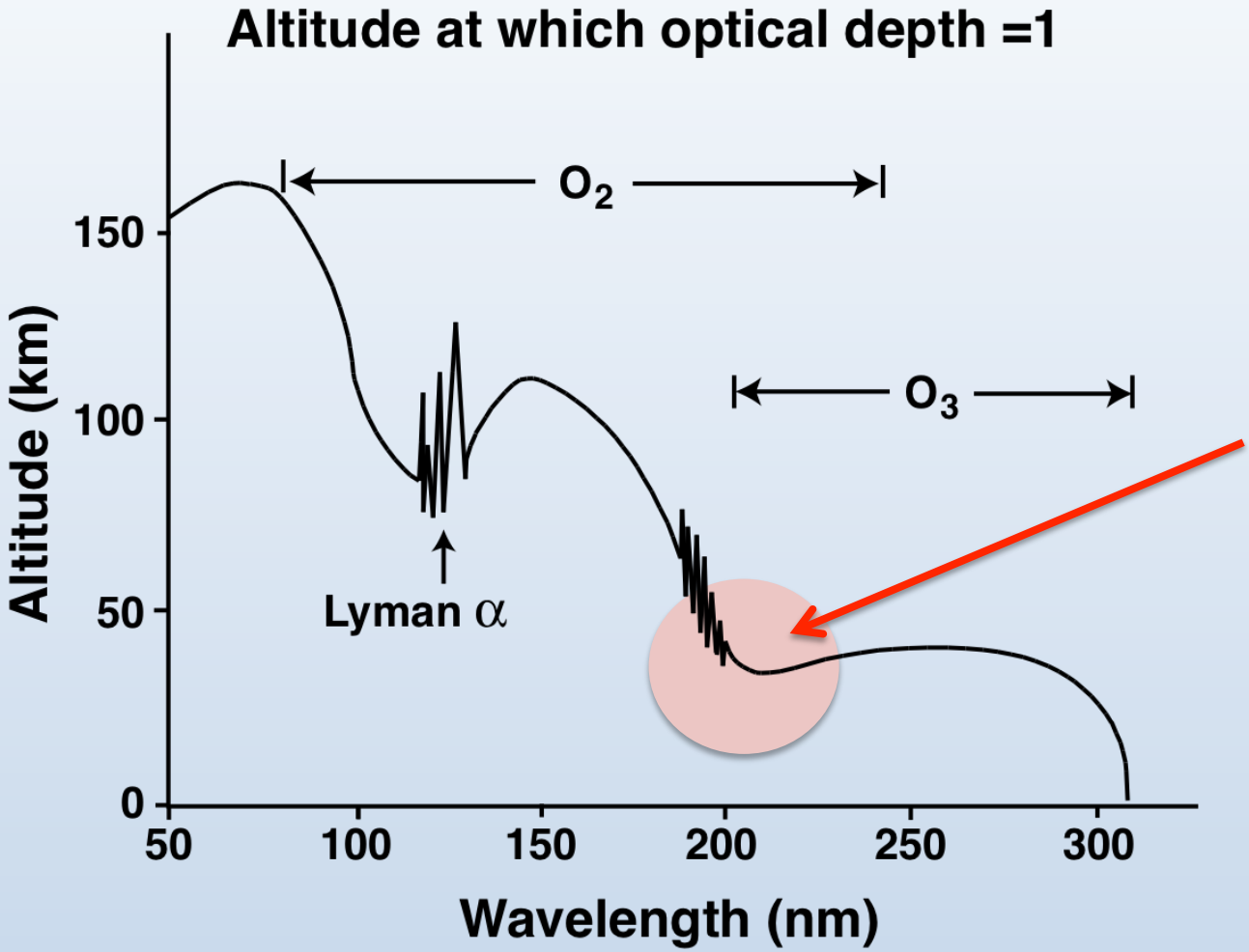
Penetration of Solar UV That has Energy to Photodissociate CFCs, N_2O

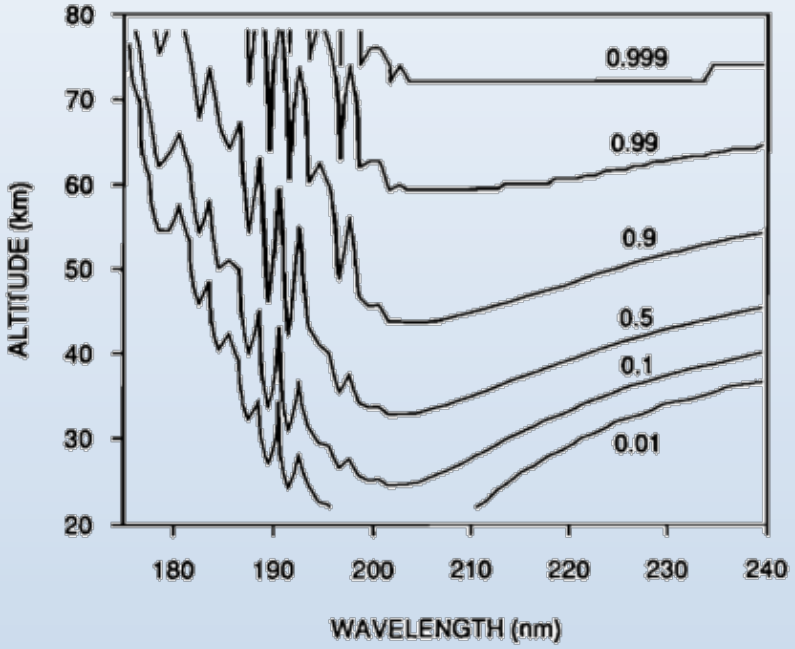


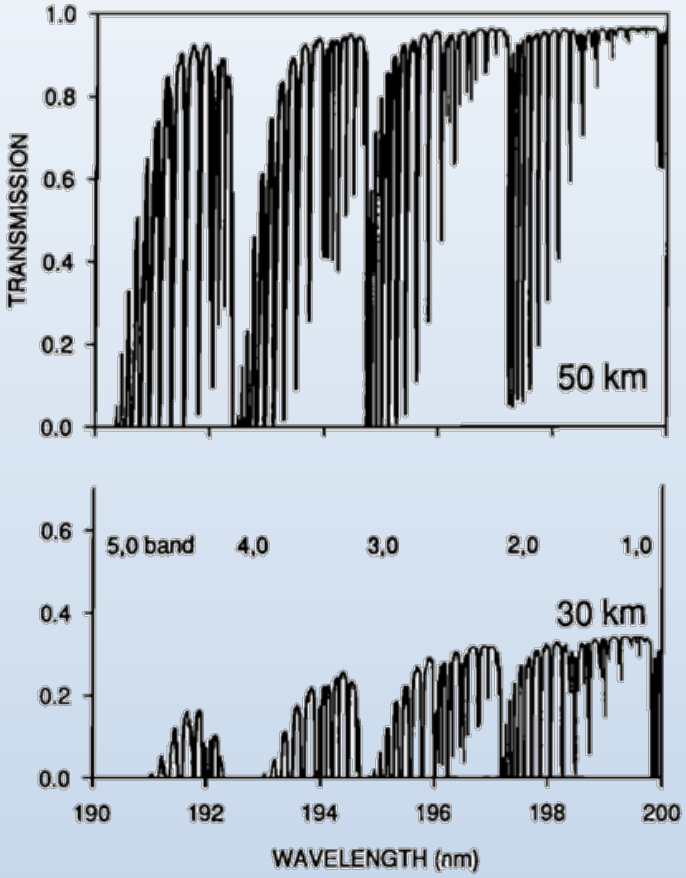
JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 98, NO. D6, PAGES 10,543–10,561, JUNE 20, 1993

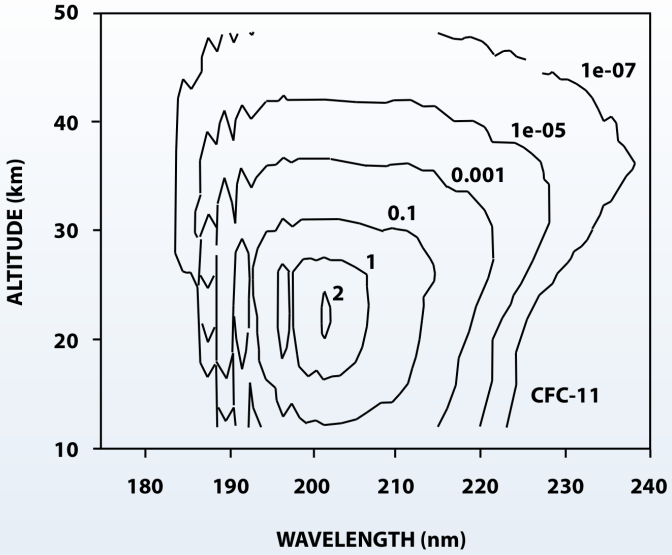
Absorption of Solar Radiation by O_2: Implications for O_3 and Lifetimes of N_2O, $CFCl_3$, and CF_2Cl_2

K. MINSCHWANER,[1] R. J. SALAWITCH, and M. B. MCELROY

Department of Earth and Planetary Sciences and Division of Applied Sciences, Harvard University, Cambridge, Massachusetts

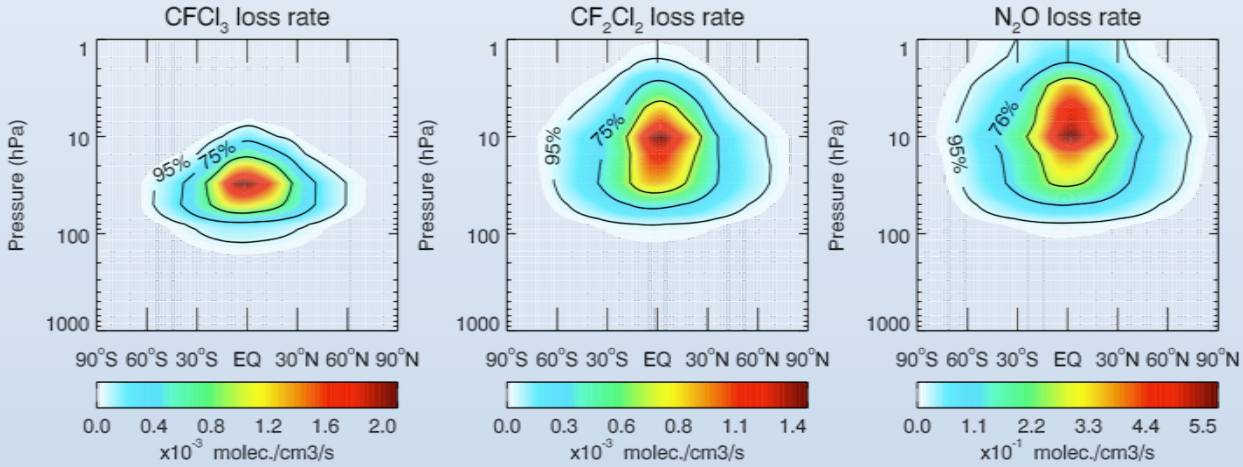






Minschwanner et al. (1993)

Loss altitudes for long-lived molecules depend on radiation penetration in the 200 nm region of the spectrum



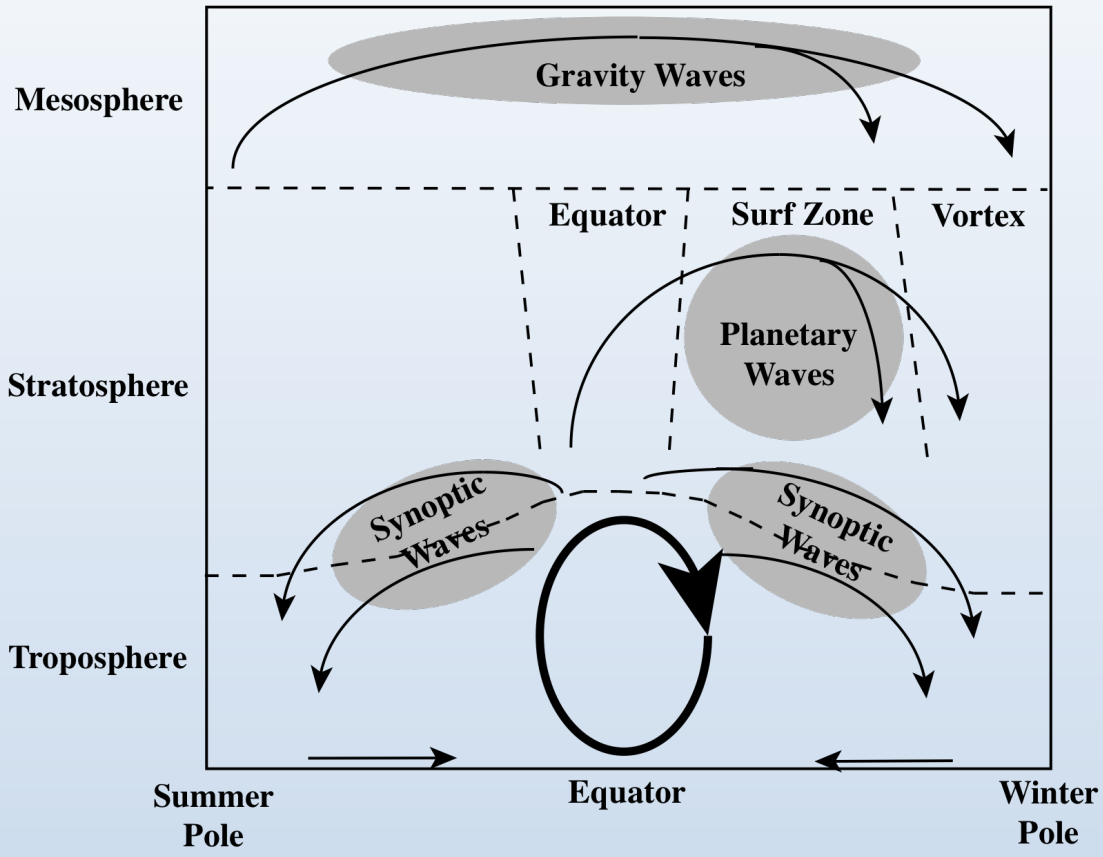
Lifetimes Re-evaluation (2013)

Some of my work on tropical lower-stratospheric ozone

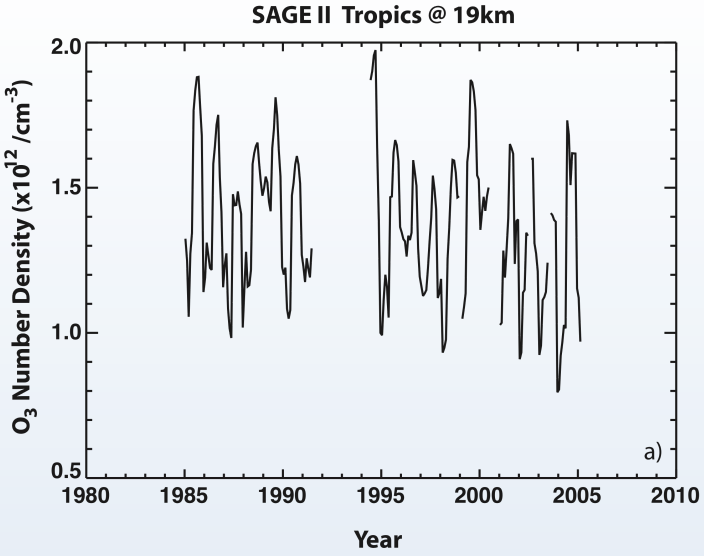
Is The Brewer-Dobson Circulation Speeding Up?

- Models say it is as a result of increased greenhouse gases
- Direct atmospheric evidence is lacking
- Not evident in age-of-air trend
- Models say that there should be a decrease in ozone in the tropical lower stratosphere
- First look at trends from SAGE data showed trend similar to what models predict
- Can we extend data beyond end of SAGE in 2005?

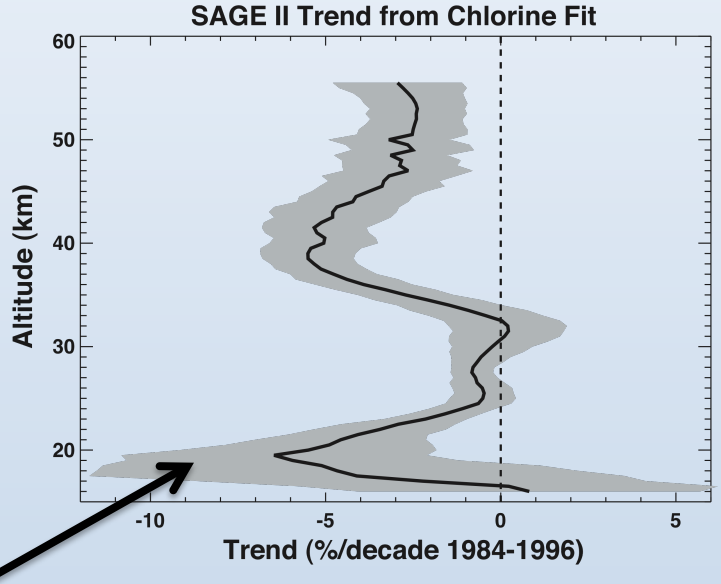
Brewer-Dobson Circulation is Really Two Superposed Circulations

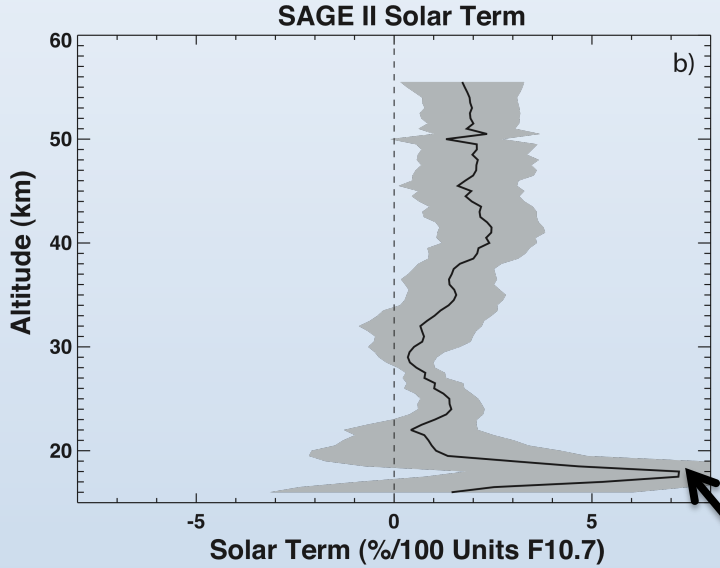


From Plumb (2002)



SAGE data ends in 2005





Basic Trend Analysis

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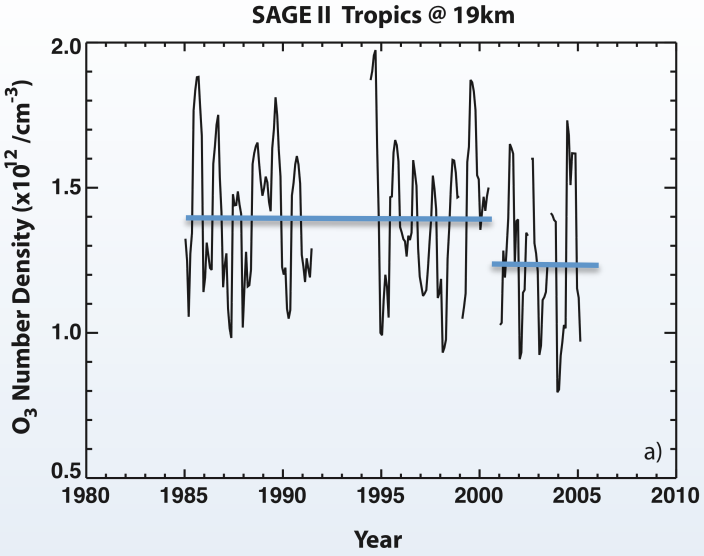


SAGE data ends in 2005

Perhaps it is not a trend, but a jump in 2001

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 111, D12312, doi:10.1029/2005JD006744, 2006

Click Here for Full Article

Decreases in stratospheric water vapor after 2001: Links to changes in the tropical tropopause and the Brewer-Dobson circulation

William J. Randel,[1] Fei Wu,[1] Holger Vömel,[2] Gerald E. Nedoluha,[3] and Piers Forster[4]

Received 6 October 2005; revised 18 January 2006; accepted 20 March 2006; published 27 June 2006.

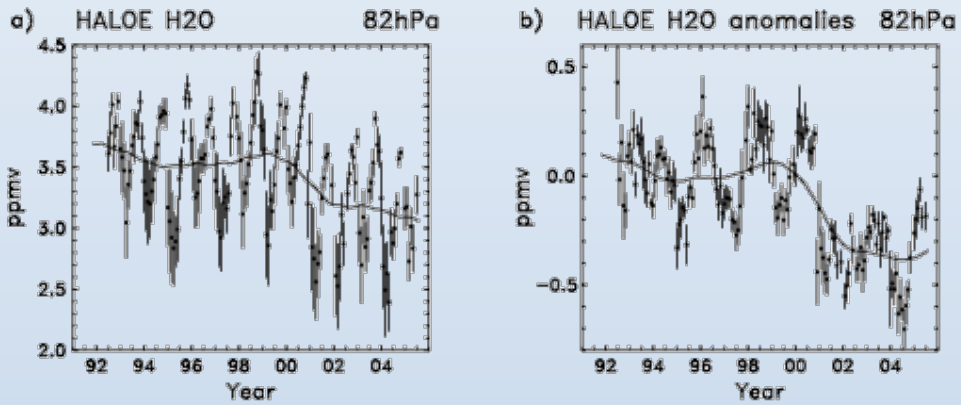
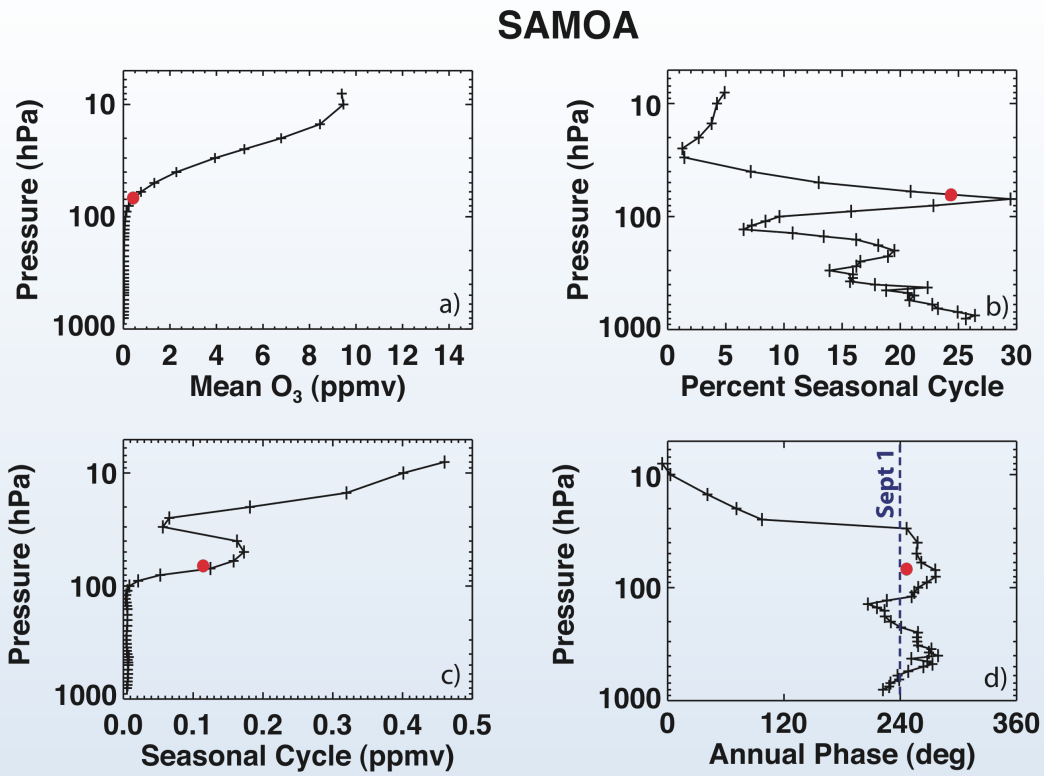


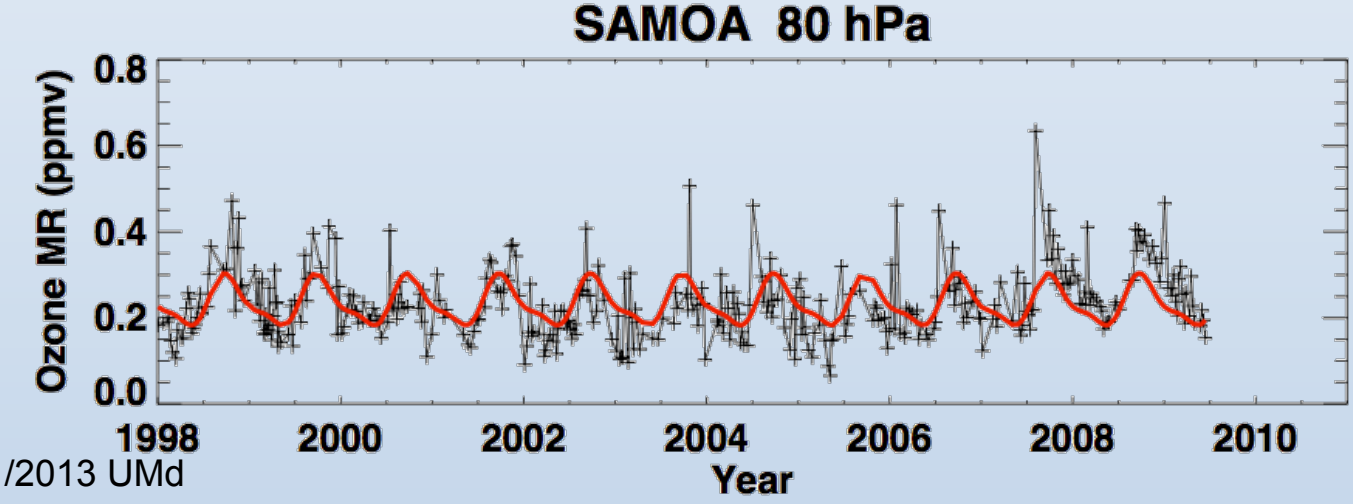
Figure 1. (a) Time series of near-global mean (~60°N-S) water vapor at 82 hPa derived from HALOE data. The circles show monthly mean values, and error bars denote the monthly standard deviation. (b) Deseasonalized near-global mean H_2O anomalies at 82 hPa. In both panels the solid lines are running Gaussian-weighted means of the individual points (using a Gaussian half width of 12 months).

Best way to find out is extend the record

- **Decided to use SAGE and MLS with SHADOZ ozonesondes as a transfer standard**
- **Started by comparing seasonal cycles to see if data sets were compatible**
- **Discovered an interesting pattern of seasonal magnitude that sidetracked me to a different direction**



Properties of ozonesonde time series from Samoa station



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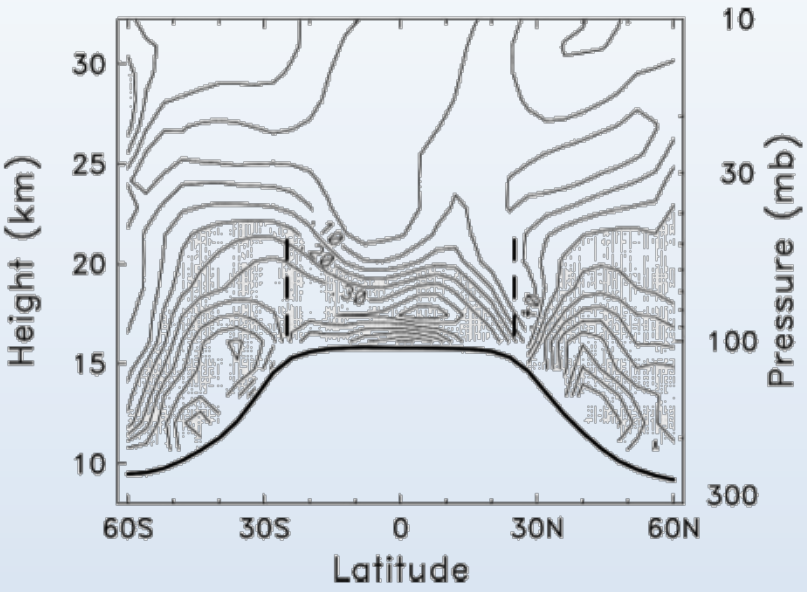
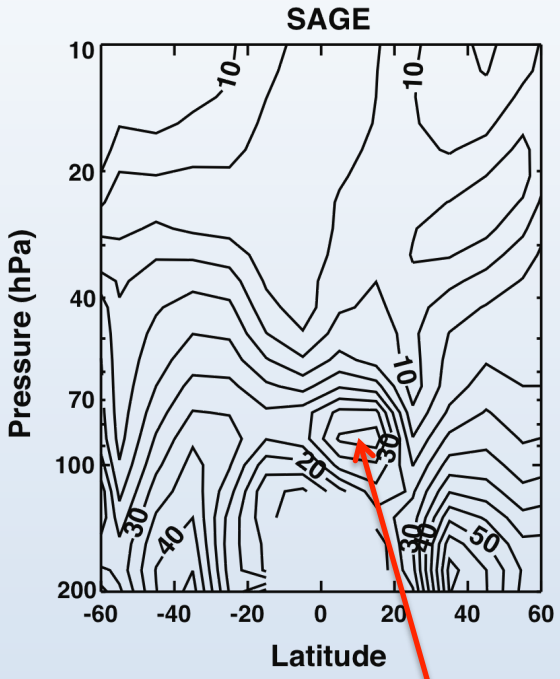
What do we see from satellite?



Randel et al. (2007)

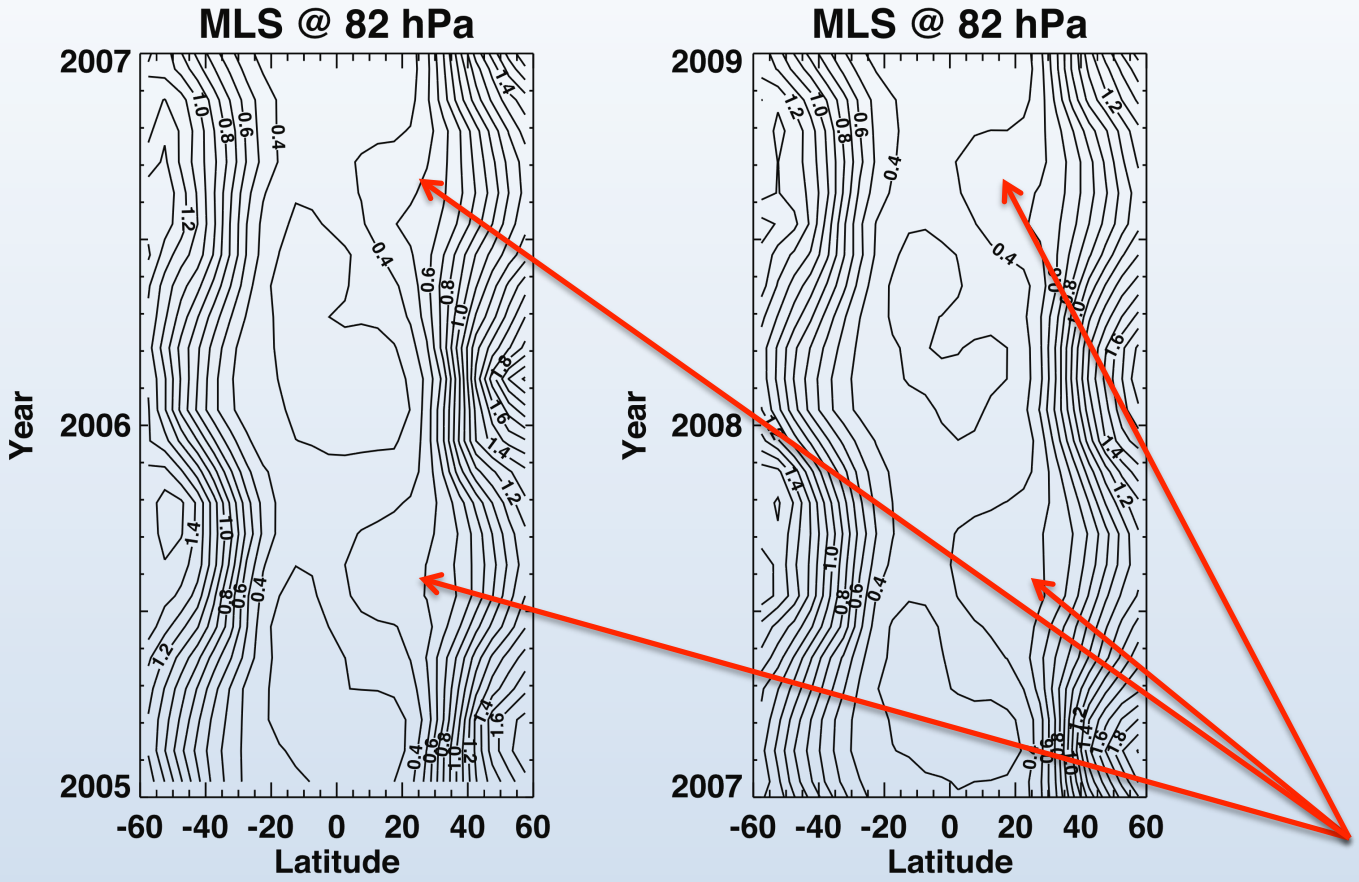


Analysis from SAGE II data

Note maximum is in Northern Tropics

Annual cycle magnitude

4 Years of Aura MLS Data



NH Summertime Mixing

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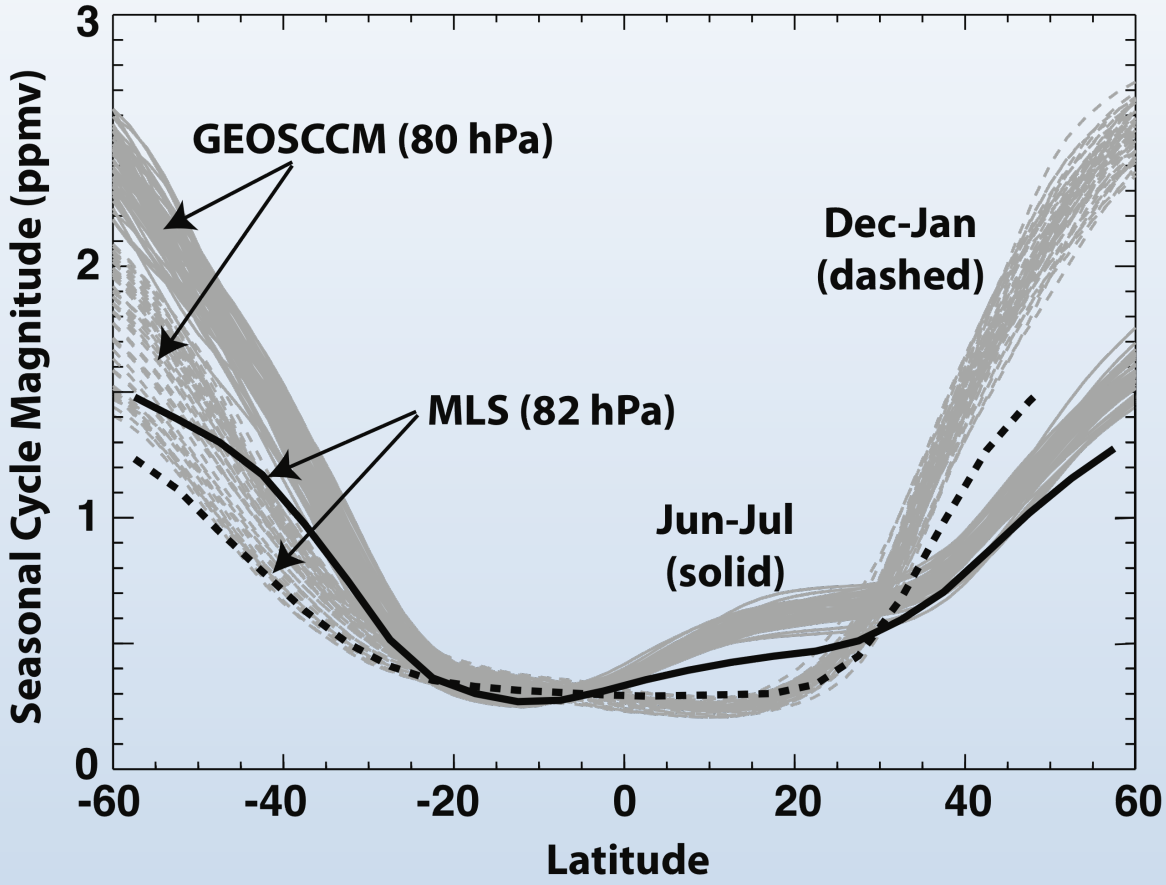
MLS Data at 82 hPa Compared to GEOSCCM



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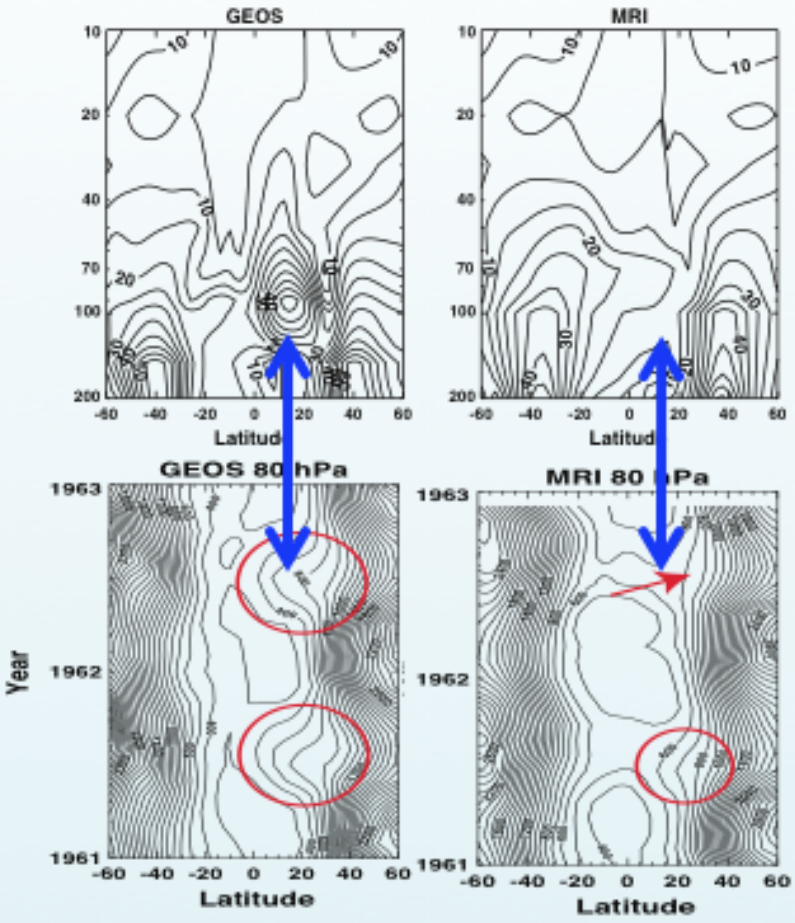
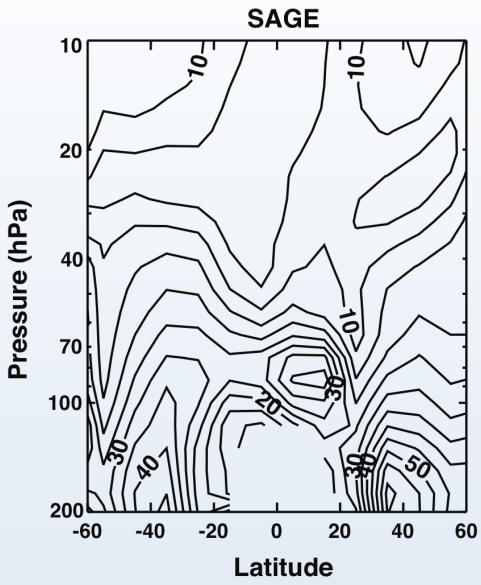
Models show a variety of patterns for the annual cycle magnitude: two examples are shown below

GEOS has same pattern, but much stronger

MRI has weaker pattern with some hint of QBO



Summer separation of contours at 80 hPa is consistent with mixing into tropics



Seasonal cycle pattern may be useful diagnostic of how models balance upwelling versus mixing in the tropics

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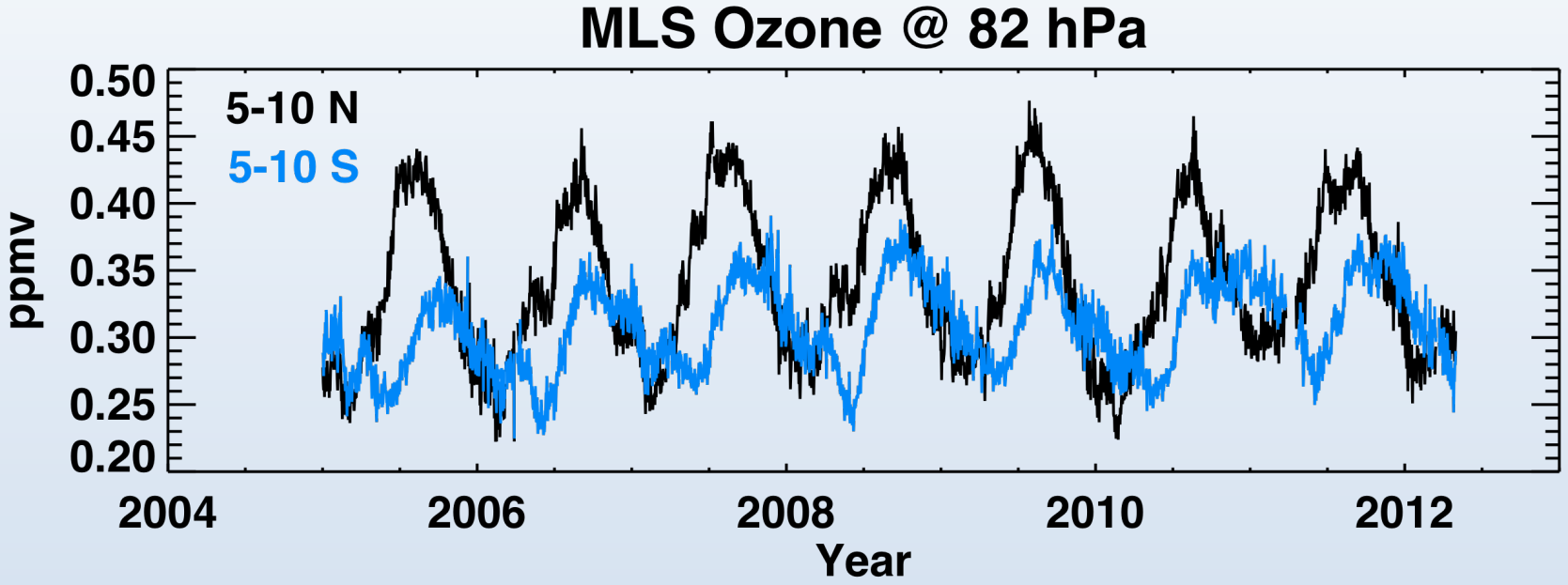
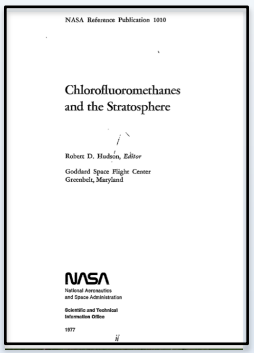
Phase of maximum in southern hemisphere trails that in northern hemisphere by 2 months

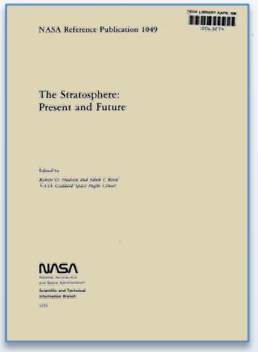


This is a consequence of the timing of upwelling vs. mixing in the two hemispheres and suggests that analyses should consider the northern and southern tropics separately.

Bob Hudson and the Ozone Assessments

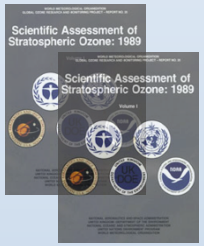
Ozone Assessment Reports

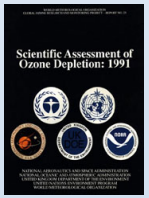


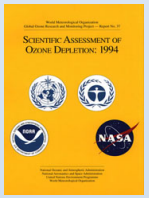


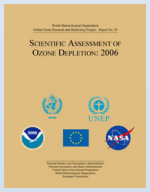
NASA Assessments 1977, 1979

WMO Assessments/Reports 1981, 1985, 1988









Official UNEP Assessments for the Montreal Protocol
1989, 1991, 1994, 1998, 2002, 2006, 2010

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Paraphrase of Bob Hudson advice on approach to the NASA ozone assessments

We are here to try to reach consensus on what we know and don't know about the stratospheric ozone layer and its possible perturbation. We will work hard to try to reach consensus. But, if there are topics on which there is no consensus or are opposing views, the we will state that lack of consensus or will give the alternative views.