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

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

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(The guy with the Polish name)  
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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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- 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

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 \( \text{N}_2, \text{O}_2, \text{Ca}, \text{Sr}, \text{Ba}, \text{K}, \text{Na}, \text{Li}, \text{Kr}, \text{Xe} \)
- Culminated in extensive, highly-cited, review in 1971

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

R. D. Hudson

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

1 Visiting Fellow 1968-1969; now at NASA Manned Spacecraft Center, Houston, Texas.
“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.”
“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?
“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.
“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 1857 and 1859 Å at 300, 600, and 900°K. Taken from Hudson and Carter (1968).
Penetration of Solar UV That has Energy to Photodissociate CFCs, N$_2$O

Altitude at which optical depth = 1

Altitude (km)

Wavelength (nm)

O$_2$

O$_3$

Lyman $\alpha$
Absorption of Solar Radiation by $O_2$:
Implications for $O_3$ and Lifetimes of $N_2O$, CFCl$_3$, and CF$_2$Cl$_2$

K. MINSCHWANER, R. J. SALAWITCH, and M. B. McELROY

Department of Earth and Planetary Sciences and Division of Applied Sciences, Harvard University, Cambridge, Massachusetts
Loss altitudes for long-lived molecules depend on radiation penetration in the 200 nm region of the spectrum

Minschwanner et al. (1993)

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
SAGE data ends in 2005

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

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$_2$O 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

SAMOA

SAMOA 80 hPa

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What do we see from satellite?

Randel et al. (2007)

Annual cycle magnitude

Analysis from SAGE II data

Note maximum is in Northern Tropics
4 Years of Aura MLS Data

NH Summertime Mixing

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MLS Data at 82 hPa Compared to GEOSCCCM
Models show a variety of patterns for the annual cycle magnitude; two examples are shown below.

- GEOS has the same pattern, but much stronger.
- MRI has a weaker pattern with some hint of QBO.

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


Official UNEP Assessments for the Montreal Protocol

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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.