

Stratospheric Ozone: Science and Policy

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STRATOSPHERIC OZONE: SCIENCE AND POLICY

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The discovery in 1985 of a "hole" in the atmospheric ozone layer near the South Pole has focused worldwide interest on what is happening to ozone, a minor yet important constituent of the earth's atmosphere. It has also raised concern about possible depletion of ozone on a global scale and resulting health effects, particularly an increase in the skin cancer rate.

An issue dating back to the 1970 controversy about the effects of supersonic transport aircraft has resurfaced: To what extent are human activities producing ozone changes? In particular, the emission into the atmosphere of chlorofluorocarbons (CFCs) has raised fears of "destroying" the ozone layer and has led to demands that the production of these chemicals be curtailed or even abolished (See Rowland, 1989).

The case against CFCs is based on a plausible but still incomplete theory, whose predictions are in a state of flux; on observations of the Antarctic ozone hole (AOH), whose future is uncertain; and on an assertion, as yet unverified, that ozone has been declining on a global scale.

Theory

As understanding of the complicated ozone photochemistry has improved-- it involves over 150 simultaneous reactions-- estimates of the effects of the CFCs have fluctuated. In recent years, the calculated effects have diminished; for example, the National Academy of Sciences in 1979 calculated an 18 percent ozone depletion due to CFCs, a 9 percent effect in 1982, and only a 3 percent effect in their 1984 report. But more recent calculations suggest between 5 and 7 percent ozone depletion for a CFC scenario of continued production. We have also learned that other polluting gases released by human activities, such as NO_x , methane, and carbon dioxide, all tend to diminish the CFC effects-- an interesting and entirely fortuitous circumstance. (For an up-to-date review, see UNEP/WMO 1989.)

A major criticism of the calculations is that they do not consider the input of chlorine and bromine from various natural sources-- that would dilute the effects of CFCs by an unknown amount: volcanoes (Symonds, Rose & Reed, 1988), and ocean biota (Manley & Dastoor, 1987; Singh, Salas, & Stiles, 1983) and salt particles (Finlayson-Pitts, Ezell & Pitts, 1989).

(Antarctic Ozone Hole) AOH

The Antarctic ozone hole was not predicted by current theory. It was discovered by British scientists operating an observing station on the Antarctic continent. After they reported their findings in 1985, NASA scientists searching their records of satellite data confirmed the effect. Indeed, the "hole" has been around since the mid-1970s, and getting larger every year, reaching a depletion of about 50 percent

(Rowland, 1989). Concern has centered on the rapid increase and the fear that it may grow to engulf the whole globe.

(Of course, the "hole" is not really a hole at all, but a temporary thinning in the stratospheric ozone layer. This phenomenon takes place for a few weeks, around October, in the region of the Antarctic. As far as we can tell, there have been no long-term changes in the ozone elsewhere, although the evidence is not conclusive.)

In spite of recent discoveries related to the mechanism of the AOH, we do not yet have a sufficient scientific base to answer the important policy questions: Is the AOH a completely new phenomenon? Is it produced by human activities? What is its likely future behavior? Will it persist, grow, or weaken? And what can and should be done about it?

There is little doubt that chlorine chemistry is the immediate cause of the seasonal (October) ozone decrease at around 18 km in the southern polar regions-- rather than purely meteorological effects based on dynamics or direct solar influences related to the solar cycle (Rowland, 1989). It is also probable that the major source of the chlorine is man-made chlorofluorocarbons (CFCs)-- although no precise estimate exists of the chlorine contributed by various natural sources (see above).

Yet how does one explain the sudden onset and rapid growth of the AOH phenomenon? Starting from essentially zero in the mid 1970s, the thinning reached, within a few years, about 50 percent of the vertical ozone column-- and essentially saturation in the lower stratosphere. This rapid change presents an important clue. The CFC content of the atmosphere has not risen quite so rapidly, nor should one expect any trigger effect related to the chlorine concentration. The research results suggest that, in addition to the chlorine, ozone destruction requires the presence of ice particles, "polar stratospheric clouds," that can form in the coldest part of the earth's atmosphere, the lower Antarctic stratosphere (See Rowland, 1989). But it is highly unlikely that the water vapor content could have increased so suddenly within a few years' time-- although increased emissions of methane should lead to increased injection of water vapor into the stratosphere (Singer, 1971). Recent measurements have confirmed and extended this hypothesis (Blake & Rowland, 1988). By an analogous mechanism, anthropogenic activities may contribute atmospheric sulfur compounds and thus increase stratospheric aerosols (Hoffman 1990).

This line of reasoning has led me to propose that the trigger for the AOH has been a gradual cooling of the stratosphere, which took the temperature below the freezing point; this cooling could have taken place as a part of a general climate fluctuation of the earth (Singer, 1988). And indeed, there has been an unusual surface temperature increase since about 1975; under some theoretical models of climate change, such a surface warming should be accompanied by a cooling of the upper atmosphere (Ramanathan, 1988).

It this hypothesis is borne out by appropriate measurements, then the AOH should disappear-- or at least become less pronounced-- if the stratosphere warms again, perhaps in conjunction with a cooling of the earth's surface. Conversely, a further cooling of the stratosphere could induce an Arctic ozone hole and a larger Antarctic hole.

The policy implication is that the AOH would not be much affected by further slow increases of atmospheric CFC, nor could it be removed if the CFC concentration were to decrease. In other words, the AOH phenomenon should now be reasonably insensitive to stratospheric chlorine concentration, and extremely dependent on the exact value of the temperature minimum in the lower Antarctic stratosphere (Singer, 1988).

Global Ozone Decreases?

In March 1988, the Ozone Trends Panel of NASA, after a massive re-analysis of data from ground stations and satellites, announced the existence of a declining trend in northern hemisphere ozone over the period of 1970 to 1986. A press release was issued, but as of this date (August 1991) the full underlying analysis has not been released for independent examination. A news story in Science (Kerr, 1988) quotes an average decline of -0.2 percent per year, which is greater than predicted from the current CFC-ozone theory. Since the decline is "worse than expected," the surprising, and not very logical, conclusion was reached that CFCs must now be phased out completely. (A more logical conclusion might have been that the analysis, or the theory, or possibly both, are incorrect.)

While the NASA panel's report is not yet available, a parallel report from the Center for Applied Mathematics of Allied-Signal, Inc. was distributed at a UNEP Ozone Science Meeting at the Hague in October 1988. The Allied study (Bishop, Hill & Marcucci, 1988) carries out a sophisticated regression analysis of the same data as the NASA study. After correcting for many natural variations, including the 11-year solar cycle, they derive a decline of 1.9 percent over the period 1970 to 1986-- which is only 1-1/2 solar cycles. But their sensitivity analyses show that the result depends on the time interval under consideration, suggesting therefore that the solar cycle correction was not adequate and that the decline is at least partly an artifact of the analysis (Singer, 1990).

EPA's recent revelation (reported in Science 252, p.204) that atmospheric ozone is eroding twice as fast as announced by the international Ozone Trends Panel (OTP) in March 1988 should be taken with several grains of salt.

Ozone has well-known, quite large, and irregular natural variations, ranging from seasonal swings of some 10 to 50 percent within a few weeks, to an 11-year variation of up to 5 percent, tied to the sunspot cycle (Angell 1989). This makes it difficult to extract a long-term trend of only a few tenths of a percent per year. The task becomes virtually impossible, however, when each solar cycle is different and produces a unique variation of ozone, and when the data cover only a short

time period -- little more than one sunspot cycle. (See Fig 1)

In this particular case, the EPA decided, quite arbitrarily, to draw a straight line through the uncorrected, fluctuating satellite data from 1979 to 1990, and then misinterpreted it a "depletion trend." By contrast, the experimenters at the NASA-Goddard Space Flight Center, who produced the data, identified an ozone decrease between 1979 and 1983, followed by an increase starting at the sunspot minimum in 1986 (Herman et al, 1991). (Fig 2)

In claiming that the depletion is twice as large as the one suggested by the OTP, EPA has compounded its error. Overlooked was the fact that the OTP had tried to subtract the solar-cycle and other natural variations before "discovering" an ozone trend value of about 0.2 percent per year.

Based on the data thus far, the jury is still out on ozone depletion--regrettably. One must have satellite data covering more than one sunspot cycle to make any small long-term trend stand out against the natural variations.

The Skin Cancer Issue

The possible connection of skin cancer with stratospheric ozone first gained public attention during the SST controversy in 1970. Certain forms of common skin tumors, basal cell and squamous cell carcinomas, have a much greater incidence at lower latitudes. They are more than twice as common in south Texas than in Minnesota--presumably because of the greater UV exposure in Texas due to the steeper sun angle there. With ozone weakened, more UV would reach the earth's surface everywhere, causing more tumors. It was this emotional skin cancer issue, more than anything else, that persuaded Congress to cancel the SST program. It is ironic that on the basis of current theory, SSTs flying in the lower stratosphere are believed to enhance ozone there rather than destroy it (Kinnison & Wuebbles, 1988).

Further relevant information adds important perspectives to the skin cancer discussion.

1. The increase of UV-B radiation that is feared to result from the thinning of ozone does in fact occur simply as a result of moving closer to the equator. (The reason is the steeper sun angle, leading to less absorption of UV by the horizontal ozone layer.) Thus ozone decreases of the order of 5 percent would cause the same UV increase as a move of less than 100 miles.

2. Non-melanoma skin tumors [nearly 100 percent curable] do show an increase towards lower latitudes-- the only one of the effects to show a latitude dependence. But it is not sure that all of the increase is due to UV-B intensity, as generally assumed when predicting future increases due to stratospheric ozone depletion. Much of the increase probably comes from greater exposure and other lifestyle factors at the warmer locations.

3. As far as the quoted EPA estimate of 200,000 skin cancer deaths in the next 50 years is concerned, that is not just a simple misinterpretation of the data; it is pure hype.

EPA scientists should certainly know that solar ultraviolet (UV) radiation at the earth's surface has not increased, as would be expected from an ozone depletion. On the contrary, published data from eight U.S. monitoring stations show long-term UV decreases (Scott et al, 1988). The reason is not known, but air pollution is a likely candidate for screening out the UV. If confirmed, then the EPA, enamored as it is of alarming skin cancer forecasts, should perhaps warn the public that removal of urban smog would also increase skin cancer rates.

Summary

The science of stratospheric ozone is at an interesting crossroads. The CFC theory is not yet good enough to explain the observations; and the observations are not yet good enough to confirm the theory. The policy question is whether drastic worldwide controls should be instituted immediately or whether one should wait for a better scientific understanding.

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References

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- Manley, S.L., M.N. Dastoor. 1987. Methyl Halide (CH₃X) Production from the Giant Kelp, Macrocystis, and Estimates of Global CH₃X Production by Kelp. Limnol Ocean. 32(3): 709-715.
- Ramanathan, V. 1988. The greenhouse theory of climate change:

A test by an inadvertent global experiment. Science 240: 293.

Rowland, F.S. 1989. "Chlorofluorocarbons and Stratospheric Ozone," in Global Climate Change (S.F. Singer, ed.) Paragon House, New York, 1989.

Scotto, J. et al. 1988. "Biologically effective UV radiation: Surface Measurements in the US, 1974 to 1985." Science 239: 762.

Singer, S.F. 1971. Stratospheric water vapor increase due to human activities. Nature 223: 543.

Singer, S.F. 1988. "Does the Antarctic Ozone Hole have a future?" Eos 69, No.47 (Nov.22)

Singer, S.F. 1990. "What Could Be Causing Global Ozone Depletion?" in Climate Impact of Solar Variability, NASA-Goddard SFC, Greenbelt, Md., April 1990

Singh, H.B., L.J. Salas, R.E. Stiles. 1983. Methyl Halides in and over the Eastern Pacific (40N-32S). J.Geophys. Res. 88: 3684-3690.

Symonds, R.B., W.I. Rose, and M.H. Reed. 1988. "Contributions of Cl- and F- bearing gases in the atmosphere by volcanoes." Nature 334: 415.

UNEP/WMO (UN Environment Programme/ World Meteorological Organization) Scientific Assessment of Stratospheric Ozone: 1989, Aug. 1989

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Figure Captions

Figure 1:

a) Change (in percent) of total ozone vs. sunspot number (Angell 1989). A sunspot maximum occurred in 1969-70; a minimum in 1986

b) Long-term trends in solar activity, as demonstrated by variations since 1650 in the annual mean sunspot number R.

Figure 2:

a) Global average of total ozone, between latitudes 69N and 69S, as observed by the Nimbus satellite (Herman et al, 1991). The authors show a decline between 1979 and 1983, and an increase after the solar minimum of 1986.

[8/5/91 strozone]

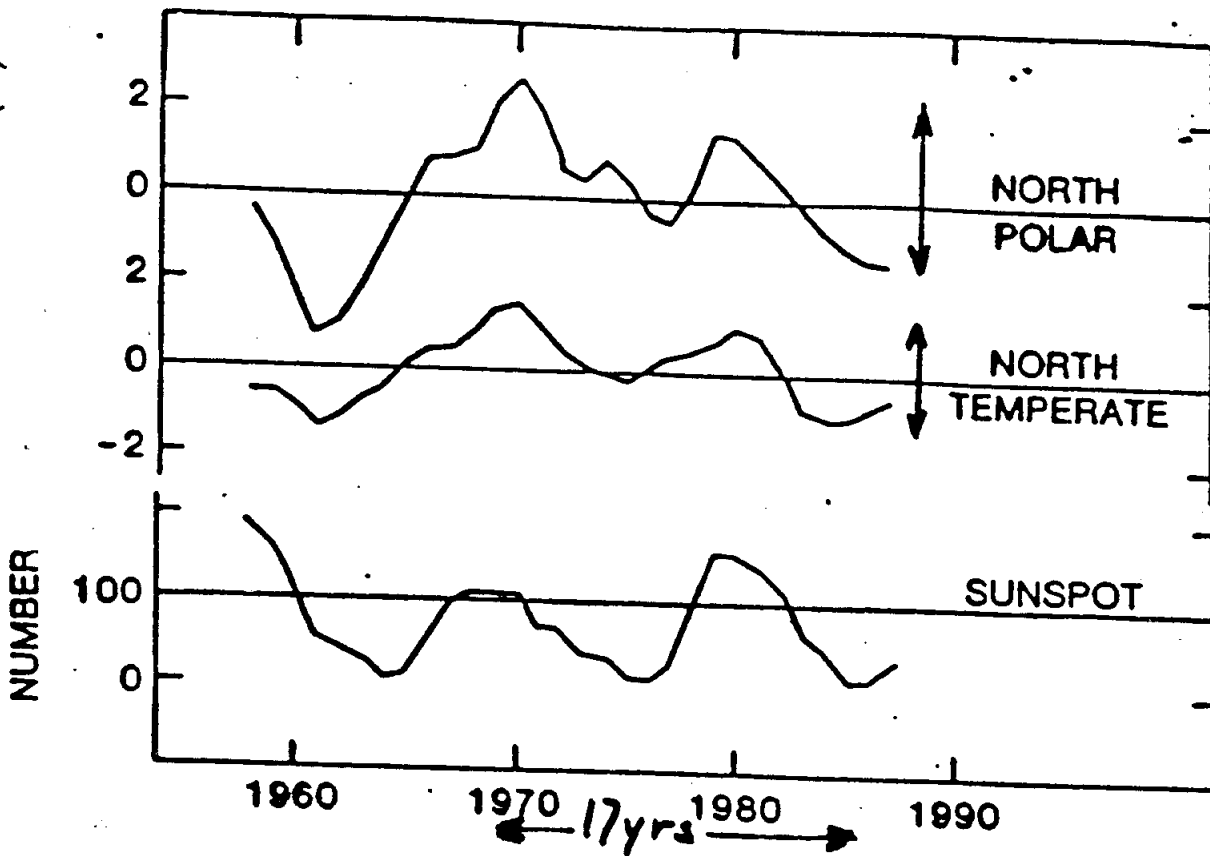


Fig. 1. Total ozone change (in %) and Sunspot number (Angell 1989)

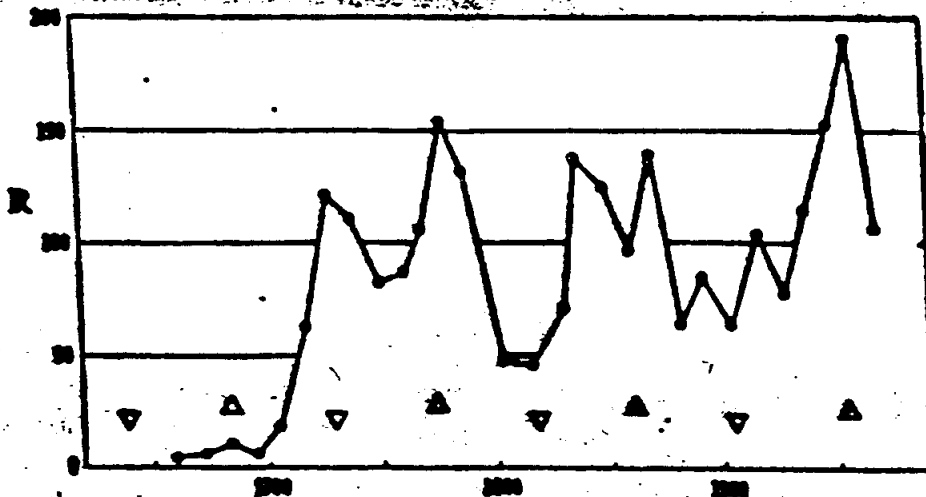
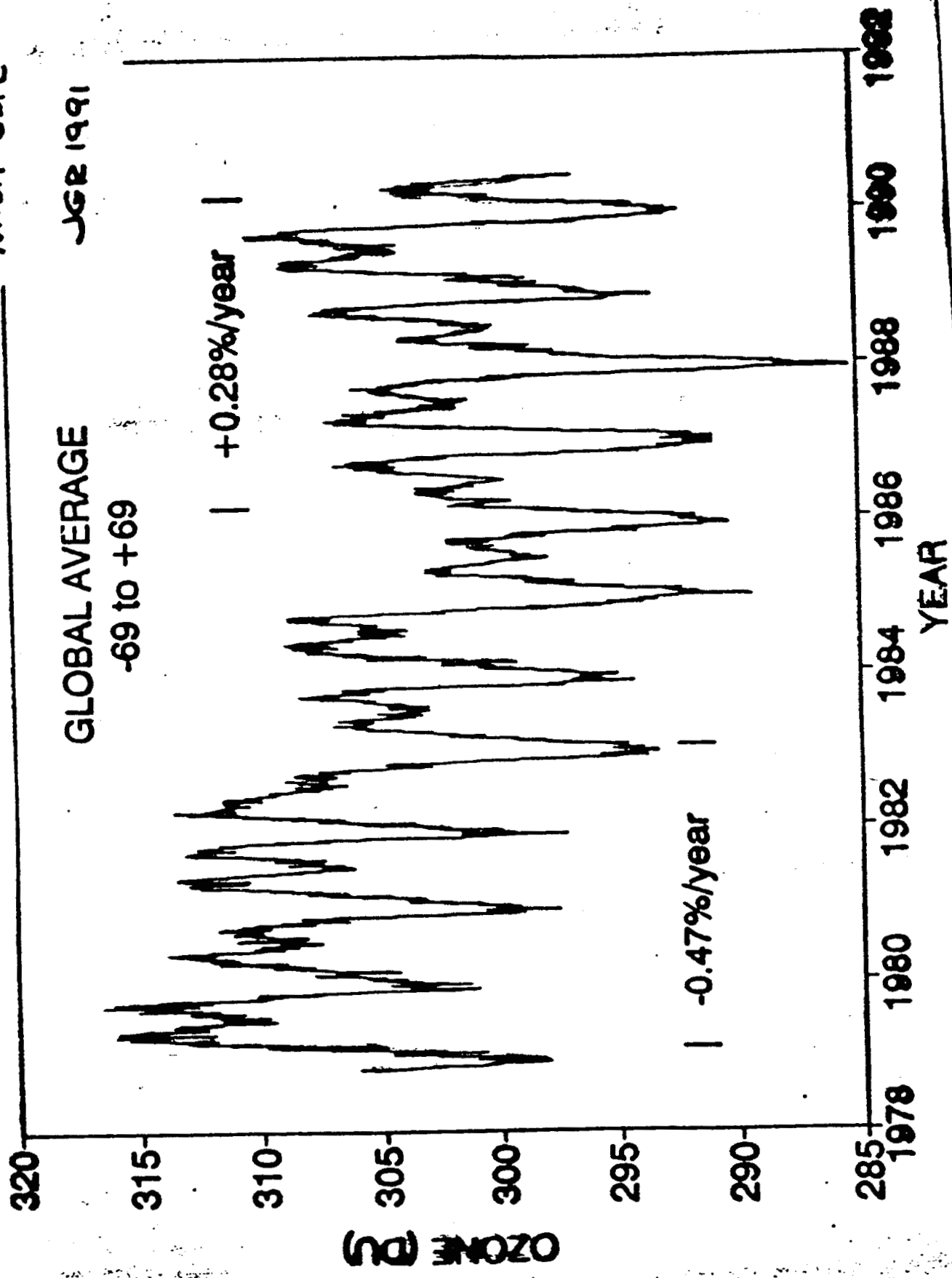


Fig. 2. Annual mean sunspot number R at maxima of the 11-y cycle, A.D. 1945 to present, to demonstrate long-term trend in solar activity. Evident is the 68-year "Gleisberg cycle" (extrema shown as triangles) imposed on a perturbed 11-year cycle since the Maunder Minimum.

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NASA - GSFC



Michaels' Citations in Scientific Publications

[Source, unless otherwise noted, is RT Pierrehumbert's review [3/96] of last ten years of the Scientific Citation Index]:

USGCRP was based on 11/95 review of the Geological Society of America Bibliography of International Geology Titles (under topics such as climate and meteorology)

1995

Michaels, PJ; Knappenberger, PC; Gay, DA, "Predicted and Observed Long Night and Day Temperature Trends", Atmospheric Research, v 37, n1-3 (Jul), p 257-266, 1995. (note funding from UVA and Cato Institute) (GET) NEW
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[this MAY be his one other peer-reviewed paper disputing the sulfate model -- see his testimony (Nov) p 5)

Marshall Institute - bill

1994

PJ Michaels and DE Stooksbury, "Climate Change and Large-Area Corn Yield in the Southeastern United States," Agronomy Journal, Vol 86, Issue 3, pp 564-569 (1994) (CHECK) requested

PJ Michaels, SF Singer, PC Knappenberger, "Analyzing Ultraviolet-B Radiation -- Is there a Trend?", Science, Vol 264, Iss 5163, pp 1341-42 (1994)

[This was a peer-reviewed technical comment on an article which had appeared previously, and it was cited in the Ozone Assessment; have full text (see also USGCRP p 16-21)]

et al, Technology: J. Franklin Institute, 331A, 123-33 (have??) - same as Singer? NEW, GET
- see board - Chauncey Storm + Fred Seitz

Lins & Michaels, EOS, 1994 (cited in Michaels comments to IPCC) (re Karl precipitation data) NEW,
GET

1993

PJ Michaels, "Benign Greenhouse," Research and Exploration, Vol 9, Iss 2, pp 222-233 (1993) (CHECK) [This is apparently a National Geographic Society publication] requested

PJ Michaels, "Global Warming -- A Reduced Threat -- Reply," Bulletin of the American Meteorological Society, Vol 74, Iss 5, pp 856-857 (1993) (GET CHECK) (presumably) requested

response to letters from 1992 article) (note that Michaels claims this is in the refereed literature in his response to our questions)

Chip Knappenberger, Patrick Michaels "Frequency of weather related tree damage in Virginia," Va State Climatology Office, Dept of Environmental Sciences, U of VA (Columbia SC Southeast Regional Climate Center, South Carolina Water Resources Commission Technical Paper Series 8 p (Research Paper No. 050593) (have summary) (source USGCRP p 4-5; nothing to do with GCC)

Chip Knappenberger, Patrick Michaels, "Return Intervals for 2, 3, 5, 7 and 10-day precipitation amounts for Virginia," Southeast Regional Climate Center, South Carolina Water Resources Commission Technical Paper series No 050193 (have summary) (source USGCRP p 5; nothing to do with GCC)

Knappenberger, Paul C.; Michaels, Patrick J, "Cyclone Tracks and wintertime climate in the mid-Atlantic region of the USA," International Journal of Climatology, New York, NY 13(5): 509-531, July-August 1993. (have summary) (source USGCRP, p 6-7; Pierrehumbert; nothing to do with GCC)

1992

PJ Michaels, DE Stooksbury, "Global Warming -- A Reduced Threat," Bulletin of the American Meteorological Society, Vol 73, Iss 10, opp. 1563-1577, 1992 (also in USGCRP p 7; **CHECK**) *requested*

PJ Michaels & PJ Stenger, "Climatic Change in Mixed-Layer Trajectories over Large Regions," Theoretical and Applied Climatology, Vol 45, Iss 3, pp 167-175, 1992 (source: USGCRP and Pierrehumbert) (have summary p 7-8) (relates specifically to Virginia weather, not climate change.)

Patrick J Michaels, John C Purvis, David J Smith, "Tornados in Virginia, 1950-1990", (Southeast Regional Climate Center, South Carolina Water Resources Commission, Technical Paper Series, TP121092, 1992) SOURCE:USGCRP (have summary p3; nothing to do with GCC)

Patrick J. Michaels, "Global Warming: beyond the popular vision," in Majumdar, Shayamal K., et al (eds), Global Climate Change: implications, challenges & mitigation measures., Easton PA, Pennsylvania Academy of Sciences, 1992 (p 100-116) (have summary) source:USGCRP summary p 4. **GET CHECK.** Invited article? Previously published? *?*

1991

PJ Michaels, DE Stooksbury, "Cluster Analysis of Southeastern United States Climate Stations," *Theoretical and Applied Climatology*, Vol 44, Iss 3-4, pp 143-50, 1991. (also in USGCRP p 8; have summary; nothing to do with climate change)

Patrick Michaels, "Global Pollution's Silver Lining," *New Scientist*, 132 (1796): 40-43 (23 Nov 1991) [The dirty habits of the fossil fuel industry may prove to have their good side, delaying the onset of a warmer world] SOURCE: USGCRP, p 1 **GET CHECK**

Pielke, RA; Song, A; Michaels, PJ, Lyons, WA; Arritt, RW, "The predictability of sea-breeze generated thunderstorms," *Atmosfera, Mexico DF, Mexico* 4(2):65-78, April 1991. (have summary; source USCGRP p 8; nothing to do with GCC)

1990

Michaels, PJ; Sappington, DE; Stooksbury, DE; Hayden, BP, "Regional 500-mb heights and US 1000-500-mb thickness prior to the radiosonde era," *Theoretical and Applied Climatology*, New York, NY 42(3): 149-154, 1990. (have summary: source USGCRP p 9)(estimated past century warming from cyclone tracks to avoid urban or site bias; found 1.5 degrees C warming until 1955, then drop of .7 degrees to 1980; overall, for 103 years of record, .3 degrees above mean by 1987.) (have summary, source USGCRP p 9)

1989

PJ Michaels, "The Greenhouse Effect -- Chicken Little and Our Response to Global Warming," *Journal of Forestry*, Vol 87, Iss 7, pp 35-39, 1989.

[I have copy; it is an "opinion feature." Editors note says clearly, "In the interest of maintaining an open and lively forum for the discussion of ideas, the Journal will, at the discretion of the editor, open its pages from time to time to the expression of individual opinion. Opinion Features are not intended to be scientific but simply well reasoned, and will not be peer reviewed. Opinions expressed are those of the author."]

Note also says that the article is a reprint of a January 8, 1989 article which ran in the *Washington Post*. (see other list -- article was called "The Greenhouse Climate of Fear.")

Patrick J. Michaels, "Crisis in Politics of Climate Change Looms on the Horizon," *Forum for Applied Research and Public Policy*, 4:4, pp 14- 23, Winter 1989.

[I have copy; clearly not a scientific peer-reviewed piece; it is a policy piece in an issue that focused on climate change policy issues.]

1988

Michaels, Patrick J; Sappington, David E.; Stooksbury, David E., "Anthropogenic warming in North Alaska?", *Journal of Climate*, Boston, 1(9): 942-945, Sept. 1988 (previous research using permafrost boreholes discussed; any warming shown by the boreholes occurred before 1948, before major emissions of thermally active trace gases.)(source: USGCRP, p 11)(have summary)

- earliest
GCC

1987

PJ Michaels & BP Hayden, "Modeling the Climate Dynamics of Tree Death," *Bioscience*, Vol 37, Iss 8, p 603-610

PJ Michaels, DE Sappington & PJ Stenger, "Climate and the Eastern Repository -- A Comparative Study," *Environmental Management*, Vol 11, Iss5, p 627-636, 1987

PJ Michaels, JT Mcqueen, RA Pielke, DE Sappington, "Composite Climatology of Florida Summer Thunderstorms," *Monthly Weather Review*, Vol 115, Iss 11, pp 2781-2791 (also in USGCRP p 11, have summary; nothing to do with GCC)

Knappenberger, Paul C, Michaels, Patrick J., "Hurricanes, droughts, and southeastern crop yields," in: *Southeastern Drought Symposium*, Columbia, S.C. March 4-5, 1987, Proceedings. (South Carolina Water Resources Commission, 1987, p 14-18) South Carolina State Climatology Office Publication G-30. (have summary; USGCRP p. 10, nothing to do with GCC)

1986

PJ Michaels, DE Sappington, PJ Stenger, "Modeling Changes in the Epidemic Range of Southern Pine Beetle Using Temperature and Objective Moisture Indicators," *Theoretical and Applied Climatology*, Vol 37, Iss 1-2, pp 39-50, 1986. (Also in USGCRP p 12, have summary; nothing to do with GCC)

1984

Michaels, Patrick J.; Gerzoff, Robert B., "Statistical relations between summer thunderstorm patterns and continental midtropospheric heights," *Monthly Weather Review*, Boston 112(4):778-789, April 1984 (source USGCRP p 13, have summary, nothing to do with GCC)

1983

Michaels, Patrick J., "Price, weather, and 'acreage abandonment' in western Great Plains wheat culture," *Journal of Climate and Applied Meteorology*, Boston 22(7):1296-1303, July 1983. Source USGCRP, p 14, have summary, nothing to do with GCC)

1982

Michaels, Patrick J., "Response of the 'green revolution' to climatic variability," *Climatic Change*, Dordrecht, Holland 4(3):255-271, 1984 (source USGCRP, p 12; have summary; nothing to do with GCC)

1981

Michaels, Patrick H., "Climate sensitivity of green revolution wheat culture in Sonora, Mexico," *Environmental Conservation*, Lausanne, Switzerland, 8(4): 307-312, Winter, 1981. Source USGCRP p 14, have summary, nothing to do with GCC.

1978

Michaels, Patrick J., "A predictive model for winter wheat yield in the United States Great Plains," *Climate/Food Research Group, Center for Climatic Research, Institute for Environmental Studies, University of Wisconsin-Madison*, 1978. (in LOC collection)

A Partial Listing of Michaels NON-Scientific work

1996

Editor, State of the Climate Report, funded and published by Western Fuels Association. It is not peer reviewed, although Michaels claims the sources for the report are from the peer reviewed literature. Also published on the Web. (have copy)

1995

edited World Climate Report, a biweekly newsletter, as a successor to the quarterly World Climate Review (see below). Funded by Western Fuels Association and other "associated companies." Also published on the web. (Have some copies.) (See Western Fuels press release announcing new newsletter to "address breaking news stories more quickly" than the World Climate Review. (I have copy.) WFA annual report describes it as a means to "provide a rapid response to the spurious reports that try to create virtual climate reality, a phony picture of increasing weather catastrophes caused by CO2 emissions."

Fall, 1992- Spring or Summer, 1995

Edited World Climate Review, a quarterly "research" publication. Funding was provided by the Western Fuels Association under a contract with the University of Virginia; not peer reviewed. (have some copies) (Newsletter article quoting from WFA press release says that WCR will contain articles written for nonscientists in a lively and informative manner." (skeptics notebook)

1994

"Global Warming -- Failed Forecasts and Politicized Science," Waste Management, v14, N2, p89-95, 1994. (Corp Source id as UVA and Cato) (Article says study was done for Washington University's Center for Study of American Business.)

"Hot air rises from freeze in Washington," Insight, v10,n18,p34, May 2, 1994 (fallacy of global warming) (have article)

1993

"Beware of misleading facts in reports of global warming," Insight on the News, v9, n6, p20, Feb 8, 1993 (Have article.)

"Health Costs will engender dangerous tax." Insight on the News, v9, n9, p20, March 1, 1993. (Re carbon tax.) (Have article.)

"Environmental rules should be based on science," *Insight on the News*, v9, n15, p21, April 12, 1993. (Argues for demise of Endangered Species Act and Delaney Clause re pesticide residue in food.) (Have article.)

Economic Affairs, 16, 19. (Michaels cites this in his response to our answers)

GET

1992

Sound and fury: the science and politics of global warming, Washington, D.C. , Cato Institute, 1992.

"Fast Forward Hysteria," *Washington Times*, Feb 20, 1992 (rush on CFC phaseout)(article?) *don't think I have*

"Reporters cry wolf about the environment," *Insight on the News*, v8, n47, p 20, Nov 23, 1992 (attacking reports about increased UVB in Chile) (have article)

"Global Warming -- The High Ground," *Aerospace America*, v30, n6, Jun, pb32, 1992

"Pregnant Men and blind sheep," *Washington Times*, pg E1, June 29, 1992. (have article)

"Free Markets, Free Science," *Washington Times*, p F1, December 15, 1992. (have article; attacks govt scientists) (Michaels is described as a Cato Institute Fellow.)

"Gore doesn't let a little thing like reality get in the way," *Insight on the News*, v8, n36, p 18, Sept. 7, 1992, p 18 (have article)

"Climate Update that isn't," *Washington Times*, p G2 (date unknown, probably 92 or 93 from context) (have article)

"Emissions bill flunks the science test," *Washington Times*, 5/13/92, G3 (distorts his testimony before the Science committee and calls hearing a witchhunt) (have article)

"Apocalypse Not Now: Science, Politics, and Global Warming (Part 1)", *Journal of Regulation and Social Costs*, v.2, Mar 1992 p 77-98 (have copy in 11/95 book); Part 2, v 2, June 1992, p 5-32.

1991

"The New National Academy of Sciences Report," *CATO Review of Business and Government*:20-23 (Summer 1991) (don't know what this is about)

"The Political Science of Global Warming," paper prepared for Cato Institute Conference on "Global Environmental Crises: Science or Politics?", Washington, D.C., June 5-6, 1991. (have copy in 11/95 book)

1990

"The Science and Politics of global warming," Backgrounder, Heritage Foundation (April 19, 1990).

1989

"The Greenhouse Climate of Fear", Washington Post, Outlook, January 8, 1989, p C3. ← *first*
