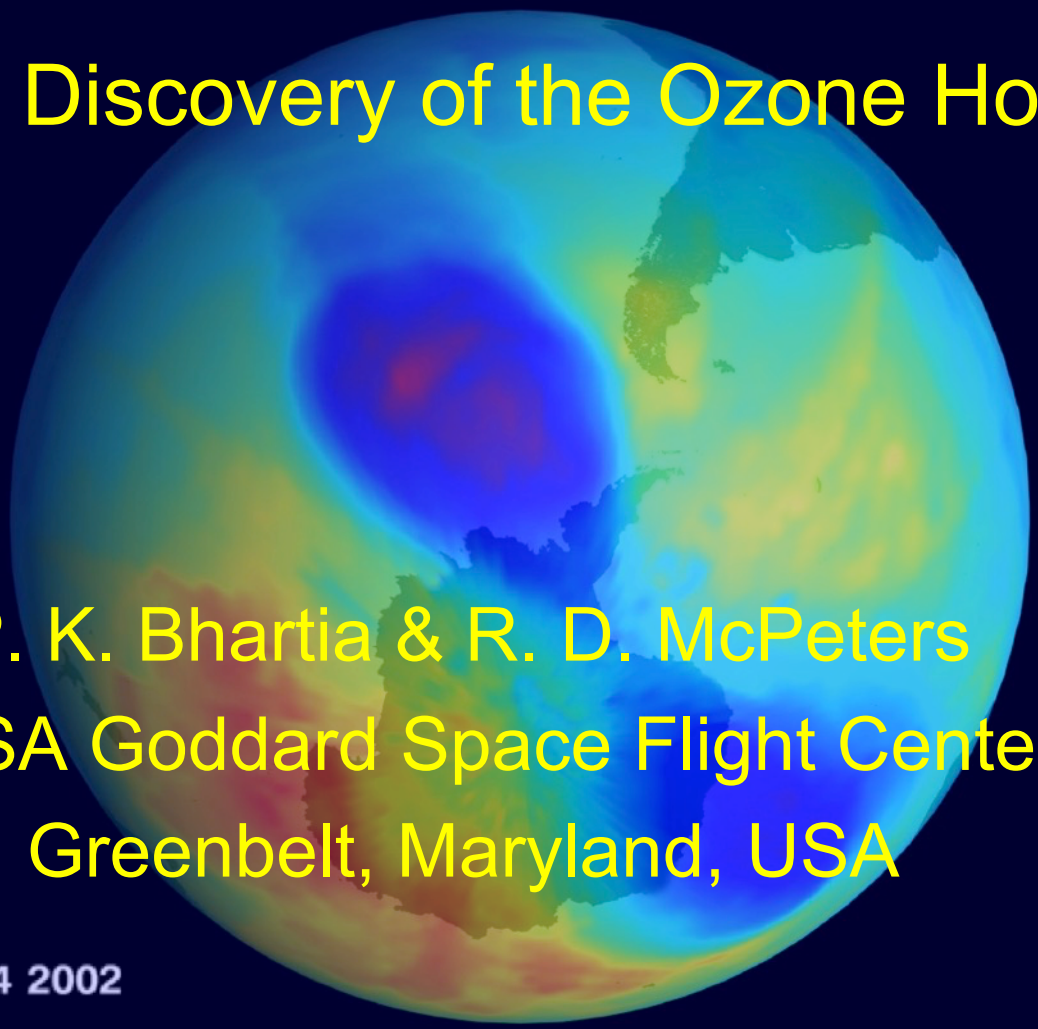
The Discovery of the Ozone Hole



P. K. Bhartia & R. D. McPeters
NASA Goddard Space Flight Center
Greenbelt, Maryland, USA

SECOND EDITION

WITH A NEW SECTION: "ON ROBUSTNESS & FRAGILITY"

NEW YORK TIMES BESTSELLER

THE BLACK SWAN

The Impact of the HIGHLY IMPROBABLE

"The most prophetic voice of all."
—*GQ*

Nassim Nicholas Taleb

A black swan event is an event that is:

- statistically improbable
- had no prior warning
- has a major effect

The Antarctic ozone hole fits this definition well.

- It was a >20x event
- It was a total surprise
- It changed the course of a multi-billion $ industry

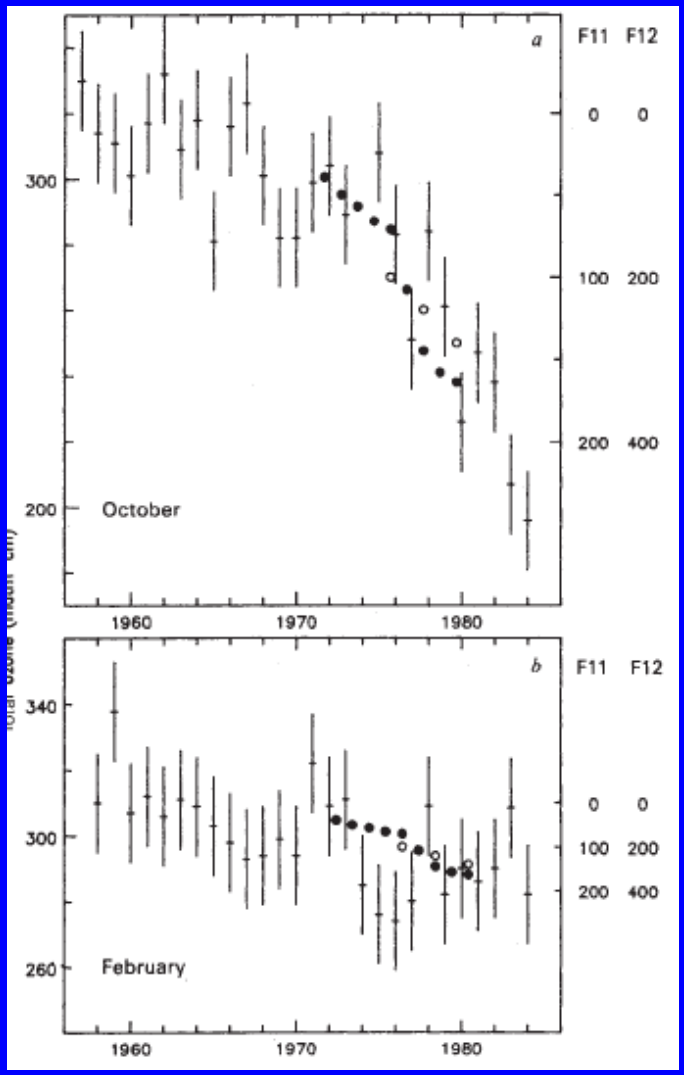
Discovery of Antarctic O_3 Depletion

Large losses of total ozone in Antarctica reveal seasonal ClO_x/NO_x interaction

J. C. Farman, B. G. Gardiner & J. D. Shanklin

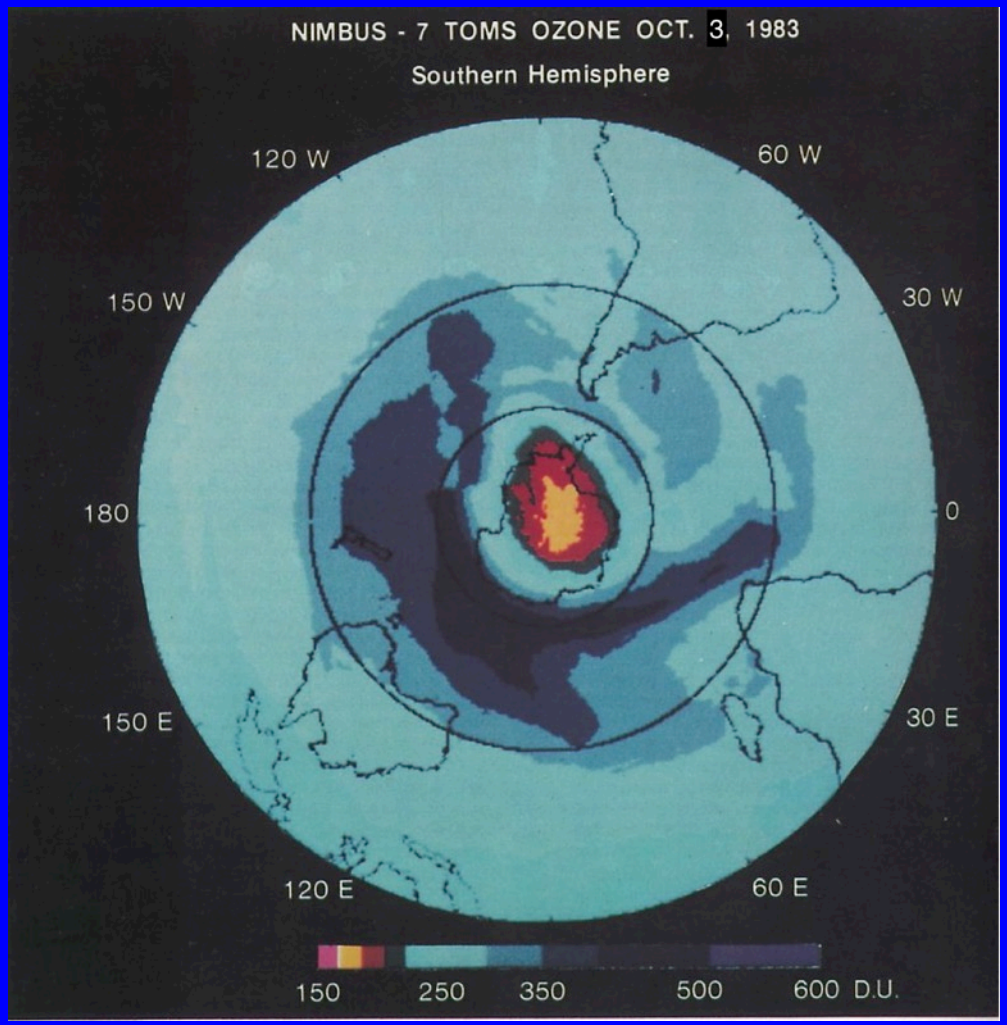
British Antarctic Survey, Natural Environment Research Council, High Cross, Madingley Road, Cambridge CB3 0ET, UK

NATURE VOL. 315 16 MAY 1985



Halley Bay 76°S

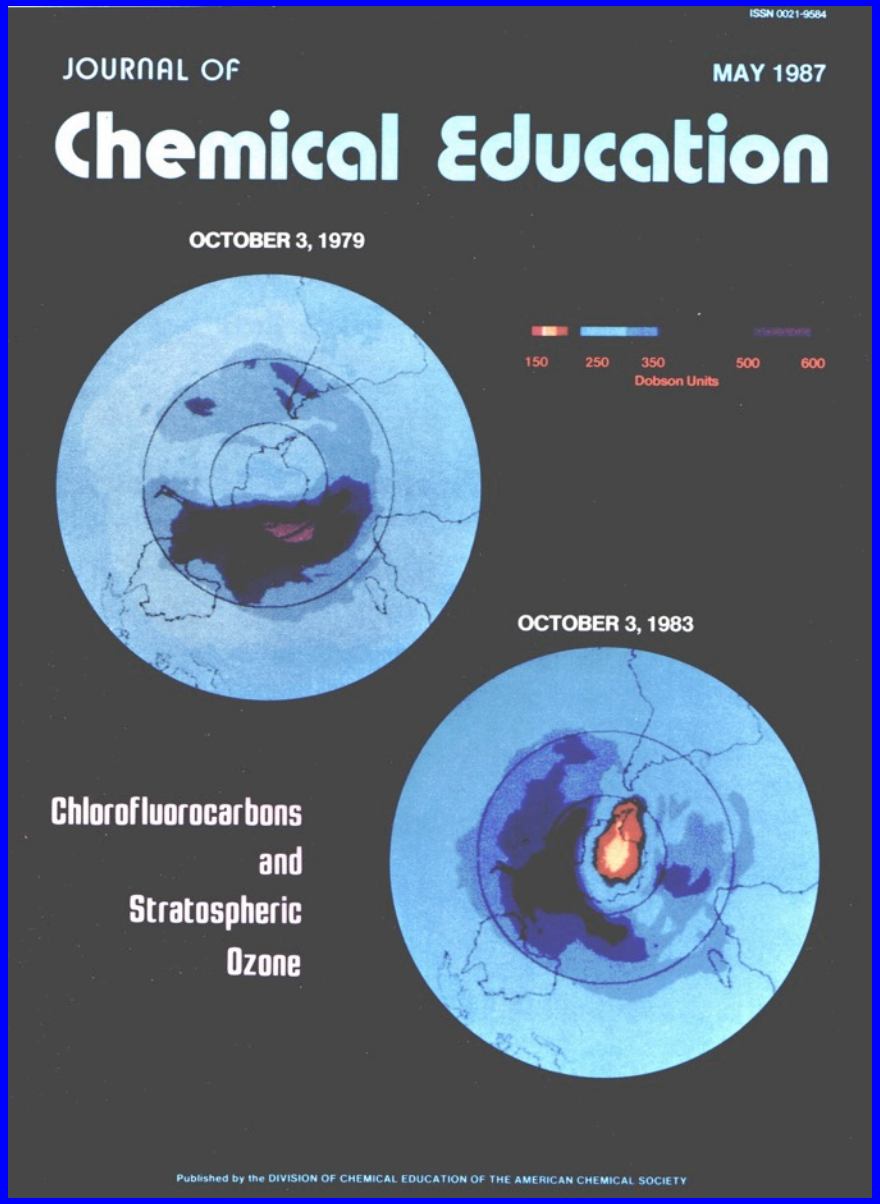
1st Image of Antarctic O_3 Hole



Presented at IAGA/IAMA
Prague, Aug 1985

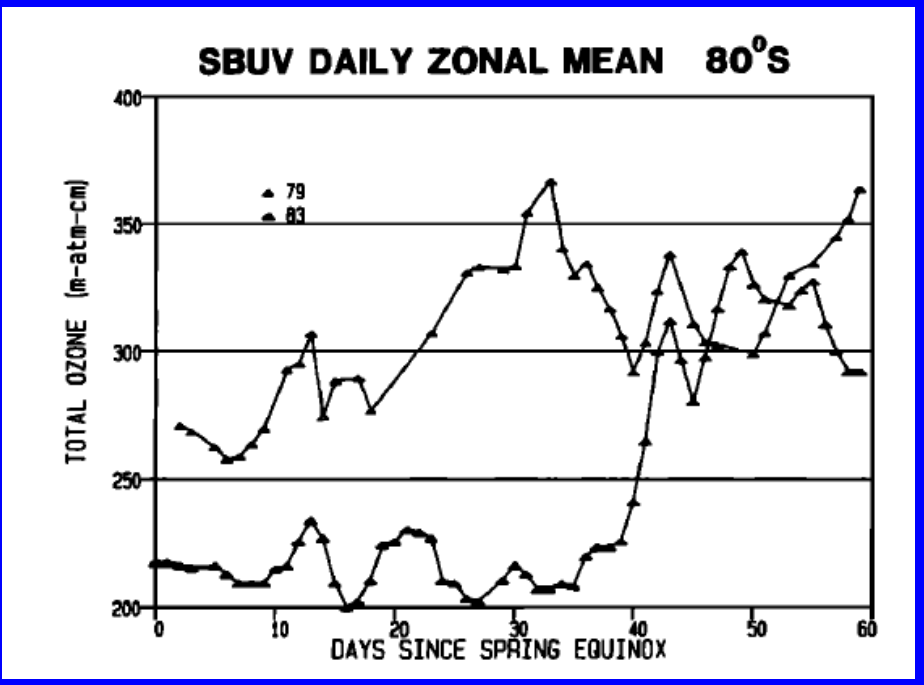
Bhartia, P. K., Heath, D. F. & Fleig, A. F., *Observation of Anomalously Small Ozone Densities in South Polar Stratosphere during October 1983 and 1984,* Symposium on Dynamics and Remote Sensing of the Middle Atmosphere, 5th Scientific Assembly, Int. Assoc. of Geomagn. and Aeron., Prague, Czechoslovakia, Aug 5-17,1985.

Complete Vugraph

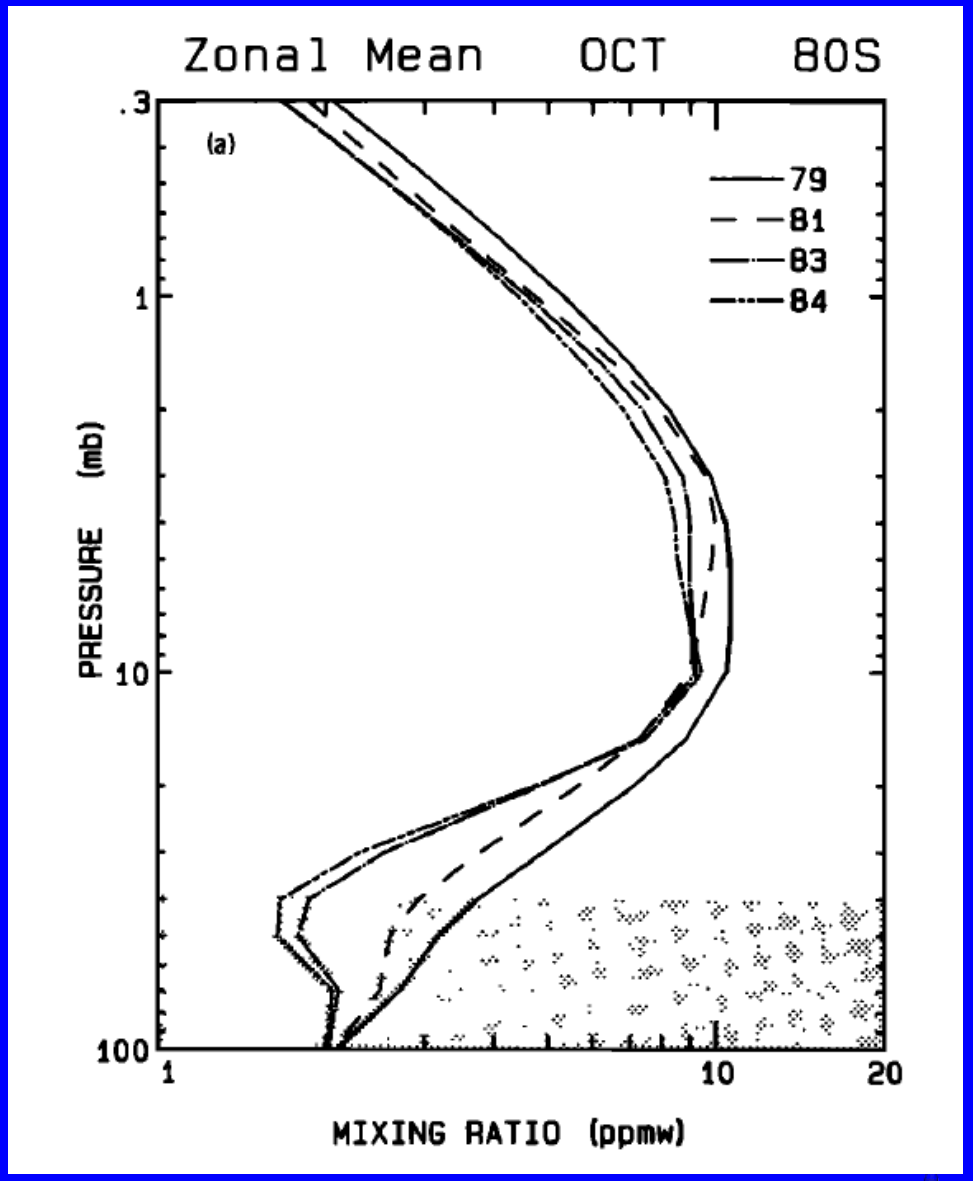


Nimbus-7 TOMS/ NASA

Other Results presented at the mtg



Nimbus-7 SBUV/ NASA



Follow-on meeting in Salzburg, Austria

August 1985

Low Ozone Level Found Above Antarctica

By WALTER SULLIVAN

Satellite observations have confirmed a progressive deterioration in the earth's protective ozone layer above Antarctica, according to scientists who analyzed data recently sent back from space.

Each October, the data show a "hole" appears in the ozone layer there, scientists say, and each year the layer in that area becomes less able to shield the earth from damaging solar ultraviolet rays.

Since 1974 scientists have been predicting a gradual depletion of stratospheric ozone as a result of increased pollution of the atmosphere. The new data have persuaded some researchers that the ozone loss is proceeding much faster than expected.

Link to Skin Cancer

It has been predicted that a significant depletion of the ozone layer would substantially increase the rate of skin cancer worldwide. Even under normal conditions, however, the ozone layer is subject to wide variations, and whether the recent depletion is part of a long-term trend is difficult to establish.

Several substances introduced into the atmosphere as pollutants are suspected of contributing to the depletion, chief among them fluorocarbons, such as the Freon used for refrigeration, and methane, nitrous oxide and a variety of bromine compounds.

The satellite measurements indicating a rapid decrease over Antarctica have been made by two devices riding the Nimbus-7 satellite, which was launched in 1978. Dr. Donald F. Heath of the Goddard Space Flight Center in Greenbelt, Md., who for several years has been monitoring the recordings, said yesterday a quick look at last month's data indicated that the decline is continuing.

In his view, however, the reason for it remains uncertain. It was first blamed on sulfur compounds and other particles ejected into the stratosphere by the 1982 eruption of El Chichon in Mexico.

Scientists Backs Theory

This explanation was also advanced by H. U. Dutsch of the Federal Institute of Technology in Zurich, Switzerland, based on ozone measurements at Arosa in the Swiss Alps.

The measurements there, as at numerous other ground stations, are based on recording two wavelengths of sunlight. Ozone absorbs sunlight at one of the wavelengths, so the relative strength of the two wavelengths is an indication of how much of the gas is in the atmosphere. The 1983 average was the lowest in 60 years. If that was entirely caused by material from El Chichon, Dr. Rowland said in a recent interview, the level should now be returning to normal, but it is not.

According to Dr. Heath, however, there are other possible explanations. The decrease could be linked to the sunspot cycle, which is now near a minimum. According to a study by NASA scientists, the chemical reactions that produce stratospheric ozone are stimulated by a form of ultraviolet radiation that becomes weak when sunspots are fewest.

Unusual Conditions Noted

Nor is it clear, Dr. Heath said, whether the Antarctic readings manifest a local change in atmospheric circulation, rather than a global depletion. The condition of the winter atmosphere over Antarctica is not matched anywhere else. The atmosphere, immersed in the polar night, remains highly stable and becomes extremely cold. Then, when spring comes to the Southern Hemisphere about October, it is suddenly bathed in sunlight and, it is hypothesized, ozone depletion runs at full speed.

According to the report observations at Halley Bay in Antarctica, "Comparable effects should not be expected in the Northern Hemisphere where the winter polar stratospheric vortex is less cold and less stable." The report, published earlier this year in Nature, was by J. C. Farman, B. G. Gardiner and J. D. Shanklin.

That fluorocarbons are responsible for the newly observed depletion of the ozone layer has been proposed by scientists of the British Antarctic Survey, based on observations conducted since 1957 at Halley Bay, and by Dr. F. Sherwood Rowland of the University of California at Irvine. It was Dr. Rowland, Dr. Mario J. Molina and Dr. Harold Johnston who in 1974 first warned of such a danger.

In 1980 a committee of the National Academy of Sciences concluded that the projected ozone depletion, through increased ultraviolet radiation, could increase skin cancer, curtail crop production and destroy the larvae of some marine organisms. A 16 percent ozone reduction, it said, would probably produce each year "thousands" of additional cases of melanoma — the most lethal skin cancer.

Effect of Ban

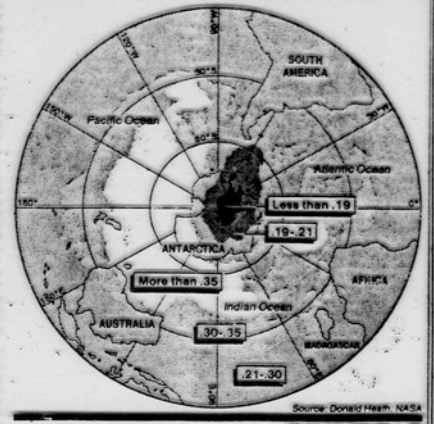
In 1977 a ban was imposed on fluorocarbons as spray-can propellants, but it became evident that the ozone varies in response to a variety of interacting natural and human influences. By 1984 an academy report estimated ozone reduction, due to fluorocarbons, at only 2 percent to 4 percent.

An annual 20 percent increase in the atmospheric content of bromine compounds that also endanger the ozone layer has been reported by a group from the Max Planck Institute for Aeronomy in Lindau, West Germany. Their instruments were lifted 15 miles above southern France by balloon in the fall of 1982, 1983 and 1984. Production of such compounds, including those used in fire extinguishers, appears to be increasing rapidly.

The original warning by Dr. Rowland and Dr. Molina concerned the chlorine that would be released when fluorocarbons are exposed to ultraviolet rays in the stratosphere. While those synthetic compounds are normally very stable, when exposed to ultraviolet light they break down and one of their constituents is chlorine, which can remove ozone from the atmosphere. The molecules of ozone gas are formed of three oxygen atoms, whereas oxygen gas contains only two of them. When chlorine reacts with an ozone molecule, breaking it up, the chlorine remains intact, ready to attack another one.

Decrease in Ozone over Antarctica

Measurements from the Nimbus 7 satellite have shown a "hole" in the ozone layer over Antarctica. These, recorded on Oct. 4, 1983, and now confirmed, indicate ozone abundances in terms of how deep a layer would be formed by the gas, in centimeters, at normal atmospheric temperature and pressure. In addition to the depleted area near the South Pole, there is a persistent high concentration south of Australia.



The New York Times / Nov. 7, 1985

Navy to Shorten Deployments

WASHINGTON, Nov. 6 (AP) — Adm. James D. Watkins Jr., Chief of Naval Operations, has issued guidelines specifying shorter overseas deployments and more time in home ports for ships and aircraft squadrons.

The directive, which Admiral Watkins signed last week and released Monday, commits Navy fleet commanders to planning maximum six-month deployments and "turnaround ratios of 2-to-1 or better," meaning that for every month a ship or squadron is at sea, two months should elapse before the next deployment.

Even more important to Navy personnel, the new rules specify that when a ship is between deployments crew members should be allowed to spend at least 50 percent of their time at home. At present, a ship may be assigned to her home port but is actually off the coast of the United States on training exercises.

The new guidelines are expected to result in shortened deployments as early as Jan. 1, when new quarterly schedules take effect. About one-third of the Navy's 570,000 active-duty personnel are at sea at any given time.

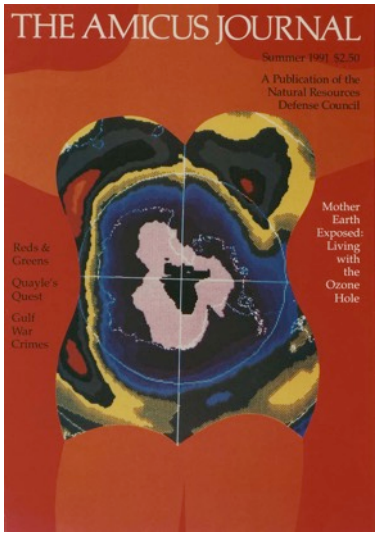
Admiral Watkins noted in his directive that "since the number and quality of ships and squadrons have grown significantly over the past five years," it was time to take advantage of the buildup.

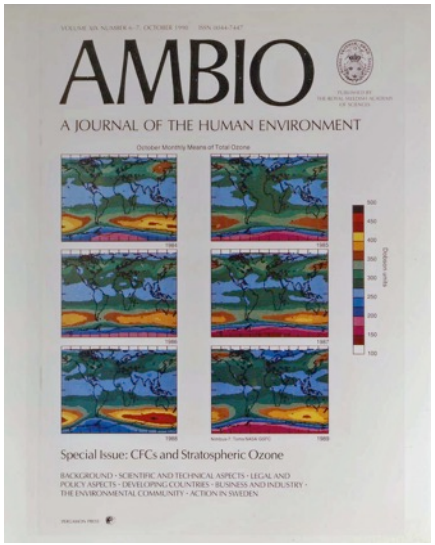
The Navy now has 540 ships, as against 480 at the start of President Reagan's first term. It expects to reach a goal of 600 ships by 1988.

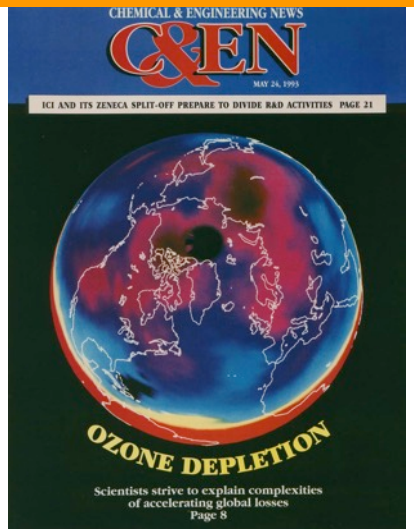
Washington Watch
Monday in Business Day
The New York Times

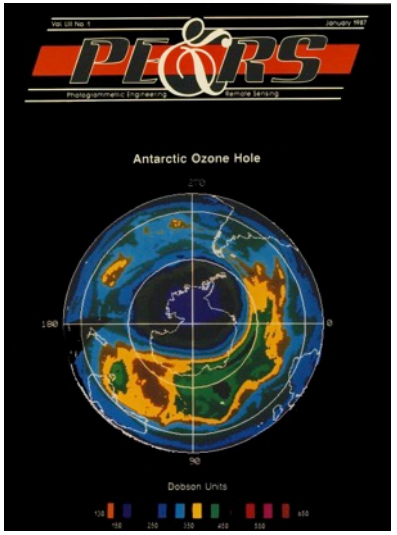
New York Times Article
November 7, 1985

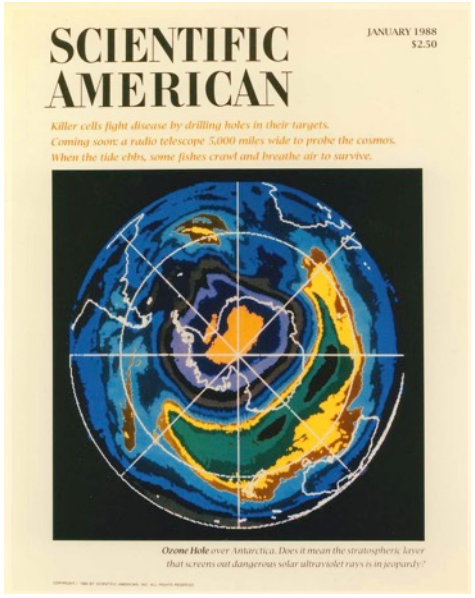
A small sample from diverse range of of publications with NASA/TOMS-produced images on the cover

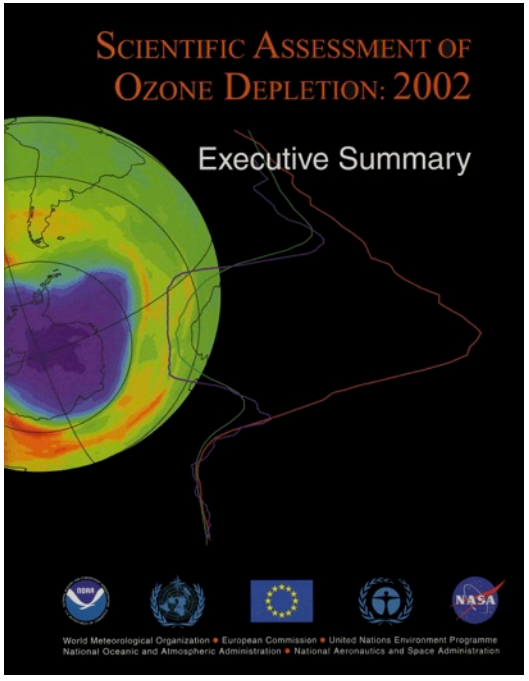


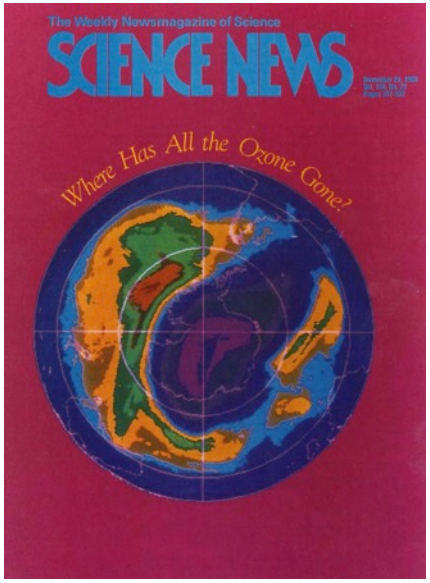




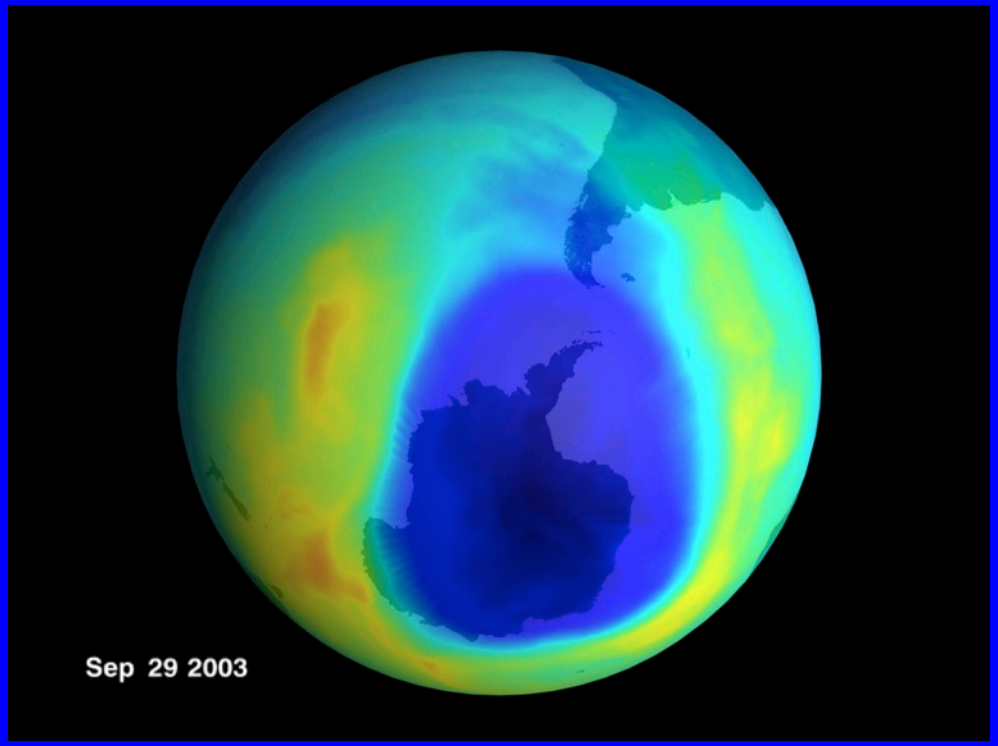








Why did these Images have so much Influence?



Antarctic Ozone Hole
Sept 23, 2003
Earth Probe TOMS/ NASA

Total Solar Eclipse
Aug 21, 2017
Weiser, Idaho, USA

Why Did NASA Miss the Discovery of the Ozone Hole?

Excerpt from Atmospheric Chemistry & Physics
By Seinfeld & Pandis, 1998 (page 189)

"(After the publication of Farman paper) it turned out, upon inspection of the satellite data that the low ozone concentrations were indeed observed, but were being systematically rejected in the database as being outside the reasonable range of data."

50th anniversary of first paper on Satellite UV total ozone algorithm

JOURNAL OF THE ATMOSPHERIC SCIENCES

A Preliminary Study on the Possibility of Estimating Total Atmospheric Ozone from Satellite Measurements

J. V. DAVE AND CARLTON L. MATEER

National Center for Atmospheric Research, Boulder, Colo.

(Manuscript received 31 October 1966, in revised form 6 March 1967)

6 Standard O_3 profiles

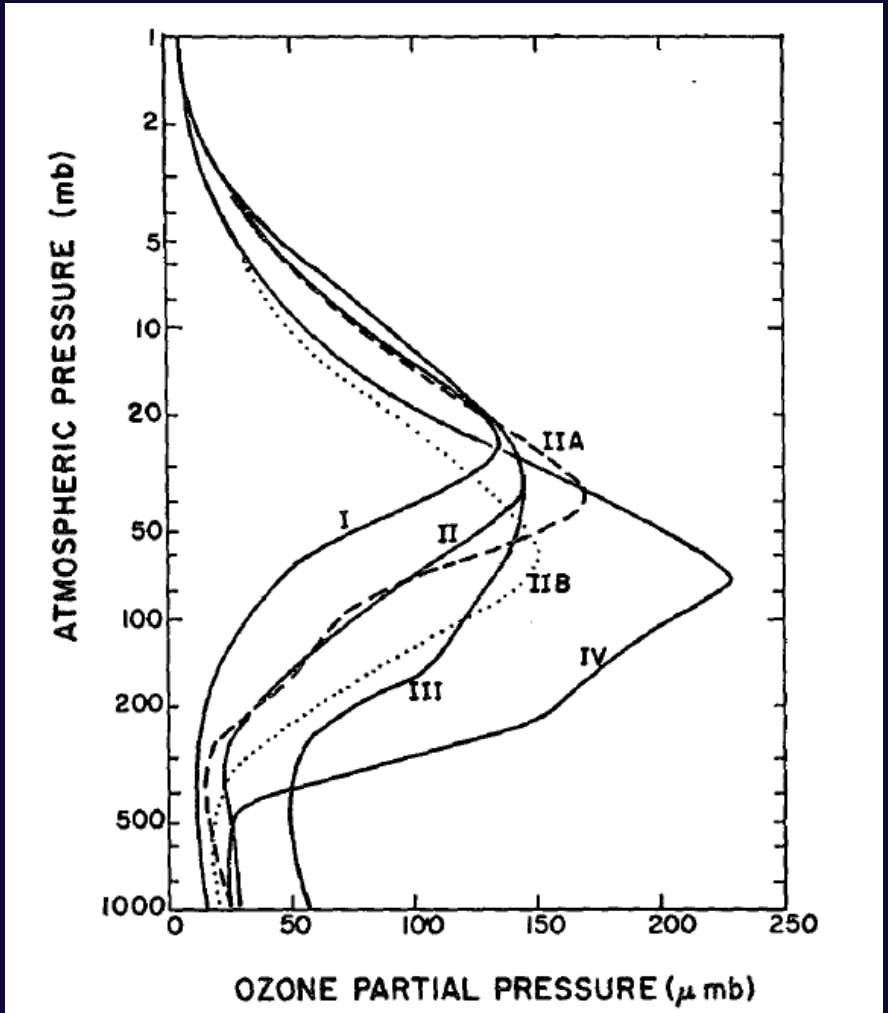


FIG. 1. Vertical ozone distributions used in this study. For distribution above 1 mb, see Dave and Furukawa (1966).

Only 4 years later!

Estimation of Total Ozone from Satellite Measurements of Backscattered Ultraviolet Earth Radiance

CARLTON L. MATEER

Canadian Meteorological Service, Toronto

AND DONALD F. HEATH AND ARLIN J. KRUEGER

Goddard Space Flight Center, Greenbelt, Md.

14 April 1971

ABSTRACT

Total ozone is estimated from Nimbus IV satellite measurements of the attenuation of backscattered radiances at wavelengths between 3100 and 3400 Å. A measurement of the backscattered radiance at 3800 Å, outside the O_3 absorption band, is used to determine an equivalent Lambert albedo for the cloud-ground-haze surface viewed by the instrument. The measured relative attenuation at two wavelengths is compared

Standard O_3 profiles extended to 16

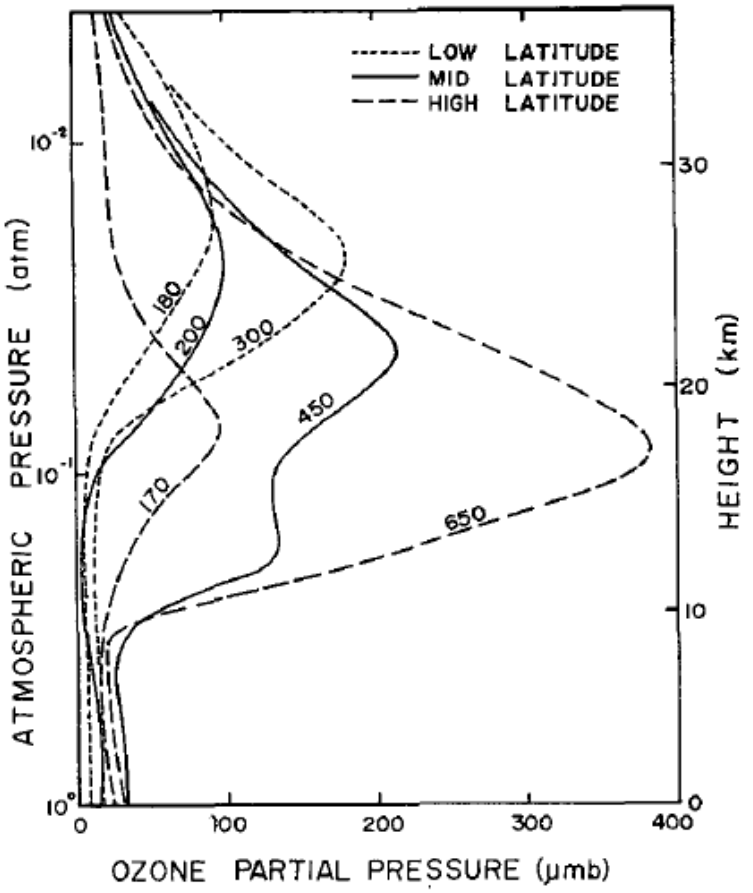
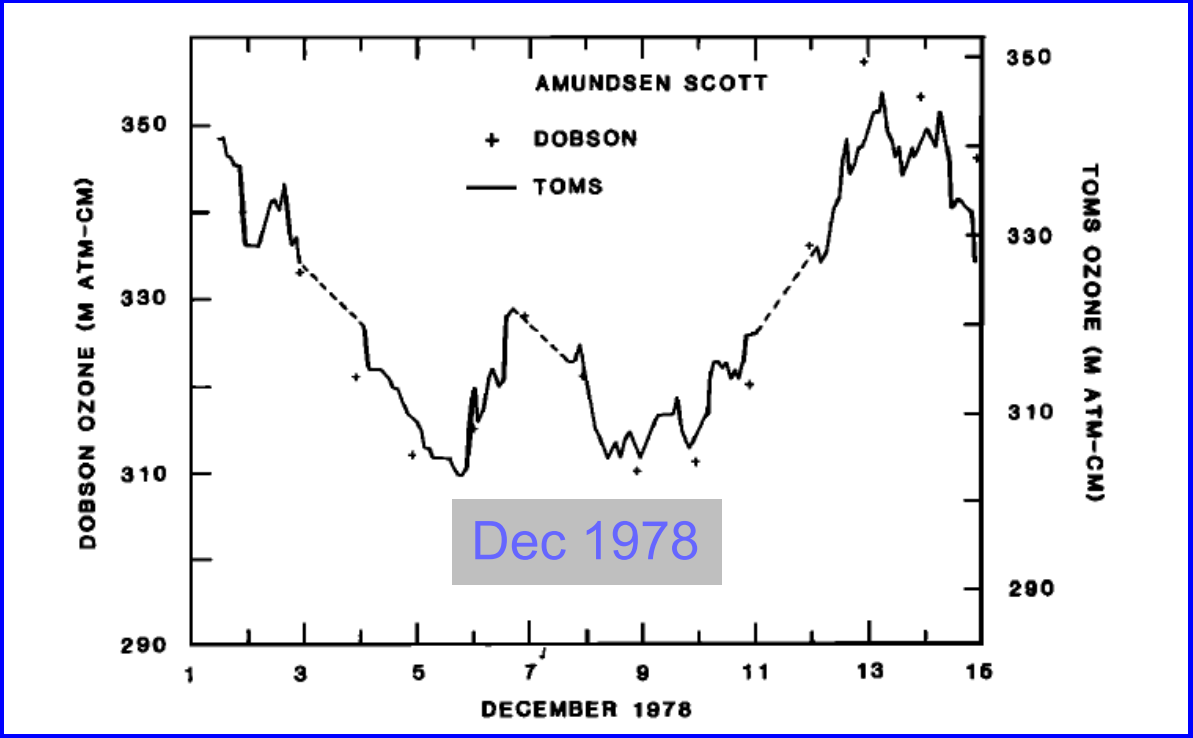


FIG. 1. Standard ozone profiles for lowest and highest total ozone (m atm-cm) for low-, mid-, and high-latitude series.

Comparison of TOMS data with South Pole Dobson Station



Bhartia et al., JGR, 89. D4, 1984

- Oct 1983: TOMS: ~170 DU, Dobson: ~350 DU, Dobson data were later retracted
- Oct 1984: Dobson/TOMS results became similar

Lessons Derived

- In-situ measurements are essential for interpreting remote sensing data
  - They provide prior information as well as missing information
- High quality data from ground-based remote sensing are needed to validate satellite data
  - As satellite data improve so should ground-based data
- A robust observing system requires all 3 types of measurements

For more information

Role of Satellite Measurements in the Discovery of Stratospheric Ozone Depletion

- P. K. Bhartia

Twenty Years of Ozone Decline, Proceedings of the Symposium for the 20th Anniversary of the Montreal Protocol, pp 183-189, Eds: Zerefos et al.

Backup Slides

Communication between
Wallops Is/NASA & BAS
In Oct/Nov 1983

Mr Harry Bloxom,
Ozonesonde Mission Manager,
NASA Wallops Flight Center,
Wallops Island,
Virginia,
USA 23337

1983 October 10

Dear Mr. Bloxom,

Our base at Halley Bay, Antarctica is currently reporting rather low values of ozone. Values are around 200 dobson units, which is considerably lower than our 1957 - 72 average. We would be interested to know if this is confirmed by satellite data. If so, is it possibly connected with the El Chichon erruption - there is some evidence that an increased aerosol load has been detected by turbidity measurements with an angstrom pyrheliometer.

Yours sincerely,

Jonathan D. Shanklin

Mr Harry Bloxom,
Ozonesonde Mission Manager.
NASA Wallops Fl
Wallops Island,
Virginia,
USA 23337

National Aeronautics and
Space Administration
Goddard Space Flight Center
Wallops Flight Facility
Wallops Island, Virginia 23337

NASA

001429

NOV 29 1983

Reply to Attn of: 1001

British Antarctic Survey
Attention: Mr. Jonathan D. Shanklin
High Cross Madingley Road
Cambridge, England CB3 OET

Dear Mr. Bloxom

Subject: Request for Ozone Data

Our base at Hal
rather low valu
units, which is
We would be int
satellite data.
El Chichon erru
aerosol load ha
with an angstro

Your request of October 10, 1983, for ozone data has been forwarded to Mr. Alfred C. Holland (Code 963) of the Applications Directorate at this Facility. Our group is no longer involved in this activity.

Mr. Holland may be reached at telephone (804) 824-3411, extension 328.

Harvey C. Needleman, Head
Balloon Projects Branch

Yours sincerely

25th Anniversary
1958-1983

Jonathan D. Shanklin