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Robert T. Watson of NASA Receives NAS Award for Scientific Reviewing of Stratospheric Ozone Dynamics

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Robert T. Watson, an atmospheric chemist who has played a key role in our understanding of the threats posed by ozone depletion, is the 1992 recipient of the National Academy of Sciences Award for Scientific Reviewing. This annual award, established in 1977, is jointly sponsored by Annual Reviews, Inc., of Palo Alto, California, and the Institute for Scientific Information® (ISI®), Philadelphia.

Watson, a program office director in the Earth Science and Applications Division of the National Aeronautics and Space Administration (NASA) has been described as a "national asset."[1] (p. 289) This much-deserved appellation has been applied because Watson, through his reviews, science, and administrative feats, has supplied the evidence to a skeptical world that proves there is such a thing as ozone depletion in the upper stratosphere, particularly over Antarctica, and that it threatens humankind's well-being. This subject has been addressed in past essays in *Current Contents®* (*CC®*).[2-5] The award, which carries a prize of $5,000, honors James Murray Luck, the founder of Annual Reviews. Table 1 lists many of Watson's contributions to scientific reviewing.

Recent Alarming Reports

The citation, read at the award ceremony in Washington, DC, the evening of April 27, described Watson's papers and reports as providing "the basis for industrial/government decisions to regulate the atmospheric emissions of chlorofluorocarbons" (CFCs). While Watson's work extends back to the mid-1980s and before, just this February, NASA reported finding alarming levels of ozone-destroying chemicals over Canada, the US, and Europe. The report, based on aircraft and satellite data, finds that chlorine monoxide, (ClO) a chemical produced by the breakdown of CFCs, reached unusually high levels over parts of the Northern Hemisphere in January of this year.[6]

Photo courtesy of NASA

Robert T. Watson

As is now generally known, the ozone layer acts as a shield from the sun's ultraviolet radiation. Any depletion of the layer raises the risk for humans of increased in-

Table 1: Contributions to scientific reviewing by Robert T. Watson and colleagues. Items are listed in chronologic order.

Watson R T. Rate constants for reactions of ClO_x of atmospheric interest. *J. Phys. Chem. Ref. Data* 6:871-917, 1977. (Cited 160 times.)

Baulch D L, Cox R A, Hampson R F, Kerr J A, Troe J & Watson R T. Evaluated kinetic and photochemical data for atmospheric chemistry. *J. Phys. Chem. Ref. Data* 9:295-471, 1980. (Cited 225 times.)

Baulch D L, Cox R A, Crutzen P J, Hampson R F, Kerr J A, Troe J & Watson R T. Evaluated kinetic and photochemical data for atmospheric chemistry: supplement I. *J. Phys. Chem. Ref. Data* 11:327-496, 1982. (Cited 235 times.)

Baulch D L, Cox R A, Hampson R F, Kerr J A, Troe J & Watson R T. Evaluated kinetic and photochemical data for atmospheric chemistry: supplement II. *J. Phys. Chem. Ref. Data* 13:1259-380, 1984. (Cited 175 times.)

Watson R T, Stolarski R S & Geller M A. *Present state of knowledge of the upper atmosphere: an assessment report.* Submitted to EPA and US Congress, 1984.

DeMore W B, Golden D M, Hampson R F, Howard C J, Kurylo M J, Margitan J J, Molina M J, Ravishankara A R & Watson R T. *Chemical kinetics and photochemical data for use in stratospheric modeling: evaluation #7.* Pasadena, CA: Jet Propulsion Laboratory, 1985. JPL Publication 85-37.

Watson R T, Stolarski R S, Geller M A & Hampson R F. *Present state of knowledge of the upper atmosphere: an assessment report.* Washington, DC: NASA, 1986. NASA Reference Publication 1162.

WMO Global Ozone Research and Monitoring Project. (Watson R T, chairman.) *Atmospheric ozone 1985: assessment of our understanding of the processes controlling its present distribution and change. Report no. 16.* Geneva, Switzerland: World Meteorological Organization, 1986. 3 vols.

Watson R T, Prather M J & Kurylo M J. *Present state of knowledge of the upper atmosphere 1988: an assessment report.* Washington, DC: NASA, 1988. NASA Reference Publication 1208.

WMO Global Ozone Research and Monitoring Project. (Watson R T, chairman.) *Report of the International Ozone Trends Panel—1988. Report no. 18.* Geneva, Switzerland: World Meteorological Organization, 1990. 2 vols.

WMO Global Ozone Research and Monitoring Project. (Watson R T & Albritton D, chairmen.) *Scientific assessment of stratospheric ozone: 1989. Report no. 20.* Geneva, Switzerland: World Meteorological Organization, 1990. 2 vols.

Watson R T, Rodhe H, Oeschger H & Siegenthaler U. Greenhouse gases and aerosols. (Houghton J T, Jenkins G J & Ephraums J J, eds.) *Climate change: the IPCC scientific assessment.* Cambridge, England: Cambridge University Press, 1990. p. 1-40.

Watson R T, Kurylo M J, Prather M J & Ormond F M. *Present state of knowledge of the upper atmosphere 1990: an assessment report.* Washington, DC: NASA, 1990. NASA Reference Publication 1242.

cidence of skin cancer, cataracts, and damage to the immune system from the sun's rays. Crops are also at risk. CFCs, used as coolants in refrigerators and air conditioners, escape into the atmosphere when this equipment is charged, vented, or otherwise leaks. The dramatic findings of a 1991 ozone assessment[7] prompted President Bush to move up the deadline for halting US production of CFCs, from the year 2000 to the end of 1995.

Just last month, as we were preparing this essay, the first "ozone friendly" supermarket opened in Glens Falls, NY.[8] The 35,000 supermarkets in the United States account for 20 percent of refrigeration in the US. Every refrigerator and air conditioner releases CFCs. The new refrigerator at the Stop n' Save in Glens Falls uses a refrigerant called 134a, which contains no chlorine—the chemical culprit destroying the ozone in the stratosphere. However, 134a is known to trap heat in the atmosphere, though it is described as only one-tenth as harmful as CFCs. The day following the supermarket opening, the space shuttle *Atlantis* blasted off on a special mission devoted to further studying ozone depletion.

A Scientific Detective Story

One of the great scientific detective stories of our time, rivaling the exploits of Sherlock Holmes, has been the search for the chemical agent responsible for the disappearance of great quantities of ozone. Watson, known among his peers for high energy and diplomacy, helped solve the mystery. It is a tale of money, South American intrigue, a converted U-2 spy plane flown on risky missions by Vietnam-era pilots to collect data, and international politics.

In the mid-1970s, the chemistry of the stratosphere became the subject of congressional debate over the use of CFCs as propellant gases in aerosol sprays. Congress, as part of the regulatory process, directed NASA to report to it every two years on the state of the ozone layer. Watson's PhD work at Queen Mary College, London University, in the early 1970s involved chemical reactants, such as Cl and ClO, now known to be very important in the stratosphere.

In fact, the earliest critical compilation of chemical reactions in the ClO_x chain was put together by Watson in 1974 and issued as a National Bureau of Standards publication. It later was published in the *Journal of Physical and Chemical Reference Data.*[9] Meanwhile, Watson traveled to the US where, after postdoc stints at the University of Maryland and the University of California, Berkeley, he joined the staff of the Jet Propulsion Laboratory in Pasadena, California.

The Seminal Rowland/Molina Paper

Two early, principal warriors in the battle to bring the ozone layer crisis to the attention of the world were F. Sherwood (Sherry) Rowland and Mario J. Molina. In their first publication in 1974, they theorized that CFCs could destroy the ozone layer.[10] This was followed by a much longer paper in 1975[11] that was the subject of a *Citation Classic*® commentary by Rowland in 1987,[12] which now has been cited in more than 365 publications. It would be left to Watson, though, to marshal the scientific forces and resources to either prove or disprove the theory.

1985: Farman's Ominous Data

In many ways, the ozone story, still unfolding, is a tale that highlights the importance of scientific papers in the research process—how they often drive the regulatory and political process. In 1984, Joe Farman and his colleagues at the British Antarctic Survey, in Cambridge, England, decided they could no longer postpone publishing a paper on a trend they had been observing over the past few years: It had become crystal clear—ozone levels monitored over Halley Bay in Antarctica were 40 percent below normal. The ominous data would have to be published and explained.[13]

"Joe Farman and most every other scientist connected with atmospheric studies could remember only too well the thundering response of an indignant chemical industry on several continents to the 1974 Rowland-Molina paper that indicted CFC's as a threat to ozone, and a potential instrument of increased skin cancer and crop damage. 'Preposterous!' industry had raged, trotting out an impressive array of company chemists and public relations people flanked by political lobbyists all trying to make the point that there was no proof of ozone depletion in the sky, and without proof there was no reason to damage a money-making industrial product—the eight-billion-dollar-per-year CFC industry!"[1] (p. 32)

The ozone layer floats somewhere between eight and thirty miles above the planet. By 1986, Farman's data had been verified by NASA satellite data readings. The existence of the ozone hole was accepted as fact. However, more information, readings, and observations were imperative. A series of scientific expeditions to Antarctica was needed. It fell to Watson to organize and orchestrate them.

"Watson was known for doing the impossible. In fact, with his unremitting energy and reputation for being a dynamo with limited understanding of the word "no," his ability to blend the diplomatic and administrative with the scientific was somewhere between rare and unparalleled. He seemed to thrive on organizational challenges, overwhelming bureaucratic roadblocks by force of logic and reason cloaked in diplomacy and personal charm."[1] (p. 97)

The Watson Antarctic team included many world-class scientists. Too many to mention here. However, Susan Solomon of the National Oceanic and Atmospheric Administration can be singled out—selected by Watson, she led two key ground-based expeditions to the McMurdo Station, Antarctica, in 1986 and 1987—as can James Anderson, a professor at Har-vard, who designed a crucial ER-2 instrument on short notice.

ER-2: Into the Blue Gases

Watson's efforts finally brought together some 150 American scientists at Punta Arenas, Chile, for a six-week expedition that would extend from mid-August to the end of September 1987. The data collection on one expedition would feature the use of two aircraft—a DC-8 and the ER-2, a modified U-2 spy plane. These aircraft would carry 21 specially constructed instruments. Computer modelers were on hand to analyze the data as soon as they came in.

"I believe this is probably the single most important Earth science project in a decade," Watson told *Chemical and Engineering News* days before the trip. "Scientists—at least some of us—were getting complacent, thinking that they had started to understand the stratosphere and what controls ozone. This phenomenon in Antarctica was absolutely unexpected, absolutely unpredicted. We don't know if it's chemistry, we don't know if it's dynamics."[14] (p. 212)

The four ER-2 Vietnam-era pilots flew their missions at the mercy of a single engine, without Antarctic survival gear, and with no place to land if the engine quit. The winds at 60,000 feet reached 125 to 150 knots, with temperatures at times reaching minus 90 degrees. Watson himself often went on the 11-hour DC-8 flights, calmly munching popcorn while, as the program manager, making operational decisions on routing the aircraft in order to maximize scientific return.

Chlorine the Culprit

In December 1986, Watson convened a new review group called the International Ozone Trends Panel. This review group reported in March 1988 that a massive loss of ozone had occurred over Antarctica and was caused by chemical reactions initiated by chlorine—most of it released by CFCs. In addition, a loss of ozone was reported over the Northern Hemisphere during winter months. With this overwhelming consensus of research, DuPont, Allied Signal, and other manufacturers agreed to discontinue CFC production by the year 2000. Then, in October 1991, researchers released the findings of the most recent scientific ozone assessment, based on satellite and ground-based data.[7] These data confirmed the loss of ozone in all seasons and at all latitudes except the tropics. The agreed date for discontinuing CFC production is now 1995.

To date, Watson has been responsible for five NASA reviews of the ozone layer status for Congress—all in response to the Clean Air Act. More significant, though, is the fact that he has chaired or cochaired international scientific assessments of ozone since 1982 that have been cosponsored by various international and national organizations. The unanimity of opinion developed in these assessments has made a strong case for ozone chemistry and dynamics, giving scientists, regulators, and industry a common set of data with which to work.

In addition to the October 1991 review noted above, three others that have resulted in regulatory actions are *Atmospheric Ozone 1985*, a three-volume, 1,180 page work published in 1986,[15] *Report of the International Ozone Trends Panel—1988*, a two-volume, 864-page work published in 1990,[16] and *Scientific Assessment of Stratospheric Ozone: 1989*, in two volumes, cochaired with Albritton and published in 1990 at 960 pages.[17] And, the conclusions of two of these[14,17] have been adopted by the US Congress and the Montreal Protocols.

Watson's Citation Record

Most previous recipients of the NAS award for scientific reviewing have written high impact papers in traditional review journals. While review papers, on average, are cited with greater frequency than typical research papers, they are subject to the same variations in influence and acceptance. Some clearly are blockbusters, written at the right time. Others are only cited four or five times each year for a decade or more. The reasons for these large variations in the citation frequency of reviews are similar to those for original research papers. Clearly, the size and pace of the research field covered in a review is but one factor.

As one would expect, though, a body of work on a subject as important as Watson's ozone research is bound to include some highly cited papers. His four most-cited papers are indicated in Table 1. We must note here, though, that while these are certainly highly cited, the primary impact of his work may well be on national and international environmental and industrial policy rather than directly on the research of other scientists. It is a tribute to the work of Watson and his colleagues that this research, and these reviews, have had both citation and policy impacts.

Other NAS Awards

In addition to Watson, 12 other scientists received awards at the academy's 129th annual meeting. The NAS Award in Chemical Sciences went to Donald J. Cram, S. Winstein Professor of Organic Chemistry in the Department of Chemistry and Biochemistry at the University of California, Los Angeles. He received a bronze medal and $10,000 prize for work on "fundamental questions of stereochemistry and reaction mechanism and for pioneering work on the synthesis and properties of designed inclusion complexes."

Cram received the 1987 Nobel Prize in chemistry. In 1978, he wrote a *Citation Classic* commentary[18] for *CC* on a 1952 paper he coauthored with F.A.A. Elhafez on the subject of stereochemistry.[19]

The other awards went to Joseph L. Reid, professor of oceanography at Scripps Institution of Oceanography—the Alexander Agassiz medal; George C. Williams, professor emeritus, Department of Ecology and Evolution, State University of New York, Stony Brook—the Daniel Giraud Elliot Medal; Andrew J. Majda, professor of mathematics, Princeton University—the NAS Award in Applied Mathematics and Numerical Analysis; and Alice F. Gast, associate professor, Department of Chemical Engineering, Stanford University, and Sangtae Kim Wisconsin Distinguished Professor, chemical engineering, fluid mechanics, and rheology, University of Wisconsin—the NAS Award for Initiatives in Research.

Others included: Robert MacPherson, professor of mathematics, Massachusetts Institute of Technology—the NAS Award in Mathematics; Thomas W. Cline, professor of genetics, Department of Molecular and Cell Biology, University of California, Berkeley, and Bruce Baker, professor, Department of Biological Sciences, Stanford University—the NAS Award in Molecular Biology; Martha Farah, associate professor, Department of Psychology, Carnegie Mellon University—the Troland Research Award; Stefan Bengtson, docent, Institute of Paleontology, Uppsala University, Sweden—the Charles Doolittle Walcott Medal; and Philip Hauge Abelson, retired editor of *Science*—the 1992 Public Welfare Medal, the academy's highest honor.

Last year's award for scientific reviewing, as we noted in *Current Contents*,[20] went to Alexander N. Glazer, a professor of biochemistry and molecular biology at the University of California, Berkeley. He was honored for shedding new light on the photosynthetic process in cyanobacteria.

* * * * *

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