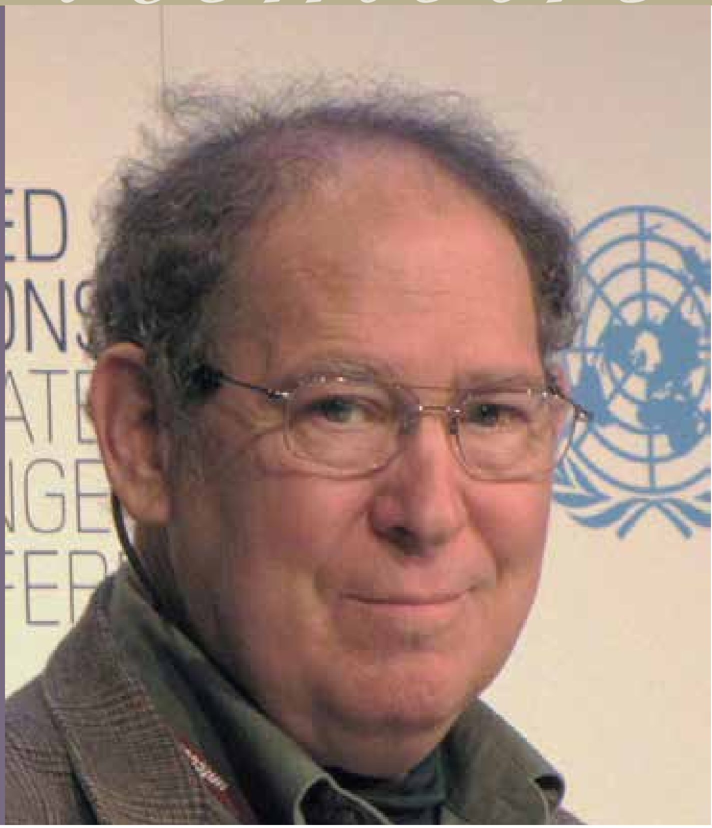
Stephen Schneider

1945–2010

BIOGRAPHICAL *Memoirs*



A Biographical Memoir by
B. D. Santer
and P. R. Ehrlich

NATIONAL ACADEMY OF SCIENCES

Stephen Henry **SCHNEIDER**

February 11, 1945–July 19, 2010

Elected to the NAS, 2002

By B. D. Santer and P. R. Ehrlich

Steve Schneider made fundamental contributions to scientific understanding of human effects on Earth's climate and ecosystems. His research helped to show that human beings are now active agents of changes in the climate system—not just innocent bystanders—and that we are already influencing the distributions and abundances of most plants and animals. In a number of different areas, from oceans to clouds and from modeling to impacts, "Steve was at the vanguard of climate science."[1] A man with infectious enthusiasm for science and for life, a key figure in the success of the Intergovernmental Panel on Climate Change, and an adviser to eight U.S. administrations, Steve was also a pre-eminent communicator of climate science to the public and policymakers, with "a truly exceptional voice embodying both scientific excellence and extraordinary communications skills."[2]

Early life

Steve Schneider spent his formative years in Long Island. There are a number of apocryphal stories about those early years—how he built his own telescope to study the rings of Saturn,[3] and how he and his brother Peter souped up the engine of their father's car (without their father's knowledge).

In 1966, Steve received a B.Sc. in Mechanical Engineering from Columbia University, followed in 1971 by a PhD in Plasma Physics, also from Columbia. While at Columbia, he attended seminars by Joseph Smagorinsky, one of the early pioneers of atmospheric general circulation modeling, and Ishtiaque Rasool. Both seminars piqued Steve's interest in climate modeling.[4] This interest led to a post-doctoral research associate position at the NASA Goddard Institute for Space Studies (GISS) in New York, where Steve and Jim Hansen were contemporaries.[5]

Developing climate models

Steve's first publications in climate science were related to the role of anthropogenic aerosols. A paper published in *Science* magazine in 1971,[6] the year he received his PhD, taught him a powerful lesson about scientific understanding being dynamic, not static. This was a defining moment in Steve's career. The Rasool and Schneider paper

…for me that is a very proud event—to have discovered with colleagues why our initial assumptions were unlikely and better ones reversed the conclusions—an early example of scientific skepticism in action in climatology.

> *…suggested that the cooling effects of aerosols could dominate the warming effects of greenhouse gases. In this nascent field, findings quickly emerged that showed the effects of aerosols to be regional rather than global, and that warming effects would dominate.*[3]

The Rasool and Schneider *Science* paper also gave Steve his first contact with individuals who did not share his goal of improving scientific understanding. He learned that scientists do not have the luxury of simply retreating into their offices when they encounter unjustified public criticism of their findings—particularly when those findings have important implications for public policy. They also have the responsibility of explaining their research findings in plain English, and of setting the record straight when those findings are willfully or unintentionally misinterpreted by others.[7]

As Steve wrote many years later about this early research:

> *all good scientists are skeptics and should be challenging every aspect of what we do that has plausible alternative hypotheses. I personally published what was wrong (with) my own original 1971 cooling hypothesis a few years later when more data and better models came along and further analysis showed [anthropogenic global warming] as the much more likely…In fact, for me that is a very proud event—to have discovered with colleagues why our initial assumptions were unlikely and better ones reversed the conclusions—an early example of scientific skepticism in action in climatology.*[8]

In 1972, Steve moved to the National Center of Atmospheric Research (NCAR) in Boulder, Colorado, initially as a Fellow in the Advanced Study Program, eventually as head of the program and, in 1980, as a Senior Scientist at NCAR.

The study of aerosol effects on climate would have fully occupied other scientists, but Steve's interests were remarkably broad and deep. In the early 1970s, he turned his attention to an issue that remains of great scientific importance: the role of clouds in the climate system.[9, 10] Steve "…pointed out that climate change would be critically linked not just to changes in cloud amount, but also to even very small changes in cloud top height."[11]

As "Ram" Ramanathan noted, Steve:

> *…was the first to show through a most detailed radiative transfer estimate, that cloud feedback is a major source of uncertainty in climate projections (or predictions). His estimate for the net cooling effect of clouds was verified by cloud forcing estimates from the Earth Radiation Budget Experiment (within 10%). Ten years after his paper, his conclusions about cloud feedback are still true.*[12]

Steve then turned his attention to the role of the ocean in modulating a human-caused climate change signal—an issue that had received relatively little scientific scrutiny up to that point. In a number of seminal publications, first with Starley Thompson[13, 14, 15] and then with Danny Harvey:[16, 17]

> *Steve was instrumental in showing that slow heat transfer to the deep ocean can lead to lags of a decade or more in the response of the climate system. But the oceans are not of equal depth, and do not cover the same fraction of the Earth's surface at all latitudes. Schneider pointed out that this would lead to latitudinally varying lags in the climate response to greenhouse gases, and that the temperature gradients induced by these lags could change the atmospheric circulation. This in turn implies important regional impacts on climate, as well as on ecology and economics.*[11]

In the 1970s and early 1980s, the incredible potential of numerical models of the climate system was becoming increasingly obvious. With these sophisticated numerical representations of the atmosphere (and much simpler representations of the ocean), it was possible to perform the kind of "Gedankenexperimente" that Einstein was fond of—

thought experiments that could not be conducted in the real world. How might Earth's climate respond to human-caused changes in atmospheric levels of greenhouse gases? Could models provide credible estimates of the climate of the Cretaceous? How does the climate system respond to massive volcanic eruptions, or to changes in the Sun's energy output? What are the strengths and weaknesses of simpler energy-balance climate models and full three dimensional models of the climate system?

Steve was one of the first to appreciate and embrace the power of climate modeling. As he later wrote, "It was absolutely exciting to me that I could sit down at a key punch, type up a box of cards, and hold in my hands the capacity to simulate the Earth, polluted or not."[4]

Steve recognized that he and his colleagues had the power to perform systematic numerical experiments with and without human influences, and for current, past, and future climates. He saw that the power of modeling could lead to real scientific breakthroughs: to a better understanding of the key drivers of climate change, and of fundamental properties of the climate system. Steve also understood that, despite their imperfections, these models, which he once called "cloudy crystal balls," were the only tools scientists had to obtain credible projections of 21st century climate change.

One under-appreciated aspect of Steve's research contributions relates to his work on the statistical properties of climate model simulations. In the late 1970s, Steve, Bob Chervin, Larry Gates, and Warren Washington grappled with the "signal to noise" problem in climate response studies.[18, 19, 20] They realized that in both the real world and the virtual world of climate model simulations, any "signal"—such as a coherent, slowly evolving warming signal in response to gradual human caused changes in greenhouse gases—is embedded in the rich background "noise" of natural climate variability. How large must the signal be before it is discernible relative to this noise? What strategies are helpful in enhancing signal-to-noise ratios? These were some of the questions that Steve and his colleagues attempted to answer.

This pioneering early research set the stage for what would later be known as climate change detection and attribution studies, which seek to separate anthropogenic climate change signals from the year-to-year and decade-to-decade noise of natural variability. Steve and his colleagues recognized that it was essential to have a solid statistical framework for anthropogenic signal detection. Many of the insights from this early work are still valid and relevant 40 years later, particularly in terms of the need to enhance signal-to-noise ratios by ensemble averaging, and by averaging over space and time. Steve also understood that model simulations could help to identify climatological "canaries in the coal mine," and might provide valuable guidance as to when and where one should look for the first signs of human caused warming.[21]

Nuclear winter

In the early 1980s, the first studies began to consider the potential climatic and ecological consequences of nuclear war.[22, 23] Steve was uniquely well positioned to look at the climate implications of the smoke produced by the uncontrolled urban fires that would arise from a large scale nuclear bomb exchange. The scientific pump was primed. With Ishtiaque Rasool, Steve had examined the climate impact of anthropogenic aerosols from industrial emissions. With Cliff Mass, Steve had studied the cooling caused by another type of aerosol—the liquid-phase sulfuric acid droplets generated by large volcanic eruptions.[24] Through his work with Danny Harvey and Starley Thompson, Steve was already aware of the critical role of the ocean's thermal inertia in modulating the warming signal arising from human-caused changes in greenhouse gases. This modulating effect would prove to be crucial in understanding differences between some of the first estimates of the post-nuclear war surface cooling and the cooling estimates obtained by Steve's group at NCAR.

Initial calculations of the surface temperature response to a large-scale nuclear exchange were published by Rich Turco and colleagues in *Science* in 1983.[25] As Steve and Sarley Thompson wrote in a review article in *Nature*[26] in 1988, the Turco et al. *Science* paper

> *predicted average surface temperatures below freezing in land in the northern hemisphere, and included maximum decreases in surface temperature of…about 35° Celsius." Because the cooling predicted by Turco et al. was comparable to the difference between summertime and wintertime temperatures at mid-latitudes, this effect was subsequently referred to as "nuclear winter."*
>
> Nuclear winter captured the attention of the world. As John Maddox succinctly summarized in a *Nature* editorial accompanying the Schneider and Thompson review paper:[27]
>
> *By now, the essence of the problem is widely understood. If there were a nuclear war, many parts of the surface of the Earth would be set alight, the fires would carry large amounts of smoke into the atmosphere, the passage of solar radiation to the surface of the Earth would be impeded,*

we should all, for a time, feel cold and, seriously, there would be a chance that the climatic consequences would persist for weeks or even months, not just days—long enough to interrupt processes such as photosynthesis on which continued survival depends.

In a series of papers published between 1984 and 1988, Steve, Starley Thompson, and Curt Covey, together with colleagues at NCAR and in Russia, used three-dimensional atmospheric general circulation models (with simplified representation of the ocean) to re-examine initial "nuclear winter" findings.[26, 28, 29, 30] The focus of the NCAR work was threefold: to include the large heat capacity of the ocean in calculations of the surface cooling induced by massive injections of smoke; to evaluate the impact of the atmospheric general circulation on the vertical and horizontal distribution of smoke; and to consider the sensitivity of results to such factors as the seasonal timing of the nuclear exchange.

In 1988 Steve and Starley Thompson summarized the insights from this body of work, saying that in their 1988 review paper:[26]

The original estimates of severe, long-term, widespread northern hemisphere temperature declines following a large nuclear war have been mitigated by successive generations of more comprehensive climate models. Maximum summertime, northern hemisphere, average land surface temperature changes of 5-15°C for typical baseline smoke injection scenarios—similar to the mid-latitude change from summer to autumn—have replaced the winter-like estimates of 25-30°C surface cooling over land…it remains plausible that the sum of climate disturbances, radioactive fallout, ozone depletions and the interruption of basic social services, could threaten more people globally than would the direct effects of nuclear explosions."

In the later stages of his career, Steve was unjustly accused of being "alarmist" for his very clear public portrayal of the risks associated with human-caused climate change. Such critics were apparently unfamiliar with Steve's contributions to scientific understanding of the climatic impacts of nuclear war. These contributions were driven by one prime directive: to get the science right. Steve followed this prime directive throughout his scientific career.[31]

Founding *Climatic Change*

No account of the scientific contributions of Steve Schneider would be complete without mention of *Climatic Change*, the journal he founded in the mid-1970s. The first issue of *Climatic Change* was published in March 1977. In the editorial for this inaugural issue, Steve noted that:

> *Climatic Change is a new journal designed to provide a means of exchange among researchers from a variety of disciplines who are working on problems related to climatic variations. Climatic Change will give authors an opportunity to communicate the essence of their studies both to researchers in other climate related disciplines and to interested non-disciplinarians, who might be unable to follow the details of new results published in highly technical journals. The intention of this exchange will be to stimulate interdisciplinary interest that will lead to new research possibilities and will help to define and sharpen issues that have a climatic component–issues that could relate ultimately to public policy questions.*

Now, 37 years and 121 issues later, *Climatic Change* remains vital and relevant, an intellectual marketplace for the interdisciplinary exchange of ideas and scientific information. It is a lasting and living tribute to Steve Schneider. As the Editorial Board of *Climatic Change* wrote in a "Dear Steve" letter[32] published after Steve's death:

> *You set the standard of excellence by example for an entire community of scholars from a multitude of disciplines. We understand completely that it is now up to us to make certain that your legacy survives so that the planet has a fighting chance to endure humans' persistent abuse. We pledge to try, as a community, to fill the enormous gaps that your passing has left.*

The first issue of *Climatic Change* included an article authored by Steve.[33] In this article, Steve explored the "uncertainty is not our friend" theme—a theme he would continue to pursue for the remainder of his career:

> *…uncertainty in present scientific estimates of potential climatic consequences of increased energy use is not biased toward optimism. The sword of uncertainty cuts in two directions, and thus we must face the uncomfortable reality that the only estimates we can make of potential*

human impacts on climate generally involve the use of imperfect mathematical models of the climate, models that must rely on tentative physical theories whose verification comes very slowly because of a limited data base of atmospheric and oceanic variables.

Moving to Stanford

In 1992 Steve moved to Stanford, where he took up an appointment as professor in the Department of Biological Sciences. Stanford remained Steve's intellectual home for the rest of his life. The geographical change from Boulder to Palo Alto was accompanied by a shift in scientific focus. Steve took a step back from the world of three-dimensional climate modeling, and focused instead on the ecosystem and socio-economic impacts of human-caused climate change.

Steve was one of the first scientists to recognize that assessing the impacts of human-caused climate change on things people truly cared about—such as crop yields, human health, and plant and animal distributions—required moving beyond simple consideration of broad-brush changes in average temperature and rainfall. To do meaningful impact analysis work, it was also necessary to understand changes in variability, and in the statistical properties of extreme events.[34, 35]

At Stanford, Steve became an active practitioner of climate impact analysis and interdisciplinary earth systems science. He interacted with a whole new set of colleagues, with expertise in ecology, economics, and social sciences. This led to fruitful collaborations with Terry Root, Paul and Anne Ehrlich, Larry Goulder, Ken Arrow, Chris Field, and many others—including a number of the students Steve had mentored.

The collaboration with Terry Root was both professionally and personally rewarding. Terry had detailed knowledge of the historical changes in species distribution and populations—particularly for dozens of species of birds. From his modeling days at NCAR and GISS, Steve was very familiar with the changes in climate that are expected to occur in response to human-caused changes in greenhouse gases. He understood many of the physical mechanisms likely to drive the seasonal and regional "granularity" of these climate changes. And he was intimately familiar with key uncertainties in the model simulations. This dovetailing of Steve's expertise in climate science and Terry's expertise in ecology led to one of the most successful collaborations in interdisciplinary earth systems science—and to a very happy marriage.

Typical of Steve was that his collaboration with Terry led to him acquiring from her, in a remarkably short time, a great interest in birds and bird watching. He and Terry traveled over much of the world together, often with friends, in pursuit of rare and interesting birds. As in everything he was drawn to, under Terry's tutelage he quickly became an expert, and was always happy to point out novelties to less experienced colleagues.

In their initial papers, Terry and Steve outlined a strategy for dealing with the problem of combining small-scale field studies of ecological impacts with results from large-scale studies.[36] Next, they documented the changes in a wide range of plant and animal species.[37] Their analysis revealed

> *…a consistent temperature-related shift, or 'fingerprint', in species ranging from mollusks to mammals and from grasses to trees…the balance of evidence from these studies strongly suggests that a significant impact of global warming is already discernible in animal and plant populations.*

Was it possible to determine, in a formal statistical detection and attribution study, whether human-caused changes in climate were the main cause of the changes in species distribution Terry and Steve had identified? This was the key question they addressed in their 2005 *PNAS* paper with Dena MacMynowski and Mike Mastrandrea.[38] The Root et al. *PNAS* paper showed that:

> *…human activities contribute significantly to temperature changes and human-changed temperatures are associated with discernible changes in plant and animal traits.*

This was one of the pioneering studies in what came to be called "joint attribution"—the formal demonstration of a causal chain linking anthropogenically—induced changes in atmospheric composition, climate change, and changes in species properties. Publication of this paper generated substantial scientific interest in the "joint attribution" problem. This interest eventually led to the inclusion of a chapter entitled "Detection and Attribution of Observed Impacts" in the Working Group II contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC).

As human activities were having an influence on plant and animal species because of a changing climate, Steve was having a discernible influence on the IPCC. Steve's involvement with the IPCC dated back to the IPCC's First Assessment Report in 1990. He served as either a Co-Author, Lead Author, or Convening Lead Author on all five

IPCC Reports. Together with Richard Moss, Steve wrote the influential "uncertainty guidance paper" for the IPCC's Third Assessment Report.[39] In public remarks made at a memorial gathering at Stanford in December 2010, John Holdren noted that Steve's

> *…clear-eyed focus on the uncertainties in the science of climate change —and his insistence that these be candidly acknowledged and accurately portrayed in every forum, professional or popular, where such science is presented—was a Schneider hallmark. That particular aspect of his scientific personality and output, all by itself, had a profound and positive impact on the whole field and, notably, on the approach and the publications of the Intergovernmental Panel on Climate Change.*[40]

In essence, Steve and Richard Moss (who were sometimes referred to as the "uncertainty cops"[41]) provided the IPCC with a framework for expressing levels of confidence in key scientific findings. The importance of this contribution is worth highlighting, particularly in view of specious claims that recent IPCC Reports do not accurately characterize scientific uncertainties. To honor Steve's decades of service to the IPCC, and his significant impact on all phases of its work, the IPCC Plenary Session in Busan, South Korea, dedicated the Synthesis Report of the 2014 IPCC 5th Assessment to him.[42]

In 2001, the issue of how to deal with scientific uncertainty became intensely personal. As described by Richard Somerville,[43] Steve was diagnosed

> *…with mantle cell lymphoma, an especially aggressive life threatening cancer. This is a rare type of non-Hodgkins lymphoma for which there is no standard cure and for which very few clinical trials data are available. Schneider, typically rational, found parallels with problems in climate science and decided to partner actively with his medical team in designing his treatment path. He later said that his doctors explained oncology to him while he explained Bayesian statistical inference theory to them.*

This was the ultimate form of interdisciplinary science: how to transfer a lifetime's worth of insights from the analysis of climate-change risks to the medical problem of figuring out the most effective treatment protocol for a rare form of cancer. Steve decided that Bayesian updating was the optimal way of proceeding. Make periodic measurements of key cancer markers, and constantly update the chemotherapy treatment (with the drug Rituxan) based on the measurements.[44] And for nearly 10 years, Steve's brilliance, persistence, and courage enabled him to beat the medical odds, and to load the dice[45] in favor of his own survival.

Others in Steve's difficult situation would have put all work on hold while enduring a bone-marrow transplant, radiation treatment, and chemotherapy. Not Steve. As one of us wrote in a tribute in *Science*:[46]

> *Whenever we (Paul and Anne Ehrlich) scrubbed and gowned to visit him in his hospital room, we would find him sitting up in bed with a computer on his lap and Terry handing him papers, working on e-mail or a manuscript, and ready with a quick joke about his condition.*

Incredibly, his scientific voice and output was undiminished during years of lymphoma treatment. In addition to continuing his day job and editing *Climatic Change*, Steve wrote an influential book on his medical battle,[47] and then took much of his time to counsel others with cancer.

His generosity with the precious gift of time was one of Steve's defining characteristics. As Bill Anderegg, (the last student Steve supervised) wrote in a tribute published in 2010:[48]

> *Above all else he was amazingly, incomprehensibly selfless. He gave his time freely to students, colleagues, reporters, and donated years of his life to defending science and contributing to the IPCC…He exemplified what it meant to be a mentor.*

Another of Steve's defining characteristics was his ability to translate complex science into plain English—to find the apt metaphor, the lightning-quick repartee, the memorable turn of phrase. A tribute from Bud Ward captures Steve's unique communication skills:

> *Among the many things that made Schneider unique in the climate change science community is the level of respect he earned not only from his science colleagues, but also from those in the news media trying most conscientiously to cover the issues in ways consistent with sound science and quality journalism. He was an unrelenting critic of lazy journalism, and in so being he endeared himself to those reporters most serious about their work.*[2]

John Holdren also recalled Steve's amazing communication skills, saying:[40]

> *He used, with consummate skill, virtually every mechanism and communication channel there is. He was a brilliant classroom teacher and superb one-on-one mentor; a sought-after lecturer by the most distinguished universities and most prestigious professional societies in the world; and an unbelievably prolific author and editor of books about climate, ecosystems, and society, of popular as well as professional, peer-reviewed articles, and of op-ed pieces and letters to the editor.*

And finally, there is Steve the man. He was not one-dimensional, with an exclusive focus on science:

> *Steve's nonscientific enthusiasms, apart from Terry, were many, including bird prints, wine tasting, and good food, accompanied by a fine sense of humor and a love of music. Steve delighted in playing folk songs and rock tunes on his 12-string guitar. He said he started as an undergraduate at Columbia in the 1960s when, in his words, "guitar-playing was a substitute for a personality." He wasn't shy about singing, despite a less than velvety voice. Steve and Terry hosted many dinners that were followed by spirited guitar-strumming and singing to tunes by Bob Dylan, Simon and Garfunkel, and others. Steve and Stanford environmental economist Larry Goulder[49] collaborated and performed publicly a few original songs as well, including their "Climate Change Blues," and a warped version of the Beatles' "When I'm 64."[46]*

Many have attempted to bottle the essence of Steve in a few brief sentences. He was a MacArthur Fellow. A brilliant scientist and science communicator. A mentor who changed lives. A man with infectious enthusiasm for science, and for life. A key figure in the success of the IPCC. An adviser to eight U.S. administrations. A loving father, husband, and brother, and:

> *…a giant in his field, a wonderful friend, a hero, and more. His myriad friends will miss him intensely, and so…will billions of people who never heard of him, whose lives he so determinedly strove to improve.[46]*

Steve's colleague and friend John Holdren, remembered him with these words:

> *The world needs more Steve Schneiders. The most valuable thing we could do to honor his life and secure his legacy would be to redouble our efforts to inspire, to train, to help, and to honor those young people who have the aptitude and the energy to be, as he was, deep and broad inter-disciplinary climate scientists, first class communicators, and committed contributors to the improvement of public policy. That is surely what he would want us to do.*[40]

ENDNOTES

1. Email from Jeff Kiehl, National Center of Atmospheric Research, to Myles Allen and undisclosed recipients, July 21, 2010.
2. Ward, Bud. Mourning the huge loss of a 'giant': Stanford climatologist Stephen H. Schneider. *The Yale Forum on Climate Change and the Media*, July 20, 2010. http://www.yaleclimatemediaforum.org/2010/07/stanford-climatologist-stephen-h-schneider/
3. Mastrandrea, Mike. Stephen Henry Schneider (1945-2010). *Nature* 466:933.
4. Stephen Schneider: An extraordinary life. *NCAR/UCAR AtmosNews*, July 21, 2010. http://www2.ucar.edu/atmosnews/features/2270/stephenschneider-extraordinary-life
5. In an email to Veerabhadran "Ram" Ramanathan (and other undisclosed recipients) dated July 21, 2010, Jim Hansen wrote that "…we often had lunch together at a grill just down Broadway from GISS: when the GISS Director publicly lambasted Steve for writing a *NY Times* letter-to-the editor (and some colleagues criticized his willingness to spend so much time talking with the media), Steve never flinched, he kept right on doing what he was doing—Steve was as tough as nails".
6. Rasool, S. I., and S. H. Schneider, 1971. Atmospheric carbon dioxide and aerosols: Effects of large increases on global climate. *Science* 173:138-141.
7. Steve Schneider's first letter to the editor. Gavin Schmidt, post on *Real-Climate*, 25 April, 2011. http://www. realclimate.org/index.php/archives/2011/04/steve-schneiders-first-letter-to-the-editor/
8. Email from Steve Schneider to Petr Chylek and undisclosed recipients, Dec. 5, 2009. The "new book" referred to in the email is: Schneider, S. H., 2009. *Science as a Contact Sport: Inside the Battle to Save the Earth's Climate.* Washington, DC: National Geographic Society.
9. Schneider, S. H., 1972. Cloudiness as a global climate feedback mechanism: The effects on the radiation balance and surface temperature of variations in cloudiness. *Journal of Atmospheric Sciences* 29:1413-1422.
10. Schneider, S. H., W. M. Washington, and R. M. Chervin, 1978. Cloudiness as a climatic feedback mechanism: Effects on cloud amounts of prescribed global and regional surface temperature changes in the NCAR GCM. *Journal of Atmospheric Sciences* 35:2207-2221.
11. Santer, B. D., and S. Solomon, 2010. Stephen H. Schneider (1945-2010). *Eos* 91:372.
12. Email from Veerabhadran "Ram" Ramanathan to Myles Allen and undisclosed recipients, July 21, 2010.
13. Thompson, S. L., and S. H. Schneider, 1981. Atmospheric CO_2 and climate: Importance of the transient response. *Journal of Geophysical Research* 86:3135-3147.

14. Thompson, S. L., and S. H. Schneider, 1981. Carbon dioxide and climate: Ice and ocean. *Nature* 290:9-10.

15. Thompson, S. L., and S. H. Schneider, 1982. CO_2 and climate: The importance of realistic geography in estimating the transient response. *Science* 217:1031-1033.

16. Harvey, L. D. D., and S. H. Schneider, 1985. Transient climate response to external forcing on 1-1000 year time scales. Part I: Experiments with globally averaged, coupled, atmosphere and energy balance models. *Journal of Geophysical Research* 90:2191-2205.

17. Harvey, L. D. D., and S. H. Schneider, 1985. Transient climate response to external forcing on 1-1000 year time scales. Part II: Sensitivity experiments with a seasonal, hemispherically averaged coupled atmosphere, and ocean energy balance model. *Journal of Geophysical Research* 90:2207-2222.

18. Chervin, R. M., W. L. Gates, and S. H. Schneider, 1974. The effect of time averaging on the noise level of climatological statistics generated by atmospheric General Circulation Models. *Journal of Atmospheric Sciences* 31:2216- 2219.

19. Chervin, R. M., and S. H. Schneider, 1976. On determining the statistical significance of climate experiments with General Circulation Models. *Journal of Atmospheric Sciences* 33:405-412.

20. Chervin, R. M., W. M. Washington, and S. H. Schneider, 1976. Testing the statistical significance of the response of the NCAR General Circulation Model to North Pacific ocean surface temperature anomalies. *Journal of Atmospheric Sciences* 33:413-423.

21. Thompson, S. L., and S. H. Schneider, 1982. Carbon dioxide and climate: Has a signal been observed yet? *Nature* 292: 645-646. One of the prescient remarks in this paper is that: "A better way of identifying regional climatic changes with potentially good signal-to-noise ratios would be to search for these in the results of time-dependent simulations performed with a coupled atmosphere/ocean model using realistic geography and plausible CO_2 increase scenarios."

22. Ehrlich, P. R., A. H. Ehrlich, and J. P. Holdren, 1977. *Ecoscience: Population, Resources, Environment.* pp. 690-691. San Francisco: Freeman.

23. Crutzen, P. J., and J. W. Birks, 1982. The atmosphere after a nuclear war: twilight at noon. *Ambio* 11:115-125.

24. Schneider, S. H., and C. Mass, 1975. Volcanic dust, sunspots, and temperature trends. *Science* 190:741-746.

25. Turco, R. P., O. B. Toon, T. Ackerman, J. B. Pollack, and C. Sagan, 1983. Nuclear winter: global consequences of multiple nuclear explosions. *Science* 222:1283-1292.

26. Schneider, S. H., and S. L. Thompson, 1988. Simulating the climatic effects of nuclear war. *Nature* 333:221-227.

27. Maddox, J., 1988. What happened to nuclear winter? *Nature* 333:203.

28. Covey, C., S. H. Schneider, and S. L. Thompson, 1984. Global atmospheric effects of massive smoke injections from a nuclear war: Results from General Circulation Model simulations. *Nature* 308:21-25.

29. Thompson, S. L., V. V. Aleksandrov, G. L. Stenchikov, S. H. Schneider, C. Covey, and R. M. Chervin, 1984. Global climatic consequences of nuclear war: simulations with three-dimensional models. *Ambio* XIII:236-243.

30. Schneider, S. H., S. L. Thompson, and C. Covey, 1986. The mesoscale effects of nuclear winter. *Nature* 320:491-492.

31. "Oh well, we'll just keep doing it (science) for history and let the politics fall where they may…" Email from Steve Schneider to Ben Santer, Dec. 18, 1997.

32. Editorial Board of Climatic Change, 2010. Stephen H. Schneider, 1945- 2010. *Climatic Change* 102:1-7.

33. S. H. Schneider, 1977. Climate change and the world predicament: A case study for interdisciplinary research. *Climatic Change* 1:21-43.

34. Mearns, L. O., R. W. Katz, and S. H. Schneider, 1984. Changes in the probabilities of extreme high temperature events with changes in global mean temperature. *Journal of Climate and Applied Meteorology* 23:1601-1613.

35. Mearns, L. O., S. H. Schneider, S. L. Thompson, and L. McDaniel, 1990. Analysis of climate variability in General Circulation Models: Comparison with observations and changes in variability in 2×CO_2 experiments. *Journal of Geophysical Research* 95:20,469-20,490.

36. Root, T. L., and S. H. Schneider, 1995. Ecology and climate: Research strategies and implications. *Science* 269:334-341.

37. Root, T. L., J. T. Price, K. R. Hall, S. H. Schneider, C. Rosenzweig, and J. A. Pounds, 2003. Fingerprints of global warming on wild animals and plants. *Nature* 421:57-60.

38. Root, T. L., D. P . MacMynowski, M. D. Mastrandrea, and S. H. Schneider, 2005. Human-modified temperatures induce species changes: Joint attribution. *Proceedings of the National Academy of Sciences U.S.A.* 21:7465-7469.

39. Moss, R. H., and S. H. Schneider, 2000. Uncertainties in the IPCC TAR: Recommendations to Lead Authors for more consistent assessment and reporting. In: *Guidance Papers on the Cross Cutting Issues of the Third Assessment Report of the IPCC.* eds. R. Pachauri, T. Taniguchi and K. Tanaka. pp. 33-51. Geneva: World Meteorological Organization.

40. Holdren, J. P ., 2010. Climate-change science and sanity: Steve Schneider's extraordinary contributions to both. Text of remarks made at public memorial event for Steve Schneider, Stanford University, Dec. 12, 2010.

41. Giles, J., 2002. When doubt is a sure thing. *Nature* 418:476-478.

42. "Hello from Busan, Korea, where the IPCC Plenary, after a minute of silence for Steve and very kind words by Dr. Pachauri, approved of the dedication of the AR5 Synthesis Report to Steve." Excerpt of email from Jean-Pascal van Ypersele to Terry Root, Oct. 13, 2010.

43. Somerville, R. C. J., 2010. The passing of a climate prodigy. Bulletin of the Atomic Scientists, July 23, 2010. http://thebulletin.org/passing-climateprodigy

44. "…post treatment maintenance therapy is no longer viewed by the open minded as radical—a major clinical trial (is) finally underway and preliminary results (are) dramatic—as I bet my life on 6 years ago." Excerpt from Steve's email to Paul Edwards and Ben Santer, April 10, 2008.

45. "Loaded dice" were a recurrent metaphor in Steve's climate science communication activities.

46. Ehrlich, P. R., 2010. Stephen Schneider (1945-2010). *Science* 329:776.

47. Schneider, S. H., and J. Lane, 2006. *The Patient from Hell: How I worked with my doctors to get the best of modern medicine and how you can too.* Cambridge, MA: Da Capo Press.

48. Anderegg, W. R. L., 2010. Stephen H. Schneider: In Memoriam. *Thought & Action: Magazine of the National Education Association* Fall 2010 issue:33-34.

49. Larry Goulder was also one of Steve's key scientific collaborators in studies of the costs and benefits of different policy options for addressing the problem of human-caused climate change. See, e.g., Schneider, S. H., and L. H. Goulder, 1997: Achieving low-cost emissions targets. *Nature* 389:13-14., and Goulder, L. H., and S. H. Schneider, 1999: Induced technological change and the attractiveness of CO_2 abatement policies. *Resource and Energy Economics* 21:211-252.

SELECTED BIBLIOGRAPHY

1971 With S. I. Rasool. Atmospheric carbon dioxide and aerosols: effects of large increases on global climate. *Science* 173:138-141.

1972 Cloudiness as a global climate feedback mechanism: the effects on the radiation balance and surface temperature of variations in cloudiness. *Journal of Atmospheric Sciences* 29:1413-1422.

1974 With R. M. Chervin and W. L. Gates. The effect of time averaging on the noise level of climatological statistics generated by atmospheric General Circulation Models. *Journal of Atmospheric Sciences* 31:2216-2219.

1975 With C. Mass. Volcanic dust, sunspots, and temperature trends. *Science* 190:741-746.

1976 With R. M. Chervin. On determining the statistical significance of climate experiments with General Circulation Models. *Journal of Atmospheric Sciences* 33:405-412.

With R. M. Chervin and W. M. Washington. Testing the statistical significance of the response of the NCAR General Circulation Model to North Pacific ocean surface temperature anomalies. *Journal of Atmospheric Sciences* 33:413-423.

1977 Climate change and the world predicament: A case study for interdisciplinary research. *Climatic Change* 1:21-43.

1978 With W. M. Washington and R. M. Chervin. Cloudiness as a climatic feedback mechanism: Effects on cloud amounts of prescribed global and regional surface temperature changes in the NCAR GCM. *Journal of Atmospheric Sciences* 35:2207-2221.

1981 With S. L. Thompson. Atmospheric CO_2 and climate: Importance of the transient response. *Journal of Geophysical Research* 86:3135-3147.

With S. L. Thompson. Carbon dioxide and climate: Ice and ocean. *Nature* 290:9-10.

1982 With S. L. Thompson. CO_2 and climate: the importance of realistic geography in estimating the transient response. *Science* 217:1031-1033.

With S. L. Thompson. Carbon dioxide and climate: has a signal been observed yet? *Nature* 292:645-646.

1984 With L. O. Mearns and R. W. Katz. Changes in the probabilities of extreme high temperature events with changes in global mean temperature. *Journal of Climate and Applied Meteorology* 23:1601-1613.

With C. Covey and S. L. Thompson. Global atmospheric effects of massive smoke injections from a nuclear war: Results from General Circulation Model simulations. *Nature* 308:21-25.

With S. L. Thompson, V. V. Aleksandrov, G. L. Stenchikov, C. Covey, and R. M. Chervin. Global climatic consequences of nuclear war: Simulations with three-dimensional models. *Ambio* XIII:236-243.

1985 With L. D. D. Harvey. Transient climate response to external forcing on 1-1000 year time scales. Part I: Experiments with globally averaged, coupled, atmosphere and energy balance models. *Journal of Geophysical Research* 90:2191-2205.

With L. D. D. Harvey. Climate response to external forcing on 1-1000 year time scales. Part II: Sensitivity experiments with a seasonal, hemispherically averaged coupled atmosphere, and ocean energy balance model. *Journal of Geophysical Research* 90:2207-2222.

1986 With S. L. Thompson and C. Covey. The mesoscale effects of nuclear winter. *Nature* 320:491-492.

1988 With S. L. Thompson. Simulating the climatic effects of nuclear war. *Nature* 333:221-227.

1990 With L. O. Mearns, S. L. Thompson, and L. McDaniel. Analysis of climate variability in General Circulation Models: Comparison with observations and changes in variability in $2\times CO_2$ experiments. *Journal of Geophysical Research* 95:20,469-20,490.

1995 With T. L. Root. Ecology and climate: Research strategies and implications. *Science* 269:334- 341.

1997 With L. H. Goulder. Achieving low-cost emissions targets. *Nature* 389:13-14.

1999 With L. H. Goulder. Induced technological change and the attractiveness of CO_2 abatement policies. *Resource and Energy Economics* 21:211-252.

2000 With R. H. Moss. Uncertainties in the IPCC TAR: Recommendations to Lead Authors for more consistent assessment and reporting. In: *Guidance Papers on the Cross Cutting Issues of the Third Assessment Report of the IPCC.* Eds. R. Pachauri, T. Taniguchi and K. Tanaka. pp 33-51. Geneva: World Meteorological Organization.

2003 With T. L. Root, J. T. Price, K. R. Hall, C. Rosenzweig, and J. A. Pounds. Fingerprints of global warming on wild animals and plants. *Nature* 421:57-60.

2005 With T. L. Root, D. P. MacMynowski, and M. D. Mastrandrea. Human-modified temperatures induce species changes: Joint attribution. *Proceedings of the National Academy of Sciences U.S.A*. 21:7465-7469.

2006 With J. Lane. *The Patient from Hell: How I worked with my doctors to get the best of modern medicine and how you can too*. Cambridge, MA: Da Capo Press.

2009 *Science as a Contact Sport: Inside the Battle to Save the Earth's Climate*. Washington, DC: National Geographic Society.