Nuclear Winter Debate Heats Up

A study by the National Center for Atmospheric Research suggests most of the world would experience a mild nuclear winter, not a deep freeze

The dust and smoke of continents in flame will defeat the light of the sun and utter darkness will reign anew upon the world . . . Eternal snows will cover the Sahara desert. The vast rain forests of the Amazon, destroyed by hail, will disappear from the face of the planet, and the age of rock music and heart transplants will revert to its glacial infancy.—Gabriel Garcia Marquez, writing on nuclear winter in October 1986.

MARQUEZ'S description of the world after nuclear war is not science, to be sure. But it captures an image many people may recall from 1983 and 1984, when the scientific theory of nuclear winter was heavily publicized. It also happens to be wrong, according to a new analysis.

World War III, although cataclysmic, probably would not freeze the globe nor eliminate the human race, according to Starley Thompson and Stephen Schneider of the University of Colorado at Boulder. In fact, they say the average worst-case summer temperatures in the United States following a war would be mild. Some areas would experience "quick freezes," as in autumn. But the likelihood of human extinction has become "vanishingly low."

Thompson and Schneider base these conclusions on the output of a state-of-the-art computer model designed at the National Center for Atmospheric Research (NCAR), where they work. They have not yet published these data, but some implications appear in the summer 1986 issue of *Foreign Affairs*.

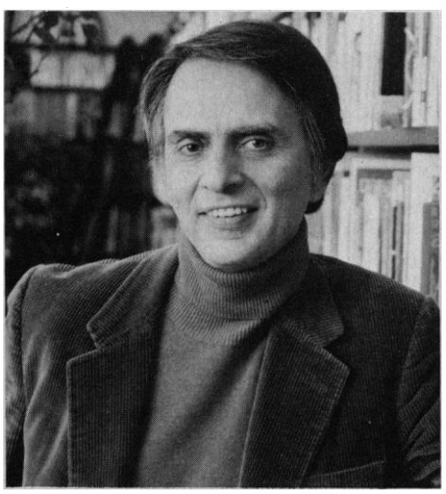
Several other atmospheric scientists contacted by *Science* agreed that the severity of the worst-case temperature drop may have been overstated by at least a factor of 2 in the original paper on nuclear winter.

In response, defenders of the theory say their basic conclusions remain intact. They point out that their worst-case estimates included a caveat that they had not analyzed the warming effect of the oceans. They say that even if the NCAR study is right, it still shows that smoke from a nuclear war would affect the climate. In summer, patches of freezing could appear in the Northern Hemisphere. Tropical weather patterns could be disrupted. Crops could be devastated around the globe. Hundreds of millions, or even billions, of people might die of starvation.

The best known presenter of the original theory, Carl Sagan of Cornell, claims there is "nothing new" to make him alter his description of nuclear winter or the conclusions drawn from it. The threat to human life makes it imperative, he says, that the superpowers cut their nuclear arsenals by at least 90%.

Sagan's refusal to acknowledge merit in NCAR's analysis—known as "nuclear autumn"—sends some people up the wall. One wall climber is George Rathjens, professor of political science at MIT. "Is this another case of Lysenkoism?" he asks, referring to an erroneous genetic theory forced on Soviet scientists in the 1940s by Trofim D. Lysenko. Rathjens answers himself: "I am afraid there's a certain amount of truth in that." The claim that the original nuclear winter model is unimpeached, he adds, is "the greatest fraud we've seen in a long time."

Rathjens, who agrees that nuclear arsenals should be reduced, is particularly upset by what he calls a "close to dishonest" use of science by nuclear winter theorists to promote their views.



Carl Sagan: *planetary scientist, celebrity, and nuclear winter theorist, finds "nothing new" in recent studies to diminish his forecast of a smoky apocalypse.*

Rathjens is highly critical of others, too, notably those promoting interceptor devices ("Star Wars") as a means of civil defense. He calls the idea "a joke . . . like the tooth fairy." But he says the scientific community should be hard on all fuzzy ideas, whether they come from the White House or from well-intentioned private groups. He considers nuclear winter a fuzzy idea.

Comments like these have inspired some visceral attacks on Sagan and his coauthors, known as the TTAPS group. (TTAPS stands for the last initials of the authors: Richard Turco, Owen Toon, Thomas Ackerman, James Pollack, and Sagan.) One such attack by Russell Seitz, a fellow at Harvard's Center for International Affairs, appeared recently in *The National Interest*, a Washington, D.C., quarterly, and *The Wall Street Journal*. Seitz, who is not a diploma-holding scientist, gibes at TTAPS's mixing of physics and advertising.

Seitz notes that Sagan published the nuclear winter thesis in *Parade* magazine a month before it appeared in *Science*. He writes: "The peer review process at *Parade* presumably consisted in the contributing editor conversing with the writer, perhaps while shaving—Sagan is both." Anyone who wanted to verify the data on which the conclusions were based, according to Seitz, had to set off on a "paper chase." Policy recommendations laid out in *Foreign Affairs* (winter 1983/1984) rested on data published simultaneously in *Science* (23 December 1983, p. 1283). But, as noted in the *Science* article, "details may be found in (*15*)." Reference 15 states in full: "R. P. Turco, O. B. Toon, T. P. Ackerman, J. B. Pollack, C. Sagan, in preparation." It refers to a paper that has never been published in a peer-reviewed (or any other) journal. Rathjens also grumbles about the hard-to-get data. The entire thesis, he says, is "a house of cards built on reference 15."

Turco, chief modeller for TTAPS, acknowledges that the work cited in reference 15 was not published in a journal. He says the rush of events in 1983 and revisions in

Wide World

Experimental burn. *The Forest Service helped torch the National Forest near Los Angeles last December to provide data on smoke clouds. The fire was disappointing.*

the scenario made the paper obsolete. Rather than rewrite it and submit it to a journal, he decided to mail it in its original form (known as the "blue book") along with a handful of referenced papers to anyone who wrote in asking for it.

Turco and Sagan regard as "absurd" the implication that their work was inadequately reviewed. They say it probably received a wider and more critical vetting than most studies, and they point to two meetings of scientists they called in 1983, for the express purpose of reviewing the thesis before publication.

Since the gush of papers in late 1983 and early 1984, two major peer-reviewed works on nuclear winter have appeared. One comes from a committee of the National Academy of Sciences (*Science*, 20 September 1985, p. 1245). It confirms the worst-case hazards described by TTAPS, but stresses the uncertainty in any statement about the postwar environment and challenges the idea that the human race would be eliminated. A second major report known as SCOPE, after its sponsor, the Scientific Committee on Problems of the Environment, came out the year after. (This committee is part of the International Council of Scientific Unions.) This report also recognizes the potential for a cataclysm, but remains silent on the question of extinction. Rathjens comments that, if the TTAPS report and these later ones appear similar, it is "hardly surprising, since Rich Turco was the key modeler in all three."

The most incendiary charge against TTAPS may be Seitz's assertion that nuclear winter was hatched in 1982 "within the inner circle of the world's disarmament activists" as a means to terrify the public. He sees in this a plot to bamboozle the public into supporting a nuclear freeze. Seitz claims there have been strategic consequences for the United States already. The popular version of nuclear winter, he argues, is partly responsible for the antiweapons movement in Australia and New Zealand. Nuclear-armed U.S. ships have been barred from some South Pacific ports.

Turco brushes Seitz aside as "zany." And Sagan responds with a question: If nuclear winter is a fraud created by the freeze movement, why does the Department of Defense take it so seriously and why has it funded the research? Turco finds some of Seitz's comments libelous and responds with remarks that are just as actionable. Many say Seitz's contribution to the debate has been to step up the acrimony. One weary researcher says: "A pox on Seitz and Sagan."

Where there is smoke, these days, there is no fire, just a computer model. The substantive argument over nuclear winter centers on what should and should not be put into an equation predicting the color of the atmosphere after a nuclear war. There are fundamental dilemmas in designing such an equation, each one a quarrel waiting to be ignited. Many have been.

For quite a few variables in the nuclear winter equation, choosing a "high" or "low" value can make the difference between a black or a rosy outcome. One major unknown, for example, is the number of bombs to be exploded. The TTAPS model (revised in late 1983) assumes in its "baseline" analysis that 5,000 megatons are expended in 10,400 explosions. Sagan regards this as a low number; strategic planners call it high. Turco and others are now investigating a scenario in which just a few megatons are dropped on refineries and fuel storage tanks. Turco says the resulting sooty clouds would create a global catastrophe similar to the one posed by the baseline scenario in the original paper. While either high or low megatonnage is defensible, a low choice makes nuclear winter unlikely, and a high one makes it plausible.

But the uncertainty does not end here. Some natural events are described by assumptions as arbitrary as the bombing scenarios. Furthermore, several pose the same dilemma: choosing one value wipes out nuclear winter, and choosing another makes it real. Nor is it clear that a midrange between the extremes is in any sense "better" than a high or low value.

Consider how land and atmospheric heat are treated. No experiment can mimic the smoke and turbulence rising from 100 burning cities. Sagan and Turco think it best to assume the atmosphere would behave very differently from what we now experience. Turco says a smoky atmosphere would become "decoupled" from the earth's surface, with unpredictable results. No model based on a peaceful environment can give an adequate picture of this, he says. Schneider says this view overstates the effect of a smoke cloud, which would not be uniform, but patchy.

Current arguments on nuclear winter focus on more tractable issues, however. Some of the contested points are noted here.

■ **Smoke height and washout.** Turco, designer of the TTAPS model, points to two key variables in the NCAR model which he thinks are extreme values not justified by physical data. He says they strongly affect the conclusions. One is the altitude of the smoke cloud. For convenience, he says, the NCAR modelers assume a uniform mixing rate of smoke instead of a uniform density. The effect is to put the smoke into the picture at a low height, half of it below 2.8 kilometers and half above. The TTAPS model assumes the midpoint would be over 5 kilometers. Combined with an assumption for rapid washout, this model removes the smoke much faster than the TTAPS model or another model used by the Los Alamos National Laboratory.

Thompson and Schneider have looked into this complaint and find it trivial. Using other assumptions changes the results only by "a few degrees" on average. Schneider says: "We are tired of being told about our radical washout assumptions; it just isn't so."

■ **Unfair comparisons.** Turco says Thompson and Schneider have not published a peer-reviewed scientific article laying out their thesis. (Turco is an editor of the *Journal of Geophysical Research*, to which

the article has been submitted. Presumably, it will be published if it passes muster.) The *Foreign Affairs* article, according to Turco, unfairly compares TTAPS's annual average temperatures with NCAR's July temperatures. He argues that all variables should be "normalized" to permit a fair comparison.

Schneider finds little merit in this plea. The NCAR modelers chose to look at July because it is the time of year when the temperature shift should be greatest. The worst acute effects NCAR predicts are spotty incidents of quick freezing in the first week or two after a nuclear exchange.

■ **Manipulating the models.** When investigators looked into the assumptions for smoke production in the TTAPS model, they found that wildfires are given too much credit for blackening the sky. But as this variable went down, others went up. Rathjens and his colleague Ronald Siegel write: "There has been a tendency, as estimates of fuel and smoke are reduced, to increase estimates of the blackness of the smoke in a way that substantially offsets the other changes. We are not persuaded of the justification of these increases, and feel that they may convey a misleading sense that little has changed." In an interview, Rathjens referred to this tinkering as "a pretty sharp practice."

Sagan declines to respond to this comment, but Turco regards it as ill informed. While people are assuming a lower volume of smoke, they also have been compelled to increase its blackness because it includes more soot, he says. In addition, data reported at a recent meeting of the Royal Society in London suggests that soot is many times more absorptive of light than had been recognized before.

■ **Freezing to extinction.** Schneider says, "Human extinction should never have been brought up." The notion of a frozen, dead planet following a nuclear war has "zero credibility."

Turco argues that this view is based on "feelings" rather than facts, because no one can prove or disprove that extinction would occur. He concedes that it may be necessary to reduce the estimates of freezing in the TTAPS original paper by as little as 10%. At most, the revision may be a factor of 2. He thinks humanity probably would not be eliminated. Sagan thinks it would.

■ **A nuclear winter threshold.** In the original *Foreign Affairs* article, Sagan argues that the atmosphere can absorb a limited amount of smoke before crossing a "threshold" beyond which lies the apocalypse. He translates the threshold into bomb blasts: a few hundred over cities or 2000 to 3000 open blasts outside cities. To Sagan, this implies that nuclear arsenals must be reduced by 90 to 99%.

Thompson and Schneider find no evidence to support a threshold theory, dismissing it as "an artifact of a simplified model."

In general, atmospheric scientists put credence in NCAR's model because it describes events in three dimensions, rather than one, which TTAPS did. Unlike the TTAPS version, it incorporates the warming effect of the oceans. For these reasons, it is not surprising that NCAR's winter is milder.

Some questions about the data will never be resolved. However, the federal government is financing research to narrow the range of uncertainty in several areas, including the optical properties of smoke and patterns of plume and cloud behavior over large fires. Funding has grown from less than $1 million in 1983 to a level of $5.5 million annually today. The next general review of this program will occur in late February or early March, according to a spokesman for the Defense Nuclear Agency. A major issue to be addressed is whether the government should begin to study the biological effects of a large smoke pall, a research topic that has not been well financed to date.

In December, researchers converged on a dramatic open fire experiment in the National Forest near Los Angeles. They hoped to sample smoke at various heights and observe cumulus cloud formation above the blaze. An accident caused a delay and a rainstorm intervened, leading to disappointing results.

Meanwhile, the National Academy of Sciences is reviewing its role. Members of a panel cochaired by George Carrier of Harvard and Vice Admiral William Moran—authors of the Academy report on nuclear winter—met in Washington on 14 January to decide whether to enter the fray again. They will discuss the new data from NCAR and write a decision memo for Frank Press, president of the Academy. ■

ELIOT MARSHALL

Berkeley Changes Tack on Reactor

The University of California, Berkeley, has announced that it will close down the research reactor on campus that was the target of criticism because it was used on occasion for military-related research. University officials insist the decision was made without regard to the protest.

In early December, Berkeley physics professor Charles Schwartz challenged the university administration to respond to a series of charges generated by the discovery that the reactor had been used for experiments for military contractors, including tests of radiation effects on missile components (*Science*, 2 January, p. 23).

University officials insist that the decision to close the reactor was prompted by the prospect of using the site for a badly needed new computer science facility. Berkeley vice chancellor Roderic B. Park says that internal and external reviews of the 1-megawatt research reactor had revealed "low usage" of the facility for teaching and research and made clear that "something would have to be done. But we didn't see where the money would come from." Clearing of the reactor site would require a costly decommissioning process.

Two things happened to change the situation, he says. Studies done for a new computer facility pointed to the existing reactor installation as the favored site for the building. And funds became available from the University of California system that could be used to pay some costs of the reactor decommissioning. University officials say that a recommendation was made in early December by engineering dean Karl S. Pister to close down the reactor.

Substantial uncertainties remain on timing and finance. Funds still have to be raised and plans drawn for construction of the building to replace the reactor. Sources in the engineering school say that obtaining permission from the Nuclear Regulatory Commission to decommission the reactor will take at least 6 months. Dismantling of the reactor probably could not begin before the end of the year. The decommissioning and site-clearing process could take 2 to 4 years and cost $3 million. Funding depends on action by the University of California regents. And Berkeley's nuclear engineers will want firm assurances of an alternative source of neutrons before the reactor is turned off.

Commenting on the university's explanation of the decision on the reactor, Schwartz said he was sure the "all those elements" were considered, but he noted that the Berkeley city government was planning to hold hearings on the reactor and that there was "a clear political concern." He said it was hard to avoid the conclusion that the reactor's continued operation would cause "considerable embarrassment." He said the university's decision could be "properly called a victory for antinuclear sentiment in the community and is of interest elsewhere." ■

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