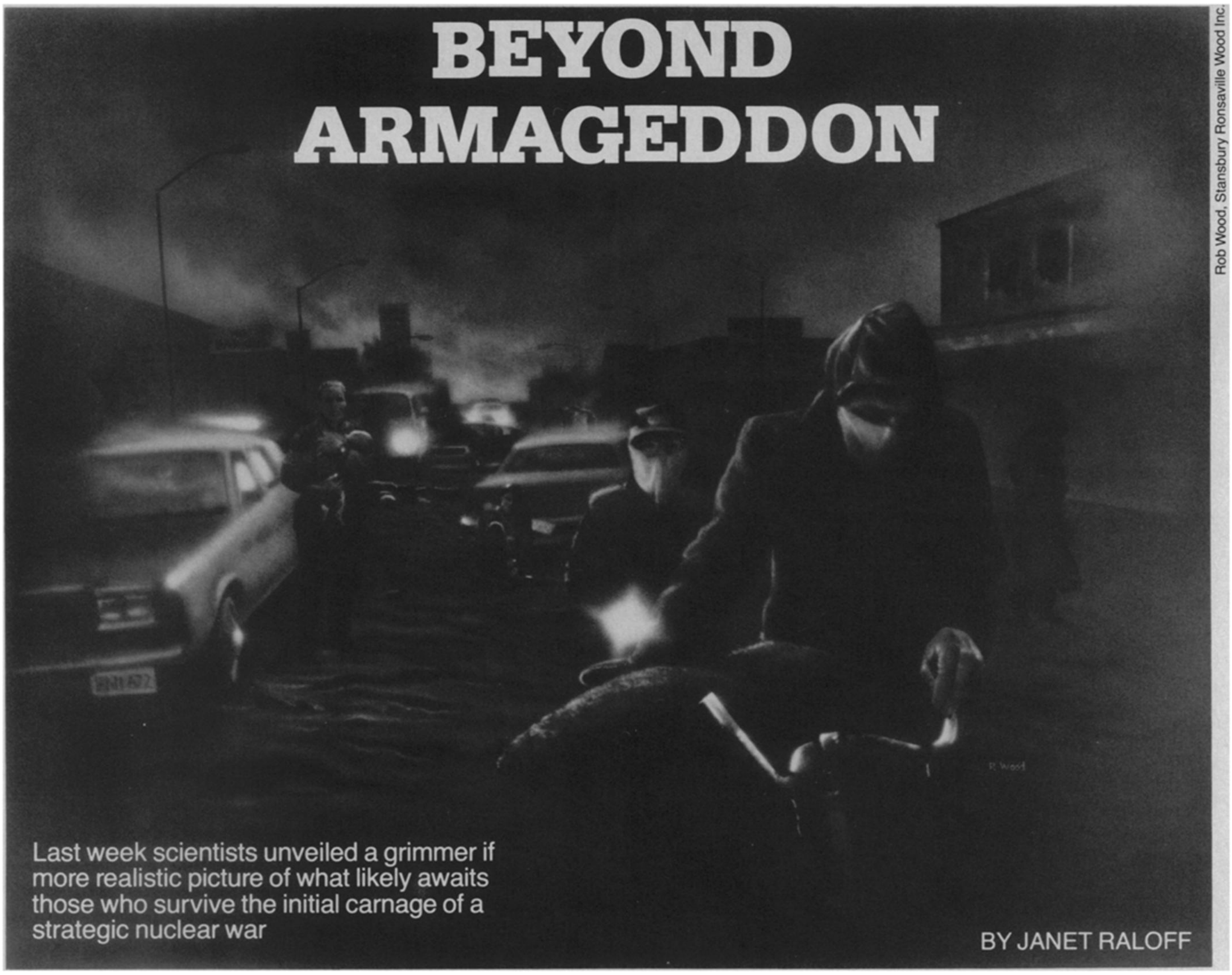
BEYOND ARMAGEDDON



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Last week scientists unveiled a grimmer if more realistic picture of what likely awaits those who survive the initial carnage of a strategic nuclear war

BY JANET RALOFF

More and more civilian scientists are not only thinking the unthinkable, but also dissecting it. And the collaborative result of several independent teams of these researchers, representing well over 100 scientists, has been to construct a distinctly sobering picture of the hostile environment that will face survivors of even a "modest" strategic nuclear battle.

A grim consensus of those who developed data presented at "The World After Nuclear War," a conference last week in Washington, D.C., was offered by Stanford University ecologist Paul Ehrlich: "The two to three billion who are at least able to stand up after the last weapon goes off are going to be — at least in the Northern Hemisphere — starving to death in a dark, smoggy world." He added that within days, that world would also cool down precipitously as the Northern Hemisphere settled into the beginning of its first "nuclear winter."

A recent study by the World Health Organization (WHO) concluded that a major nuclear war involving the United States and the Soviet Union could leave 1.1 billion dead from prompt nuclear effects — the blast, fireball and radiation. Added to that would be another 1.1 billion seriously injured. But with medical care almost nonexistent, the WHO study anticipated most of these people would also die. The ultimate toll, then, from direct bomb effects was projected at more than 2 billion people, or roughly half the world's human population.

But prospects facing those who survived would hardly be comforting, according to the projections presented at last week's conference. Within only a few days following the closing nuclear salvos, temperatures in the plains of North America and steppes of central Asia could plummet 40°C (72°F) — meaning it could literally freeze in July. If the war broke out in summer, the abrupt cold would kill most plants (even winter-hardy species usually require some acclimatizing). If the war occurred in winter, effects carrying into spring would likely rule out spring planting or seed germination, Ehrlich said. Moreover, any plant not killed by the cold or radiation — and data presented last week upgraded estimates of the postwar levels appreciably — would undoubtedly suffer badly from the heavy chemical smog generated in industrial fires around urban areas. And then there's the gloom; even at noon, Ehrlich noted, it would be almost dark — a result of the millions of tons of dirt and debris that nuclear detonations kicked skyward during the battle.

Light could prove insufficient to sustain photosynthesis, noted plant physiologist Joseph Berry of the Carnegie Institution of Washington. Incident light in some regions could fall to as little as 5 or 10 percent of former ambient levels, several atmospheric chemists said. Under such conditions, Berry said, net photosynthetic activity in many plants "is going to stop," because at least 15 to 20 percent of a plant's daily photosynthesis generally is needed just to keep up with its respiration.

So plants would die. Most mammals would die. Food would be scarce. And this all amid darkness and unseasonable cold (regardless of the time of year), Ehrlich said. Eventually survivors would probably set off in search of some place better. "Things will be so horrible for them that they will probably assume things have to be better somewhere else," Ehrlich said. But the climatological forecasts presented at the conference last week suggested that is not necessarily true. Based on the mag-

(Left) Cold, hungry and thirsty, urban survivors would likely try to get away from their dark and polluted environment -probably on foot.

nitude of the war and where the salvos had rained, the entire globe could be affected to a significant degree.

Initial recognition of this potential climatological aftermath of a nuclear Armageddon—including the nuclear-winter phenomenon — is being credited to Marina del Rey (Calif.) research scientist Richard Turco, Cornell University astronomer Carl Sagan, and three of their colleagues at the National Aeronautics and Space Administration's Ames Research Center in Moffett Field, Calif. — Brian Toon, Thomas Ackerman and James Pollack. In a paper they authored — and now known as TTAPS (an acronym spelled by their names) — they analyzed for each of 40 different nuclear-exchange scenarios how much soot and soil would likely be flung into the atmosphere and the extent to which these particles might filter sunlight from the earth's surface.

Their calculations indicated light levels for the Northern Hemisphere mid-latitudes could drop to as low as 5 or 10 percent of normal, Sagan reported last week. The resulting gloom could last weeks to months, depending on the scenario (whether bombs were detonated in the air or on the ground; their explosive yield; and the degree to which these bombs ignited major fires).

Fine soil particles or dust could be hurled into the upper atmosphere (stratosphere) by high-yield (several-megaton yield) ground bursts. From a military standpoint, these attacks are prized for their effectiveness in knocking out "hardened" (massively protected) ballistic-missile silos. However, because the stratosphere is relatively stable, once dust is lofted into it, the particles tend to remain there for some time — typically a year or so. And Sagan noted that more than 100,000 tons of dust would be catapulted into the stratosphere for each megaton exploded in ground bursts.

Urban, military and industrial areas are more vulnerable to attack, and it is anticipated they would easily be destroyed by air bursts with significantly smaller (kiloton-yield) devices. Though the explosive value of these weapons is not insignificant — even a small one would probably pack 10 to 100 times the explosive yield of the bomb exploded at Hiroshima—it is the potential for initiating large fires that threatens to make the urban attack so climatologically devastating. The high carbon content that makes soot so black also makes it an ideal optical absorber — far better, in fact, than dust. As such, it would be a major atmospheric filter of sunlight. However, because soot seldom climbs above the lower atmosphere (troposphere), it would be subject to possible rain-out during storms, and therefore quick atmospheric removal.

Surprisingly, the soot factor was largely overlooked until about two years ago when Paul Crutzen, now director of the Max Planck Institute for Chemistry in Mainz, Germany, and John Birks of the University of Colorado published calculations estimating the quantity of smoke that might be generated by urban, industrial and forest fires in the aftermath of a nuclear war. At the Washington meeting, Crutzen reported that in the nuclear-exchange scenario he considered, one could expect that a total land area of roughly 500,000 square kilometers (km^2) would go up in flames. Based on analyses of forest fires, the combustion of oily petrochemicals and urban conflagrations, he estimated how much carbon might enter the troposphere in the 30° to 60° N. latitude belt under conditions set by his scenario. (Known as the Ambio scenario — for the Swedish journal in which it was published — it assumed the detonation of 14,747 warheads having a 5,742-megaton total yield.) Crutzen said his calculations showed that after one month, sunlight transmission to earth's surface in this zone would be cut by 90 percent.

Sunlight warms this planet. By absorbing sunlight, soot particles and dust in the atmosphere foster a dramatic change in the earth's normal energy balance. As the particles absorb light, they contribute to a heating of the atmosphere. Deprived of this heat, the earth's surface cools. Hence the onset of the nuclear winter.

The TTAPS team's involvement in this research "began in an unexpected fashion in 1971," Sagan explained last week. When the Mariner 9 spacecraft arrived to study Mars, it found the planet completely shrouded by a dust storm, which, Sagan noted, "happens often on Mars." Data sent back by the spacecraft revealed the Martian atmosphere was "considerably warmer than usual," Sagan recalled, and the planet's surface significantly cooler than normal. When the dust settled three

Nuclear Exchange Scenarios

Case	Total Yield (MT)	Percent Yield Surface Bursts	Percent Yield Urban or Industrial Targets	Warhead Explosive Yield (Range in MT)	Total Number of Explosions
A. Baseline exchange, countervalue and counterforce	**5,000**	**57**	**20**	0.1-10	**10,400**
B. 3,000 MT nominal, counterforce only	3,000	50	0	1.0-10	2,250
C. 100 MT nominal, countervalue only	**100**	**0**	**100**	0.1	**1,000**
D. 5000 MT "severe," counterforce only	5,000	100	0	5.0-10	700
E. 10,000 MT "severe," countervalue and counterforce	**10,000**	**63**	15	0.1-10	**16,160**

TTAPS/Sagan et al

Sampling of scenarios TTAPS analyzed. Countervalue *attacks are those on industries and cities; main effects would result from smoke carried to the troposphere and stratosphere from fires.* Counterforce *attacks are on missile silos and super-hardened facilities; they assume a lot of dust, but no smoke, injected into the stratosphere.* Nominal *cases require many guessed-at parameters.* Severe *cases were not considered to be so exaggerated as to be implausible.*

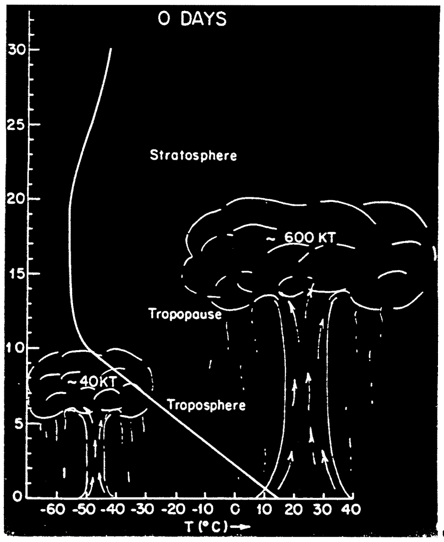
months later, temperatures returned to expected levels.

Together with his NASA-Ames colleagues, Sagan applied this knowledge to predict how dust hurled into the atmosphere by major volcanic eruptions might cause a similar warming of earth's atmosphere and cooling at its surface. Comparisons with actual post-eruption measurements confirmed the validity of the approach.

But it was only after reading the Crutzen and Birks soot-emission work, Sagan says, that the new TTAPS study took shape.

After developing a range of what they believed to be potential and credible nuclear-war scenarios (see p. 315), TTAPS' authors constructed a computer model to calculate how much dust and smoke might be generated under each scenario. Then, using a one-dimensional computer simulation of the atmosphere, the group analyzed how much sunlight would be absorbed in each case, how much surface and atmospheric temperatures would change, how the particles in the atmosphere might travel longitudinally or latitudinally, and finally, how long the particles might remain airborne. Because nuclear fission products would travel with these fine particles, TTAPS calculations also provided estimates of the extent and timing of the radioactive fallout likely to be associated with each scenario.

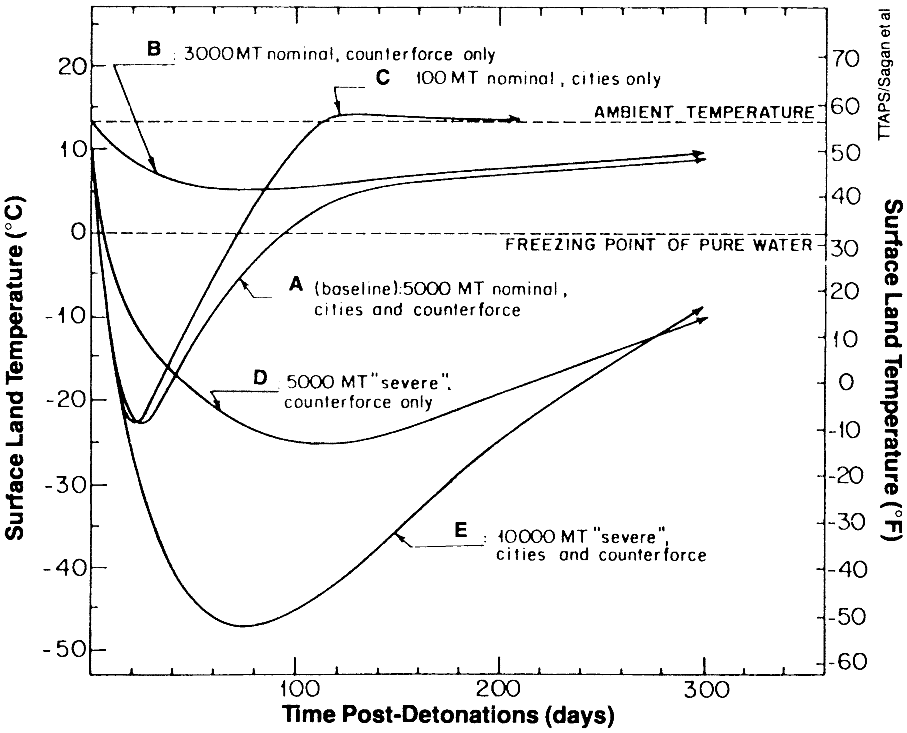
TTAPS' baseline case was a 5,000-megaton (MT) war involving 38 percent of the U.S. and Soviet strategic arsenals (which include land- and submarine-based intercontinental ballistic missiles and warheads carried aboard intercontinental bombers). For this scenario, sunlight in the continental interiors of the Northern Hemisphere would drop "to about one percent of former ambient levels for some weeks," Sagan said, with temperatures plummeting at the same time to about -20°C. For a 10,000-MT exchange, Sagan reported temperatures would go much lower, "like -50°C, and the worst of the lower temperatures [wouldn't] go away for many months." Daylight would drop to a mere 0.1 percent of normal for the same period.



Solid line approximates ordinary temperatures in earth's atmosphere at northern or southern middle latitudes (y-axis measured in kilometers). Smoke from fires is mainly restrictd to troposphere where soot falls out (usually with rain) rather rapidly. Dust from high-yield groundbursts –at silos or other hardened facilities –is largely injected into stratosphere. Minimum explosive yield needed to inject material into stratosphere is about 300 kilotons (KT).

But "perhaps the most remarkable finding," Sagan said last week, "was that if 0.8 percent of the global strategic arsenals were dropped — 100-MT on [a total of] 100 cities — that would trigger an effect about as bad as the 5,000-MT case. In other words, these climatic results are very independent of the kind of war we're talking about. And there is a threshold of 100 MT (more or less) — let's say 1,000 nuclear weapons — at which this climate effect can be triggered."

That "threshold" is not hard and fast, Sagan noted, because smaller, kiloton-sized battlefield weapons send little into the stratosphere. And if the particles rain out of the troposphere too quickly, climatic impacts will be shorter and more regional.



Surface-temperature changes expected to occur over continental areas in Northern Hemisphere as a result of several different nuclear-exchange scenarios. Each is based on degree to which smoke and dust in atmosphere would filter sunlight. Smallest temperature drops (associated with Case B) –of about 5° to 10° C –would be sufficient to turn summer to winter. Even smallest (MT-yield) scenario, Case C, would result in two months of subfreezing temperatures.

Climate modeler Stephen Schneider believes Sagan's use of "threshold" is an unfortunate choice of words. "The real issue is how much smoke can you get in the air," he said. Like the TTAPS team, Schneider was immediately impressed by the Crutzen-Birks study's potential to inject more realism into post-nuclear-war climate forecasting. So for the past two years, as deputy director of the Advanced Study Program at the National Center for Atmospheric Research (NCAR) in Boulder, Colo., he has directed studies into how soot-loading of the atmosphere would change the postwar climate. And unlike TTAPS' one-dimensional climate model, NCAR's is a three-dimensional model of atmospheric processes — one of the most sophisticated in existence.

The TTAPS model "has no dynamic feedback," Schneider explained, "the winds don't blow. In our model, winds blow." And wind can have a significant impact on the outcome of an atmospheric forecast, Schneider pointed out. Since oceans, with their large thermal reservoirs, will not freeze during the nuclear winter, they will keep coastlines relatively warm. But the major land-sea temperature differential that will develop could lead to a fairly constant gale-force buffeting of coastal regions.

More important, winds have the potential for transporting atmospheric particles far beyond the battlefield from which they ascended, bringing the devastating dark and cold with them. Since it is expected that a strategic nuclear war would be waged largely in the Northern Hemisphere's middle latitudes, wind modeling is essential for determining how much of the Southern Hemisphere will be affected by devastating atmospheric changes.

And as Schneider told conference parti-

Fireball from very large explosions (upper left of image below) would penetrate stratosphere and destroy ozone layer. Explosions over cities and forests (near right) would ignite enormous fires that burn for weeks. Smoke spreading downwind would eventually shroud atmosphere above most of Northern Hemisphere (far right) with cloud of light-filtering particles.

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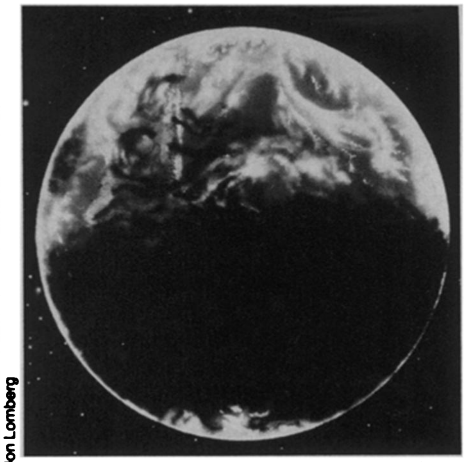

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cipants last week. "Our data suggest very strongly that soot would be lifted up and then carried toward the Southern Hemisphere," much as the TTAPS data predict. In fact, he said, "Everything that we've seen so far suggests that although details do vary [from the TTAPS analysis], the basic picture [that TTAPS paints] is hard to get rid of."

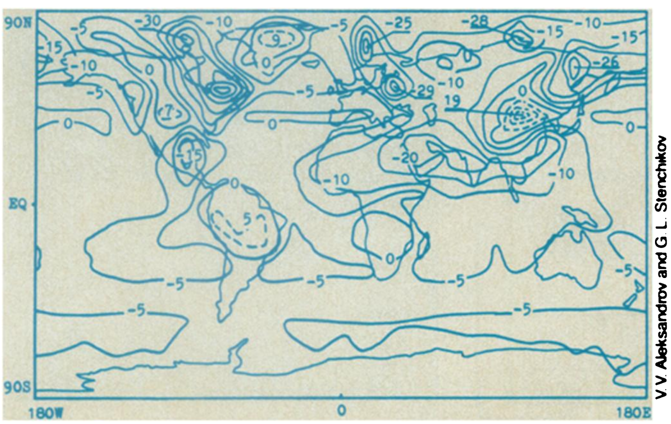
Specifically, Schneider told SCIENCE NEWS, TTAPS' lack of wind modeling leads it to estimate colder surface temperatures — by perhaps a factor of two — for coastal regions than the NCAR general-circulation model forecasts. However, he said temperatures from the NCAR model for the central parts of continents end up being almost as cold as TTAPS' — a 40°C drop below normal for regions in the central United States and Siberia. He explained, "That's because the central parts of the continents are not as influenced by winds."

Vladimir V. Aleksandrov of the U.S.S.R. Academy of Sciences Computing Center in Moscow presented strikingly similar data from a climatological model which differs in significant ways from that used by the NCAR group. In detail, again — such as precise temperature projections for a particular region — his results varied slightly from those Schneider reported. "But in the main two findings we were completely in agreement," Schneider said. "We both show the basic [climatic] circulation structure completely reversed from normal. Normally, for the time of year we're talking about, air rises over the equator, moves toward both poles and sinks in the subtropics over the deserts. What we showed is exactly the opposite: Air rises in the subtropics — driven by the heating of the atmosphere by the soot — and then moves toward the equator." Schneider also noted that both models suggest rising air would spread toward the Southern Hemisphere. Finally, both the NCAR and Soviet models showed lots of subfreezing temperatures in mid continents.

Because nuclear weapons also hold the potential for catalyzing a depletion of the atmosphere's ultraviolet-shielding ozone layer, all climate analyses project a significant "greenhouse-effect" warming to occur once light-filtering soot and dust settles back to earth. So far, however, most analyses for this warming phase are sketchy. "Our first priority was to look at the smoke problem," Schneider said, adding that "we're looking into long-term greenhouse effects here at NCAR too. It's just that we were not exactly worried about a 2° or 3° temperature rise in year two or three [after the war] if we're going to have subfreezing temperatures for several weeks or months in year one."

Aleksandrov's model — which began with the Ambio nuclear-exchange scenario — did project what might be the first catastrophic reversal of the initial nuclear winter. By day 243 (after the war), his forecast still projected temperatures to be depressed (see map, below) by 32°C in the northeast U.S., by 30° in central Europe, by 10° in central Africa and by 24° over the Arabian Peninsula. However, it also revealed a "strong warm-up of the air over large mountain systems," he said. Increases of 5° to 6°C above normal were projected for the Andes, 7° above normal for the Cordilleras, and a whopping 20° above normal for Tibet. This change in the heat balance affecting mountain snows and glaciers has the potential for provoking continent-size floods, Aleksandrov said.

Last April, a group of about 80 biologists met in Cambridge, Mass., to analyze ecological implications of the TTAPS study. As Ehrlich reported last week, "Those of you familiar with the scientific enterprise know that to get more than 50 scientists to agree — with no significant dissent — to a broad set of conclusions is unusual. To get them to agree on conclusions that bear on a problem of great and current public concern is extraordinary." But the group was absolutely unanimous in its conclusions, Ehrlich said: "With all of the uncertainties and so on, if there is a full scale nuclear war, odds are you can kiss the Northern Hemisphere goodbye . . . odds are also that the effects will be catastrophic in the Southern Hemisphere." Even more importantly, he said, "we decided, I think for the first time among serious scientists, that should the effects spread widely into the Southern Hemisphere, that we could not preclude the extinction of *homo sapiens.*"



V. V. Aleksandrov and G. L. Stenchikov

Map for day 243 following a global nuclear conflict showing projected increases or decreases in surface temperature (as measured from the norm, in Celsius). Mean cooling for middle latitudes in the Northern Hemisphere is 10°C, based on the projected atmospheric pollution.

An announcement was made before the conference that as one of its ground rules, no discussion would be allowed concerning the politics of nuclear war, military policy or arms-control policy. Yet Ehrlich tread very close to doing just that when he pronounced: "The overkill in the biological area is so large that there's simply no question of what the long-term effects of any size nuclear war are going to be. Catastrophic. So there is no need to hang tough, wait for more research, see what happens, play the 'acid rain game.' We know more than enough right now for decisionmakers to start making policy relative to these results." □