NUCLEAR WAR AND CLIMATIC CHANGE - GUEST EDITORIAL

The practical applications of global climatic modeling are generally thought to have a rather leisurely time-scale: perhaps a few thousand years or more to the next semi-periodic glaciation (temperature declines of about 10°C), or a century for a global warming (a few degrees °C) from the burning of fossil fuels and the attendant CO_2 greenhouse effect. But, quite unexpectedly, a recent study (Turco *et al.*, 1983), known from the names of its authors as TTAPS, shows the possibility of global (or at least hemispheric) temperature declines of several tens of °C on a time-scale of a month – following a nuclear war in which cities are targeted. Fine dust injected into the stratosphere by high yield ground bursts, and soot – injected into the troposphere (and possibly the stratosphere) from the burning of cities, forests, and grasslands by airbursts of any yield – appear fully capable of producing a pall of high optical depth, even if spread uniformly over the globe. Moreover, the effects seem to be fairly independent of the character of the nuclear war; less than one percent of the world's strategic arsenals can produce such effects – for example, by the burning of the central cores of 100 to 200 NATO and Warsaw Pact cities.

The heating of an optically thick and spatially extensive cloud of fine particles in the Northern Hemisphere seems likely to produce a dramatic change in the general circulation and, in contravention of some conventional wisdom, carry large quantities of fine particles into the Southern Hemisphere; thus it is possible that a northern mid-latitude war will have global climatic consequences. In many scenarios, recovery to ambient conditions takes a year or more. Biologists and ecologists, considering these consequences, have drawn very dire implications for life on Earth, including massive species extinctions, and the possibility that our own species would be fundamentally imperiled by nuclear war (Ehrlich *et al.*, 1983). Suddenly, global (and regional) climatic modelling has become one of the most practical and urgent areas of scientific inquiry.

Several dozen nuclear war scenarios and variations of imperfectly known parameters are included in the TTAPS study. A number of other independent simulations, including two in the Soviet Union, give comparable results. Nevertheless, the TTAPS study has the important limitation that it is dependent on a one-dimensional radiative-convective model (or perhaps 1.5 dimensions, since land and ocean were modeled separately). It is also far from fully interactive: for example, the heating of fine particles aloft moves the atmosphere profoundly towards isothermal in what used to be the lower troposphere, with a massive temperature inversion at higher altitude; in the resulting very stable lower atmosphere, the time-scale for recovery to ambient conditions may be much longer than has been estimated.

What is clearly needed is a high spatial resolution, fully interactive, three-dimensional model. In the TTAPS paper, minimum requirements for an adequate such model are described as follows: "Horizontal resolution of 10° or better, high vertical resolution through the troposphere and stratosphere, cloud and precipitation parameterizations that allow for excursions well outside present-day experience, ability to transport dust and

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smoke particles, an interactive radiative transport scheme to calculate dust and smoke effects on light fluxes and heating rates, allowance for changes in particle sizes with time and for wet and dry deposition, and possibly a treatment of the coupling between surface winds and ocean currents and temperatures. Even if such a model were available today, it would not be able to resolve questions of patchiness on horizontal scales of less than several hundred kilometers, of localized perturbations in boundary-layer dynamics, or of mesoscale dispersion and removal of dust and smoke clouds." This is an ambitious but essential agenda.

Preliminary three-dimensional models are being developed at the National Center for Atmospheric Research, the Computer Center of the Soviet Academy of Science in Moscow, Lawrence Livermore National Laboratory, The Los Alamos National Laboratory, and other places. Indeed, such modeling seems to be becoming a growth industry in the Department of Defense in the United States, which is all to the good, if somewhat belated. But it is very important that the bulk of such work be performed in unclassified facilities, where every step in the argument is subject to open scrutiny by any competent investigator. The stakes are much too high for any essential link in the chain of argument to be taken on faith.

Historically, there has been a systematic tendency to underestimate the consequences of nuclear war. It is by no means excluded that we are still underestimating them. Can the massive destruction of coniferous and tropical forests produce an albedo feedback mechanism that lowers the Earth's temperature still further? Might such desertification lead to a continuous global pall of windblown dust? Are there circumstances when temperatures, even locally, can drop below the frost point of atmospheric carbon dioxide? More generally, are there any positive feedback loops by which nuclear war can trigger an extensive ice age?

No matter how elaborate general circulation models become, this subject will always be clouded in some uncertainty. The climatic consequences of nuclear war is not a subject amenable to experimental verification – or, at least, not more than once. But because the stakes are so high, even rather small probabilities of disaster need to be taken extremely seriously. And the present, admittedly preliminary, state of the subject suggests that the probabilities of a global climatic disaster attendant to nuclear war are by no means small.

It is unexpected and a little ironic that the threat of nuclear war is stimulating major advances in understanding climatic change on Earth (and other planets, which provide instructive and relevant natural experiments). There seems to be a real possibility that climatology can make a vital contribution to reducing the prospects of nuclear war, while the subject itself thereby experiences major growth and maturation.

Laboratory for Planetary Studies
Cornell University, Ithaca NY 14853

CARL SAGAN

References

Ehrlich, P. R., Harte, J., Harwell, M., Raven, P., Sagan, C., Woodwell, M. *et al.*: 1983, *Science* **222**, 1293–1300.

Turco, R. P., Toon, O. B., Ackerman, T. P., Pollack, J. B., Sagan, C.: 1983, *Science* **222**, 1283–1292.