Nuclear winter

US National Academy urges greater caution

Washington

A NATIONAL Academy of Sciences panel has concluded that* while the "nuclear winter" scenario — recently popularized by Carl Sagan — is a "clear possibility", the uncertainties are so great as to make it impossible to "put a number on the temperature changes or other climate effects". George Carrier of Harvard University, chairman of the panel, said he believed that both Sagan and Edward Teller, his most prominent critic, have been taking the results of recent calculations of the climatic effects of nuclear war "too literally", and that current atmospheric models can at best give "indications" of the magnitude of the global cooling that might follow an all-out nuclear exchange.

In testimony to Congress and in repeated public statements, Sagan has raised the possibility that the fall in temperature following a nuclear war would be so great (37 degrees centigrade, according to his model calculations) and of such duration (several months or longer) that the survival of the human race would be threatened.

The panel's calculations produced similar results — a cooling of 20 to 25 degrees centigrade in the Northern Hemisphere, lasting for 6–20 weeks. But throughout their report, the panel stressed that uncertainties in both the assumptions and the models could vastly alter these numbers. The major uncertainty identified by the panel is the quantity of smoke that would be generated in fires set off by nuclear blasts. Small smoke particles are very efficient absorbers of solar radiation; the panel estimated that 180 million tonnes of smoke would be produced in a nuclear war that involved half the world's nuclear arsenal, and that more than 90 per cent of the incoming sunlight would be absorbed as a result. But the plausible range of smoke emissions is great, from 20 to 650 million tonnes; and because of the exponential relationship that determines total absorption, the light loss would diminish rapidly as the amount of smoke drops below 40 or 50 million tonnes.

Even with additional research, the panel acknowledges, the climate effects of nuclear war will not be defined with great precision in the next few years. Indeed, because many factors depend on human decisions that can be changed at will, any calculation involves a significant measure of irreducible uncertainty.

The panel raised several apparently new questions about the nuclear winter phenomenon. One is the seasonal variations. The panel's global-circulation model calculations suggest that the effect would be much greater in the summer than in the winter. And models of spring and summer conditions also suggest that a large transport of smoke particles across the Equator could occur in those seasons, spurred by solar heating of the debris cloud.

The panel's study was commissioned by the Department of Defense early in 1983, several months before Sagan publicized his findings. Although the report was completed almost a year ago, it went through an arduous review process before its release last week. A number of reviewers had strongly opposed the inclusion of any numerical results, no matter how strongly qualified, arguing that they would be misinterpreted. Indeed, several newspaper accounts reported the academy as having given its "seal of approval" to Sagan's conclusions. **Stephen Budiansky**

The effects on the atmosphere of a major nuclear exchange, National Academy Press, Washington, DC, 1985, $14.50.

Uncertainties of climatic change

THE academy report on nuclear winter studiously avoids the use of that term, even in quotation marks. The bulk of the report is concerned with the analysis of the assumptions on which calculations of the climatic effects of the nuclear war have been based. The committee has not constructed climatic models of its own, but has persuaded climatologists to re-run their models with different assumptions.

The committee's starting assumption is that 6,500 megatons of Soviet and US nuclear weapons would be detonated in northern mid-latitudes (compared with the 5,000 megatons in the Turco *et al.* baseline case). This hypothetical war involves warheads yielding 1.5 megatons or less, directed at hardened missile silos (one ground-burst each) and at economic targets (mostly in populated centres). But one of the variants considered includes an extra 100 20-megaton explosions.

For the study's baseline case, the quantity of the fine sub-micrometre dust carried into the stratosphere works out at 15 million tonnes (but could be twice as much), rather less than that calculated by Turco *et al.* But the addition of 20-megaton explosions makes it credible that 1,000 million tonnes of fine dust might be lofted there.

The academy study agrees with the conclusion of Turco *et al.* that soot carried into the stratosphere from fires ignited by nuclear explosions would have a more marked effect than dust on the flux of solar radiation absorbed in the atmosphere, chiefly because of the abundance of particles with sizes of the order of 0.1 micrometres in the smoke from burning fires.

The most important part of the report is the committee's careful discussion of the variables affecting smoke production, together with its review of the observations (from forest fires, for example) leading to the view that the size-distribution of the particles is log-normal. The conclusion is that in the baseline case, 180 million tonnes of smoke would be produced (five-sixths of it from urban fires), that most of this would be distributed in the lower 9 kilometres of the troposphere and that very little would be injected into the stratosphere.

In the committee's baseline case, 250,000 square kilometres each of forest and urban landscape would be burned, with urban areas yielding 100 times as much smoke (3 g cm^{-2}) as forest. Uncertainty stems from possible variations not merely in smoke loading but also in the optical properties of the smoke particles and, in particular, the efficiency of the particles in absorbing visible radiation. The committee says that it cannot combine its estimates of uncertainty due to separate parameters because so little is known of the dispersion of the various sources of error.

Among the sources of error in the model calculations of the climatic effects of these smoke loadings, the committee singles out the impossibility, as things are, of incorporating into climatic models "the cloud microphysical processes that are primarily responsible for the removal of particulates from the atmosphere".

The results of the modelling studies carried out for the committee are qualitatively similar to those of Turco *et al.* Briefly, in the first few days after a nuclear exchange on the scale assumed, the Northern Hemisphere would contain several patches above which the optical depth of the smoke-laden atmosphere would exceed 20 (where the optical depth is the natural logarithm of the ratio of incident and transmitted intensities). Temperatures beneath the cloud of smoke would indeed be sharply decreased, in the worst case by a maximum of 35 degrees centigrade over six months but, with different assumptions about the speed with which smoke would be removed by rainfall, by a maximum of 15 degrees centigrade and to a substantial extent over a period of a month. □