Nuclear winter not yet established

Talk of some of the consequences of nuclear warfare had better be postponed until the underlying assumptions are better understood.

WHEN all the bombs go off, will we frizzle or be frozen? Or, more accurately, can those who survive the first fate hope also to escape the second? These are among the questions raised by the renewed interest among geophysicists in the climatic consequences of several nuclear explosions. It is too soon to answer them with any clarity.

That the surface temperature of the Earth would be reduced if the atmosphere of the Earth were laden with dust and aerosol after a nuclear war is not, as a general proposition, open to dispute. Substantial amounts of dust in the atmosphere would alter the natural balance of radiation near the Earth's surface in two ways, by preventing solar radiation reaching the surface and by depositing energy in those regions of the atmosphere where the dust lies, changing the hydrodynamic behaviour of the atmosphere and thus the weather in the process. Developments such as these are responsible for the climatic consequences of volcanic eruptions and have also been invoked (in conjunction with the arrival of meteoric objects) to account for species extinction at the end of the Cretaceous (see *Science* **208**, 1195; 1980).

Difficulties arise only when attempts are made to calculate the climatic consequences of atmospheric dust. Even the empirical correlation of the magnitude of volcanic eruption and their climatic aftereffects is made fuzzy by the variability of the character of the dust and aerosol injected into the atmosphere (see *Nature* **307**, 107; 1984). By expectation and empirically, the size distribution of the ejected material is important for two reasons — smaller particles will remain in the atmosphere for longer, while their larger specific surface area will more directly influence the radiation balance.

Much of the recent interest in the recalculation of the climatic consequences of nuclear war has been stimulated by measurements of dust particles from eruptions of volcanoes such as Mount St Helens and El Chichon, which have suggested that fine material may be unexpectedly conspicuous. The topic was aired at a public meeting in Washington last autumn and also at a symposium at the meeting of the American Geophysical Union at Los Angeles in December, but the only published account of the calculations so far is that of Professor Carl Sagan and his associates (see *Science* **222**, 1283; 1983). A committee of the US National Academy of Sciences is due to report on the subject later in the year. Meanwhile, the article by Covey, Schneider and Thompson (this issue, p.123) should be regarded as but the latest contribution to what seems certain to be a prolonged and contentious argument.

The Sagan calculation, acknowledged by its authors to be preliminary, turns on the assumptions made about the input of dust and aerosol into the atmosphere in the aftermath of a nuclear war, but otherwise involves a simple model of the energy balance within the atmosphere. That document is less than convincing for two reasons — the promised detailed discussion of the assumptions remains unpublished, while the pardonable simplicity of the calculation of climatic effects, innocent as it is of the feedback mechanisms likely to occur in the real atmosphere, is likely to exaggerate the severity of what is called the nuclear winter. What Covey *et al.* have now done usefully complements this earlier calculation, but only on the second of its weak points.

The new model of the Earth's atmosphere is nevertheless sophisticated enough to deal with at least low-frequency variations of climatic quantities with both latitude and longitude, while the atmosphere is represented vertically by no fewer than nine successive slices. Moreover, the new climatic model breaks new ground by means of its allowance for the occurrence of cloudiness in the lower troposphere. The failure to include such effects has been one of the weaknesses of attempts to calculate the climatic consequences of, say, the accumulation of carbon dioxide in the Earth's atmosphere. It is not clear whether the new model will successfully accommodate these complications, and it may even be thought unfortunate that it has been applied to the calculation of the nuclear winter before much has been published of its usefulness in more conventional calculations.

With these reservations, the new calculations do soften the results described by Sagan *et al.* in the expected direction. Covey *et al.* explain that they have arranged in their model calculation that, in middle latitudes, solar radiation should be predominantly absorbed by atmospheric dust. Virtually none of it will reach to the surface in middle latitudes. The conclusion is that the grip of the nuclear winter will be strongest on the land masses of the Northern Hemisphere (where, it is supposed, the bombs will go off). Some may think it ironic that the territory of the superpowers will be most affected, although this is a consequence of the assumptions made about the relative specific heat of land and sea.

The assumptions about the input of atmospheric dust are, by contrast, no more persuasive than those of Sagan *et al.* Faced with the understandable difficulty of predicting the course of a nuclear war, Covey *et al.* conservatively neglect the effects of dust kicked up mechanically, much of which is known from test explosions to be carried into the stratosphere. Instead, they confine their attention to the smoke from postwar fires, which they assume will be enough virtually to make the atmosphere opaque to solar radiation. For want of a technique for predicting what might actually occur, they suppose that the smoke will remain in place, neither spreading nor settling, during the twenty days spanned by their calculations. Correctly, the authors draw attention to this limitation of their work. They do not say explicitly, no doubt because the point is obvious, that their calculated winter must be an exaggeration.

The result is that while the new calculation shows that the grip of the nuclear winter will vary from place to place much as does the weather, there is still a long way to go before its intensity can be calculated. That unremarkable conclusion, at this early stage in the development of climatic models and in the face of prevailing ignorance about the likely behaviour of large amounts of atmosphere dust, should cause no surprise. If, on the basis of calculations so far published, some people should refuse to believe that there would be a long winter after a nuclear war, they cannot easily be refuted.

Reasonable people will no doubt prefer to follow an intermediate course. Because some parts of the world's population would not be directly affected by a nuclear war, it is not simply an academic matter to consider what the climatic consequences would be. Moreover, as Covey *et al.* point out, the problem is interesting. In time, it should also be tractable. Until then, however, there is the strongest case for asking that the prospect of a nuclear winter should not be made into a more substantial bogeyman than it is by those who earnestly wish to avert the prospect of nuclear war as such. By clouding the case with disputable predictions, they are in danger of weakening it.

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