Nuclear Winter: A Possible Atmospheric Consequence of Nuclear War

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Introduction

Since 1982 there has arisen considerable discussion about the impact on global climate of smoke generated from fires following a nuclear war. Dr A.B. Mullan of the Research Division has been monitoring the scientific literature on this topic.

This paper was prepared by Dr Mullan for discussion by the Parliamentary Select Committee on Disarmament and Arms Control. It is reproduced here for general information of staff and for distribution to enquirers. Please note that a considerable research effort on the topic is taking place in many overseas institutions. While this paper represents not only Dr Mullan's view but the official view of the Service as of February 1985, the view may be modified in the light of new research findings.

J.T. Steiner,
Acting Director.

ORIGIN OF CONTROVERSY

The term "nuclear winter" refers to a period of reduced sunlight and colder temperatures that is predicted to occur in the aftermath of a large-scale nuclear war in the Northern Hemisphere. The idea that a nuclear war could initiate serious climatic changes was first suggested by Crutzen and Birks (1982), who postulated that sufficient smoke would be generated by burning cities and forests to substantially reduce the amount of sunlight reaching the surface of the earth. Earlier studies (such as the 1975 report by the U.S. National Academy of Sciences) had considered the effect of dust raised by nuclear explosions but overlooked the effect of smoke.

Turco, Toon, Ackerman, Pollack and Sagan (1983), commonly referred to as TTAPS, quantified the smoke effects for a 5000 megaton war and, using a simplified model of the atmosphere, calculated a maximum surface cooling of 30-40^{o}C over continental land areas in the Northern Hemisphere (but a cooling of only 2-3^{o}C over the oceans because of their greater heat capacity).

THEORY

Effect of many simultaneous fires

The surface temperature of the earth is determined to a large extent by the balance between incoming solar radiation and outgoing heat (infrared) radiation from the surface. A thick layer of smoke disturbs this balance by absorbing solar energy (which therefore does not get through to warm the surface), while still allowing the infrared radiation to pass through (so the surface continues to lose heat energy). As a result, the surface cools until a new equilibrium is reached. Of particular significance is the fact that smoke is about 100 times more effective than dust at absorbing solar energy - hence analogies with surface cooling caused by volcanic dust emissions are not appropriate.

Magnitude of the cooling

The temperature drop predicted by the TTAPS model is similar for various scenarios of bomb targetting, although the duration of the effect is more variable.

Duration of the cooling

Particulates in the atmosphere are normally removed by settling out under gravity (which may involve prior coagulation of many fine particles into fewer large ones), or by rainfall literally washing the particles from the air.

The normal atmospheric residence time of smoke from small fires or from a single large fire is about one week. This is sufficient time, for example, for smoke from Australian bush fires to reach New Zealand. However, it is believed that the large smoke clouds produced by nuclear fires could remain in the atmosphere for considerably longer than a week for two reasons:

(i) the intensity of the fire would inject the smoke higher into the atmosphere, above the level where particulates are removed rapidly by rainfall; and

(ii) the heating of the smoke itself (by absorption of solar radiation) would stabilise the lower atmosphere and prevent the usual convective processes that lead to rain.

IMPLICATIONS FOR THE SOUTHERN HEMISPHERE AND NEW ZEALAND

A more complete treatment of the atmospheric consequences of nuclear war, allowing for the full three-dimensional circulation of the atmosphere, was first carried out by Covey et al. (1984). By allowing for horizontal heat transports, the predicted cooling in continental interiors was cut by half from the TTAPS result. This work also indicated the possibility of rapid spreading of nuclear-generated debris into the Southern Hemisphere, and hence the chance that we in New Zealand could suffer lowered light levels and cooler temperatures too, albeit much less severe than in Northern Hemisphere countries. These effects could begin within a few weeks of a nuclear exchange, and bring with them more radioactive debris and toxic gases than previously believed likely. A secondary result, which is important from New Zealand's point of view, is that of a strong seasonal dependence in this cross-equatorial transport. Smoke is much more likely to be driven rapidly across the equator if a war occurred in the Northern Hemisphere spring or summer - and fortunately this is the time for us (local autumn or winter) when plants in New Zealand would be relatively dormant and therefore less sensitive to lowered temperatures.

A drop in temperature of as much as $2^{\circ}C$ in any season and lasting for several weeks would probably have a significant effect on New Zealand agriculture. The overseas research suggests this eventuality is possible, but additional studies may lead to a revision of this estimate. Other climatic changes that we can do no more than speculate about are the incidence of increased storminess and altered windflow and rainfall patterns.

MODELLING UNCERTAINTIES

The largest uncertainties include the amount of smoke generated, its distribution with height, and the length of time it remains in the atmosphere.

There are also shortcomings in the atmospheric circulation models that are particularly important when considering Southern Hemisphere effects. The general circulation models are to a limited extent 'tuned' to present-day conditions, so their reliability is suspect when simulating conditions far removed from normal. They also do not handle smaller-scale circulations such as coastal storms that might be induced by the large temperature contrast between land and ocean, (and such storms could play a major role in cleansing continental air of nuclear-generated debris).

Another unrealistic feature of the models is their treatment of the smoke distribution. They assume the smoke is initially uniformly distributed throughout Northern Hemisphere mid-latitudes, and do not move it around with the atmospheric motions.

Hence, any predictions of local climatic changes must be treated with some scepticism. It is noteworthy that the U.S. National Academy of Sciences, in its 1985 report, was unwilling to put a number on the temperature changes even for the Northern Hemisphere.

NEW ZEALAND METEOROLOGICAL SERVICE INVOLVEMENT

The Meteorological Service informed the then Minister of Civil Aviation and Meteorological Services on 15 May 1984 about the possible climatic effects of a nuclear war. The matter was drawn to the attention of the current Minister on 18 September 1984. There have also been exchanges of information with other government departments (DSIR, Defence).

The Service does not have the facilities to make a direct contribution to the modelling of the nuclear winter effect: very large computers are needed for such studies. However, we have the expertise to monitor the overseas literature, and interpret it critically within the New Zealand context. Attendance at international meetings is also a valuable way of keeping up with the latest developments, and a Service officer attended the 'Australia and New Zealand Workshop on the Environmental Effects of Nuclear War' in Melbourne, 28-29 March 1985.

A specific piece of research that the Service can undertake is estimating the impact of lower temperatures on New Zealand agriculture. A start has already been made on mapping the altered growing season of important crops under various temperature-change scenarios. It may also be feasible to monitor smoke plumes from wild fires in Australia, if the smoke passes over New Zealand.

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