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Nuclear winter: science and politics

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Both science and politics have been involved in the debate over 'nuclear winter'. Political interests seem to have influenced the degree of scientific attention to the nuclear winter effect, some of the assumptions underlying the models developed to study it, and the criticisms made of it. Conversely, nuclear winter results have been used as tools to promote particular stands on nuclear policy-making.

In all this, most scientists involved with the studies have tried to define science as separate from politics. The debate raises in acute form the contradiction involved in science allegedly being objective and apolitical while at the same time it is intermeshed with policy disputes.

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In response to queries, valuable comments about the nuclear winter debate were provided by Curt Covey, Paul Crutzen, Paul Ehrlich, Michael MacCracken, John Maddox, Barrie Pittock, Stephen Schneider, Russell Seitz and Richard Turco. Valuable comments in response to an earlier draft of this paper were provided by Ted Bryant, Michael MacCracken, Clyde Manwell, David Mercer, Barrie Pittock, Russell Seitz, Richard Turco and Mick Kelly.

SINCE THE FIRST nuclear explosions in 1945, scientific and popular attention has focused at different times on different actual and potential effects on nuclear weapons. First highlighted were the immediate effects of blast and heat. Because the explosions over Hiroshima and Nagasaki were air bursts, the full implications of radioactive fallout were not realised until the extensive atmospheric testing of hydrogen bombs in the 1950s.[1] In the 1970s, it was realised that nuclear explosions could inject large amounts of nitrogen oxides into the stratosphere, acting as a catalyst to reduce ozone levels and thereby allow increased amounts of ultraviolet light to penetrate to the earth's surface.[2]

It was only in 1982 and 1983 that another possible consequence became the subject of intensive scientific investigation and extensive political discussion: severe climatic effects. A major nuclear war would lead to vast amounts of soot and dust being lofted into the atmosphere, most importantly from the burning of cities. This material would absorb incoming solar radiation but continue to allow infrared heat from the earth's surface to escape to outer space.

The result could be a significant drop in surface temperatures, especially in continental interiors. The temperature drop could cause massive death by freezing and destruction of ecosystems. The popular term for this is 'nuclear winter', which, for convenience, I will use in preference to some other less emotive but more cumbersome phrases such as 'global climatic effects of nuclear war, especially temperature decreases'.

The nuclear winter issue illustrates the interplay between what are usually called science and politics. Proponents of the strong nuclear winter position — those who emphasise the most serious consequences — have consistently adopted the mantle of science, trying to distance themselves from political motives, while at the same time a few of them have been active in spelling out what they believe to be the policy implications of the science. Critics of the strong position — those who emphasise uncertainties and the likelihood that the effects may be less than the worst — have also adopted the mantle of science. In addition, a few critics have questioned the motivations behind nuclear winter research.

For the sake of exposition, I will continue to talk

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of 'science' — scientific knowledge, the methods used in generating and validating it, and the community of people who produce it — and 'politics' — the exercise of power and social arrangements embodying the distribution of power[3] — as distinct entities. I first deal with ways in which politics may have entered the science of nuclear winter, then with ways in which the science of nuclear winter has entered politics and, finally, with ways by which the distinction between science and politics is maintained. In conclusion, some implications for science and public policy are spelled out.

The approach used here draws on the sociology of scientific knowledge,[4-7] which examines the social mechanisms which serve to establish what counts as knowledge. These mechanisms include economic and political structures, potential applications, professional interests and interpersonal dynamics. Data, arguments, claims about method, status and tradition all can be used as 'resources' or 'tools' to persuade other scientists that certain things constitute valid knowledge.

This approach to studying science does not attempt to judge what is scientifically 'correct'. The analysis includes examination of social processes associated with all knowledge claims, whether the balance of informed scientific judgement accepts or rejects those claims now or in the future.

Politics enters science

More than 'pure science' is involved when a researcher decides that a particular area is 'scientifically interesting'. Many features of wider society influence the process of choice of research, including the availability of funding, possible applications, technological infrastructure, ideas prevalent in society and the social position of scientists. Each of these factors played a role in turning nuclear winter into a priority research area in the 1980s.

The resurgence of the peace movement in the early 1980s provided fertile ground for discovering the nuclear winter effect. The upsurge in peace activism spread throughout numerous organisations and occupational groups, including doctors, scientists and engineers. In this context, the editors of the environmental journal *Ambio,* published by the Swedish Academy of Sciences, planned a special issue in 1982 to cover the effects of nuclear war including an article by Paul Crutzen on the effects of nuclear war on the atmosphere.

Crutzen in his PhD did pioneering work in showing the important effect of nitrogen oxides in regulating the amount of ozone in the stratosphere.[8] His work came just at the height of the debate over supersonic transport (SST) aircraft in the United States. Crutzen, along with Harold Johnston, was the first to draw attention to the possible impact of SSTs on ozone due to the nitrogen oxides in their exhaust.[9-10] So from an early stage Crutzen was attuned to the sensitivity of natural systems to human impacts.

A later development in the SST debate was comparison of the effects of SST exhausts on ozone with the effects of nuclear explosions, which also produce nitrogen oxides. Ironically, the first studies of the effects of the atmospheric nuclear explosions on ozone were done in the early 1970s to show that SSTs would not affect ozone significantly.[11] The debate over the effects of past nuclear tests on ozone continued[12] for a couple of years before a few researchers pointed out that a full-scale nuclear war could have catastrophic effects on ozone.[13] This led to a study in 1975 by the US National Academy of Sciences on the long-term effects of nuclear weapons.[14]

In 1981, journalist Jonathan Schell wrote a series of articles in the *New Yorker* arguing that nuclear war could cause extinction of human life, principally through destruction of stratospheric ozone. Schell's articles, made into a book,[15] were inspired by the burgeoning peace movement and in turn were widely taken up by it. Yet, by the time he made his argument, the basis for massive ozone destruction by nuclear weapons had largely evaporated.

This is what Crutzen and his collaborator John Birks found in 1982 as they ran their computer models dealing with stratospheric ozone to determine the effects of a nuclear war. Because the large multi-megatonne nuclear bombs deployed in the 1950s were being replaced by larger numbers of smaller warheads, not as much nitrogen oxide would be lofted far up into the stratosphere. Crutzen and Birk's model did not predict a significant reduction in stratospheric ozone using the *Ambio* reference scenario.

Crutzen and Birks had each examined over the years a wide range of physical and chemical processes which could affect the dynamics of the atmosphere. As they dealt with the problem of the effects of nuclear war on the atmosphere, they happened to think about the smoke released by fires caused by nuclear attacks. Quick calculations showed that the smoke could absorb a large fraction of sunlight, leading to 'twilight at noon'. In short order they included this in their now-famous paper for *Ambio.*[16]

The Crutzen–Birks paper was immediately taken up as heralding an important and hitherto unrecognised effect of nuclear war. The next step, to nuclear winter, was taken by Richard Turco, Owen Toon, Thomas Ackerman, James Pollack and Carl Sagan, the so-called TTAPS group. Taking the Crutzen–Birks idea that smoke and dust from a nuclear war would block out sunlight, they calculated that this would lead to massive cooling at the earth's surface: sunlight in the visual region could not penetrate the smoke, but much infrared radiation from the earth's surface could still escape.[17-18]

The nuclear winter idea was spread to a highly

Smoke and dust from a nuclear war would block out sunlight leading to massive cooling at the earth's surface: sunlight could not penetrate the smoke but infrared radiation could escape

receptive audience, including the peace movement, the mass media and much of the general population. Research groups around the world have examined the issue in greater depth.

Previous military research had not pursued the possibility, at least for wider evaluation. Arguably, the military has been more interested in the immediate effects of nuclear war, since those are the ones of significance for fighting wars and providing an obvious deterrent. In addition, military scientists are not as free to report their results in open forums.

Edward Teller refers to studies in the 1960s of the climatic effects of dust raised by nuclear explosions done at the Lawrence Livermore National Laboratory, a nuclear weapons design laboratory.[19] But these studies were not perceived or promoted as uncovering an area potentially crucial for nuclear policy-making.

Assumptions

Turning now to the actual research: does the science of nuclear winter embody in any way assumptions about politics? The original TTAPS paper[20] and accompanying Ehrlich *et al* paper[21] illustrate the way this can occur. I argue here that they make a series of assumptions which emphasise the worst case for the effects of nuclear war.

Targeting. The TTAPS paper uses a baseline case of 5000 megatonnes (MT), supplemented by a wide range of other scenarios which also lead to nuclear winter effects. Though in general terms some of the scenarios appear reasonable, no detailed strategic rationale is offered for any of them.[22] A cynic might say that the key characteristic of the scenarios is that they produce sufficient smoke or dust to produce nuclear winter. This is illustrated by the 100MT scenario, which is often misinterpreted as 100 bombs on 100 cities.

Actually it involves 1000 bombs and the burning of a vast number of cities each of just the right size. It is easy to misinterpret the results for this scenario as showing that any 100MT war is enough to trigger nuclear winter, whereas any militarily realistic targeting of 100MT would cause relatively few cities to burn and probably produce little cooling according to present models.

If the scenarios had been designed to produce a spread of soot injections rather than a fairly constant soot injection for different megatonnages, the result of nuclear winter would have seemed more sensitive to variations in targeting.

Ehrlich *et al* concentrate on a 10,000MT scenario which generates more severe environmental effects than either the *Ambio* scenario[23] or the TTAPS baseline case. They state that they take the TTAPS 10,000MT 'severe' case as their reference because of policy implications.[24] (According to Michael MacCracken, TTAPS in their draft paper presented a 10,000MT baseline. After receiving comments, they corrected an error of a factor of 2 in the smoke density and also reset the baseline to 5000MT. These two changes counteracted each other, leaving the baseline consequences unchanged. Ehrlich *et al* considered a maximum but, to them, plausible scenario which, after the factor of 2 adjustment, turned out to be the TTAPS 10,000MT scenario.[25])

The threshold. The TTAPS paper suggests the existence of a sharp threshold, above which severe nuclear winter effects are 'triggered'. The 100MT scenario is identified as above the threshold. The idea of a sharp threshold is convenient for policy purposes, since one can argue that arsenals should be reduced below the threshold level, as Sagan has done.[26] Later researchers have discounted or qualified the idea of a sharp threshold.[27-28]

One-dimensional model. TTAPS use a one-dimensional model with annually averaged insolation and temperatures. The model shows dramatic temperature drops over land but little effect over the oceans. The authors comment on the moderating effect of the oceans in the text,[29] but these qualifications have been lost on most readers and commentators who have concentrated on the tables and abstract, where the extreme land results are highlighted. Ehrlich *et al* focused on the land results from TTAPS and applied them over the whole globe in assessing the biological effects of nuclear winter.

Extinction. Ehrlich *et al* itemise all sorts of disasters from nuclear war. For example, they raise the issue of decreases in stratospheric ozone and resulting increases in ultraviolet (after the smoke and dust clears), not noting that changes in the size of warheads have made this threat much less serious. They add up a set of hazards to conclude that human extinction may occur, without explaining precisely how everyone could die.[30-31]

While listing many dangers from nuclear war, they do not mention factors which might ameliorate the problems. For example, food shortages due to crop failures are highlighted, plus difficulties in transporting stored food to population centres. For the rich countries, there is no mention of changing from a meat diet to a grain diet or of reducing caloric intake, which together would extend food reserves by a large factor.

For Third World countries, they emphasise dependence on imports of food from rich countries. They do not mention the exports of food to rich countries, nor the high level of cash cropping for export to industrialised countries, which could be replaced by food crops for local consumption.[32-34]

The suggestion that extinction of human life could occur is made without considering any counter examples. For example, consider Tasmania. As an island in the southern hemisphere, nuclear winter effects would be minimised. It has large hydropower capacity for providing heat and power, and the large sheep population could help tide the modest human population through a failed harvest. Such examples are not addressed by Ehrlich *et al.*

The possibility of extinction is not even discussed in the text of Ehrlich *et al*'s paper. It is only raised in the summary and conclusion.[35]

The combination of these assumptions leads to concentration on worst cases. The selection of results for key diagrams and abstracts makes the drawing of certain policy implications much easier. In other words, the TTAPS and Ehrlich *et al* papers are not

'value-neutral' pieces of research, but 'push' certain conclusions on readers through technical assumptions in model construction, selection of evidence and highlighting of results.

One response to these points is that the authors should have been slower to rush into print and more careful in their presentation of results, given that portions of the media are well known for sensationalism. But, as described later, some of the initial researchers were also active in the media promotion of nuclear winter, certainly more so than in issuing qualifications concerning media exaggerations.

The above points have not been lost on critics of nuclear winter. They have homed in on various assumptions and limitations of the research.[36-47]

I have devoted more attention here to the assumptions underlying the models of the nuclear winter proponents because in the debate so far they have held the greater scientific status and credibility. The critics too can be assessed as having made assumptions, selected evidence and emphasised results which support their conclusions. For example, some of them have drawn comparisons with volcanic eruptions which have put large amounts of dust into the atmosphere to suggest that nuclear war would be no worse; these comparisons, argue the proponents, have overlooked the differences between soot and volcanic dust in absorbing sunlight. The vigorous responses of the proponents[48-51] provide insights into the ways the critics 'push' their conclusions.

The critics use many of the same techniques as the proponents of nuclear winter in reaching their conclusions. But there is an asymmetry between the two sides in that the critics have not developed their own models. Their usual approach is to offer methodological criticisms and emphasise uncertainties in the existing models. For example, the models have been criticised for not adequately taking account of the coagulation of soot, the raining out of soot and dust, and gaps in soot clouds in the first few weeks after fires.

Proponents vs critics

The differences between proponents and critics can be attributed to differences in assumptions about what it is necessary to prove in the research. TTAPS, Ehrlich *et al* and others emphasise worst cases because they assume (and sometimes state) that their task is to show that there is some possibility that these worst cases may actually result. Ehrlich *et al* state "decision-makers should be fully appraised of the potential consequences of the scenarios most likely to trigger long-term effects" (page 1294), namely the worst cases.

The critics, on the other hand, can be interpreted as assuming that it is more appropriate to determine the most likely estimates.[53] They lay the burden of proof on the proponents to demonstrate that nuclear winter will occur with a high degree of certainty; with this assumption, their methodological criticisms and emphasis on uncertainties are natural responses.

As scientific research and the controversy have proceeded,[54-61] the distinction between proponents and critics, never an exhaustive nor clearcut categorisation, has become more blurred. A variety of effects have been studied; some increase and some decrease the likelihood of a severe nuclear winter. Starley Thompson and Stephen Schneider, important figures in the early work, have come to the conclusion that the likely effects are better described as 'nuclear autumn',[62] but have resisted the interpretation that this means a rejection of the basic points made about nuclear winter.[63-64]

The proponents of nuclear winter emphasise worst cases because they may actually result, whereas the critics assume it is more appropriate to determine the most likely estimates

The effect of politics on nuclear winter science becomes harder to assess as the models become more complex and the debate becomes more differentiated.[65-66] What is important here is the basic process involved rather than the intricate details, and the process is best illustrated by the early models and criticisms.

A number of the key figures in the nuclear winter dispute participated in earlier scientific controversies, often concerning the impacts of technological development of the environment. In nearly every case, individual assumptions about the fragility or resilience of ecosystems have remained the same.

Paul Ehrlich is a world-famous ecologist. Over the years he has consistently warned of dangers to ecosystems from various sources. In *The Population Bomb* and other books he has emphasised dangers to the environment from human activities.[67] In the nuclear winter debate he has taken the same orientation, emphasising worst cases and the possibility of extinction.[68] To a lesser extent, Carl Sagan has commented on a number of environmental issues, emphasising sensitivity to disruption.[69]

Critics of the 'extreme' claims on nuclear winter have included several individuals who have previously attacked prophecies of environmental doom. John Maddox, editor of *Nature,* who has issued a series of cautionary comments about nuclear winter studies,[70] is a long-time critic of environmental doomsdayism.[71] Edward Teller, who has argued that nuclear winter claims are exaggerated,[72] has been a supporter of a capability to engage in nuclear war-fighting as a method of preventing war.

S Fred Singer, who has made criticisms of nuclear winter studies,[73] earlier did calculations which upset those who claimed that supersonic transports might seriously affect stratospheric ozone.[74] P Goldsmith, participant in a research team analysing an effect which would reduce nuclear winter effects,[75] earlier was member of a team downplaying the environmental effects of Concorde.[76]

That there is continuity in the perspective that an individual has on the world should be neither surprising nor especially worrying. It does not mean that what a scientist has to say is necessarily wrong. But it does indicate that scientists come to scientific problems with various preconceptions, preferred

methods of analysis and background concerns which can shape the way they define the problem, select evidence, build models, treat uncertainties and present results.

Nuclear winter is an extremely complex area scientifically, laced with major uncertainties,[77] and this allows a freer range of assumptions and interpretations than many other areas. Nuclear winter is also an area which has considerable potential policy implications, and this means that the impact of 'politics' on the development of nuclear winter 'science' is likely to be much more apparent than in other, more esoteric, research fields.

Science enters politics

Compared to the subtle and contentious processes by which politics has entered the science of nuclear winter, the processes by which science has entered the political or policy domain are open and transparent. Nuclear winter has been used as a political 'resource' or 'tool'. Particular individuals and groups have used claims about nuclear winter to pursue explicitly political agendas. The two main groupings are members or supporters of the peace movement, who have unreservedly taken up nuclear winter to argue for nuclear disarmament, and defenders of existing military policies who have minimised the impact of nuclear winter for policy-making.

The promotion of nuclear winter for public and policy impact reached high peaks even before scientific publication of the theory. The major tool in this promotion has been the mass media, and the key figure at the interface between the researchers and the media has been Carl Sagan, a media personality in his own right.

The promotion has included Sagan's article in *Parade*[78] (a Sunday newspaper supplement, circulation 30 million), well publicised scientific conferences, press releases and press conferences, meetings with members of Congress, and television appearances. A minimum of many tens of thousands of dollars have been devoted to public relations about nuclear winter.[79] Activist groups involving scientists have sent large amounts of nuclear winter material to politicians. According to one perspective on 'social problems', the reason it is perceived as an important issue is precisely because there is a social movement promoting it as such.[80]

The scientist publicisers of nuclear winter have had much sympathy from members of the media. Without support from journalists and tolerance from proprietors, the massive promotion might not have led to such worldwide coverage. The receptiveness of the media can be understood at more than one level.

Most directly, nuclear winter is a good story. Doom and destruction are staples of media coverage. The more extreme claims of freezing, darkness and extinction have received much more coverage than cautionary comments about the limitations of the models.

More than this, the great strength of the peace movement in the 1980s has meant that peace concerns are much more acceptable. With a large fraction of the US public supporting a freeze on nuclear arsenals, reporting nuclear winter is not seen as stepping outside the bounds of public opinion.

A comparison with the issue of the effects of nuclear war on ozone is instructive. When this came to the fore in the middle 1970s, it received comparatively little media attention. The scientists concerned did not mount a big media operation, partly because the peace movement was in the doldrums and provided little incentive. For the media, the issue of nuclear war was not a hot topic. Ozone depletion from nuclear war only became a major political issue years later with Jonathan Schell's writings which drew on and inspired peace movement activism.

Another possible reason for the receptiveness of the media to nuclear witner issues is a social structural affinity between scientists and journalists. Both groups make their living by dealing with knowledge. Their respective claims to special understandings, access or presentations of knowledge constitute the basis for their claims to occupational status and economic rewards. They are part of what has been called the intellectual class, the professional-managerial class or the New Class.[81-84] This class or stratum can be contrasted with corporate managers and politicians, whose power derives from control over economic assets and policy-making machinery.

Some scientists and journalists orient their work to corporations, government and the military, but others use their claims over knowledge to challenge these groups. Members of the New Class are prominent in the peace movement.[85] Nuclear winter is a prime case of a challenge to traditional political elites, whose power is rooted in established bureaucratic machinery, by a group of outsiders whose demands are based on claims to special knowledge and expertise.

Strategic experts challenged

The group of intellectuals who traditionally have exercised influence over nuclear policy-making are the strategic experts.[86-87] These are mostly insiders with knowledge about arsenals, technical capabilities, targeting plans, crisis decision-making methods and so forth. Their influence depends on claims to special knowledge, much of which is inaccessible to others for reasons of national security. Included here are some elite scientists connected with weapons development.[88]

Nuclear winter represents a major challenge to the role of the strategic experts. Those with expertise in weapons development, war gaming and international politics were suddenly confronted by a group of atmospheric scientists and ecologists some of whom demanded, on the basis of their special expertise, that certain policy measures be adopted.

The nuclear winter scientists have developed their scenarios and drawn their conclusions with little input from nuclear strategists, yet some of the nuclear winter scientists make dramatic demands for policy changes on the basis of their own expertise. Nuclear winter as science thus forms the basis for a major political challenge to the normal basis for strategic policy-making.

The basic implication for policy, as seen by a number of nuclear winter scientists, is towards

nuclear disarmament. An extreme nuclear winter implies that more people will die in non combatant countries, mainly from starvation, than in combatant countries from the direct effects of nuclear attacks. If human extinction is a possibility then, it is argued, nuclear war is unthinkable. Even short of extinction, nuclear war becomes strategically counterproductive, since the aggressor country may suffer from nuclear winter as seriously as the victim of the attacks.

While most scientists have avoided extensive involvement in policy issues, their work has undergirded the platform for a few active scientists. Carl Sagan has argued for "deep cuts" in nuclear arsenals, to reduce them below the threshold for nuclear winter.[89] Barrie Pittock, the most prominent promoter of nuclear winter in Australia, has argued against Australia's nuclear alliance with the United States.[90]

Some Soviet nuclear winter scientists who are close to Gorbachev seem to have used nuclear winter arguments to influence Soviet disarmament proposals.[91] These Soviet scientists seem to have emphasised the worst effects of nuclear war even more than western scientists.[92]

In spite of all the attempts to affect policy, the influence of nuclear winter has been less than many of its publicisers hoped. What has happened, for the most part, is that nuclear winter has been variously interpreted in ways which provide the least threat to prevailing beliefs and practices.

Most members of peace movements, and indeed the general public, have long believed that nuclear war means the death of most or all people on earth.[93-96] If this was true before, nuclear winter is likely to only affirm the concern of peace activists or the apathy and hopelessness of many other people.

On the other hand, when information about nuclear winter is linked to messages of hope, as for example in workshops by Joanna Macy,[97] then this can lead to greater peace movement activism. Arguably, though, this is due less to information about nuclear winter than to contact with activists who show by example what can be done.

On the other hand, governments and militaries of the nuclear weapons powers have only grudgingly acknowledged nuclear winter and for the most part have denied that it has any major significance for policy. The US Department of Defense found that nuclear winter was a serious consideration, but also that it affirmed the necessity to avoid nuclear war by maintaining military strength.[98] The Australian government has used the rhetoric of nuclear winter to support its military alliance with the US, saying that, since everyone would be affected by nuclear winter, there was nothing for Australia to gain by removing US military bases from the country and reducing the likelihood of nuclear attack.[99]

Some Third World governments have used nuclear winter to argue for nuclear disarmament by the nuclear powers. But they have been making these arguments well before nuclear winter appeared on the scene, and indeed this demand is written into the Nuclear Non-Proliferation Treaty dating from the 1960s.

Nuclear winter on its own does not automatically lead to certain policy implications.[100] To draw a policy implication, other assumptions or values are involved. Carl Sagan assumes that the risk of global catastrophe or even extinction must be removed, and so argues for deep cuts (an "apparently inescapable conclusion"[101]) since civilian and military leaders of nuclear states cannot be trusted with doomsday weapons, nor can technical controls against nuclear war be guaranteed.[102] The pro-military establishment argument is based on the opposite assumption that leaders will continue to be responsible in their use of nuclear weapons in the same way they have used them to maintain peace in Europe since 1945.

Some Soviet scientists seem to have emphasised the worst effects of nuclear war even more than western scientists and have influenced Soviet disarmament proposals

The uncertainties associated with the science of nuclear winter aid the drawing of divergent political conclusions. Some will emphasise the possibility of disaster and draw the implication that action is necessary to avoid even a small risk of major catastrophe achieved by one particular route. Others can emphasise the need to avoid rash action, which might also result in catastrophe, until uncertainties are clarified. Just as uncertainties facilitate the subtle building of political assumptions into scientific work, so they facilitate a drawing of divergent policy conclusions from scientific results.

This is not to say that nuclear winter is a neutral concept which can be used equally easily to justify any policy. In practice, because everyone professes to be opposed to mass killing, nuclear winter is easier to use to attack present nuclear policies than to defend them. This explains why nuclear winter scientists and peace movement activists have highlighted and promoted the possible dangers while defenders of nuclear establishments have emphasised uncertainties and reservations.

Defining science and politics

Is science really separate from politics? The answer to this question is itself the subject of a continual struggle to define both science and politics. Science, if it is seen as pure and unadulterated by non-scientific factors, usually takes on a greater status. In this situation, those who have the dominant claim over scientific authority prefer to portray science as not political. Scientists who are challenging scientific orthodoxy tend to use scientific arguments, also presenting their own views as apolitical.

In both cases, especially when scientific results are overtly being used in a political fashion, those on the other side are alleged to be political. To even say this, to suggest that political factors are entering what is presented as a scientific debate, is to discredit the other side.

The power to be derived by using science to justify political conclusions is greater when the science is seen as being quite separate from politics. Consequently, the struggle to privilege science as being above politics, which involves a constant redefinition as to what is true, unbiased science, is of

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fundamental importance in scientific-political disputes.[103]

In the case of nuclear winter, the proponents have held the scientific high ground. They have had the weight of numerous eminent recommendations, prestigious journal publications and scientific committee endorsements. Therefore they have everything to gain by portraying their favoured results as strictly scientific and as aloof from political squabbling.

Most of the critics, on the other hand, have not been in the position of presenting alternative model results but have had to resort to raising methodological criticisms and pointing to outstanding uncertainties. By and large they have argued within the scientific context. But being in a much weaker position, they have more often raised overtly political criticisms.

There are many routine processes by which science is socially constructed as being at a distance from politics. One is the alleged separation between motivation for doing research and the results of the work. As noted earlier, the 1980s peace movement provided the context for the discovery and promotion of nuclear winter.

This background is normally assumed by all concerned not to affect the validity of the knowledge produced. This is the disjunction between the contexts of discovery and justification, a central feature of Popperian philosophy of science.[104] The relativist sociology of scientific knowledge, used in this paper, rejects this disjunction, noting that a selection of what problems to study and what questions to ask to some extent influences the sort of answers obtained.

The routine separation between motivation and product is inherent in the normal way that scientific papers are written up, which avoids mention of real motivations, preconceptions, failures and reconstructions.[105] Furthermore, in technical journals, explicit treatment of policy issues is frowned upon. The image is maintained that what is being presented is objective scientific knowledge, unsullied by the political context. Although there are occasional statements against war found at the end of nuclear winter papers,[106-107] the usual stance of these scientists is to try "to refrain from political advocacy."[108]

Avoidance of policy implications

The way in which the categories of science and politics can be socially constructed as different and separate was most dramatically shown in the Conference on the Long-Term Worldwide Biological Consequences of Nuclear War, held in Washington, DC beginning 31 October 1983. This famous conference provided a major media launch for nuclear winter and was designed to reach "educators, scientists, business executives, public officials, and other citizen leaders and representatives of other nations, as well as environmentalists".[109]

It happened to start the day after Sagan's *Parade* article appeared; the TTAPS and Ehrlich *et al* *Science* papers were published a couple of months later. The highlight of the conference was a television link with scientists in Moscow.[110]

The conference was officially set up to discuss only 'science' and to eschew any discussion of 'policy'. The boundary between science and policy was often confronted at the conference, especially in the question and answer periods. For example, when Ralph Nader asked whether a successful nuclear first strike would invite suicide for the aggressor and thus be self-deterring, Carl Sagan answered:

> I think I have to decide, Ralph, forgive me, that this is a policy area. I don't want to discuss it at length; but I think that to take out all major fixed strategic targets reliably, you have to exceed the nuclear winter threshold.
>
> Mr Nader: I think you are drawing too fine a line. My question basically was in terms of the richochet effect. To put it more simply, what would be the threshold of a ricochet effect on the first launch, first-strike period?
>
> Dr Sagan: We have an excellent chance that if Nation A attacks Nation B with an effective first strike, counterforce only, then Nation A has thereby committed suicide, even if Nation B has not lifted a finger to retaliate.[111]

The difficulty of separating 'science' from 'policy' is apparent here. Presumably Sagan decided that to talk briefly about 'Nation A' and 'Nation B' was not policy. Would talking at greater length about this issue or referring to the United States and the Soviet Union be entering policy?

The difficulty is that to provide any set of facts in the context of a policy issue can be interpreted as entering policy, if the selection of those facts is in any way affected by their possible policy relevance. It is as if the scientists are taking people a long distance along a particular road (selected on the basis of technical assumptions, and so on), in a situation where more than one road is available due to great uncertainty, and then saying "We can't take you any further because that would be policy".

The same process is found in the presentation of the reports of the Scintific Committee on Problems of the Environment (SCOPE).[112] These impressive reports avoid openly spelling out the policy implications of their findings, yet the Chairman of SCOPE, Sir Frederick Warner, is quoted as saying "anybody who thinks they can read this and not draw policy conclusions is making a big mistake".[113]

The key conclusion of the reports is that more people in non-combatant countries may die from a nuclear war than in combatant countries. Can it be concluded from this that, therefore, nuclear weapons should not be used? This seems to be the implication drawn by some of the reports' authors, speaking in the policy mode.[114] But others, such as the US Department of Defense, might reach a

different conclusion.[115-116]

While it is easy to criticise the claim that science and policy are kept separate, the key point is that the claim is made. It can be seen as a way to maximise the credibility of the scientists for policy purposes. Scientists claim expertise in scientific areas and claim exclusive rights to judge the quality of the science. As long as they are perceived to stay in the realm of science, they are hard to attack. But to formally enter a policy debate would be to lose credibility, since the scientists have no formal training, positions, long experience or special access to inside knowledge in this area.

Furthermore, values commonly play a more explicit role in policy disputes, and it would be hard to obtain 'scientific consensus' on questions of values. For the scientists to outpoint the strategic experts on the latter's home ground would be difficult. The most effective method is to launch a foray into policy while claiming to ground the argument in the realm of science.

The Steering Committee for the 31 October 1983 conference "felt that the inclusion of other considerations such as nuclear strategy and economic, social, and political implications would detract from the central scientific message."[117] Of course, the 'message' was not 'pure science' but rather policy implications embodied in scientific results presented in a particular social context.

The distinction between science and policy is treated by scientists as one between fact and value, the traditional distinction in the positivist philosophy of science.[118] Nuclear winter scientists present what they are doing as the generation of facts, while the policy side is to do with value judgements. Indeed, once this distinction is presupposed, policy is referred to as involving the application of science.

In a scientific-political debate, the side with more orthodox scientific credibility usually prefers to define the debate as a scientific one and to exclude overt discussion of political issues. Because science has an image of objectivity and neutrality, the side which has 'scientific' backing has little to gain by raising the political dimension. By the same token, some of those on the side with lesser scientific credibility may see an advantage in pointing to political factors involved with the orthodox science, while at the same time presenting themselves as scientific.

Typically, both sides maintain the science-politics dichotomy in regard to their own claims and allege the interference of politics in science for their opponents. But those with more scientific credibility are less likely to provide a comprehensive political discussion since they are more able to simply dismiss their opponents as 'unscientific'.

Critics undermined

This pattern can be seen in a variety of disputes. In the debate over nuclear power, there were few scientist critics, at least in early years. The proponents claimed sole authority on nuclear issues, and dismissed critics as incompetents and malcontents.[119-120] The anti-nuclear movement was seen as lacking any technical credibility. Analyses growing out of the movement challenged the 'nuclear establishment' on technical grounds but also provided a critique of the role of vested interests in promoting nuclear power.

Scientist critics of fluoridation[121] and of pesticides[122] have also come under fierce attack. In defending the orthodox position, it is most important to undermine the scientific credibility of critics; other critics can easily be dismissed as technically uninformed.

In the nuclear winter controversy, the best example of this is seen in the response to criticisms by Russell Seitz. Seitz is an Associate of the Harvard University Center for International Affairs where earlier he was a Visiting Scholar. While he has presented technical criticisms of nuclear winter on several occasions,[123-124] he really raised the hackles of nuclear winter scientists with an article in *The National Interest* entitled "In from the cold: nuclear winter melts down". In this article he not only criticises the scientific basis for nuclear winter, but also systematically argues that the whole nuclear winter argument was politically motivated: "a politicization of science sufficient to result in the advertising of mere conjecture as hard fact."[125]

Seitz points out the role of the peace movement in triggering consideration of nuclear winter. He argues that the TTAPS model is filled with assumptions which give results which the researchers wanted to achieve: "worst-case analysis run amok".[126] More damagingly, he claims that the TTAPS results sidestepped peer review. To counter Sagan's testimonials from scientists in support of the TTAPS study, Seitz quotes comments about nuclear winter from a number of prominent scientists (see appendix). These quotes are powerful because they appear to puncture the usual image of nuclear winter, presented by Sagan, Ehrlich and others as being a consensus picture of numerous researchers from many countries.

After a discussion of the media promotion of nuclear winter, Seitz turns to the substantive scientific criticisms, such as Schneider and Thompson's re-evaluation that the effect would better be called 'nuclear autumn'.[127] Seitz also offers his own technical criticisms.

Seitz's article is highly provocative with its mix of science and politics and its strong claims. He suggests that nuclear winter is virtually a conspiracy by supporters of western peace movements: "What is being advertised is not science but a pernicious fantasy that strikes at the very foundations of crisis management, one that attempts to transform the Alliance doctrine of flexible response into a dangerous vision."[128] Seitz favours maintaining US military strength against the Soviet threat, as does *The National Interest* where his article was published.

If Seitz's claims had been restricted to *The National Interest*, the proponents of nuclear winter might have ignored them. But just as the idea of nuclear winter struck a resonant chord among the peace movement, Seitz's criticisms found a receptive audience in conservative circles, and received a major airing with publication of a version of his article in the *Wall Street Journal*.

In principle, there are a number of ways in which a reply to Seitz could have been couched. One is to counter his scientific claims. More delicate is the discussion of the political motivations behind

nuclear winter research. As a piece of political analysis, Seitz's approach could be attacked as being too conspiratorial[129] or as not being grounded in an explicitly acknowledged body of social theory. But to even raise the issue of political factors influencing nuclear winter research would be damaging to the scientific objectivity claimed for the work. It is therefore not surprising that the nuclear winter proponents have not presented their own version of the interplay between science and politics.

The response of TTAPS to Seitz is revealing. Turco in an unpublished letter to *The National Interest*[130] and TTAPS in a letter to the *Wall Street Journal*[131] defended the peer review of nuclear winter and reaffirmed their own scientific work, especially by referring to other studies which have confirmed their original claims. Beyond this, the distinctive part of their reply is a vicious attack on Seitz himself.

Seitz's claim to be a scientist is challenged; he is alleged by Turco to be "actually a stock investment consultant (at R J Edwards, Inc) now dabbling in atmospheric physics", who "is not the principal author of a single peer-reviewed scientific work in *any* technical field".[132] TTAPS contrast this with the impressive credentials of nuclear winter scientists: "the American Physical Society (the primary association of physicists in the US) granted its Leo Szilard Award for Physics in the Public Interest to Paul Crutzen, John Birks and the undersigned team, known as TTAPS, for their research on the nuclear winter theory."[133]

(Turco's characterisation of Seitz appears inaccurate at least on some points. At the time, Seitz had a faculty appointment at Harvard University; previously he had worked at R J Edwards, Inc not as a "stock investment consultant" but as Director of Technology Assessment. Seitz has been principal author of peer-reviewed scientific work.[134])

The TTAPS response is an attempt to deny any credibility to Seitz as a scientist or a commentator, on the grounds that he lacks scientific experience and has made errors in his scientific comments. The response avoids any substantive comment in regard to Seitz's political analysis, except to deny it and reaffirm nuclear winter science's separation from political factors. There is no suggestion that there might be a germ of truth in Seitz's political critique.

The TTAPS response thus is one of maintaining the distinction between science and politics, at least for those scientists with credibility who have developed the nuclear winter theory. Seitz, who challenged the science-politics distinction, is attacked not only for getting the facts wrong but also for not being a real scientist. The importance of maintaining nuclear winter science as above politics is suggested by the vehemence of the personal attack on Seitz.

Conclusion

The nuclear winter controversy, like many others, is an interaction between science and politics in which there is an ongoing attempt to define distinct spheres for science and politics and at the same time to use science, seen as something above politics, to intervene in political debates. The proponents of nuclear winter, so far having the greatest claims to scientific credibility, have the greatest interest in portraying their science as untainted by politics. They implicitly promote the idea that on the one hand they can carry out objective science unaffected by political agendas and on the other hand that some of them can legitimately enter policy arenas, using their scientific credibility as a key resource.

Seitz, who challenged the science-politics distinction, is attacked not only for getting the facts wrong but also for not being a real scientist

The critics of nuclear winter, lacking the same degree of scientific credibility, have somewhat different options. Those with status as scientists mostly prefer to argue on scientific grounds, focusing on uncertainties and methodological shortcomings in nuclear winter research. This is a form of loyal opposition, since the key distinction between science and politics is not challenged (though some complaints about the public promotion of nuclear winter can be heard from this group).[135-136]

A few other critics, notably Russell Seitz, [137-138] while not neglecting scientific criticisms, have directly argued that political agendas lie behind nuclear winter research. If such claims are given any public circulation, they are very threatening to nuclear winter researchers, who have counter-attacked by disparaging the quality of Seitz's evidence and credentials. Scientist critics of nuclear winter have not leapt to Seitz's defence.

Just because 'politics' may be involved with nuclear winter research does not automatically mean that the research is scientifically wrong, tainted or inappropriate for use in policy-making. A straightforward response is to be aware of the political context of the research when evaluating it. For example, if the peace movement has provided the indirect or direct stimulation for doing the research, this may suggest that other social movements (or other strands of the peace movement) might have provided the incentive for different research or different emphases in nuclear winter research.

If the background and experiences of key nuclear winter researchers lead them towards certain presuppositions in their model-building, such as an emphasis on worst cases, then this is something to be aware of, not necessarily something to be condemned. If nuclear winter research is defended on the basis of verifications (different scientists finding the same results from similar models) rather than attempted falsifications because verifications are better suited to promoting the theory, the implications of this for policy-making should be discussed.

Arguably, all scientific research is shaped by its social context (especially research funding and potential applications) which influences what research is considered worth doing, what conceptual models are available and favoured, what results are considered significant and in what language and forums findings are presented.[139] Nuclear winter may have been subject to these processes, but certainly

no more so than decades of research into nuclear weapons where the agenda for science and its application has been overtly determined by military and political considerations.

Unfortunately, careful consideration of the social context of research is seldom possible because of the heavy investments by scientists and the institutions funding science in portraying science as separate from politics. Scientists engage in a whole set of practices which serve to define science as precisely that which is independent of social factors. The value of science as a legitimator of particular knowledge claims would be undermined, at least in the short term, if political influences were openly discussed. Neither side in a dispute such as that over nuclear winter is likely to discuss its own political dimension. Scientists who acknowledge being influenced in their research work by political influences are opening themselves to the charge of being 'unscientific'.

Nuclear winter can be seen as simply one more meta-level for arguing about military policy. There are quite a number of direct discussions about the fundamentals of military policy, but often these become transformed into other domains.

When antiwar activists damage military equipment, this is a direct confrontation. When they are brought before the court and their reasons for their actions are ruled out of order, the confrontation over military policy is turned into a legal issue. Similarly, arms control negotiations are less about the real issues of the arms race and more about managing and continuing the arms race in another forum.[140]

If debates over nuclear winter are, in part, another way of debating military policy, the important question is, what assumptions are built into this meta-debate? One important assumption is that the greater the consequences of nuclear war can be demonstrated to be, the stronger is the argument for nuclear disarmament. Sagan's argument for deep cuts is premised on this assumption; it is also manifest in the tendency of military experts to downplay the effects of nuclear war.

Yet it is easy to question the assumption and argue, for example, that the blast, heat and fallout from nuclear war are more than enough to justify the most strenuous efforts to avoid it. In some ways the controversy over the size of the effects of nuclear war is a diversion, because it is only linked to the issue of what to do about the problem of nuclear war by this dubious assumption. The key differences concerning political action are not confronted directly but only in refracted form in a 'scientific' debate.

I have argued that a key social dynamic in the nuclear winter debate is the challenge to strategic experts by newcomers to military policy, namely a small subset of atmospheric researchers and ecologists. The assumption behind this confrontation is that experts — whether strategic or scientific experts — have a key role in the decision-making. The dispute is over which group of experts has the best or most relevant expertise, not the role of expertise itself. Neither group voluntarily exposes the weak points in its claims to expertise.

The nuclear winter researchers, although strongly influenced by the peace movement and its concerns, have not had the effect of turning the debate over to the public. There have been quite a number of popularisations of nuclear winter, often written by scientists, which aim to inform members of the public about the research and its implications.[141-143] These popularisations, like the research itself, spell out a clear demarcation between science and politics. The role of the public is to digest the science and its implications for action. There has been little attempt by popularisers to offer a critical understanding of the social and political dynamics of doing science.

One of the prime aims of the peace movement has been to demystify the process of military decision-making and to uncover and challenge the assumptions associated with claims about the national interest, foreign threats, 'defence' and so forth. Among the experts who have been exposed to scrutiny are the theorists of nuclear war-fighting, who tend to underestimate or submerge the massive human cost of even their lesser scenarios.

By revealing the assumptions and human values underlying the work of the strategists, peace activists and researchers have reclaimed a role for public concern and participation.[144-146] If the experts and policy-makers are not totally objective and concerned about some monolithic social welfare, then decisions should not be left in their hands alone.

Nuclear winter promised to be a tool for peace activists, and many welcomed it with open arms. But in uncritically accepting the science behind it, they allowed the agenda to be set by another group of experts, the nuclear winter theorists. Ironically, it has been a small number of critics of nuclear winter, including a number of defenders of current nuclear weapons policies against peace movement challenges, who, in trying to expose the political agendas associated with the theory, are the most analogous to the researchers who have challenged the military establishment.

The other assumption underlying the nuclear winter debate is that the scientific status of nuclear winter makes a big difference to policy. Yet this is not borne out by responses either from militaries or peace movements. In neither case is policy or action derived directly from a rational analysis of 'the facts', whether these are military threats or threats to human survival.

Arguably, the role of the military in society is anchored more deeply than just the requirement to defend against enemies; involved is the protection and survival of the state and associated economic, organisational and political structures.[147-149] Likewise, peace movements have been triggered not just by awareness of the dangers or futility of war, but by

One of the prime aims of the peace movement has been to demystify the process of military decision-making and challenge the assumptions associated with claims about national interest

social stresses, moral concern and organisational imperatives.[150]

In this context, nuclear winter is unlikely to be a major driving force in struggles over military policy, but rather becomes a tool to be used or defended against by competing groups. But it is also wrong to treat nuclear winter as purely a social construct. Just because nuclear winter has been a political tool does not mean that the cold and the dark will be any less real, if and when they occur.

Appendix: some critical comments about nuclear winter

Russell Seitz in his article in *The National Interest* quoted a number of prominent scientists as expressing critical comments about nuclear winter models and results. The use of some of these comments has been disputed by proponents of nuclear winter. In an attempt to clarify the status of the quotes, I wrote to the individuals quoted by Seitz, referred to the specific quote and asked "Is this quote correct? Does Seitz's use of the quote give an accurate reflection of your past and present views?"

Freeman Dyson, a physicist at Princeton University, was quoted by Seitz as saying about the TTAPS study, "It's an absolutely atrocious piece of science but I quite despair of setting the public record straight. I think I'm going to chicken out on this one: Who wants to be accused of being in favor of nuclear war?" Dyson in May 1987 responded "No" to each of my questions, adding "I don't believe I ever said what Russell Seitz said I said, but I can't prove it."[151]

Richard Feynman, a physicist at the California Institute of Technology, was quoted as saying about TTAPS, "You know, I really don't think these guys know what they're talking about". Feynman on 1 July 1987 replied to me, "Regarding the quote I'm sorry, but I really don't remember if it's exactly accurate or not".

Jonathan Katz, a physicist at Washington University in St Louis, was quoted as saying about nuclear winter, after a journalist's caution against four-letter words, " 'Humbug' is six". Katz on 22 January 1988 wrote to me that Seitz's quotations attributed to him are correct.

Kosta Tsipis of the Massachusetts Institute of Technology, according to Seitz, quoted a Soviet scientist as saying "You guys are fools. You can't use mathematical models like these to model perturbed states of the atmosphere. You're playing with toys". TTAPS in their November 1986 letter to the *Wall Street Journal* said "A negative comment on mathematical modeling allegedly uttered by a 'Soviet scientist' (indisputably V V Aleksandrov of the Moscow-based Climate Modeling Center, the only Soviet at the April 1983 Cambridge review meeting referred to by Seitz), and prominently displayed in a box by th *WSJ*, was never made. The transcript of the meeting shows no such remark, and Kosta Tsipis of MIT, whom Seitz claims as his source, flatly denies the whole thing".

Tsipis in a memo of 5 January 1987, entitled 'Regarding: Seitz vs Sagan', gives his account: "When Russell Seitz came to talk to me about Nuclear Winter, I recalled that in the AAAS Meeting (in Cambridge Mass), a Russian scientist got up and said that we cannot use climate models as if the nuclear war itself would not disturb the atmosphere. The discussion at that point had evolved around the 1-D (one-dimensional) model. Mr Seitz mentioned this in his *Wall Street Journal* article, but in a context that implied that the Soviet scientist was referring to all 3-D models, quite generally. Subsequently, I had a telephone call from Carl Sagan who wanted to know what I had said to Seitz. During our conversation, two things became clear: a) that Seitz had confused my statement to mean that it referred to a 3-D model; b) that it would be very difficult to explain to the readers of the *WSJ* the distinction. For this latter reason, we agreed that Carl should simplify hs response by saying that I deny discussing the 3-D model with Seitz. In Carl's letter-response in the *WSJ*, this statement was further simplified."

Seitz later wrote to me (30 December 1987) saying that Tsipis' original remarks were recorded,[152] that the clear context was 1-D models, and that he is not aware of any confusion between 1-D and 3-D models in the text of his *Wall Street Journal* article.

Victor Weisskopf, a physicist at MIT, was quoted by Seitz as saying in early 1984, "Ah! Nuclear winter! The science is terrible, but — perhaps the psychology is good." TTAPS in their November 1986 letter to the *Wall Street Journal* comment about Seitz that "derogatory quotes are attributed to individuals who forcefully deny them (eg, Victor Weisskopf)." Weisskopf wrote to me on 10 June 1987 about the quoted comment, "I do not remember having made such a remark. I may have said the science is unreliable, but the psychology is good. I do believe that nuclear winter is not yet proved, but is made rather plausible and therefore the word unreliable is the right characterization. This was my view at the time of the interview and is at present."

One other scientist quoted by Seitz in the same section of his paper, Michael McElroy of Harvard University, did not respond to my letter.

There are at least two lessons to be learned from this material. First, in a scientific area which has important political implications, even off-the-cuff comments can take on a great significance. In this case, the comments are by prominent scientists who are not active researchers in the field in question. Both Seitz and, in response, TTAPS treat the quotes as significant. In disputes over science in public arenas, the credentials of scientists (such as being a Nobel Prize winner) are a key resource in making claims and counterclaims.

Second, the presentation and interpretation of the comments by Seitz and TTAPS, in simplifying the comments or the context in which they were made, tend to reflect the respective cases they are trying to make. Just as the construction and results of mathematical models can reflect the presuppositions of scientists, so can the meaning and significance of 'mere quotes'.

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