Could one Trident submarine cause 'nuclear winter'?

Philip Webber analyses the latest research on the potential climatic impacts of nuclear war and demonstrates that the firepower of just one of the UK's Trident submarines could be devastating for the whole planet.

In a recent letter[1] to the Bulletin of the Atomic Scientists, I raised the possibility – based on some detailed US climate research published in early 2007 – that the nuclear weapons complement of one UK Trident submarine could possibly trigger a 'nuclear winter'. This article expands that analysis, incorporating further research carried out over the last year on the climatic effects of nuclear war.

A brief history of the nuclear winter concept

First, a bit of nuclear history. Back in the mid-1980s, one of the highest points of Cold War tensions, the world's nuclear arsenal stood at over 50,000 weapons[2] and it was very clear that if conflict between the superpowers did take place, any resulting nuclear war would be catastrophic. That view is now generally accepted, although for a good while the Thatcher government did try to reassure us that we would have a much better chance of surviving a nuclear war if we could shelter under makeshift shelters constructed of tables and mind-boggling quantities of materials supposedly available in the home or garden!

Gradually, working with colleagues in Scientists Against Nuclear Arms (one of SGR's predecessor organisations), we were able to construct a detailed case that even relatively 'modest' nuclear detonations – of the order of hundreds of megatonnes (MT) – over UK cities would cause horrific deaths, injuries and long-term radiation consequences resulting in tens of millions of casualties[3,4].

However, some suspected that the longer-term consequences might be even worse due to adverse effects upon the global climate, as a result of widespread fires injecting huge quantities of soot into the upper atmosphere. Climate models were in their infancy by today's standards, but their results were nevertheless chilling. They concluded that as few as several hundred nuclear weapons could trigger a 'nuclear winter' with nightmarish consequences. This realisation was a key factor in dwindling public confidence in, or acceptance of, nuclear weapons.

> **Box 1 – How big is a megatonne?**
>
> One megatonne (MT) is the explosive power of one million tons of TNT – an energy release of 10^{15} calories. The world's current nuclear weapons arsenals total more than 5,000MT, or a little under a tonne of high explosive for every person on the planet[5]. A 'typical' nuclear warhead – such as in the Trident system – is 100kT (0.1MT)[6], or eight times the explosive force of the bomb which devastated Hiroshima[7].

Three climate modelling studies – by two US research groups and one Russian – were especially important[8,9,10]. They showed that a full-scale nuclear war – some 1,000 nuclear warheads exploded over cities and fuel-laden targets such as oil refineries – would cause reductions in surface temperature, precipitation, and insolation (energy from sunlight at the Earth's surface) so large that the climatic

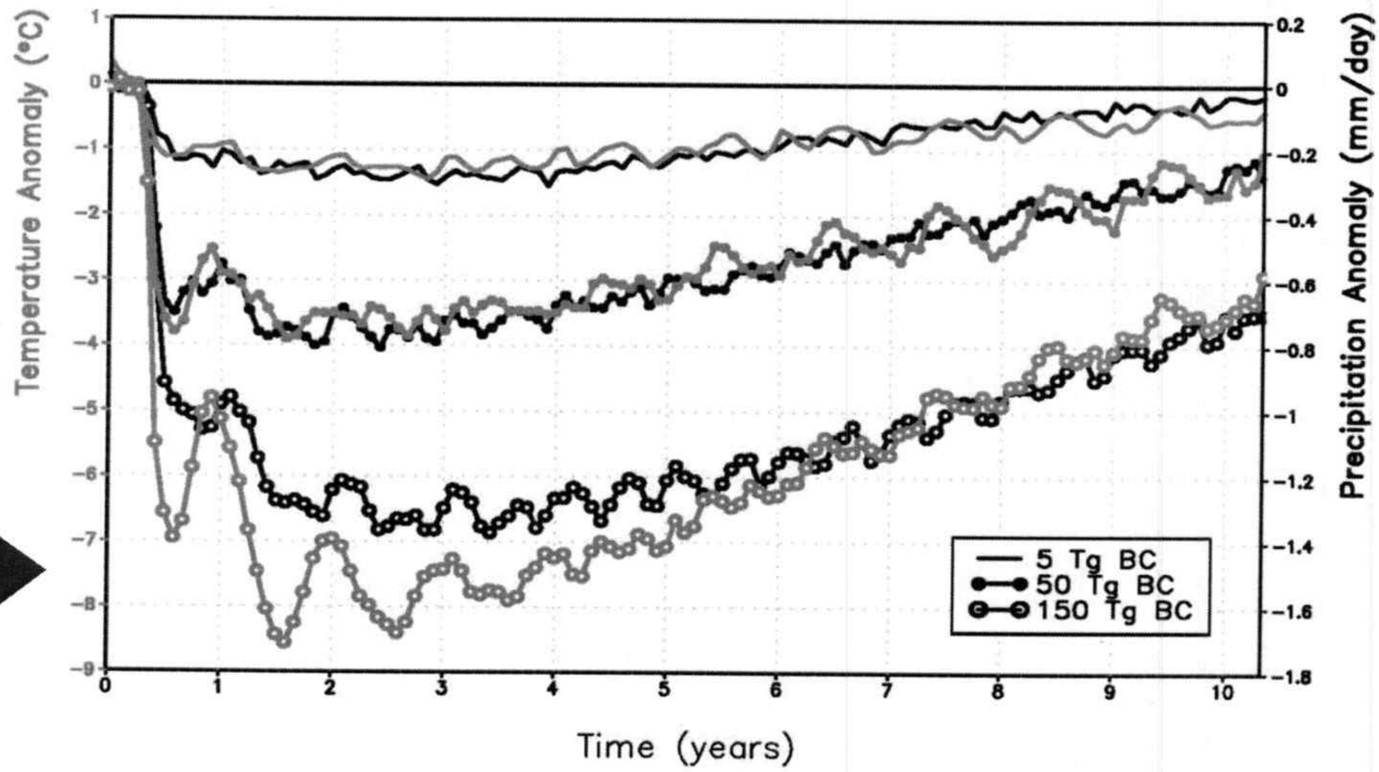

Figure 1 – Change of global average surface air temperature (grey lines), and precipitation (black lines) for the 5 Tg BC (black carbon emitted), 50 Tg BC and 150 Tg BC cases.

Box 2 – Calculating the climatic impacts of the firepower of one Trident submarine
(References are given in the text)

1 Trident warhead = 100kT
1 Hiroshima bomb = 12.5kT
i.e. Trident warhead is 8 times greater

Blast area of 1 Trident warhead = $8^{2/3}$x blast area of 1 Hiroshima bomb
i.e. Blast area of 1 Trident warhead = 4 x blast area of 1 Hiroshima bomb

1 Trident submarine carries 48 warheads (= 4.8MT)

Total blast area of Trident submarine's warheads = 4 x 48 = 192 Hiroshima bombs

100 Hiroshima bombs inject 5Tg of soot into atmosphere

Total soot injection due to Trident submarine's warheads:
Low estimate (linear scaling): 5 x 192/100 = 9.6Tg
High estimate (using Postol model): 4 x 5 x 192/100 = 38.4Tg

Interpolating from the simulations of Robock *et al* (2007), the resulting temperature drop would be 1.5-3ºC lasting approximately five years.

consequences could be described as a 'nuclear winter'. The effect would last a year or more and lead to 'darkness at noon' and other severe climatic disturbances. The stratospheric ozone layer would be destroyed, resulting in a major increase in the dangerous ultra-violet radiation reaching ground level. There would be major extinctions of wildlife, and most people on the planet would be in danger of starvation. The political response to these calculations was intense, with some arguing that the results over-emphasised the likely effects. Some even coined the term 'nuclear autumn' to discredit the work[11].

Nuclear winter confirmed

In recent years, of course, attention has shifted from global cooling due to a nuclear conflict to global warming as a result of fossil fuel burning. Research on global warming and climate change has considerably expanded over the last 20 years and, together with huge improvements in computing power, this has led to major advances in climate modelling, greatly increasing our understanding of atmospheric and other key processes.

With these advances, the Canadian organisation Physicians for Global Survival (PGS), SGR and others called for the research on the nuclear winter phenomenon to be updated[12]. In the last couple of years, this has been carried out, with several new studies having now been completed[13,14,15]. These use the latest climate models run over ten-year simulations and with detailed maps outputting average temperatures and rainfall, with more detailed studies for key crop growing regions. Three new scenarios have been published. These calculate the effects of 5,000MT, 1,300MT and 1.5MT (the latter equivalent to 100 x 15kT), resulting in 150Tg, 50Tg and 5Tg of sooty smoke respectively from fires (1Tg = 10^{12} grammes). Most disturbingly, all three simulations result in cooling effects that last not just a year or two, as in the earlier studies, but for *at least a decade*.

At the top end of the spectrum, the two higher scenarios strengthen the basic conclusion that a large-scale nuclear conflict would have devastating climatic consequences (see Figure 1). They would lead to an average global cooling of 3.5-8ºC – a change as great as moving into an Ice Age. This maximum temperature drop would last three or four years, with a return to normal temperatures taking about another seven years. Geographical plots give more detailed estimates. In the UK, for example, the average temperature drop would be about 5ºC during the initial period. The global average summer temperatures would drop by 20-30ºC. In two key crop growing areas, Iowa and Ukraine, detailed simulations show temperatures below freezing for two years and a halving of the growing season respectively, with a drought due to 50-70% reduced rainfall. Continental cooling would decrease or eliminate the land-ocean temperature contrast in the summer and this would wipe out the Indian, African and North American monsoon seasons.

In 1983, the Scope study[16] estimated that the longer-term impacts upon the climate would mean that all survivors of nuclear attacks would have to depend upon food stocks for at least one year. Even assuming that the remaining food was distributed between survivors, the resulting casualty figures were extremely stark. Assuming no food production for one year and minimal food storage, deaths of approximately 90% of global population were estimated. The only exceptions, in this scenario, were areas in latitudes 20-30º South, which includes Australia, New Zealand and parts of southern Africa and South America, where the nuclear winter effects were somewhat less severe and there could be up to 30% survivors.

But the latest calculations mean that survivors would have to rely on stored food for several years, not one. Virtually all farming would cease for over two years, with a dramatically shorter growing season (if any) due to sharply-reduced rainfall for around a decade. To put this into perspective, grain stocks in 2006 were sufficient to feed the world for just 57 days[17]. To compound matters, there would also be major shortages of fertilisers, fuel for machinery, pesticides (but not pests), and seeds, coupled with periods of darkness during daytime, unpredictable frosts, widespread radioactivity and toxic chemicals, and a food distribution system in chaos.

It is hard to overstate the level of global catastrophe that this would represent.

These results alone need to be brought into the public eye as a shocking reminder of the sheer folly and longer term devastation that a major nuclear conflict would bring, not just to the attacker and the attacked, but every country and region on the planet.

Climatic effects of a regional nuclear conflict

But if this is not shocking enough, research simulating the effects of a 'regional conflict' involving just 100 Hiroshima-sized nuclear weapons (1.5MT in total) concluded that even this could cause significant cooling for several years across the Northern Hemisphere.

Two of the studies mentioned above[18,19] investigated such a scenario. They estimated that such an attack – assumed to target city centres very rich in materials that would burn fiercely – would inject a total weight of smoke into the atmosphere of 5Tg. Their results showed a global cooling for ten years peaking at 1.3ºC. This would still be a major climatic change, especially given the speed at which it would occur. Casualties from blast, fire and radiation due to the nuclear weapons are calculated to be up to a total of 20 million if 'super-cities' such Delhi or Mumbai are included in the target list. The methodology to calculate these figures is very similar to that which we used in the book, *London after the Bomb* in 1982[20].

What could one nuclear-armed Trident submarine do?

After publication of the above results, I decided to estimate what the climatic effects might be using a small number of the larger weapons routinely deployed by the five 'official' nuclear powers. Here I take the example of a UK Trident submarine, carrying its full complement of nuclear weapons. The calculations are given in Box 2 with the explanation as follows.

One Trident submarine is capable of carrying 16 missiles with a total of 48 nuclear warheads, each one of which has a yield of 100kT and can be targeted on a separate city[21].

In order to estimate the climatic impact, we need to calculate how much black carbon (soot) each Trident warhead could send into the atmosphere. The amount of soot created for a given target is proportional to the area set on fire. Robock's 'regional conflict' scenario above used as its basis the firestorm that was witnessed at Hiroshima. Nuclear weapons effects are usually calculated on well known blast-effect scaling laws[22]. Blast damage radii scale as the cube root of the warhead size, thus blast areas scale as square of the cube root (i.e. to the power 2/3). Using the figures in Box 2, we can calculate that one Trident warhead has a blast devastation area four times as large as that in Hiroshima. Using the full complement that can be carried, one Trident submarine can therefore devastate an area 192 times that of Hiroshima. This is roughly twice the regional scenario – which assumed 100 Hiroshima sized bombs – and therefore results in twice the soot injected into the atmosphere. This also means roughly 40 million casualties if densely populated centres are targeted.

However, fire causation and spread is a complex issue and there is reason to believe the impacts could be greater. The Postol super-fire/firestorm spread model[23] predicts that for larger nuclear warheads such as those carried on Trident, fires are likely to rage over an area some 3.5-4 times larger than that estimated from simple scaling-up of the effects of Hiroshima. Taking this important factor into account, one UK Trident submarine could inject not 10Tg of soot into the atmosphere but possibly as much as 38Tg. Interpolating between the 5 and 50Tg scenarios, this magnitude of soot injection seems likely to produce a globally averaged cooling of some 1.5-3ºC over at least five years and shortening of growing seasons by 10-30 days.

It is a shocking revelation that the firepower of just one Trident nuclear submarine could not only devastate 48 cities and cause tens of millions of direct casualties, but also cause a global cooling lasting several years and of a magnitude not seen since the last Ice Age. This would have a tremendous impact on global society and natural ecosystems.

More work is needed to assess in detail the impact that such a cooling would have. As noted above, food supply is particularly vulnerable especially as world grain stocks currently stand at less than 60 days supply – their lowest level for over 30 years[24]. Helfand has estimated that 1 billion deaths could result from food shortages arising from the 'regional conflict' scenario above[25].

Implications for global and national nuclear policy

While the estimates in this article obviously need further analysis and refinement, they are nevertheless robust enough to have important policy implications.

Firstly, this analysis adds yet more weight to the argument that urgent progress is needed in global nuclear disarmament, through the nuclear Non-Proliferation Treaty or, better, through a new nuclear weapons convention. With over 26,000 nuclear weapons still in existence[26], there really should not be any further delay in pursuing this.

Secondly, any nuclear arsenal over about 5MT (i.e. about 50 Trident warheads) should be considered a threat, not just to other states and peoples against which it may be targeted, but also globally through the climatic impacts that could be wrought. The five 'official' nuclear powers – USA, Russia, China, France and the UK – all have arsenals in excess of these levels. It is also possible that the nuclear arsenals of Israel, India and Pakistan each exceed this level[27].

Regional and national instability, such as currently exists in the Middle East or in Pakistan, should be regarded as a potential threat to global society, and the provision of support and resources for peaceful resolution should be given especially high priority.

Finally, this is yet another clear argument against UK plans for Trident replacement. Deploying a weapon capable of devastating the world's climate system is a grossly disproportionate, and perhaps even suicidal, response to uncertain future security concerns. It really is time to put an end to this programme.

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