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Confronting the threat of nuclear winter

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ABSTRACT

Large-scale nuclear war sends large quantities of smoke into the stratosphere, causing severe global environmental effects including surface temperature declines and increased ultraviolet radiation. The temperature decline and the full set of environmental effects are known as nuclear winter. This paper surveys the range of actions that can confront the threat of nuclear winter, both now and in the future. Nuclear winter can be confronted by reducing the probability of nuclear war, reducing the environmental severity of nuclear winter, increasing humanity's resilience to nuclear winter, and through indirect interventions that enhance these other interventions. While some people may be able to help more than others, many people—perhaps everyone across the world—can make a difference. Likewise, the different opportunities available to different people suggests personalized evaluations of nuclear winter, and of catastrophic threats more generally, instead of a one-size-fits-all approach.

1. Introduction

The explosion of nuclear weapons causes enormous fireballs, burning everything in the vicinity. Most of the ensuing smoke rises past the clouds, into the stratosphere, where it spreads around the world and remains for a time on the order of ten to twenty years. A large enough nuclear war would send up so much smoke that the global environment would be fundamentally altered. Surface temperatures and precipitation would decline, while ultraviolet radiation increases. The effects could be catastrophic, killing a large portion of the total human population and potentially threatening the long-term viability of human civilization.

Research on the global environmental consequences of nuclear war flourished in the 1980s, including such luminaries as Carl Sagan and Nobel laureate Paul Crutzen (for a history, see Badash, 2009). The 1980s nuclear winter research garnered considerable attention, due in large part to Sagan's aggressive campaigning and high public profile. The term "nuclear winter" was coined by Sagan's colleague Richard Turco in order to avoid the political connotations of "nuclear war", ironically because "nuclear winter" itself became heavily politicized (Dörries, 2011). In precise technical terms, nuclear winter refers specifically to a temperature decline following nuclear war that yields winter-like temperatures during summer. This paper will use "nuclear winter" to refer more generically to the full set of global environmental consequences of nuclear war, since the full set is of interest in the context of catastrophic threats to humanity.

Nuclear winter research quieted down around the end of the Cold War, but has been revived in recent years with new research led by climate scientists using advanced climate models developed for the study of global warming (Mills, Toon,

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Lee-Taylor, & Robock, 2014; Robock, 2010; Stenke et al., 2013). Some research has studied post-nuclear winter agricultural declines (Özdoğan, Robock, & Kucharik, 2012; Xia & Robock, 2012) and corresponding famine (Helfand, 2013). One paper has also studied policy implications of nuclear winter for military force structures (Baum, 2015). This recent nuclear winter research has strengthened the initial research's conclusion that nuclear winter could indeed be catastrophic for humanity and for natural ecosystems.

The purpose of this paper is to survey the breadth of intervention options to confront the threat of nuclear winter. Successful confrontation of nuclear winter is defined here as any outcome in which nuclear winter does not prevent the permanent collapse of human civilization. Permanent collapse includes human extinction. Success can thus occur if nuclear winter never happens, if it happens but civilization remains intact, or if civilization collapses but recovers. This definition is consistent with contemporary understanding of the ethics of global catastrophic risk (or, alternatively, existential risk), which emphasize avoiding catastrophes that cause permanent collapse or human extinction (Beckstead, 2013; Bostrom, 2013; Maher & Baum, 2013), an understanding that has origins in the 1980s nuclear winter research (Sagan, 1983).

As with other global catastrophic risks, nuclear winter might superficially seem like such a big issue that only a select few of the elite insider scientists and policy makers can make a difference on it. It is certainly the case that some people can make more of a difference than others. However, there are options for a wide variety of people, perhaps even everyone on the planet. Motivated lay people can make a significant difference. This point holds for global catastrophic risks more generally and is well illustrated by the case of nuclear winter.

Nuclear winter is of note within the space of global catastrophic risks in that it can occur quickly and at any time.[1] Many nuclear weapons remain on hair-trigger alert, available for immediate use—many more than would be needed to cause severe nuclear winter. Some actions can help confront this present threat of nuclear winter. However (and despite the ongoing Ukraine crisis), most of the risk lies in the future. Even if the annual probability of nuclear war gradually declines to zero, it is still more likely that nuclear war, and in turn nuclear winter, will occur in some future year than at the present time. Likewise, many of the actions to confront the nuclear winter are largely oriented toward the future.

The paper is organized in chronological order following the unfolding of nuclear winter. Section 2 covers interventions to reduce the probability of nuclear war, making it less likely that nuclear winter happens in the first place. Section 3 covers interventions to reduce the severity of nuclear winter, such that human civilization will be more likely to remain intact or recover from it. Section 4 covers interventions to increase civilization's resilience to nuclear winter, again making civilization more likely to remain intact or recover. Finally, Section 5 covers several indirect interventions are considered, which can support the breadth of direct interventions. Section 6 concludes.

2. Reducing the probability of nuclear war

Nuclear winter cannot happen without a sizable nuclear war. A single nuclear weapon would not produce enough smoke to cause significant nuclear winter effects—hence there was no nuclear winter following the Hiroshima and Nagasaki bombings. A lower bound for the number of nuclear weapons needed to cause nuclear winter has not been established, and at any rate would depend on the weapons' yield and how much flammable material is in the vicinity of their detonation, among other factors. Recent research finds significant nuclear winter effects from an India-Pakistan nuclear war involving 100 weapons (50 per side) of 15 kt yield dropped on major cities (Mills et al., 2014). Until further research has been conducted, a lower bound of 50 total weapons may be appropriate for ensuring a sufficiently small probability of permanent civilization collapse.[2]

In theory, nuclear winter could be caused by nuclear terrorism. In practice however, terrorists would have a difficult time accessing and detonating a single weapon (Bunn & Wier, 2006) making it extremely difficult to procure the sizable arsenal needed to cause nuclear winter. Potentially this could change in the future if terrorists increase their capacity for nuclear weapons procurement. The most likely scenario might involve terrorists acquiring a larger arsenal from a nuclear weapon state, with Pakistan perhaps being the most likely candidate due to its instability and significant terrorist presence (Narang, 2009). But for the foreseeable future, a focus on interstate nuclear war is reasonable. Regardless, many of the details discussed here also apply to nuclear terrorism.

The ongoing probability of nuclear war is a topic of some debate. It is sometimes assumed that nuclear deterrence[3] is effectively perfect, rendering a zero or near-zero probability of nuclear war. Wilson (2013) criticizes this assumption as being inconsistent with historical deterrence cases. Hellman (2008) explains that even a small annual probability of nuclear war becomes alarmingly large over longer time periods. Barrett, Baum, and Hostetler (2013) analyze the annual probability of Russia-United States nuclear war occurring inadvertently, i.e. in response to a false alarm, finding significant sensitivity to uncertain underlying assumptions but with reasonable estimates of annual probabilities on the order of 0.1–1%. Lundgren (2013) retrospectively analyzes the probability of nuclear war over the preceding 66 years, finding a probability greater than 50%. Meanwhile, current world events offer reminders of the potential for nuclear war. At the time of this writing, Russia is

[1] Pandemics, large asteroid or comet impacts, and volcano eruptions are other examples.

[2] On acceptable probabilities of global catastrophes, see Tonn (2009). The 50 weapon limit comes from Baum (2015). Prior studies suggested limits in the range of 100–300 weapons per state (Robock & Toon, 2012; Turco & Sagan, 1989).

[3] Nuclear deterrence is, in simple terms, the strategy of preventing attacks (often nuclear attacks) by an adversary by threatening the adversary with retaliation with nuclear weapons: "If you attack us, we will attack you back".