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FORUM

The Continuing Environmental Threat of Nuclear Weapons: Integrated Policy Responses

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Humans have come to the realization that pollution of the atmosphere with gases and particles in the past 50 years is the dominant cause of atmospheric change [*Intergovernmental Panel on Climate Change*, 2007]. While land-use change can produce large regional effects, ozone depletion, global warming, and nuclear smoke all are human-driven problems that have actual or potential global adverse impacts on our fragile environment, each with severe consequences for humanity. These effects were, or would be, inadvertent and unplanned consequences of normal daily activities, the defense policies of many nations, and nuclear proliferation. Thus, we must seek ways of continuing our normal lives while protecting ourselves from environmental catastrophe.

Ozone depletion and global warming are already happening, while drastic cooling from smoke from nuclear-generated fires has so far been avoided. However, these three threats to humanity and the environment are interrelated—for example, nuclear energy is seen as an alternative to burning carbon for fuel, but also could potentially provide nations with the means to produce nuclear weapons. Chemicals harmful to ozone production are no longer used in manufacturing, but their replacements are greenhouse gases. These threats have been addressed with quite different policy responses, and with varying degrees of success so far.

In this article, we present recent research that models the environmental effects of both small-scale and widespread nuclear weapons discharges, and show how efforts to save the ozone layer, and strategies currently used to reduce greenhouse gas emissions, can be paralleled by a global call to avoid climatic catastrophes from the use of nuclear weapons.

Ozone Depletion and Global Warming

Following the discovery that substances such as chlorofluorocarbons were depleting the ozone layer—a discovery for which Mario Molina, F. Sherwood Rowland, and Paul Crutzen were awarded the 1995 Nobel Prize in Chemistry—the world's first global environmental treaty, the Montreal Protocol, was created, in 1987. The treaty was successful in pushing society to find replacements for ozone-depleting substances, chiefly chlorofluorocarbons for refrigeration, air conditioning, foam blowing, aerosol propellants, and other applications. As a result, the concentration of these substances has started to decrease in both the troposphere and stratosphere. Ozone has begun a gradual recovery and may reach its pre-1980 levels by the middle of the current century [*Ajavon et al.*, 2007]. The treaty includes built-in, continuing meetings of the parties, which have produced amendments to take into account the latest observations and scientific understanding—produced for them in regular World Meteorological Organization Ozone Assessments—and to adjust emissions regulations to ensure ozone recovery as fast as possible.

To address the problem of global warming, in 1992 the United Nations Framework Convention on Climate Change (UNFCCC) was signed by 194 countries, and has since been ratified by 189 countries. The UNFCCC was signed and ratified by the United States in 1992, came into force in 1994, and states, "The ultimate objective of this Convention... is to achieve...stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." The treaty also has a built-in mechanism for periodic "conferences of the parties" to develop mechanisms to meet its objective. The Kyoto Protocol to the UNFCCC, adopted at the third session of the Conference of the Parties in 1997, entered into force on 16 February 2005, after ratification by Russia. This protocol by itself will not meet the Convention's objective, but it is a step forward, and there are signs that even in the United States, public opinion is reaching a tipping point toward serious policy responses to deal with the problem [*Gore*, 2006].

Nuclear Winter

Although complicated by issues of national defense and prestige, nuclear proliferation has many aspects in common with global environmental issues, though they have not been considered in the same sort of policy framework. Casualties from the direct effects of a nuclear blast, radioactivity, and fires resulting from the massive use of nuclear weapons by the superpowers would be so catastrophic that we avoided such a tragedy for the first six decades after the invention of nuclear weapons. The realization in the 1980s, based on research conducted jointly by Western and Soviet scientists [*Crutzen and Birks*, 1982; *Turco et al.*, 1983; *Aleksandrov and Stenchikov*, 1983; *Robock*, 1984, *Pittock et al.*, 1986; *Harwell and Hutchinson*, 1986], that the climatic consequences, and indirect effects of the collapse of society, would be so severe that the ensuing nuclear winter would produce famine

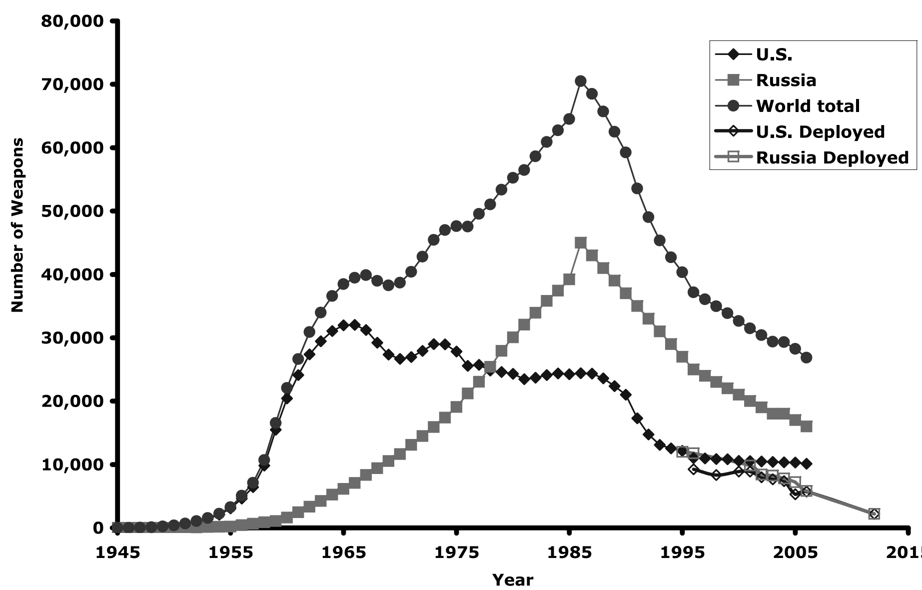

*Fig. 1. Number of nuclear warheads in Russia (USSR) and the United States and the total for all the nuclear weapons states [*Norris and Kristensen, *2006]. Russia and the United States have more than 95% of the warheads worldwide. The number of warheads began to fall after 1986 following the Intermediate-Range Nuclear Forces Treaty, and by 2005 was about one third of its value at the peak in 1986. Current treaties do not require a future reduction in the numbers of warheads, only a reduction in the numbers of warheads that are on strategic delivery systems (deployed). Weapons on strategic delivery systems should decline to 1700–2200 for each country by 2012.*

for billions of people far from the target zones, may have been an important factor in the end of the arms race between the United States and the Soviet Union [*Robock*, 1989]. Arms reductions since the 1980s (Figure 1) have cut the global nuclear arsenal to one third of its prior size, and the United States and Russia have much improved relations. This may be best symbolized by joint operation of the International Space Station and the 1993 Highly Enriched Uranium Agreement, in which highly enriched uranium from decommissioned Russian weapons is processed into low enriched uranium for use in U.S. nuclear power plants.

However, the world now faces the prospect of other states developing small, but remarkably deadly, nuclear arsenals. *Toon et al.* [2007a] address these policy issues in the context of nuclear arms control, but here we focus more specifically on policy implications related to environmental changes. *Toon et al.* [2007b] recently found that a regional war between the smallest current nuclear states involving 100 fifteen-kiloton explosions (the number of weapons likely to exist in the arsenals of new nuclear states; India and Pakistan are estimated to have 110–180 weapons between them) could produce direct fatalities comparable to all of those worldwide in World War II. *Robock et al.* [2007a] showed that smoke from urban firestorms in such a conflict would produce significant global temperature and precipitation changes, lasting a decade or more, shortening the growing season in the midlatitudes by a month in major agricultural areas, and thus affecting world food supplies. In addition, *Robock et al.* [2007b] found that although the Cold War and its associated nuclear arms race are over, the remaining American and Russian nuclear arsenals could still produce nuclear winter, threatening the lives of billions of people.

Simulations for this new work were carried out using the latest NASA Goddard Institute for Space Studies climate model, ModelE [*Schmidt et al.*, 2006], the result of decades of NASA investment, and the hard work and dedication of a large number of scientists supported by NASA. Because ModelE is able to simulate the entire troposphere, stratosphere, and mesosphere, from the Earth's surface up to 80 kilometers, and interactively transports black carbon aerosols in response to solar heating and changing wind circulation, we were able to produce fundamentally new results, showing that the smoke would persist in the atmosphere for more than 10 years, an order of magnitude longer than previously assumed. *Robock et al.* [2007b] also show that early results suggesting that nuclear autumn instead of nuclear winter would follow a full-scale war [*Thompson and Schneider*, 1986] were based upon climate models that were not adequate to fully address the problem because they did not have deep enough atmospheres, and could not be run long enough.

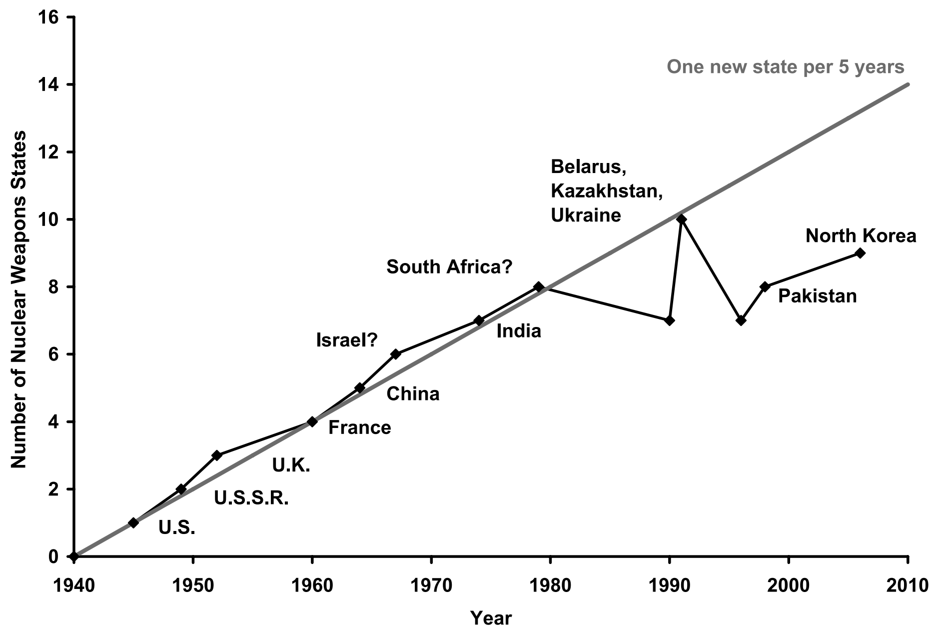

Fig. 2. New nuclear states have steadily appeared since the invention of nuclear weapons. In this figure, the date of the first test, or the date when weapons were obtained, is noted. Israel and South Africa did not test weapons so their dates to obtain weapons are uncertain. South Africa abandoned its arsenal in the 1990s. Ukraine, Belarus, and Kazakhstan also abandoned the weapons they inherited after they left the Soviet Union. The trend line is included not as a best fit or as a prediction, but just for reference.

A Global Nuclear Environmental Treaty

Work on nuclear winter has already led to important policy decisions [*Robock*, 1989]. However, we now propose that it is time for a global nuclear environmental treaty. A nuclear war cannot be won. Even a 'first strike' would be suicidal. Likewise, a 'limited' nuclear war could cause severe effects if targeted at cities and industrial areas, and it is doubtful that a nuclear war could ever be limited. 'Star Wars' (the U.S. ballistic missile defense system also known as the Strategic Defense Initiative, now the Missile Defense Agency) is not the answer, since this system will always be 'leaky.' Further, the indirect effects of nuclear winter could be even greater than the direct effects, leaving many innocent victims in noncombatant nations.

Future nuclear arms treaties need to address the environmental consequences posed by the potential use of the total number of weapons they allow to remain in the arsenals. Arms reductions of the past 20 years were not enough to protect the planet from the possible consequences of nuclear smoke, and putting nuclear weapons into the hands of more and more countries only increases the potential dangers. Figure 1 shows that Russia and the United States have reduced their arsenals by one third since their peak in the 1980s. By 2012, current agreements call for reductions in deployed weapons that will be about one twentieth of the levels in the mid-1980s. However, there will still be 10 times more of these deployed weapons than those of China, France, or the United Kingdom, and many more weapons may remain in storage. Hence much larger reductions are needed in the Russian and U. S. weapon stocks.

To make matters worse, there has been a steady increase in the number of nuclear weapons states (Figure 2). Between 1970, when the nuclear proliferation treaty was signed, and 1980, only nonsignatories to the treaty, such as Israel and India, created weapons. Now, however, signatory countries such as North Korea and Iran are violating the treaty. Unlike in prior periods, the world no longer seems united in the goal of preventing nuclear proliferation. Addressing this issue from an environmental viewpoint would provide a needed additional perspective and help the world to address all the possible consequences of current policies.

All three environmental issues—global warming, ozone depletion, and nuclear winter—are global scale, and their international resolution requires effective controls on certain economic and national activities (chlorofluorocarbon production for ozone, fossil fuel consumption for CO_2, and the nuclear fuel cycle in the case of proliferation). For all, there is an ultimate need for a complete transition to a new regime or total phaseout of certain activities (substitutes for chlorofluorocarbons in the case of ozone, alternative energy sources to limit CO_2 emissions, and total disarmament to eliminate the nuclear threat). This has been accomplished in the case of ozone, is being addressed in multiple ways to deal with global warming, and needs to be addressed in the context of nuclear weapons.

The problems of ozone depletion, global warming, and nuclear smoke are related and linked. In each case, changes to the environment are substantial. Nuclear smoke can change the climate and affect the ozone layer [*Mills and Toon*, 2006]. Ozone-depleting gases are also greenhouse gases, and their substitutes, although unstable enough not to threaten ozone, are also strong greenhouse gases and will need further substitution to address global warming. Methane chemistry links ozone with global warming. Moreover, some solutions to global warming can contribute to nuclear instability. Nuclear power plants, because of their low greenhouse gas emissions, have been suggested as a way to mitigate global warming. However, part of their fuel cycle can be used as a source of highly enriched uranium and plutonium, and therefore can be used for nuclear weapons production. Indeed countries such as North Korea, India, and Iran have obtained help from the rest of the world to construct nuclear power plants ostensibly for power production, but with the ulterior motive of building weapons.

If nuclear power is to be part of the solution to global warming, it needs to come from new proposed designs where weapons-grade nuclear materials are not part of the fuel and are not produced as waste. We need holistic policies to solve these linked human threats to our environment, so that the solution to one does not compromise the solutions to the others.

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BOOK REVIEW

Useless Arithmetic: Why Environmental Scientists Can't Predict the Future

Orrin H. Pilkey and Linda Pilkey-Jarvis Columbia University Press; 2007; 230 pp.; ISBN 0-231-13212-3; $29.50

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The book, *Useless Arithmetic: Why Environmental Scientists Can't Predict the Future,* presents a series of examples on the failure of mathematical modeling of environmental problems. The problems dealt with in this book are dominated by coastal process issues and beach erosion (three chapters) and one chapter each on nuclear storage at Yucca Mountain, surface mining, and invasive plant species.

The book starts with a historical perspective of ocean fishing and the incorrect estimates of fish stocks that have led to numerous species being overfished and brought to extinction. As an example of the improper use of quantitative estimation, the authors cite the manipulation of mathematical models by fishing proponents, which led to higher estimates of fish stocks than the actual numbers.

In Chapter 2, the authors outline several examples of improper mathematical modeling, including military modeling during the Vietnam War, transport of sand on a beach, age of the Earth based on models of cooling, hurricane path predictions, and modeling of the spread of AIDS in Africa. Chapter 3 focuses on factors regarding the storage of nuclear waste and the various geological issues that are important in preventing radiation leaks.

The next three chapters (4–6) address mathematical modeling of sea level rise, beach erosion, and problems related to beach nourishment. In particular, the authors note that the use of mathematical models to understand beach erosion suffers from subjectivity, as various assumptions that cannot be validated or that are not applicable are used repeatedly. Beach nourishment is an interesting concept, but it has failed in numerous instances, even though mathematical modeling has been used to study the consequences of nourishment.

Chapter 7 looks at environmental catastrophes related to open-pit mining and presents several examples, including that of silver and copper mining in Butte, Mont. As the aftermath of mineral exploitation, the wastes from the mines have contaminated surface (lakes) and groundwater (water table) resources. Chapter 8 focuses on invasive plant and animal species that disrupt the