EDITORIAL

Scientific Integrity: The Need for Government Standards

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The U.S. government makes substantial investments in scientific research that address the nation's need for accurate and authoritative information to guide federal policy decisions. Therefore, there is a lot at stake in having a consistent and explicit federal policy on scientific integrity to increase transparency and build trust in government science. Scientific integrity is an issue that applies not only to individual scientists working within the federal system but also to government agencies in how they use scientific information to formulate policy.

The White House issued a memorandum on scientific integrity in March 2009, and it is regrettable that it has taken so much longer than the 120 days stipulated in the president's memo for the release of recommendations by the Office of Science and Technology Policy (OSTP) (see related news item in this issue). While it is also understandable given the welter of different agencies and organizations that make up the executive branch of the government, AGU urges that these recommendations be finalized and published as soon as possible.

There is an increasing politicization of the scientific debate on some issues such as global warming. We hope that OSTP's recommendations will create a climate in which government scientists serving the nation in good faith and in compliance with federal ethics guidelines will be protected from harassment even if the results of their research do not mesh conveniently with a particular political agenda. By the same token, government scientists, like all scientists, should be held to the highest standards of professional conduct to ensure transparency in their methods and rigor in deriving their conclusions.

We commend the Department of the Interior for a secretarial order to ensure scientific integrity within the department. Of particular note for AGU, Interior's policy "encourages the enhancement of scientific integrity through engagement with the communities of practice represented by professional societies." Too often, government scientists are actively discouraged from becoming involved in professional society activities beyond going to meetings or publishing papers in journals. This Interior Department principle, which we hope will be adopted by other agencies, offers professional growth opportunities for government scientists, enhances the credibility of the government's scientific enterprise, and brings the voice of government science to the table in setting the agendas of professional societies.

AGU is committed to upholding the highest standards of scientific integrity in geophysics. To that end, we are forming a task force to review AGU's current policies on scientific integrity, to establish a set of ethical principles for the conduct of our members, and to revise our policies and practices to promote these principles. OSTP's recommendations, when published, will be a valuable resource for AGU in its deliberations regarding scientific integrity.

—Michael J. McPhaden, President, AGU; E-mail: president@agu.org

FORUM

New START, Eyjafjallajökull, and Nuclear Winter

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On 8 April 2010, U.S. president Barack Obama and Russian president Dmitry Medvedev signed the Treaty Between the United States of America and the Russian Federation on Measures for the Further Reduction and Limitation of Strategic Offensive Arms, committing the United States and Russia to reducing their nuclear arsenals to levels less than 5% of the maximum during the height of the cold war in the 1980s. This treaty is called "New START," as it is a follow-on to the 1991 Strategic Arms Reductions Treaty (START). On 14 April 2010 the Eyjafjallajökull volcano in Iceland began an explosive eruption phase that shut down air traffic in Europe for 6 days and continued to disrupt it for another month.

What do these two events have in common? Nuclear weapons, when targeted at cities and industrial areas, would start fires, producing clouds of sooty smoke. Volcanic eruptions emit ash particles and sulfur dioxide (SO_2), which forms sulfate aerosols in the atmosphere. Thus, both the use of nuclear weapons and volcanic eruptions produce particles that can be transported large distances from the source and can affect weather and climate.

While these aerosols have direct effects on climate, it is the secondary effects that link them most importantly. Both events teach us that effects on the interlinked web of food availability threaten civilization. A minor volcanic eruption reduced imports of fresh food to Europe. A "minor" nuclear war using less than 1% of the current nuclear arsenal could eliminate trade in food, affecting billions of people.

While New START is a laudable step in the right direction, this treaty will not in itself protect us from the greatest threat facing humanity and most other species on Earth: the climatic effect of nuclear weapons. A nuclear war between the United States and Europe, even after New START is fully implemented, could still produce nuclear winter, plunging surface temperatures below freezing even in summer, wiping out several years of agricultural production, and committing most people to death by famine [*Toon et al.,* 2008]. If only a tiny fraction of the current nuclear arsenal, less than 1%, were used to attack cities and industrial targets, say, in a nuclear war between India and Pakistan, the smoke from the fires could produce climate change unprecedented in recorded human history [*Robock et al.,* 2007a; *Robock and Toon,* 2010].

Volcanic eruptions affect climate by injecting aerosols and aerosol precursors into the atmosphere [*Robock,* 2000]. Small tephra particles, also called ash, are short-lived, with a lifetime of days in the troposphere and days to weeks in the stratosphere. They both absorb and scatter sunlight, heating the atmosphere and cooling the surface, but because of their short lifetimes they have little effect on climate. SO_2, on the other hand, oxidizes to form sulfuric acid aerosol droplets, and if this cloud lasts long enough, it can have a profound climatic effect. The *e*-folding lifetime (the time it takes for a quantity to decrease by a factor of *e*) of sulfur in the troposphere is about a week, but in the stratosphere it is about a year.

For example, the 1991 Mount Pinatubo volcanic eruption in the Philippines injected about 20 megatons (20 teragrams) of SO_2 into the lower stratosphere, producing a cloud that lasted for about 2 years, reducing global average surface air temperature by about 0.5 kelvin in 1992. Eyjafjallajökull, on the other hand, emitted a few kilotons of SO_2 per day into the troposphere for several weeks. Thus, because of the difference in total emissions by a factor of 1000 and the difference in lifetime by a factor of 50, the climatic impact of Eyjafjallajökull was 50,000 times less than that of Pinatubo and was therefore undetectable amidst the chaotic weather noise in the atmosphere.

Soot from the fires ignited by nuclear weapons would consist of small black particles, which are very effective at absorbing sunlight, heating the atmosphere and cooling the surface much more efficiently than lighter-colored volcanic ash. If injected into the upper troposphere, the soot particles would be heated by sunlight and rise into the upper stratosphere, where their *e*-folding lifetime is about 5 years [*Robock et al.,* 2007a]. Even if "only" 100 Hiroshima-sized nuclear weapons were used in Pakistan and India against targets that would produce the maximum amount of smoke, the global average surface air temperature would fall to levels colder than the Little Ice Age of the 1600–1800s C.E. [*Robock et al.,* 2007a]. So much sunlight would be absorbed by the smoke in the stratosphere that there would be massive ozone depletion due to stratospheric heating from the aerosols and injection of ozone-poor air and ozone-destroying chemicals from the troposphere, with enhanced ultraviolet light at the surface. The surface would get cold, dark, and dry, with significant impacts on agriculture. The growing season would be shortened by a few weeks in the agricultural regions of the midlatitudes of the Northern and Southern Hemispheres. Crop production in the United States, Ukraine, China, Australia, Argentina, and many other places would be reduced or even halted. Panic might halt all agricultural trade, producing huge shortages and famine. Imagine the trade disruption of the Icelandic volcano amplified for years, as people worry about being able to grow enough food and thus hoard what they have. And a nuclear war between the United States and Russia, with current arsenals or even those that will result from the New START reductions, could still produce nuclear winter, with surface air temperatures in midcontinents plunging below freezing even in the summer [*Toon et al.,* 2008].

But you may say, "I thought nuclear winter was disproven long ago," or "The end of the arms race in the 1980s ended the threat of nuclear winter." Both of these impressions, however, are wrong. In the past several years I have worked with Brian Toon, Richard Turco, and Georgiy Stenchikov, all pioneers in nuclear winter studies, along with two of our former students, Luke Oman and Charles Bardeen, to revisit the problem. The climate effects that were calculated in the 1980s [e.g., *Turco et al.,* 1983; *Aleksandrov and Stenchikov,* 1983] were rather uncertain because of the primitive climate models and computers that were available for us to use. Those models were not able to simulate the lofting and persistence of the smoke or the long time it would take the ocean to warm back up. Using the same climate models being used for global warming calculations, we now have actually discovered that not only would the climate effects be as large as we had gotten with simpler models but also they would last much longer than previously thought [*Robock et al.,* 2007a, 2007b]. Although we can never actually do the experiment to test our models, many analogs in nature, including volcanic eruptions and forest fires, give us confidence that our current models simulate the relevant processes well [e.g., *Robock and Toon,* 2010].

As we discussed 3 years ago here in *Eos* [*Robock et al.,* 2007c] and in *Science* [*Toon et al.,* 2007], nuclear weapons must not be used. So why do the United States and Russia now plan to continue to maintain arsenals of thousands of nuclear weapons each? None of the other nuclear powers has more than about 200 weapons. Why did China, France, Great Britain, and Israel decide to stop at this number? After all, how many nuclear weapons do you have to explode over the capital city of an enemy to deter it from attacking you? Isn't the answer one? What can we learn from these other countries?

The intense global discussion of nuclear winter in the 1980s made the world come to its senses about the insanity of a continued nuclear arms buildup. That the research in the 1980s showing the climate effects of nuclear war was done jointly by American and Russian scientists sent a powerful message that the science was not being manipulated for propaganda purposes. Mikhail Gorbachev, then leader of the Soviet Union, described in an interview in 1994 how he felt when he got control of the Soviet nuclear arsenal: "Perhaps there was an emotional side to it…. But it was rectified by my knowledge of the might that had been accumulated. One-thousandth of this might was enough to destroy all living things on Earth. And I knew the report on 'nuclear winter.'" And in 2000 he said, "Models made by Russian and American scientists showed that a nuclear war would result in a nuclear winter that would be extremely destructive to all life on Earth; the knowledge of that was a great stimulus to us, to people of honor and morality, to act in that situation." This led him to begin disarmament years before the Soviet Union ended. See *Robock and Toon* [2010] for references to these quotes and more discussion of this.

The Eyjafjallajökull eruption reminds us that now is the time to once again pay attention to the danger posed by nuclear weapons. We have to think of New START as an important, but insufficient, step toward what Carl Sagan called "elementary planetary hygiene." The United States and Russia should immediately reduce their arsenals to the same size as those of their fellow permanent United Nations Security Council members. This would remove the possibility of nuclear winter and allow the tougher negotiations on complete nuclear arms elimination to proceed. Nuclear winter theory now shows not only that the superpowers still threaten the existence of the rest of the world but also that the newly emergent nuclear powers now threaten the former superpowers, perhaps not with extinction but with serious consequences including drought and famine. The only way to eliminate the possibility of this climatic catastrophe is to eliminate the nuclear weapons.

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—ALAN ROBOCK, Department of Environmental Sciences, Rutgers University, New Brunswick, N. J.; E-mail: robock@envsci.rutgers.edu