Conversations with Professor Alan Robock, July 27 and 29, 2016

Participants

- Professor Alan Robock – Distinguished Professor, Department of Environmental Sciences, School of Environmental and Biological Sciences, Rutgers University
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Note: These notes were compiled by the Open Philanthropy Project and give an overview of the major points made by Professor Robock.

Summary

The Open Philanthropy Project spoke with Professor Alan Robock of Rutgers University about solar geoengineering and the potential climatic impacts of nuclear war. Conversation topics included possible approaches to addressing climate change, current and future research into solar radiation management, counter-geoengineering, and the possibility of a nuclear winter.

Approaches to addressing climate change

There are several possible approaches to addressing climate change:

- Mitigation. Leaving fossil fuels in the ground and transitioning as quickly as possible to alternative energy sources, such as wind and solar energy. This seems to be the most important step to prevent additional climate change.
- Adaptation. Since there will be some degree of climate change regardless of future mitigation efforts, it will be necessary to invest some effort into adaptation to the effects of climate change.
- Carbon dioxide removal (CDR, or carbon geoengineering).
- Solar radiation management (SRM, or solar geoengineering). There has not been enough research to determine whether the potential benefits of SRM outweigh the risks. In any case it would be in addition to mitigation, adaptation, and CDR, and not instead of.

Solar radiation management

Solar radiation management (SRM) is a type of geoengineering that involves reflecting sunlight to reduce global warming. Proposed methods include (for example):

- Brightening clouds over the ocean
- Covering the ocean with a layer of foam
- Releasing sulfuric acid in the stratosphere

Additional research will be needed to determine whether the potential benefits of SRM outweigh the risks. The potential benefits include reducing global warming and its negative consequences, such as rising sea levels, stronger storms, droughts, floods, and high temperatures. Professor Robock has written a list of 27 risks of SRM, which include:

- Changing the hydrological cycle.
- Changing the pattern of precipitation. This may have a particularly large impact on the approximately 2 billion people in Asia who rely on monsoon precipitation to grow their food.
- Ozone depletion could result from chemical reactions between the existing chlorine in the stratosphere and the sulfur or other particles that would be used to create a stratospheric cloud. This would enhance ultraviolet radiation.
- Catastrophic warming could result from the abrupt termination of SRM. It would be safest to terminate gradually, but there is a risk that extreme weather events could convince policymakers to terminate abruptly. The severity of the warming that could result would depend on how much geoengineering has been done and how far the situation is from equilibrium when it is stopped.
- Global nuclear war over who gets to decide what temperature the planet should be. Different countries are likely to disagree about how much global warming is acceptable; for example, northern countries may not be as negatively affected by a slight temperature increase as Pacific island nations would. It seems plausible that if one country attempts to set the global temperature, there will be other countries that are incentivized to stop it.

Some, though not all, of these risks can be tested via climate modeling or using data from volcanic eruptions as an analog.

Governance, ethical, and legal challenges

It is less obvious how to address certain governance, ethical, and legal issues, including:

- Educating the public about SRM and getting informed consent before implementing it. The Solar Radiation Management Governance Initiative (SRMGI) is exploring ways to do this.
- Governance of small-scale outdoor experiments. There is not a clear way to decide whose permission to ask before doing experiments (e.g., spraying aerosols in the atmosphere), and who would be in charge of monitoring the experiments and sanctioning scientists who break the rules.
- The possibility of the military using SRM.
- The possibility of a big company getting control of SRM technology and creating obstacles to terminating use of SRM by arguing that this would result in the loss of jobs.
- Identifying and compensating certain populations that have been negatively affected by SRM, determining who would be responsible for doing this, and whether it would be plausible to continue compensating them for decades.
- Deciding who will be held accountable for things that go wrong.
- Whether deploying SRM would violate the Environmental Modification Convention (ENMOD) treaty, which bans hostile environmental modification. No one has been challenged on this treaty and it is not clear what would be the best way to implement this.

Current SRM research

Improving climate modeling

Improved climate models could address some of the scientific questions about the effects of geoengineering. Professor Robock and his colleagues are currently working to improve their models in order to better quantify the impacts on agriculture of changes in ultraviolet radiation and the amount of ozone in the troposphere, which SRM would affect. The latter is affected by ozone depletion in the stratosphere, transport of ozone, and tropospheric chemical reactions.

Professor Robock recently received a 3-year grant from the National Science Foundation to fund his work using improved climate models to better model the benefits and risks of SRM.

Analog data

Some questions that are difficult to model directly can be investigated using analogs such as volcanic eruptions. Professor Robock and his colleagues are working on determining what factors would need to be observed after the next major volcanic eruption to improve our understanding of the possible impacts of SRM. These data may help to answer questions such as how big sulfur particles sprayed in the stratosphere would get and how long they would last.

Geoengineering Model Intercomparison Project

Professor Robock and his former student Ben Kravitz run the Geoengineering Model Intercomparison Project (GeoMIP) at Rutgers University. GeoMIP asks modeling groups around the world to run standardized experiments on the effect of different SRM methods on parts of the global climate system including the hydrological cycle, atmospheric pollution, and sea levels.

US military-funded research

The US military recently began funding geoengineering research, including climate modeling of the effects of stratospheric sulfate aerosols at the National Center for Atmospheric Research (NCAR). NCAR scientists, along with Ben Kravitz of the Pacific Northwest National Laboratory and Douglas MacMartin of Cornell University, are looking at the effect of factors including the time of year and pattern in which aerosols are sprayed.

Additional SRM research

There seems to be consensus that additional research is needed on the benefits and risks of SRM to enable us to make more informed decisions about whether and how to deploy this technology. The American Meteorological Society (AMS) statement on geoengineering, which has also been adopted by the American Geophysical Union (AGU), recommends additional research on scientific, legal, ethical, engineering, governance, and philosophical questions. The 2015 Climate Intervention Reports by the National Academy of Sciences advocate for more research on scientific, ethical, and governance issues.

Arguments in favor of additional research

If the climate continues to warm rapidly and produce significant negative effects, in 10-20 years it may become tempting to use geoengineering to lessen these effects (though not to reverse them altogether). Investing in research now will enable policymakers to make informed decisions about whether the risks of SRM can be justified, and if so, what is the safest and most effective way to deploy it.

Geoengineering research to date has mainly focused on single interventions, but researchers are beginning to consider whether multiple simultaneous interventions carry a lower level of risk. For example, computer modeling research is being done on whether putting foam on oceans to reflect sunlight could counteract the reduction in precipitation that may result from stratospheric aerosol sprays. It seems valuable to continue research in this area to find the lowest-risk options.

Response to arguments against SRM research

Argument 1: SRM research may take resources from more important projects

Some people argue that SRM research should not be conducted because it may take resources away from other, potentially more important research. However, research into what to put into climate models is also applicable to and helps to advance other areas of climate research, and therefore is likely not taking resources away from more important work.

Argument 2: SRM research increases the chances of deployment of SRM

Some people argue that SRM research should not be conducted because it may increase the chances that SRM will be deployed. However, Professor Robock has found that geoengineering research has shed light on a number of risks that may reduce the likelihood of deployment.

US national research program

There have been national SRM research programs in the United Kingdom and Germany and trans-European programs, and researchers in Finland, Norway, and China have received government grants. Creating a national research program in the US would be valuable because it would expand the field. There is not enough total funding for this work internationally, and a US program would enable more students and scientists to be trained and more experiments to be run. Much of the research being done in these countries is internationally collaborative, so it is unlikely that the US research program would be redundant to research that is being done in other countries.

Funding

It would take a relatively small amount of funding to support additional climate modeling research, because Professor Robock and his colleagues get computer time at a national lab. Outdoor experiments would be more expensive.

It is not clear why the US government has not yet embarked on a national research program in this area. Some people are opposed to such a project because they view it as giving up on mitigation efforts or worry that it would take funding away from other important programs. It is also possible that a program has not been created because of uncertainty about which agency should lead it.

Outdoor research

Researchers have expressed interest in two projects:

1. Spraying particles into clouds in Monterey, California, to test whether it would make them brighter.
2. Spraying sulfate aerosols into the stratosphere, to examine impacts on ozone. This would not significantly affect total emissions and may be possible to do in the next few years.

Funding recommendations for SRM research

SRM research projects that could potentially use funding in the short term include:

- SRM engineering and outdoor research experiments
- Support for students and postdocs to support them and to get computer time in national labs to do more detailed climate modeling experiments

However, Professor Robock believes that it is more important to fund nuclear winter research than SRM research, because he is not aware of any funding that is currently available for nuclear winter research.

Counter-geoengineering

A recent paper explored the possibility of putting short-lived greenhouse gases into the atmosphere to warm the planet for a year or two, in the event that a volcanic eruption cools the earth too much. It found that there is no known inexpensive gas that would behave this way. It would cost billions of dollars to produce enough warming, and it would have to be stored until needed, potentially for decades. This does not seem like a practical solution.

Counter-geoengineering is not likely to be a worthwhile investment because it does not solve the underlying problem. It would be more practical to invest in creating a nuclear power generation system that is less dangerous than current nuclear power systems and which could provide a better electric grid.

Nuclear Winter

The term "nuclear winter" refers to the possibility that fires caused by deployment of nuclear weapons could send large amounts of smoke into the atmosphere. This could cause enough cooling for surface temperatures to drop below freezing in the summer, which could destroy global agriculture.

As a result of the Strategic Arms Reduction Treaty (New START), as of next year, the US and Russian arsenals will each include about 2,000 nuclear weapons, and all other countries will have a total of about 1,000. While the number of nuclear weapons in existence has been declining since the end of the nuclear arms race in the 1980s, the nuclear weapons that currently exist would be sufficient to cause a nuclear winter if they were all deployed.

Modeling the amount of smoke that would enter the upper atmosphere

To model the amount of smoke that could be created during a nuclear war, Professor Robock and his colleagues calculated how much smoke would be created by 50 nuclear bombs dropped on the targets in a country that would produce the most smoke (typically large cities). They found that this would create approximately 5 million tons of smoke in China, 3.5 million tons in India, and 3 million tons in Pakistan.

Models of a nuclear war between India and Pakistan assume that these countries use 15-kiloton atomic bombs. This is the size of bomb that was dropped on Hiroshima and is considered small by modern standards, but it seems likely that India and Pakistan would have bombs this size because they are easier to make than the modern 100-500-kiloton American bombs.

A nuclear war between the US and Russia using all of the weapons that those countries have would create about 150 million tons of smoke, which would likely result in a nuclear winter, with summertime temperatures below freezing.

Modeling the effects of smoke in the atmosphere

Professor Robock's recent research with Professors Owen Brian Toon and Richard Turco found that even a relatively small nuclear war, such as one between India and Pakistan, could cause enough climate change to have a significant impact on global agriculture. Pakistan has been increasing its supply of nuclear weapons, and such a war seems to be a realistic possibility.

There are data from experiments in the 1980s in which researchers burned pools of oil and diseased areas of forests and measured the amount and properties of the smoke created. There is not a great need for further experimentation to learn about the properties of smoke.

The group ran simulations using three climate models that considered the impact of nuclear war on agriculture in China and the US, because these are the countries that produce the most food. It did not consider the impacts on agriculture in other countries. New models also enabled Professor Robock and his colleagues to measure how high smoke would go into the upper atmosphere and how long it would last. Three values for the amount of smoke created were plugged into the model: 5, 50, and 150 million tons.

Effects of 5 million tons of smoke

The effects of 5 million tons of smoke would include:

- Global temperatures falling below the temperatures during the Little Ice Age and lasting over a decade. This would be the largest climate change in recorded human history.
- Reducing precipitation.
- Reducing sunlight.
- Ozone depletion.
- Increasing ultraviolet radiation (as a result of ozone depletion).
- A 20-40% reduction in food production in the US and China over 5 years.
- A 10-20% reduction in food production in the US and China over 10 years.

Because there is little food in storage, this decrease in food production would likely lead to panic, food hoarding, and societal disruption.

Response to these results

In response to the above findings, international meetings have been held in Norway, Austria, and Mexico on the humanitarian impacts of nuclear war. The United Nations Open Ended Working Group (OEWG) on nuclear disarmament next month will hold its third and final meeting in which over 100 countries are attempting to pressure the nine countries with nuclear weapons to ban them.

[Added on August 21, 2016: On August 19, 2016, the OEWG adopted a recommendation to the United Nations General Assembly to begin negotiations to ban nuclear weapons. The vote was 62 countries (all non-nuclear states) in favor, 27 countries opposed (mostly NATO countries plus South Korea), with 8 countries abstaining (including Sweden, Switzerland, and Japan).

This recommendation was part of a more detailed OEWG report that specifically recommends with respect to the humanitarian consequences of the use of nuclear weapons, “Consider convening additional international conferences on the humanitarian impact of nuclear weapons; Support additional research and studies about risks and the long-term consequences associated with nuclear weapons; Conduct outreach through all forms of media, including conventional media, such as TV, radio and printed materials, as well as social media.”

So the climatic impact of the use of nuclear weapons is part of the international conversation, but the nuclear weapons states and some of their allies are still pushing back on measures to delegitimize and eventually ban nuclear weapons.]

Improving models

Professor Robock thinks that it would take a relatively small amount of funding and work time to create more accurate models, but it has been difficult to get funding for this work. Better models would include more accurate information on:

- The area of a modern megacity that would burn if the city were bombed, and the amount of smoke that would be emitted. Current models assume that the area burned in megacities would be equal to the area burned in Hiroshima, which was a much smaller city at the time it was bombed than it and many other cities are now.
- The effect of weather conditions such as wind and rain on the area of a city that burns.
- The properties of smoke entering the atmosphere. Current models assume that this is pure smoke, while it is more likely that the smoke would be affected by chemical reactions.
- Details of how agriculture in specific places in the world would be impacted.
- The number of climate refugees likely to be created by climatic changes of different types in different areas of the world.
- Effects on the global economic system and food trade, including changes in food prices and subsequent unrest. Changes in the global food trade could lead to political instability, particularly because many countries depend on imported food.
- The number of people who would die of famine. Current models estimate that 1-2 billion people could die of famine in a nuclear winter. A better model of this would include an adaptation effect, changes in food prices, the kind of food that is eaten in each part of the world, the kinds of food that people would be willing to eat, and the kinds of seeds that would be available and able to grow in certain soils and climates.

Publicizing results from improved models

Benefits

Publicizing more detailed information about the potential effects of nuclear war on specific areas of the world could be influential in the global debate about nuclear weapons and in updating public knowledge about these effects. While most people are aware of the damaging effects of radioactivity, there seems to be less public knowledge about the impact of nuclear war on the climate and availability of food and water. Many people think it's been demonstrated that a nuclear winter would not result from a large nuclear war, but this is not true. Educating the public and policymakers about this could inform policy decisions that are made in this area, which is the ultimate goal of this research.

It may be helpful to have a way of communicating the results of existing models to the public, such as a Twitter campaign. However, publicizing these rough data could invite justified criticism that the models are crude and unrealistic. More research is needed to understand the nuances of potential climate impacts, and it may be possible to obtain these stronger scientific results within a few years using modern climate modeling and research tools. This work is primarily constrained by funding needed to pay researchers.

American and Russian scientists researching the possible effects of nuclear war in the 1980s separately concluded that a nuclear winter was a possibility. These scientists' findings were influential in ending the nuclear arms race.

Challenges

It may be difficult to disseminate new information about climate impacts of nuclear war to the public and policymakers. The research published by Professor Robock and his colleagues has not generated very much attention or controversy among policymakers.

Prevention

In the event of a nuclear winter, it would not be feasible or advisable to use geoengineering to reduce the temperature change, both because this would be dangerous and because there is no known way to warm the climate rapidly but temporarily. Preventing a nuclear war would be much easier than addressing the consequences. While it can be difficult to convince people to take preventative rather than reactive measures, Professor Robock's goal is to create enough fear of the consequences of nuclear war to convince countries to get rid of their nuclear weapons.

Other people to talk to

People to talk to about nuclear winter:

- Owen Brian Toon – Professor of Atmospheric and Ocean Sciences, University of Colorado Boulder
- Michael Mills – Project Scientist, WACCM Liaison, National Center for Atmospheric Research, Atmospheric Chemistry Observations & Modeling
- Ira Helfand – Co-President, International Physicians for the Prevention of Nuclear War

People to talk to about geoengineering:

- David Keith – Gordon McKay Professor of Applied Physics, John A. Paulson School of Engineering and Applied Sciences, and Professor of Public Policy, Harvard Kennedy School, Harvard University
- Ken Caldeira – Senior Scientist, Department of Global Ecology, Carnegie Institution for Science
- Philip Rasch – Earth Systems Analysis & Modeling, Laboratory Fellow, Pacific Northwest National Laboratory
- Ben Kravitz – Earth Systems Analysis & Modeling, Scientist, Pacific Northwest National Laboratory
- Robert Wood – Professor, Atmospheric Sciences, University of Washington
- Thomas Ackerman – Professor, Atmospheric Sciences, and Director, Joint Institute for the Study of the Atmosphere and Ocean, University of Washington
- Trude Storelvmo – Assistant Professor, Department of Geology and Geophysics, Yale Climate & Energy Institute

- Pablo Suarez – Associate Director for Research and Innovation, Red Cross/Red Crescent Climate Center

All Open Philanthropy Project conversations are available at
http://www.openphilanthropy.org/research/conversations