16 MARCH 2020

How a small nuclear war would transform the entire planet

As geopolitical tensions rise in nuclear-armed states, scientists are modelling the global impact of nuclear war.

Alexandra Witze

India tests its Agni-5 rocket in 2013, which is capable of carrying nuclear warheads.Credit: Pallava Bagla/Corbis via Getty

It all starts in 2025, as tensions between India and Pakistan escalate over the contested region of Kashmir. When a terrorist attacks a site in India, that country sends tanks rolling across the border with Pakistan. As a show of force against the invading army, Pakistan decides to detonate several small nuclear bombs.

The next day, India sets off its own atomic explosions and within days, the nations begin bombing dozens of military targets and then hundreds of cities. Tens of millions of people die in the blasts.

That horrifying scenario is just the beginning. Smoke from the incinerated cities rises high into the atmosphere, wrapping the planet in a blanket of soot that blocks the Sun's rays. The planet plunges into a deep chill. For years, crops wither from California to China. Famine sets in around the globe.

This grim vision of a possible future comes from the latest studies about how nuclear war could alter world climate. They build on long-standing work about a 'nuclear winter' — severe global cooling that researchers predict would follow a major nuclear war, such as thousands of bombs flying between the United States and Russia. But much smaller nuclear conflicts, which are more likely to occur, could

also have devastating effects around the world.

This week, researchers report that an India–Pakistan nuclear war could lead to crops failing in dozens of countries — devastating food supplies for more than one billion people[1]. Other research reveals that a nuclear winter would dramatically alter the chemistry of the oceans, and probably decimate coral reefs and other marine ecosystems[2]. These results spring from the most comprehensive effort yet to understand how a nuclear conflict would affect the entire Earth system, from the oceans to the atmosphere, to creatures on land and in the sea.

Scientists want to understand these matters because the nuclear menace is growing. From North Korea to Iran, nations are building up their nuclear capabilities. And some, including the United States, are withdrawing from arms-control efforts. Knowing the possible environmental consequences of a nuclear conflict can help policymakers to assess the threat, says Seth Baum, executive director of the Global Catastrophic Risk Institute in New York City, who has studied the risks of triggering a nuclear winter. “Fleshing out the details of ways in which it can be bad is valuable for helping inform decisions,” he says.

Cold-war forecasts

Nuclear-winter studies arose during the cold war, as the United States and the Soviet Union stockpiled tens of thousands of nuclear warheads in preparation for all-out assaults. Alarmed by leaders’ bellicose rhetoric, scientists in the 1980s began running simulations on how nuclear war might change the planet after the initial horrific deaths from the blasts[3,4]. Researchers including the US planetary scientist and communicator Carl Sagan described how smoke from incinerated cities would block sunlight and plunge much of the planet into a deep freeze lasting for months, even in summer[4]. Later studies tempered the forecasts somewhat, finding slightly less-dramatic cooling[5]. Still, Soviet leader Mikail Gorbachev cited nuclear winter as one factor that prompted him to work towards drawing down the country’s nuclear arsenals.

After the Soviet Union collapsed in 1991, the world’s stockpiles of nuclear weapons continued to drop. But with many thousands of warheads still in existence, and with more nations becoming nuclear powers, some researchers have argued that nuclear war — and a nuclear winter — remain a threat. They have shifted to studying the consequences of nuclear wars that would be smaller than an all-out US–Soviet

annihilation.

US President George Bush and Soviet President Mikhail Gorbachev celebrate the signing of the Strategic Arms Reduction Treaty on 31 July 1991. Credit: Peter Turnley/Corbis/ VCG via Getty

That includes the possibility of an India–Pakistan war, says Brian Toon, an atmospheric physicist at the University of Colorado Boulder who has worked on nuclear-winter studies since he was a student of Sagan's. Both countries have around 150 nuclear warheads, and both are heavily invested in the disputed Kashmir border region, where a suicide bomber last year killed dozens of Indian troops. "It's a precarious situation," says Toon.

Both India and Pakistan tested nuclear weapons in 1998, highlighting growing geopolitical tensions. By the mid-2000s, Toon was exploring a scenario in which the countries set off 100 Hiroshima-size atomic bombs, killing around 21 million people. He also connected with Alan Robock, an atmospheric scientist at Rutgers University in New Brunswick, New Jersey, who studies how volcanic eruptions cool the climate in much the same way that a nuclear winter would. Using an advanced NASA climate model, the scientists calculated how soot rising from the incinerated cities would circle the planet. All around the dark, cold globe, agricultural crops would

dwindle.

But after a burst of publications on the topic, Robock, Toon and their colleagues struggled to find funding to continue their research. Finally, in 2017, they landed a grant worth nearly US$3-million from the Open Philanthropy Project, a privately funded group in San Francisco that supports research into global catastrophic risks.

The goal was to analyse every step of nuclear winter — from the initial firestorm and the spread of its smoke, to agricultural and economic impacts. “We put all those pieces together for the first time,” says Robock.

The group looked at several scenarios. Those range from a US–Russia war involving much of the world’s nuclear arsenal, which would loft 150 million tonnes of soot into the atmosphere, down to the 100-warhead India–Pakistan conflict, which would generate 5 million tonnes of soot[6]. The soot turns out to be a key factor in how bad a nuclear winter would get; three years after the bombs explode, global temperatures would have plummeted by more than 10 °C in the first scenario — more than the cooling during the last ice age — but by a little more than 1 °C in the second.

Toon, Robock and their colleagues have used observations from major wildfires in British Columbia, Canada, in 2017 to estimate how high smoke from burning cities would rise into the atmosphere[7]. During the wildfires, sunlight heated the smoke and caused it to soar higher, and persist in the atmosphere longer, than scientists might otherwise expect. The same phenomenon might happen after a nuclear war, Robock says.

Raymond Jeanloz, a geophysicist and nuclear-weapons policy expert at the University of California, Berkeley, says that incorporating such estimates is a crucial step to understanding what would happen during a nuclear winter. “This is a great way of cross-checking the models,” he says.

Comparisons with giant wildfires could also help in resolving a controversy about the scale of the potential impacts. A team at Los Alamos National Laboratory in New Mexico argues that Robock’s group has overestimated how much soot burning cities would produce and how high the smoke would go[8].

The Los Alamos group used its own models to simulate the climate impact of India and Pakistan setting off 100 Hiroshima-sized bombs. The scientists found that much less smoke would get into the upper atmosphere than Toon and Robock reported.

With less soot to darken the skies, the Los Alamos team calculated a much milder change to the climate — and no nuclear winter.

At a 2005 parade in Islamabad, Pakistan, a truck carries a Shaheen II long-range missile that can be armed with a nuclear warhead.Credit: Farooq Naeem/AFP via Getty

The difference between the groups boils down to how they simulate the amount of fuel a firestorm consumes and how that fuel is converted into smoke. “After a nuclear weapon goes off, things are extremely complex,” says Jon Reisner, a physicist who leads the Los Alamos team. “We have the ability to model the source and we also understand the combustion process. I think we have a better feel about how much soot can potentially get produced.” Reisner is now also studying the Canadian wildfires, to see how well his models reproduce how much smoke gets into the atmosphere from an incinerating forest.

Robock and his colleagues have fired back in tit-for-tat journal responses[9]. Among other things, they say the Los Alamos team simulated burning of greener spaces rather than a densely populated city.

Dark seas

While that debate rages, Robock’s group has published results showing a wide variety of impacts from nuclear blasts.

That includes looking at ocean impacts, the first time this has been done, says team member Nicole Lovenduski, an oceanographer at the University of Colorado

Boulder. When Toon first approached her to work on the project, she says, “I thought, ‘this sure seems like a bleak topic’.” But she was intrigued by how the research might unfold. She usually studies how oceans change in a gradually warming world, not the rapid cooling in a nuclear winter.

Lovenduski and her colleagues used a leading climate model to test the US–Russia war scenario. “It’s the hammer case, in which you hammer the entire Earth system,” she says. In one to two years after the nuclear war, she found, global cooling would affect the oceans’ ability to absorb carbon, causing their pH to skyrocket. That’s the opposite to what is happening today, as the oceans soak up atmospheric carbon dioxide and waters become more acidic.

She also studied what would happen to aragonite, a mineral in seawater that marine organisms need to build shells around themselves. In two to five years after the nuclear conflict, the cold dark oceans would start to contain less aragonite, putting the organisms at risk, the team has reported[2].

In the simulations, some of the biggest changes in aragonite happened in regions that are home to coral reefs, such as the southwestern Pacific Ocean and the Caribbean Sea. That suggests that coral-reef ecosystems, which are already under stress from warming and acidifying waters, could be particularly hard-hit during a nuclear winter. “These are changes in the ocean system that nobody really considered before,” says Lovenduski.

And those aren’t the only ocean effects. Within a few years of a nuclear war, a “Nuclear Niño” would roil the Pacific Ocean, says Joshua Coupe, a graduate student at Rutgers. This is a turbo-charged version of the phenomenon known as El Niño. In the case of a US–Russia nuclear war, the dark skies would cause the trade winds to reverse direction and water to pool in the eastern Pacific Ocean. As during an El Niño, droughts and heavy rains could plague many parts of the world for as long as seven years, Coupe reported last December at a meeting of the American Geophysical Union.

Beyond the oceans, the research team has found big impacts on land crops and food supplies. Jonas Jägermeyr, a food-security researcher at NASA’s Goddard Institute for Space Studies in New York City, used six leading crop models to assess how agriculture would respond to nuclear winter. Even the relatively small India–Pakistan war would have catastrophic effects on the rest of the world, he and his colleagues report this week in the *Proceedings of the National Academy of Sciences*[1]. Over the course of five years, maize (corn) production would drop by 13%, wheat

production by 11% and soya-bean production by 17% .

The worst impact would come in the mid-latitudes, including breadbasket areas such as the US Midwest and Ukraine. Grain reserves would be gone in a year or two. Most countries would be unable to import food from other regions because they, too, would be experiencing crop failures, Jägermeyr says. It is the most detailed look ever at how the aftermath of a nuclear war would affect food supplies, he says. The researchers did not explicitly calculate how many people would starve, but say that the ensuing famine would be worse than any in documented history.

Farmers might respond by planting maize, wheat and soya beans in parts of the globe likely to be less affected by a nuclear winter, says Deepak Ray, a food-security researcher at the University of Minnesota in St Paul. Such changes might help to buffer the food shock — but only partly. The bottom line remains that a war involving less than 1% of the world's nuclear arsenal could shatter the planet's food supplies.

"The surprising finding", says Jägermeyr, "is that even a small-war scenario has devastating global repercussions".

Nature **579**, 485-487 (2020)

doi: 10.1038/d41586-020-00794-y

References

. 1.

Jägermeyr, J. *et al. Proc. Natl Acad. Sci. USA* https://doi.org/10.1073/pnas.1919049117 (2020).

Article
Google Scholar

. 2.

Lovenduski, N. S. *et al. Geophys. Res. Lett.* **47**, 3 (2020).
Article
Google Scholar

. 3.

Crutzen, P. J. & Birks, J. W. *Ambio* 11, 114–125 (1982).
Article
Google Scholar

. 4.

Turco, R. P., Toon, O. B., Ackerman, T. P., Pollack, J. B. & Sagan,

C. *Science* **222**, 1283–1292 (1983).
PubMed
Article
Google Scholar

. 5.

Schneider, S. H. & Thompson, S. L. *Nature* **333**, 221–227 (1988).
Article
Google Scholar

. 6.

Toon, O. B. *et al. Sci. Adv.* 5, eaay5478 (2019).
PubMed
Article
Google Scholar

. 7.

Yu, P. *et al. Science* **365**, 587–590 (2019).

PubMed
Article
Google Scholar

. 8.

Reisner, J. *et al. J. Geophys. Res. Atmos.* **123**, 2752–2772 (2018).
Article
Google Scholar

. 9.

Robock, A., Toon, O. B. & Bardeen, C. G. *J. Geophys. Res. Atmos.* **124**, 12953–

12958 (2019).
Article
Google Scholar

Even a limited India-Pakistan nuclear war would bring global famine, says study

Soot from firestorms would reduce crop production for years

Date:

March 16, 2020

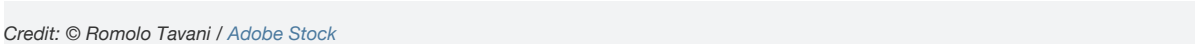
Source:

Earth Institute at Columbia University

Summary:

A new multinational study incorporating the latest models of global climate, crop production and trade examines the possible effects of a nuclear exchange between two longtime enemies: India and Pakistan. It suggests that even a limited war between the two would cause unprecedented planet-wide food shortages and probable starvation lasting more than a decade.

Share:



Credit: © Romolo Tavani / Adobe Stock

The concept of nuclear winter -- a years-long planetary freeze brought on by airborne soot generated by nuclear bombs -- has been around for decades. But such speculations have been based largely on back-of-the-envelope calculations involving a total war between Russia and the United States. Now, a new multinational study incorporating the latest models of global climate, crop production and trade examines the possible effects of a less gargantuan but perhaps more likely exchange between two longtime nuclear-armed enemies: India and Pakistan. It suggests that even a limited war between the two would cause unprecedented planet-wide food shortages and probable starvation lasting more than a decade. The study appears this week in the journal *Proceedings of the National Academy of Sciences*.

Of an estimated 14,000 nuclear warheads worldwide, close to 95 percent belong to the United States and Russia. India and Pakistan are thought to have about 150 each. The study examines the potential effects if they were to each set off 50 Hiroshima-size bombs -- less than 1 percent of the estimated world arsenal.

In addition to direct death and destruction, the authors say that firestorms following the bombings would launch some 5 million tons of soot toward the stratosphere. There, it would spread globally and remain, absorbing sunlight and lowering global mean temperatures by about 1.8 degrees C (3.25 F) for at least five years. The scientists project that this would in turn cause production of the world's four main cereal crops -- maize, wheat, soybeans and rice -- to plummet an average 11 percent over that period, with tapering effects lasting another five to 10 years.

"Even this regional, limited war would have devastating indirect implications worldwide," said Jonas Jägermeyr, a postdoctoral scientist at the NASA Goddard Institute for Space Studies who led the study. "It would exceed the largest famine in documented history."

According to the study, crops would be hardest hit in the northerly breadbasket regions of the United States, Canada, Europe, Russia and China. But paradoxically, southerly regions would suffer much more hunger. That is because many developed nations in the north produce huge surpluses, which are largely exported to nations in the Global South that are barely able to feed themselves. If these surpluses were to dry up, the effects would ripple out through the global trade system. The authors estimate that some 70 largely poor countries with a cumulative population of 1.3 billion people would then see food supplies drop more than 20 percent.

Some adverse effects on crops would come from shifts in precipitation and solar radiation, but the great majority would stem from drops in temperature, according to the study. Crops would suffer most in countries north of 30 degrees simply because temperatures there are lower and growing seasons shorter to begin with. Even modest declines in growing-season warmth could leave crops struggling to mature, and susceptible to deadly cold snaps. As a result, harvests of maize, the world's main cereal crop, could drop by nearly 20 percent in the United States, and an astonishing 50 percent in Russia. Wheat and soybeans, the second and third most important cereals, would also see steep declines. In southerly latitudes, rice might not suffer as badly, and cooler temperatures might even increase maize harvests in parts of South America and Africa. But this would do little to offset the much larger declines in other regions, according to the study.

Since many developed countries produce surpluses for export, their excess production and reserves might tide them over for at least a few years before shortages set in. But this would come at the expense of countries in the Global South. Developed nations almost certainly would impose export bans in order to protect their own populations, and by year four or five, many nations that today already struggle with malnutrition would see catastrophic drops in food availability. Among those the authors list as the hardest hit: Somalia, Niger, Rwanda, Honduras, Syria, Yemen and Bangladesh.

If nuclear weapons continue to exist, "they can be used with tragic consequences for the world," said study coauthor Alan Robock, a climatologist at Rutgers University who has long studied the potential effects of nuclear war. "As horrible as the direct effects of nuclear weapons would be, more people could die outside the target areas due to famine."

Previously, Jägermeyr has studied the potential effects of global warming on agriculture, which most scientists agree will suffer badly. But, he said, a sudden nuclear-caused cooling would hit food systems far worse. And, looking backward, the the effects on food availability would be four times worse than any previously recorded global agriculture upsets caused by droughts, floods, or volcanic eruptions, he said.

The study might be erring on the conservative side. For one, India and Pakistan may well have bombs far bigger than the ones the scientists use in their assumptions. For another, the study leaves India and Pakistan themselves out of the crop analyses, in order to avoid mixing up the direct effects of a war with the indirect ones. That aside, Jägermeyr said that one could reasonably assume that food production in the remnants of the two countries would drop essentially to zero. The scientists also did not factor in the possible effects of radioactive fallout, nor the probability that floating soot would cause the stratosphere to heat up at the same time the surface was cooling. This would in turn cause stratospheric ozone to dissipate, and similar to the effects of now-banned refrigerants, this would admit more ultraviolet rays to the Earth's surface, damaging humans and agriculture even more.

Much attention has been focused recently on North Korea's nuclear program, and the potential for Iran or other countries to start up their own arsenals. But many experts have long regarded Pakistan and India as the most dangerous players, because of their history of near-continuous conflict over territory and other issues. India tested its first nuclear weapon in 1974, and when Pakistan followed in 1998, the stakes grew. The two countries have already had four full-scale conventional wars, in 1947, 1965, 1971 and 1999, along with many substantial skirmishes in between. Recently, tensions over the disputed region of Kashmir have flared again.

"We're not saying a nuclear conflict is around the corner. But it is important to understand what could happen," said Jägermeyr.

The paper was coauthored by a total of 19 scientists from five countries, including three others from Goddard, which is affiliated with Columbia University's Earth Institute: Michael Puma, Alison Heslin and Cynthia Rosenzweig. Jägermeyr also has affiliations with the University of Chicago and Potsdam Institute for Climate Impact Research.

Story Source:

Materials provided by **Earth Institute at Columbia University**. Original written by Kevin Krajick. *Note: Content may be edited for style and length.*

Journal Reference:

1. Jonas Jägermeyr, Alan Robock, Joshua Elliott, Christoph Müller, Lili Xia, Nikolay Khabarov, Christian Folberth, Erwin Schmid, Wenfeng Liu, Florian Zabel, Sam S. Rabin, Michael J. Puma, Alison Heslin, James Franke, Ian Foster, Senthold Asseng, Charles G. Bardeen, Owen B. Toon, Cynthia Rosenzweig. **A regional nuclear conflict would compromise global food security**. *Proceedings of the National Academy of Sciences*, 2020; 201919049 DOI: 10.1073/pnas.1919049117