# Solar storms have influenced our history – an environmental historian explains how they could also threaten our future

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Coronal mass ejections from the Sun can cause geomagnetic storms that may damage technology on Earth.

*NASA/GSFC/SDO*

In May 2024, part of the Sun exploded.

The Sun is an immense ball of superheated gas called plasma. Because the plasma is conductive, magnetic fields loop out of the solar surface. Since different parts of the surface rotate at different speeds, the fields get tangled. Eventually, like rubber bands pulled too tight, they can snap – and that is what they did last year.

These titanic plasma explosions, also known as solar flares, each unleashed the energy of a million hydrogen bombs. Parts of the Sun's magnetic field also broke free as magnetic bubbles loaded with billions of tons of plasma.

These bubbles, called coronal mass ejections, or CMEs, crashed through space at around 6,000 times the speed of a commercial jetliner. After a few days, they smashed one after another into the magnetic field that envelops Earth. The plasma in each CME surged toward us, creating brilliant auroras and powerful electrical currents that rippled through Earth's crust.

You might not have noticed. Just like the opposite poles of fridge magnets have to align for them to snap together, the poles of the magnetic field of Earth and the incoming CMEs have to line up just right for the plasma in the CMEs to reach Earth. This time they didn't, so most of the plasma sailed off into deep space.

Humans have not always been so lucky. I'm an environmental historian and author of the new book "Ripples on the Cosmic Ocean: An Environmental History of Our Place in the Solar System."

While writing the book, I learned that a series of technological breakthroughs – from telegraphs to satellites – have left modern societies increasingly vulnerable to the influence of solar storms, meaning flares and CMEs.

Since the 19th century, these storms have repeatedly upended life on Earth. Today, there are hints that they threaten the very survival of civilization as we know it.

## The telegraph: A first warning

On the morning of Sept. 1, 1859, two young astronomers, Richard Carrington and Richard Hodgson, became the first humans to see a solar flare. To their astonishment, it was so powerful that, for two minutes, it far outshone the rest of the Sun.

About 18 hours later, brilliant, blood-red auroras flickered across the night sky as far south as the equator, while newly built telegraph lines shorted out across Europe and the Americas.

The Carrington Event, as it was later called, revealed that the Sun's environment could violently change. It also suggested that emerging technologies, such as the electrical telegraph, were beginning to link modern life to the extraordinary violence of the Sun's most explosive changes.

For more than a century, these connections amounted to little more than inconveniences, like occasional telegraph outages, partly because no solar storm rivaled the power of the Carrington Event. But another part of the reason was that the world's economies and militaries were only gradually coming to rely more and more on technologies that turned out to be profoundly vulnerable to the Sun's changes.

## A brush with Armageddon

Then came May 1967.

Soviet and American warships collided in the Sea of Japan, American troops crossed into North Vietnam and the Middle East teetered on the brink of the Six-Day War.

It was only a frightening combination of new technologies that kept the United States and Soviet Union from all-out war; nuclear missiles could now destroy a country within minutes, but radar could detect their approach in time for retaliation. A direct attack on either superpower would be suicidal.

An aurora – an event created by a solar storm – over Pituffik Space Base, formerly Thule Air Base, in Greenland in 2017. In 1967, nuclear-armed bombers prepared to take off from this base.

*Air Force Space Command*

Suddenly, on May 23, a series of violent solar flares blasted the Earth with powerful radio waves, knocking out American radar stations in Alaska, Greenland and England.

Forecasters had warned officers at the North American Air Defense Command, or NORAD, to expect a solar storm. But the scale of the radar blackout convinced Air Force officers that the Soviets were responsible. It was exactly the sort of thing the USSR would do before launching a nuclear attack.

American bombers, loaded with nuclear weapons, prepared to retaliate. The solar storm had so scrambled their wireless communications that it might have been impossible to call them back once they took off. In the nick of time, forecasters used observations of the Sun to convince NORAD officers that a solar storm had jammed their radar. We may be alive today because they succeeded.

## Blackouts, transformers and collapse

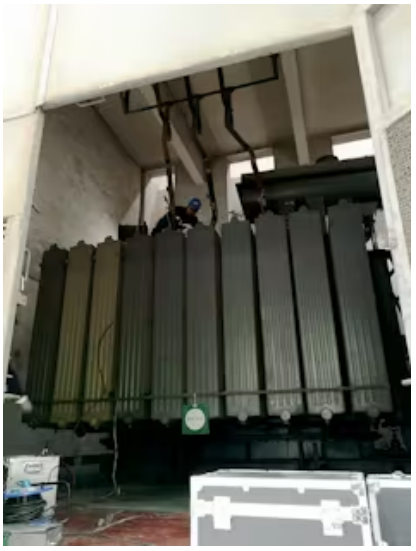
With that brush with nuclear war, solar storms had become a source of existential risk, meaning a potential threat to humanity's existence. Yet the magnitude of that risk only came into focus in March 1989, when 11 powerful flares preceded the arrival of back-to-back coronal mass ejections.

For more than two decades, North American utility companies had constructed a sprawling transmission system that relayed electricity from power plants to consumers. In 1989, this system turned out to be vulnerable to the currents that coronal mass ejections channeled through Earth's crust.

In Quebec, crystalline bedrock under the city does not easily conduct electricity. Rather than flow through the rock, currents instead surged into the world's biggest hydroelectric transmission system. It collapsed, leaving millions without power in subzero weather.

Repairs revealed something disturbing: The currents had damaged multiple transformers, which are enormous customized devices that transfer electricity between circuits.

Transformers can take many months to replace. Had the 1989 storm been as powerful as the Carrington Event, hundreds of transformers might have been destroyed. It could have taken years to restore electricity across North America.



An engineer performs tests on a substation transformer.
*Ptrump16/Wikimedia Commons, CC BY-SA*

## Solar storms: An existential risk

But was the Carrington Event really the worst storm that the Sun can unleash?

Scientists assumed that it was until, in 2012, a team of Japanese scientists found evidence of an extraordinary burst of high-energy particles in the growth rings of trees dated to the eighth century CE. The leading explanation for them: huge solar storms dwarfing the Carrington Event. Scientists now estimate that these "Miyake Events" happen once every few centuries.

Astronomers have also discovered that, every century, Sun-like stars can explode in super flares up to 10,000 times more powerful than the strongest solar flares ever observed. Because the Sun is older and rotates more slowly than many of these stars, its super flares may be much rarer, occurring perhaps once every 3,000 years.

Nevertheless, the implications are alarming. Powerful solar storms once influenced humanity only by creating brilliant auroras. Today, civilization depends on electrical networks that allow commodities, information and people to move across our world, from sewer systems to satellite constellations.

What would happen if these systems suddenly collapsed on a continental scale for months, even years? Would millions die? And could a single solar storm bring that about?

Researchers are working on answering these questions. For now, one thing is certain: to protect these networks, scientists must monitor the Sun in real time. That way, operators can reduce or reroute the electricity flowing through grids when a CME approaches. A little preparation may prevent a collapse.

Fortunately, satellites and telescopes on Earth today keep the Sun under constant observation. Yet in the United States, recent efforts to reduce NASA's science budget have cast doubt on plans to replace aging Sun-monitoring satellites. Even the Daniel K. Inouye Solar Telescope, the world's premier solar observatory, may soon shut down.

These potential cuts are a reminder of our tendency to discount existential risks – until it's too late.

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