New research shows unprecedented atmospheric changes during May's geomagnetic superstorm

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Associate Professor and Crofton Faculty Fellow Scott England. Credit: Ben Murphy for Virginia Tech.

On May 11, a gorgeous aurora surprised stargazers across the southern

United States. That same weekend, a tractor guided by GPS missed its mark.

What does the visibility of the northern lights have in common with compromised farming equipment in the Midwest?

A uniquely powerful geomagnetic storm, according to two papers co-authored by Virginia Tech's Scott England.

"The northern lights are caused by energetic, charged particles hitting our upper atmosphere, which are impacted by numerous factors in space, including the sun," said England, associate professor at the Kevin T. Crofton Department of Aerospace and Ocean Engineering.

"During solar geomagnetic storms, there's a lot more of these energetic charged particles in the space around Earth, so we see a brightening of the northern lights and the region over which you can see them spreads out to include places like the lower 48 states that usually don't see this display."

England and a team of university and industry collaborators tracked the upper atmospheric event on May 11 using NASA's GOLD instrument. It turned out to be the strongest geomagnetic storm captured in the last 20 years.

Their findings were published in *Geophysical Research Letters* in two studies, both co-authored by England. The first study, by first author Deepak Karan, from the University of Colorado, Boulder, showed unprecedented changes in location and spread of particles in the upper atmosphere. The second study, by first author and Virginia Tech alumnus J. Scott Evans, documented composition and temperature changes.

Among the collected data, England noted witnessing some "delightful swirly patterns" for the first time, and a dramatic motion of the air away from the aurora causing the formation of enormous vortices that moved air in a spiral larger than a hurricane. Specific observations included:

- Unpredictable movement of low energy charged particles from around the equator toward the aurora
- Charged particles that can be divided into two buckets: low energy and high energy, the latter of which can hurt humans working in space and damage electronics
- Changes in temperature and pressure that likely lead to the swirls and vortices seen
- Changes in locations and spread of low energy particles, which can negatively impact GPS, satellites, and even the electrical grid

"As the aurora intensifies, you see more lights, but along with that, there's more energy entering the atmosphere, so it makes the atmosphere near the poles very hot, which starts to push air away from the poles and towards the equator," England said.

"This data poses a lot of questions like, did something really different happen during this geomagnetic storm than has happened previously, or do we just have better instruments to measure the changes?"

Furthermore, what could those changes mean for the human-made technology that orbits that region of the atmosphere?

More than a northern lights show

Earth's upper atmosphere, spanning from about 60 to 400 miles above us, borders space and is the hang-out zone for satellites and the International Space Station. The upper atmosphere is made up of some of the same particles as the lower atmosphere, where we live and

breathe.

But it also has another side, the ionosphere, which can be thought of almost like an electric blanket—highly charged and constantly fluctuating. These charged particles in the ionosphere are one thing that makes this region of space so dynamic. It's common for the temperature and composition of the upper atmosphere and ionosphere to change. In fact, it does so predictably during the day and night and even changes overtime with seasons.

England said the particles in Earth's atmosphere are impacted by numerous factors in space, including the sun's activity. During a solar geomagnetic storm flare, an intense burst of radiation from the sun changes the composition and speed of the particles within the Earth's atmosphere. So why, in recent months, all over the globe have the northern lights been visible in places where they've not been seen before?

"The number of sunspots, flares, and storms changes with an 11-year cycle that we call the solar cycle," England said. "The number of flares we are seeing has been increasing gradually for the last couple of years as we move toward the peak of the solar cycle."

In addition to the visibility of the northern lights, geomagnetic storms have a range of impacts on our technology. Because radio and GPS signals travel through this constantly fluctuating "electric blanket," changes in this layer of the atmosphere can disrupt signals and impede navigation and communication systems such as GPS.

Various factors from both Earth's weather and space weather can impact this crucial layer, but there's much to be learned about why changes in the upper and lower atmosphere occur and how they might impact life as we know it.

"These storms can also increase electrical currents that flow around the Earth, which can impact technological devices that use very long wires. In recent years, there have been impacts to the power grid when too much current was flowing through the wires. During the largest geomagnetic storm ever recorded, the Carrington Event in 1859, these caused telegraph systems—peak technology at that time—to catch on fire," England said.

Scientists suspect that a storm similar to the 1859 Carrington Event, if it happened today, could cause an internet apocalypse, sending large numbers of people and businesses offline. While the May 11 storm did not cause drastic disruptions, with the peak of the solar cycle expected to occur in July 2025, we are still about a year away from knowing those potential effects.

"One reason we study geomagnetic storms is to try and build models to predict their impacts," England said. "Based on the solar cycle, we'd expect the conditions we're seeing this year to be around for about the next two years."

More information: Deepak Kumar Karan et al, GOLD Observations of the Merging of the Southern Crest of the Equatorial Ionization Anomaly and Aurora During the 10 and 11 May 2024 Mother's Day Super Geomagnetic Storm, *Geophysical Research Letters* (2024). DOI: 10.1029/2024GL110632

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