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Not My Fault: Hazards from space: another warning system that is important to support

Lori Dengler for the Times-Standard
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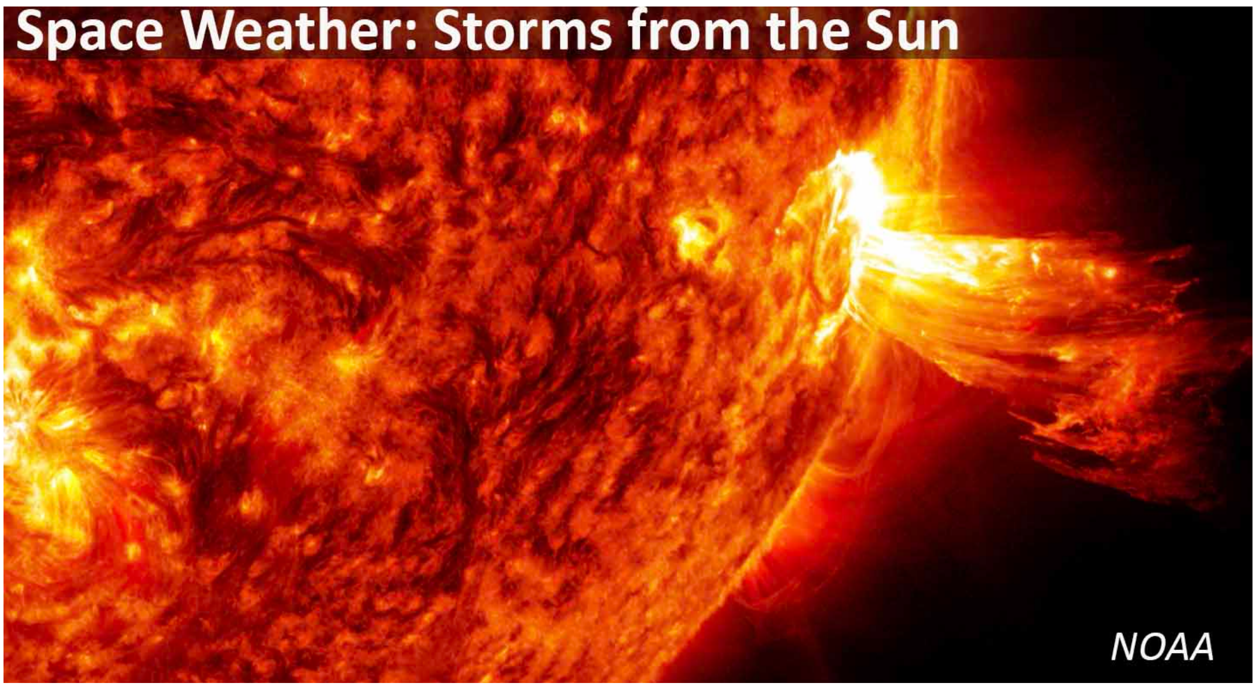

The sun is always spewing gas, particles and radiation in all directions into space. Known as space weather, these emissions can affect Earth. The Earth's magnetic field and atmosphere deflect much of the charged material, but large solar storms can damage satellites, disrupt communications, and cause large blackouts of the electric grid.

I've never thought much about space weather before I visited NOAA's Space Weather Center in Boulder two weeks ago. Like most people, I've heard about magnetic storms on the news and not paid much attention. The visit perked my interest and got me rethinking how warning systems are put together, what makes them effective and why it might be easier to alert the whole planet of an impending magnetic storm than effectively warn coastal areas for a tsunami.

Space weather seems like an odd term for charged particles and radiation emitted by the sun. The term 'solar meteorology' first appeared in the mid-nineteenth century when astronomer John Hershel called sunspots the weather of the sun. Around the same time, John Phillips, a British geologist, used 'magnetic weather' to describe rapidly fluctuating geomagnetic field strength. First thought unrelated, the timing of solar and geomagnetic fluctuations did not go unnoticed, and the fields of solar physics and earth magnetism began to overlap.

In 1859, an event occurred that made the intersection of the sun and geomagnetism not just an academic exercise. On September 1, 1859, British astronomer Richard Carrington was mapping sunspots when he observed a sudden blinding flash of white light on the sun's surface. Over the next days he carefully mapped the event and its relation to sunspot activity. At the same time, brilliant Aurora Borealis displays were observed in both the northern and southern hemispheres. It was so bright that people in the northeast could read newspapers by the aurora's light. It was observed in the Caribbean and as far south as Colombia.

The brilliant aurora wasn't the only effect on earth. Telegraph systems in Europe and North America failed, telegraph supports emitted sparks and triggered fires. The northeastern U.S. was the most strongly affected and some telegraph operators reported being shocked by their equipment. In Maine and Massachusetts, some operators were able to send and receive messages even after shutting down power supplies. The Boston Evening Reporter noted dialog between a Boston and Portland operator, "My current is very strong at times, and we can work better without the batteries, as the aurora seems to neutralize and augment our batteries alternately, making current too strong at times for our relay magnets. Suppose we work without batteries while we are affected by this trouble."

The 1859 Carrington event is considered the strongest magnetic disturbance ever recorded on earth. The bright flash that Richard Carrington observed was likely what we now call a coronal mass ejection (CME), an enormous eruption of solar plasma into space. The electrons and protons that make up the plasma may have been launched 60,000 miles above the sun's surface at speeds of over a million miles per hour. It is estimated that the oscillations in the Carrington event distorted the earth's magnetic field by 2 to 3%. That might not seem like a lot but spikes this large occurring in fractions of a second can wreak havoc on any electrical system.

Coronal mass ejections are huge and can expand into an area larger than the sun itself. They are a common part of solar activity. CMEs are highly cyclical and are related to sunspots. Sunspots, so called because they are cooler than adjacent areas of the sun's surface and emit less light, are areas of intense magnetic activity that wax and wane over an 11-year period. The sun is a violent place, where all parts are in constant movement and rotating at different speeds. Magnetic field lines are carried within the moving plasma, stretched and distorted. A sunspot is where magnetic field lines break through the surface.

Rotational dynamics produce the 11-year sunspot cycle, changing both the number and location of sunspots. During the solar minimum, the sun's magnetic field is relatively stable and quiet for weeks or months and no sunspots may be visible, and few CMEs occur. Over the next four to five years, the magnetic field grows more chaotic, and the number of sunspots increase. At the peak, roughly halfway through the cycle, a hundred or more sunspots can dot the sun's surface, and up to six or seven CMEs may be ejected every day. We are currently in the declining limb of Solar Cycle 25, the last solar maximum was in October 2024, and CME emission has fallen to an average of four per day. CMEs occur all over the sun's surface and fortunately only a few are directed into the narrow arc of space where earth is located. Once ejected, the particles travel up to 1,800 miles per second and, if headed in our direction, can reach earth in as little as a day.

Massive CMEs are not the only aspect of space weather of concern. Even without sunspots, the sun constantly emits a stream of charged particles and magnetic fields. This so-called solar wind travels at speeds of 250 to 500 miles per second, interacting with the earth's magnetic field, compressing the side facing the sun and stretching out the far side into a tear drop shape. We should all be thankful for our protective magnetic shield. In the early years of the solar system, Mars had a liquid core and a magnetic field. Mars is much smaller than earth and the core solidified during the first half billion years of its history destroying the fluid movement that fed a magnetic dynamo. Once the magnetic field was gone, solar winds quickly stripped the planet of its atmosphere.

The sun also emits solar flares, localized bursts of light and radiation as large as our whole planet but still contained within the sun's immediate atmosphere. Unlike CMEs, a solar flare contains no particles and travels at the speed of light, reaching our planet in about eight minutes. Like CMEs, solar flares are tied to the sunspot cycle. Rare during the quiet phase, dozens occur daily in the solar maximum. Potential impacts are less than CMEs, but solar flares are capable of distorting radio and GPS signals.

Cosmic rays emitted by the sun and from deep space constantly bombard the earth. The earth's magnetic field deflects most, but some hit the upper atmosphere, ionizing air molecules and contributing up to 15% of the background radiation our bodies are exposed to each day. Computer systems and critical technology are hardened to detect this signal and correct errors they may cause. One of the results of this bombardment is the conversion of a small percent of the carbon in every living creature to a radioactive isotope. The decay of Carbon-14 provides an important dating tool for geologists and anthropologists.

We can't change solar activity, but it is possible to respond to magnetic storms and minimize impacts through quick detection and response. Early alerts allow the managers of electric power grids to modify grid loads and shut down equipment, avoiding costly damage and outages. Data Centers are particularly vulnerable to disruptions in the electrical grid and strong magnetic storms can overload a fry the repeater systems on optical cable systems on land and under water.

Airplane systems and communications are highly vulnerable to magnetic storms, especially at cruising altitudes where the atmosphere is thinner and provides less shielding. Advance notification allows rerouting of flight paths or in the case of severe storms, canceling flights. Satellites navigation systems are vulnerable to space weather and alerts allow reorienting them into a safer direction or shutting down systems. CME alerts can delay rocket launches and send space station astronauts into a heavily shielded room to avoid radiation exposure.

The NOAA Boulder Space Weather Center is a room filled with computers and two duty space meteorologists staffed 24/7 on 10-hour shifts. Several of the screens feature detailed images of the sun's surface where to measure sunspot activity. NOAA's GOES satellites not only gather earth weather information, but they also collect solar X-ray flux that can mean a solar flare. The SOLAR-1 satellite sits in a gravitational sweet spot directly between the earth and the sun carrying instruments strictly dedicated to space weather. It is capable of delivering a 15-minute to 60-minute warning before a magnetic storm hits the earth's atmosphere.

As I was listening to the space weather presentation, one thought popped out, the time window similarity to tsunamis. If an anomaly pops up on SOLAR-1, there is not much time to analyze the threat and get it to the people who need the information. Millions of dollars are at stake both in potential losses and in the adverse effects of calling an alert that turns out to be unnecessary. Similar issues arise when a large earthquake occurs nearby, and we need to react quickly.

There is one very big difference between calling a space weather alert and issuing a tsunami warning. Almost all the users of space alerts are professionals; people trained to be aware of and know how to respond to a warning. It's part of their job to understand what an alert means and the importance of a quick response. For tsunamis, it's a far broader spectrum of who needs to be informed, many of whom pay little attention to the threat until a notice pops up on their phones. If only I could convince everyone who lives in a coastal area that knowing what a tsunami warning is and how to respond to take it as seriously as their job, we could make tsunami alerting as effective as space weather warning.

Note: dig deeper into the history of 'magnetic weather' at https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2014SW001141 and how NOAA monitors it https://www.spaceweather.gov/.

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