Space Weather 101

Understanding space weather and the inherent uncertainty in its predictions serves as a powerful reminder of the importance of vigilance, awareness, and preparedness.

Below you will find answers to:

Q: What is Space Weather?

A: Activity on the Sun can create a variety of events here on Earth, known as Space Weather. These events take place when the Sun releases an outburst of energy that impacts our atmosphere and can potentially harm our technology.

Q: What are the different types of Space Weather?

A: There are three main types of space weather events, solar flare, coronal mass ejections, and particle events. First are solar flares, huge, bright explosions from the Sun that can last several minutes to an hour or so. By the time we see the flare with our instruments, the effects are already being felt at Earth's upper atmosphere, on the daylit side, causing changes that can disturb high-frequency radio communications. They've historically been called radio blackouts, but technology has advanced to the point that radio disturbances are a more accurate description.

Coronal mass ejections (CMEs) are the second type of event. They're often, but not always associated with solar flares. A CME happens when the Sun ejects part of its outer atmosphere—called the corona -- into space. Unlike the energy of a solar flare, which reaches us in 8 *minutes*, CMEs take from 15 to 96 *hours* to reach Earth. The most energetic CMEs are usually associated with solar flares, although they can occur without a flare. CMEs carry complex magnetic configurations from the Sun to the Earth. When this magnetism interacts with Earth's magnetism, **geomagnetic storms** occur. The storms produce impacts ranging from aurora borealis to GPS failures to power outages, depending on the strength of the storm.

Solar particle events are the third, much less frequent, phenomena we'll discuss. They happen when the Sun releases a large number of high-energy protons and heavy ions in conjunction with solar flares and CMEs. These particles can reach Earth within minutes to hours following the solar event. They can cause **solar radiation storms** that primarily impact astronauts and spacecraft, but occasionally are significant enough to impact aviation at high altitudes and latitudes.

Q: Who can be impacted by Space Weather?

A: In general, with the exception of seeing the aurora, space weather impacts are limited to specialists in sectors making use of susceptible technology. However, the impacts on the technology can eventually extend beyond those industry sectors to affect the general public if a given space weather event is significantly large.

Q: What can Space Weather impacts look like?

A: Space weather can impact our electrical power grids, our navigation and aviation systems (including GPS), space exploration, satellite operations and communications (potentially causing collisions in space), survey operations that use magnetic fields for guidance (including farming equipment and precision drilling operations), and high-frequency radio communications.

The result of a space weather event can be:

- Electrical grid impacts,
- High-frequency radio disturbances,
- GPS and other navigational systems outages, and
- Satellite operations disruptions.

These impacts can last minutes, hours, or even days depending on the storm.

Q: Who monitors Space Weather?

A: The National Oceanic and Atmospheric Administration's **Space Weather Prediction Center (SWPC)** monitors Space Weather 24 hours a day 7 days a week.

SWPC works closely with NASA, the Department of Defense, the US Geological Survey, and the Air Force Weather Agency to ensure accurate predictions. They use three different scales, each rated on a 1-5 with 1 being the least concerning, and 5 being the most concerning.

The scales are as follows:

1. Radio Blackout Scale (R1-R5) caused by solar flares
    a. Potential impacts to our high frequency radio communications systems.
2. Solar Radiation Storm Scale (S1-S5) caused by solar particle events
    a. Potential impacts to our high frequency radio systems around the North and South Poles.
    b. Potential impacts to some navigation systems.
    c. Potential impacts to our satellite systems.

d. Potential delay of space launches.

e. Elevated radiation exposure for astronauts and some airplane passengers/crew.

3. Geomagnetic Storm Scale (G1-G5) caused by coronal mass ejections (CMEs)

   a. Likely to create aurora, which, depending on the size of the storm, could be visible from the poles, to closer to the Equator.

   b. Potential impacts to our power systems including possible grid blackouts.

   c. Potential impacts to spacecraft operations including issues with tracking satellites and space launches.

   d. Potential impacts to navigation, GPS, and radio communications.

Q: How do we know when Space Weather is coming our way?

A: The **Space Weather Prediction Center (SWPC)** puts together forecasts based on the Sun's activities using the **R, S, and G scales** detailed above.

For potentially large storms, they alert the rest of the federal government and industry stakeholders for awareness. This helps governments and infrastructure owners and operators take appropriate preventative actions, including protecting satellites, warning or rerouting aircraft, and protecting the power grid. For a G5 geomagnetic storm or an S5 radiation storm, FEMA will disseminate alerts to states through the National Warning System.

Q. What factors determine the severity of a space weather event?

1. The **solar plasma magnetic field** is oriented in the same direction of Earth's magnetic field.

   a. Like magnets, the same magnetic orientation would repel each other, causing no impacts.

2. The solar plasma magnetic field is opposite of the Earth's magnetic field.

   a. Like magnets, the opposite charges would attract each other, causing potential impacts from the storm based on the following variables:

      i. How directly the two magnetic fields meet. The closer to a direct hit, the more intense the impacts can be.

      ii. How long the two magnetic fields connect for. The longer they are in contact, the more intense the impacts can be.

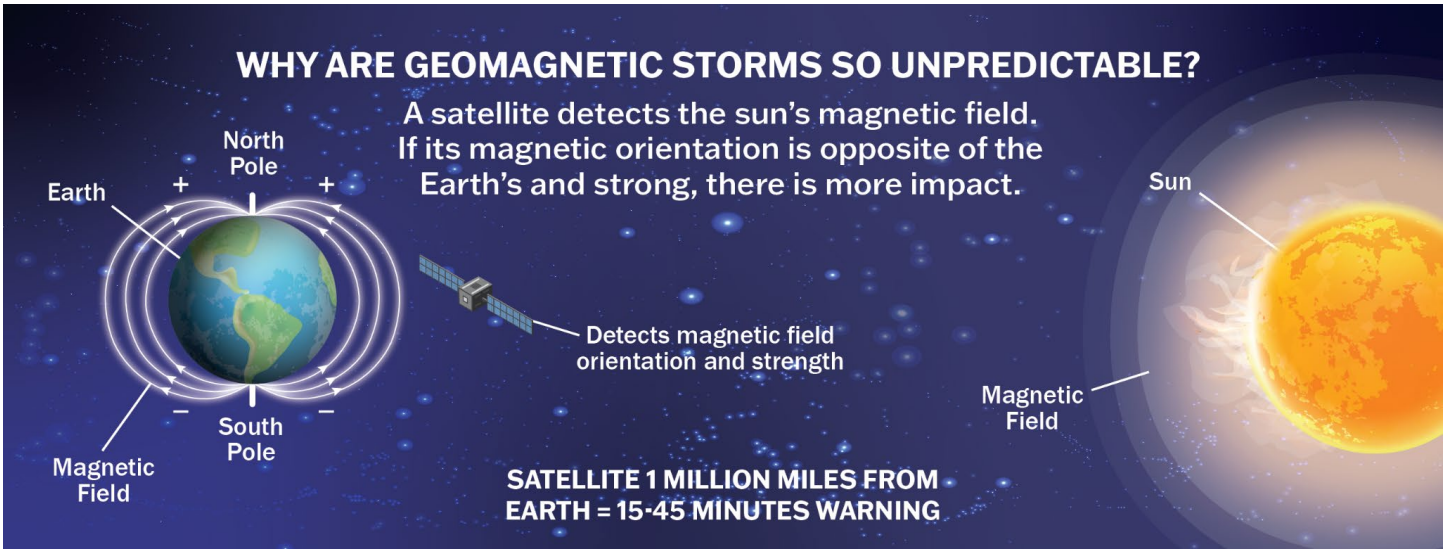
Every G5 geomagnetic storm has different properties. The 1859 Carrington Event is considered the largest, benchmark storm for governmental and industry planning and is estimated to have been 3-5 times stronger than the May 2024 storm.

TABLE 1: Comparison: 1859 Carrington Event and the May 2024 G5 Geomagnetic Storm		
	September 1859 (Carrington Event)	**May 2024 (G5 Event)**
Disturbance Storm Time (DST) Index* ▪ Measured in nano-Teslas [nT]	approximately - 1200 nT	- 410 nT
Effects	**1859:** Disrupted telegraph equipment around the globe. **Today:** Could debilitate power, internet, GPS, radio and satellite systems	GPS disruptions to aviation and agriculture systems. **Agriculture:** Lost $500 million due to delays in seed planting and other precision navigation farming **Satellite control:** corrected the orbit of nearly 5,000 satellites causing the largest satellite migration event in history

** The Disturbance Storm Time Index tells us how much Earth's magnetic field is being disturbed. The results are usually **negative** during a geomagnetic storm. **The more negative the number, the bigger the disturbance.***

Q. Why are the impacts of space weather hard to predict?

While we can predict the storm's intensity, limitations in our space observations cause high levels of uncertainty. We cannot predict the level of impact because it is based on both the intensity and how long the solar plasma's magnetic field and Earth's magnetic field remain in contact. The intensity and the sun's magnetic field orientation is measured by a detector about 1 million miles from Earth, giving between 15-45 minutes of warning.



Q: What can we do to prepare for Space Weather?

A: Don't underestimate the power of space weather! The potential for a large storm exists anytime but are most likely to occur in and around solar maximum.

Be informed by visiting spaceweather.gov.

BE PREPARED BY HAVING SUPPLIES FOR GPS AND POWER OUTAGES, INCLUDING:

- Paper maps
- Flashlights with backup batteries,
- Radio
- Battery or solar-powered chargers for critical devices,
- Any medications you may need in case a large-scale power failure requires you to leave your home.