My NASA Data

Space Weather

Grade Band

- 3-5
- 6-8
- 9-12

What is space weather?

Space weather refers to the conditions of the space environment driven by the Sun and its impacts on objects in the solar system.

- The Sun affects the space around us through a constant stream of plasma known as the solar wind, with occasional bursts from solar flares and coronal mass ejections.
- The solar wind carries its own magnetic field, so when it collides with Earth's magnetic field, the two magnetic fields can repel or attract each other like two magnets. This repulsion and attraction creates geomagnetic disturbances.
- Space weather events produce the beautiful glow of the northern and southern lights, but they can also endanger astronauts, disrupt radio communications, and even cause large electrical blackouts.
- Every planet in the solar system experiences its own space weather as the solar wind interacts with the planet's own magnetic field (or lack thereof).

What is heliophysics?

Heliophysics is the study of the Sun and its effects on Earth and the solar system.

The three major questions that drive NASA's heliophysics mission objectives are:

- What causes the Sun to vary?
- How do Earth, the solar system, and the heliosphere respond to changes on the Sun?
- What are the impacts of the changing Sun on humanity?

Space Weather

The Sun and Your Everyday Life

Though it is almost 100 million miles away from Earth, the Sun influences our daily lives in ways you may not realize. A farmer stops their planting operations due to poor GPS signal for their autonomous tractor. A power grid manager changes the configuration of their network to ensure a blackout doesn't occur due to voltage instability. A pilot switches to back-up communication equipment due to loss of high-frequency radio. A commercial internet company providing service to the military must change the orbit of their spacecraft to avoid a collision due to increased atmospheric drag.

These are a few examples of the ways the Sun influences our everyday lives. This is what we define as **space weather** – the conditions of the space environment driven by the Sun and its impacts on objects in the solar system.

Credit: NASA

Nevada farmer Denise Moyle in her alfalfa fields. Credits: NASA/courtesy of Glow by G Photography

Solar Wind

The solar wind starts its journey at the Sun. It emanates from features on the Sun such as dark and cool regions called coronal holes and active regions, which are characterized by strong magnetic fields. These regions release solar wind with different speeds and densities, but all release the same basic components of solar wind — electrically charged particles such as protons and electrons. This wind whips at speeds exceeding one million miles per hour as it traverses to the edge of interstellar space bathing everything in its path. The solar wind's many impacts include creating aurora and stripping planets' atmospheres.

Fast and Slow Solar Wind

Fast and Slow Solar Wind | https://youtu.be/-oJaMg7_I6o | Credit: NASA's Goddard Space Flight Center Conceptual Image Lab

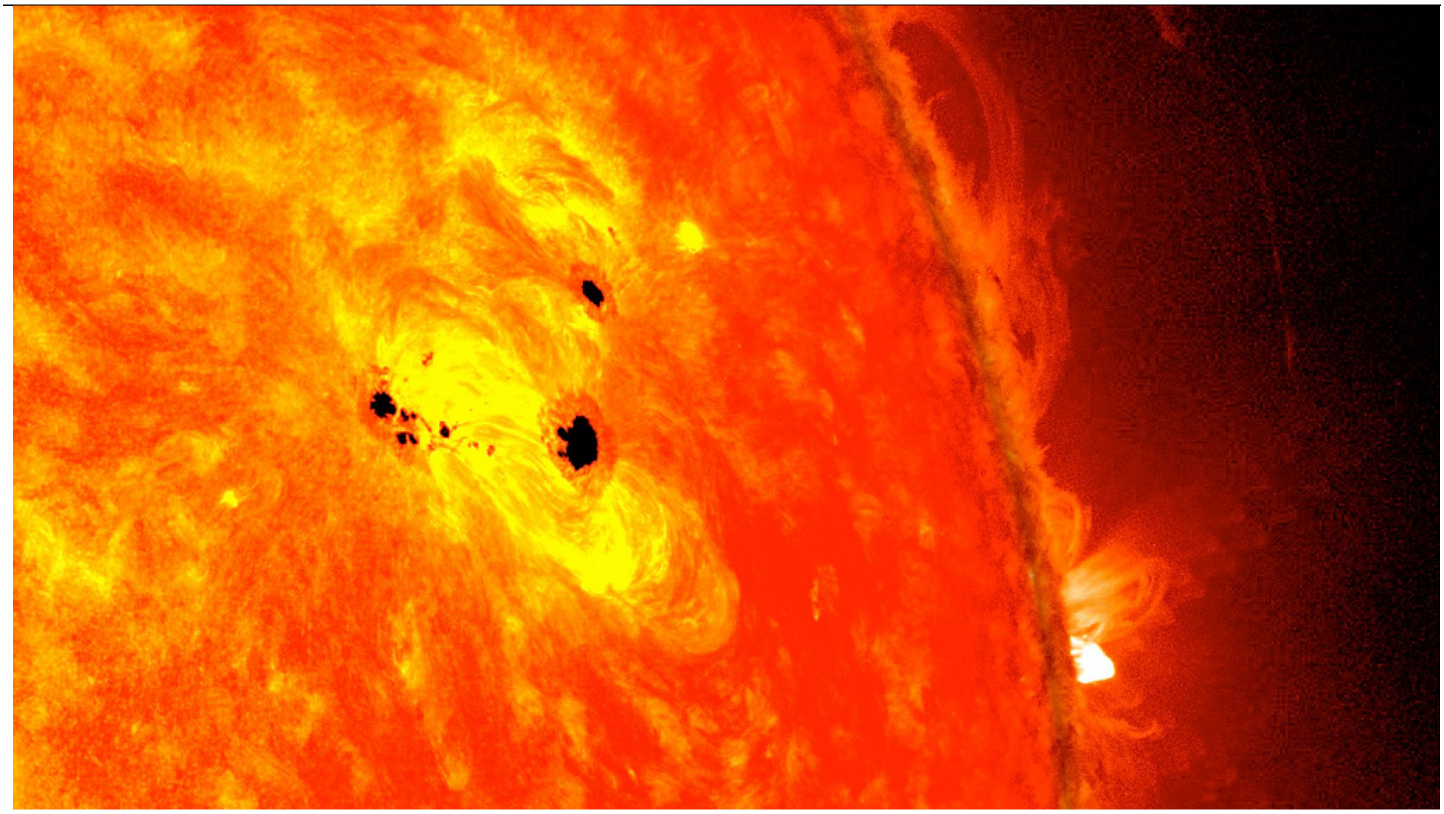
Aurora

Aurora are a brilliant display of light in the night sky. The aurora borealis and aurora australis—also known as the northern and southern lights—occur mainly near Earth's poles. When the solar wind reaches Earth's **magnetosphere**, it can send charged particles trapped in Earth’s magnetic field raining down toward Earth's poles, driven by a powerful process called **magnetic reconnection**. Along the way, particles can collide with atoms and molecules in Earth's upper atmosphere, which provides the atoms with extra energy that they release as a burst of light. These interactions continue at lower and lower altitudes until all the excess energy is lost. Studying aurora offers insights on how our magnetosphere reacts to near-Earth space weather. The probability of aurora being observed at lower latitudes is higher during solar maximum, when the Sun is at its most active.

This image of a colorful aurora was taken in Delta Junction, Alaska, on April 10, 2015. All aurora are created by energetic electrons, which rain down from Earth’s magnetic bubble and interact with particles in the upper atmosphere to create glowing lights that stretch across the sky.Credits: Image courtesy of Sebastian Saarloos

Solar Cycle

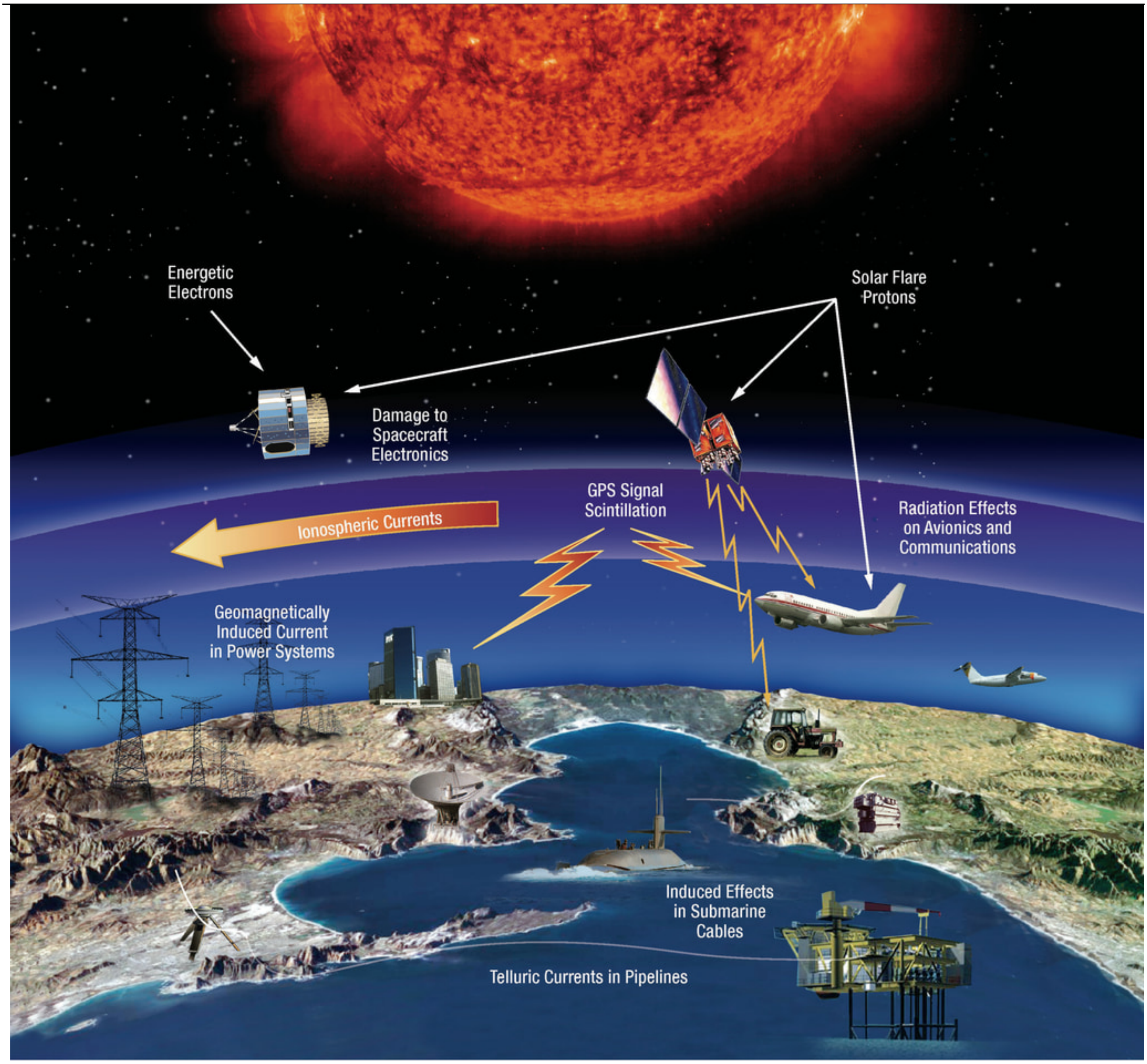
The number of **sunspots,** which are cooler, darker spots on the Sun, increases and decreases over time in a regular, approximately 11-year cycle, called the sunspot cycle. The exact length of the cycle can vary. It has been as short as eight years and as long as fourteen, but the number of sunspots always increases over time, and then returns to low again. More sunspots mean increased solar activity, when great blooms of radiation known as **solar flares** or bursts of solar material known as **coronal mass ejections** (CMEs) shoot off the Sun's surface. The highest number of sunspots in any given cycle is designated "**solar maximum**," while the lowest number is designated "**solar minimum**." Each cycle varies dramatically in intensity, with some solar maxima being so low as to be almost indistinguishable from the preceding minimum.



SDO captured this image of sunspots in February 2013. The bottom two clusters appeared over the course of two days and are over six Earths across. Credit: NASA's Goddard Space Flight Center, Images courtesy of NASA/SDO

Geomagnetic Storms

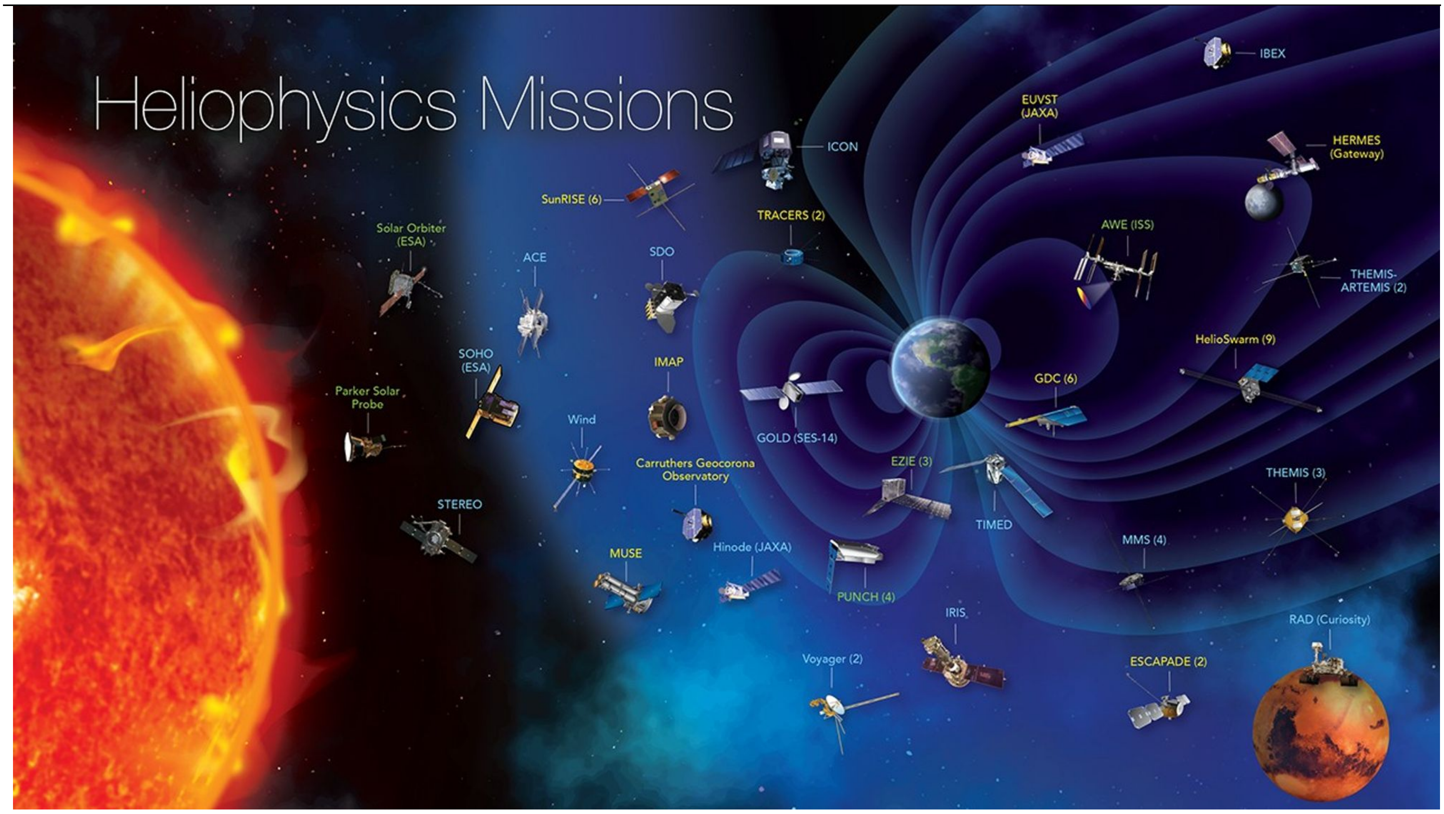
A geomagnetic storm is a major disturbance of Earth's **magnetosphere** that occurs when there is a very efficient exchange of energy from the **solar wind** into the space environment surrounding Earth. Geomagnetic storms result from variations in the solar wind that produce major changes in the currents, plasmas, and fields in Earth’s magnetosphere. The solar wind conditions that are effective for creating geomagnetic storms are sustained (for several to many hours) periods of high-speed solar wind, and most importantly, a southward directed solar wind magnetic field (opposite the direction of Earth’s field) at the dayside of the magnetosphere. This condition is effective for transferring energy from the solar wind into Earth’s magnetosphere. Severe space weather that causes geomagnetic disturbances has the potential to endanger astronauts, disrupt radio communications, and even cause large electrical blackouts.



Technological and infrastructure affected by space weather events. Credit: NASA's Goddard Space Flight Center

Heliophysics Missions

Viewing the Sun’s Influence from Multiple Perspectives



Mapping this interconnected system requires a holistic study of the Sun's influence on space, Earth and other planets. NASA has a fleet of spacecraft strategically placed throughout our heliosphere—from Parker Solar Probe at the Sun observing the very start of the solar wind, to satellites around Earth, to the farthest human-made object, Voyager, which is sending back observations on interstellar space. Each mission is positioned at a critical, well-thought out vantage point to observe and understand the flow of energy and particles throughout the solar system—all helping us untangle the effects of the star we live with.

- Some missions look directly at the Sun and gather data on the Sun's structure and monitor solar activity like solar flares and coronal mass ejections (CMEs).
- Some missions study the magnetic environment around the Earth and how the solar wind interacts with Earth's magnetosphere and atmosphere.
- Some missions study the edge of the heliosphere, where the solar wind creates a bubble around the solar system.

Some of the missions are described below.

Missions orbiting the Sun.

- Parker Solar Probe is flying into the outermost part of the Sun's atmosphere, the corona, and is collecting measurements and images to expand our knowledge of the origin and evolution of solar wind. It also makes critical contributions to forecasting changes in the space environment that affect life and technology on Earth. Parker Solar Probe has flown closer to the Sun than any other mission, making its closest orbit just 3.9 million miles from the Sun's surface.
- Solar Orbiter An international cooperative mission between the European Space Agency (ESA) and NASA, Solar Orbiter is the first mission to ever take close-up images of the Sun's

polar regions, measuring the composition of the solar wind and linking it to its area of origin on the Sun’s surface.

Missions studying the Sun from low-Earth orbit. It can be easier to study from low-Earth orbit because launching objects toward the Sun is very challenging.

- Solar Dynamics Observatory (SDO) studies how solar activity is created and drives space weather, by monitoring the Sun’s interior, atmosphere, magnetic field, and energy output. SDO has a geosynchronous orbit, which means it maintains a consistent orbit with respect to Earth.
- Polarimeter to Unify the Corona and Heliosphere (PUNCH) is a constellation of four small satellites in low Earth orbit that make global, 3D observations of the entire inner heliosphere to learn how the Sun's corona becomes the solar wind. PUNCH has a polar and Sun-synchronous orbit, which means it maintains a consistent orbit with respect to the Sun.

Missions orbiting Earth that study the influence of the Sun on Earth's atmosphere and the effects of space weather.

- The Global-scale Observations of the Limb and Disk (GOLD) mission measures densities and temperatures in Earth’s thermosphere and ionosphere.
- The Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED) mission is studying the influence of the Sun and humans on regions of Earth's atmosphere – the mesosphere and lower thermosphere / ionosphere. This region is a gateway between Earth and space, where the Sun's energy is first deposited into Earth's environment.

Missions orbiting Lagrange Point 1 (L1), a point between the Earth and the Sun where the gravitational forces balance out.

- The Solar and Heliospheric Observatory (SOHO) studies the Sun from its orbit around L1 which allows SOHO to maintain a stable position relative to both Earth and the Sun, providing an unobstructed view of the Sun.
- The Wind mission’s position at L1 gives it the perfect place to study how the solar wind first impacts the magnetosphere.
- Launched in 2007, THEMIS’s (Time History of Events and Macroscale Interactions during Substorms) five spacecraft were launched into a low-Earth orbit to study the physical processes initiating aurora. In 2010, two of its five spacecraft (P1 & P2) were repurposed as ARTEMIS (Acceleration, Reconnection, Turbulence and Electrodynamics of Moon 's Interaction with the Sun) and moved to new locations (Lagrange Points L1 and L2) to study similar processes closer to the Moon. These spacecraft have been sending scientists valuable information about the lunar environment, and laying the groundwork critical for returning humans to the Moon. THEMIS-ARTEMIS is NASA’s only long-term monitor of conditions in and around the lunar environment.
- Interstellar Mapping and Acceleration Probe (IMAP) is designed to orbit L1 and study the edge of the heliosphere, where the solar wind collides with material from interstellar space (the space between stars). It is scheduled for launch in 2025. The mission will study how particles are accelerated to high energies within the heliosphere, a process crucial for understanding space weather and its potential impact on Earth and technology.

Missions studying the edge of the heliosphere, the protective bubble of particles and magnetic fields generated by the Sun.

- Voyager 1 and its twin Voyager 2 are the only spacecraft ever to operate outside the heliosphere. Launched in 1977, Voyager 1 reached the interstellar boundary in 2012, while Voyager 2 (traveling slower) reached it in 2018. After completing the first in-depth reconnaissance of the outer planets, the twin Voyagers are on a new mission to chart the edge of interstellar space.
- The Interstellar Boundary Explorer (IBEX) is studying how our heliosphere, the magnetic bubble surrounding our Sun and planets, interacts with interstellar space. IBEX orbits Earth and created the first maps showing the interactions at that border and how they change over time.

To learn more about NASA's entire science fleet of missions visit https://science.nasa.gov/science-missions/

Instruments

While each mission carries a unique set of instruments designed specifically for its specific objectives. Many heliophysics missions include common instruments.

Remote Sensing Instruments

These instruments "see" the Sun and return imagery.

- **Telescope** - a solar telescope is a specialized telescope designed for safe observation of the Sun. Different types of telescopes collect different wavelengths of light.
- **Imager** - like a camera, it stores the data collected by the telescope
- **Spectrometer** - analyzes the light emitted by the Sun, providing information about the composition and temperature of different layers of the solar atmosphere
- **Coronagraph** - an instrument used in telescopes to block out the light from a bright object, like a star, so that fainter objects near it, like planets or the star's corona, can be observed.

In Situ Instruments

These instruments work by "touch." They measure the environment immediately surrounding the spacecraft, including solar wind plasma - the electrified gas streaming from the Sun - and the electric and magnetic fields embedded within it.

- **Particle Detector** - measures the electrons as they flow out from the sun along the magnetic field lines
- **Magnetometer** - measures the magnetic field of the Sun and its variations, and of the strength and direction of Earth's magnetic field

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Sources:

1. NASA. “NASA Space Weather.” *NASA Science*, NASA, 2025, https://science.nasa.gov/heliophysics/focus-areas/space-weather/. Accessed 11 August 2025.
2. Gannon, Megan. “Agriculture.” *NASA Applied Sciences*, https://appliedsciences.nasa.gov/what-we-do/food-security-agriculture. Accessed 11 August 2025.
3. “Heliophysics Topics.” *Framework for Heliophysics Education*, NASA, 29 01 2025, https://science.nasa.gov/learn/heat/topics/. Accessed 08 11 2025.
4. NASA, and NASA's Goddard Space Flight Center Conceptual Image Lab. “Fast and Slow Solar Wind.” *NASA Scientific Visualization Studio*, NASA, 28 09 2021, https://svs.gsfc.nasa.gov/20347/. Accessed 11 08 2025.
5. NASA, et al. “NASA Measuring the Pulsating Aurora.” *NASA*, NASA, 07 10 2015, https://www.nasa.gov/science-research/heliophysics/nasa-measuring-the-p…. Accessed 11 08 2025.
6. Fox, Karen. “NASA SVS | Fast-Growing Sunspots.” *NASA Scientific Visualization Studio*, 10 December 2015, https://svs.gsfc.nasa.gov/12073. Accessed 11 August 2025.
7. NASA, and Amy Moran. “How Do Space Weather Effects & Solar Storms Affect Earth?” *NASA Scientific Visualization Studio*, 29 September 2023, https://svs.gsfc.nasa.gov/31248/. Accessed 11 August 2025.
8. NASA. “Heliophysics Mission Fleet Chart.” *NASA Science*, NASA, 13 May 2025, https://science.nasa.gov/heliophysics/missions/mission-fleet-diagram/. Accessed 11 August 2025.