



Making Sun-Earth Connections: A New Perspective



**Presenter's Guide
Grades: 6-8**

Making Sun-Earth Connections: **A New Perspective**

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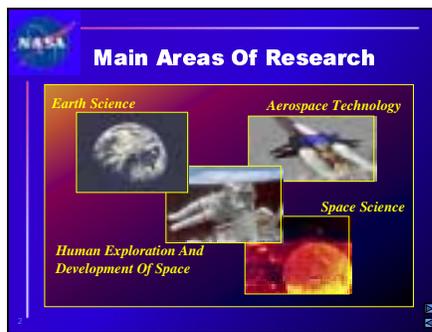
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When you view the Sun from the surface of Earth, it appears static, constant. But in space, NASA satellites employ instruments that reveal much more than you can see with the naked eye. When we observe the Sun in radio waves, X rays, ultraviolet light -- even visible light -- we find that our nearest star is quite dynamic.

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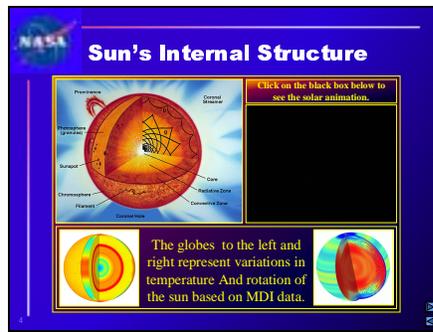
To better understand the Sun-Earth connection, NASA and its international partners are conducting an in-depth, system-wide study of the Sun, the Earth, and the space in between. This research is important not only for its own sake, but because it affects much of the other work NASA does in space. With information about the solar wind and the environment in near-Earth space, aerospace researchers can build satellites the live longer and fly farther. Observations of the changes in solar activity will help Earth scientists to better understand the dynamics of our atmosphere and climate. Astrophysicists looking beyond our solar system can gather insight from the only star that they can observe up close. And since the radiation from the Sun can affect human health, Sun-Earth connections research can help NASA find safer and more efficient ways to help humans to explore space.

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Equipped with cutting-edge telescopes and cameras, as well as sophisticated physics and chemistry sensors, satellites can study the interior of the Sun, its visible surface, its atmosphere, the solar wind, and the magnetic space around Earth. Satellites orbiting from two hundred miles above Earth to one million miles away make observations that allow us to track space weather events and to study our closest star.

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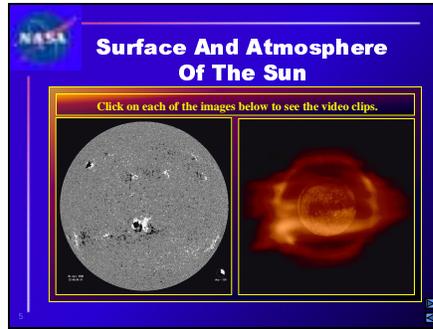


The Sun is believed to have six main regions:

- The core is the Sun's furnace, where nuclear fusion turns hydrogen into helium and releases photons of light. Temperatures at the core are estimated to be about 15 million degrees.
- The radiative zone surrounds the core. Gas is so tightly packed together here that it takes hundreds of thousands of years for a photon of light to punch through on its way up to the sun's surface.
- The next layer, the convective zone, is a churning region of plasma that circulates like water boiling in a pot. Plasma rises from the interior of the Sun and circles back down to the interior.
- The visible surface of the Sun, or photosphere, is the layer that radiates the light and heat we need on Earth. Temperatures in the photosphere are about 6000 degrees.
- The chromosphere is a thin reddish-orange layer of gas directly above the photosphere. It is the transitional layer between the surface and the Sun's tenuous atmosphere.

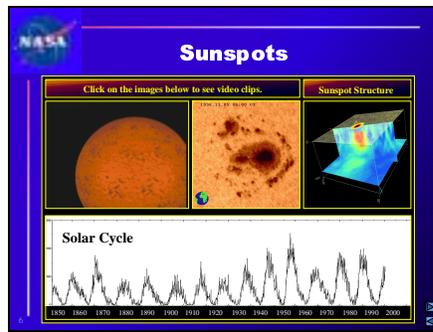
Finally, the Sun's outer atmosphere, or corona, is a faint halo of plasma that surrounds the Sun. Temperatures in the corona can approach two million degrees.

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The features of the Sun that are most readily observed from great distances are those on the visible surface in the corona.

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Sunspots are slightly cooler areas that appear dark when compared to the visible surface of the Sun. These areas are cooler because much of their energy is tied up in intense magnetic fields that are 1000 times stronger than the magnetic field of Earth. More than a century of observations has shown that the number of spots on the Sun changes in a cyclical pattern.

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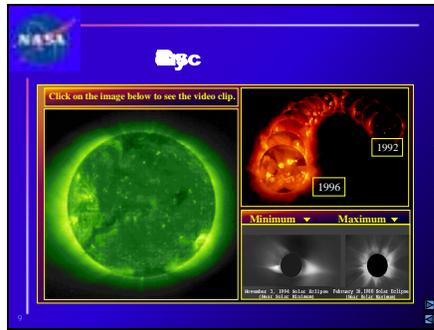
Flares are bright, intense explosions near the surface of the Sun. Flares occur when magnetic energy in the solar atmosphere is suddenly released in a burst equivalent to 10 million hydrogen bombs. Though they last just a few minutes, flares can spew intense X rays, gamma rays, and radio waves toward Earth, causing problems with radio signals. These blasts can also accelerate particles toward Earth, harming spacecraft and endangering astronauts.

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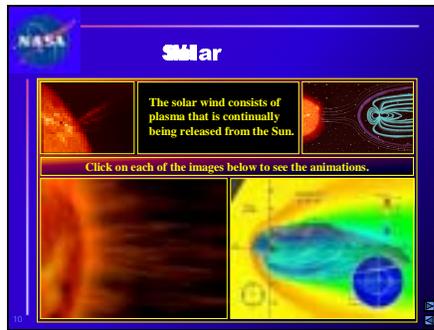
Perhaps the most violent space weather event is the coronal mass ejection. CMEs are large structures that erupt from the Sun and they are one of the principle ways that the Sun ejects material and energy into the solar system. The Sun's corona rips open and spews as much as 20 billion tons of material into space -- equivalent to the mass of 200,000 cruise ships. These huge bubbles of plasma travel at millions of miles per hour across space, sometimes toward Earth.

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Like Earth, the Sun has seasons. More precisely, it has a cycle that lasts about 11 years. The number of sunspots rises and falls and rises again in about 11 years – scientists call it the solar cycle. Similarly, the number and intensity of flares and CMEs also waxes and wanes with this eleven-year cycle. The period marked by many sunspots and explosions is known as solar maximum, while the quiet periods with fewer sunspots is known as solar minimum.

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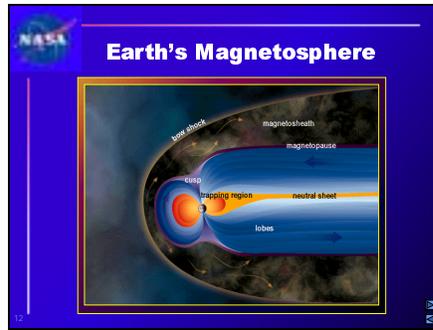
The Sun continuously emits a solar wind of electrically charged particles – known as plasma. These protons and electrons are blown away from the Sun in every direction, traveling well beyond the planets to the edge of the solar system. The solar wind confines the Earth's magnetic field inside a cavity known as the magnetosphere. Under the right conditions, the energy and pressure of the solar wind can distort the magnetosphere and cause auroras and magnetic storms.

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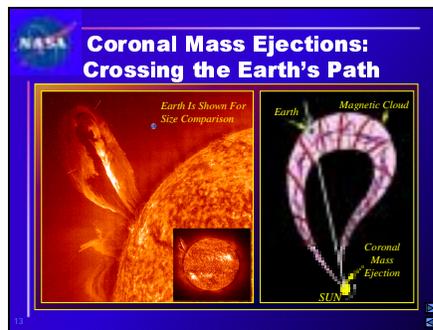
Today, satellites and space shuttles are propelled across space by expensive, heavy rockets. Chemical fuels can give a rocket a huge boost, but they are inherently inefficient. You have to carry the fuel with you, adding mass and slowing the same spacecraft you are trying to move. The extra mass makes it difficult to get to the outer planets and into interstellar space. But what if we could propel a spacecraft with sunlight? In the next ten to twenty years, NASA plans to fly satellites that require no fuel. They will glide with sails pushed by photons of light from the Sun.

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The magnetosphere is the outer edge of Earth's environment, the region that shields Earth's atmosphere and surface from direct blasts of radiation from the Sun. It is a region dominated by the Earth's magnetic field, which stretches tens of thousands of miles into space and deflects the solar wind around the Earth. The solar wind buffets and distorts the magnetosphere, exciting the plasma trapped in the Van Allen radiation belts and ionosphere, causing magnetic storms.

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Coronal mass ejections occur frequently, anywhere from a few times a week during solar minimum to a few times a day at solar maximum. Some of these plasma clouds end up crossing paths with Earth's. Though CMEs carry billions of tons of charged particles, most of that plasma is diverted by the magnetosphere around the Earth. But the force of that CME cloud and the magnetic energy it carries can wreak havoc on the shape and stability of the magnetosphere.

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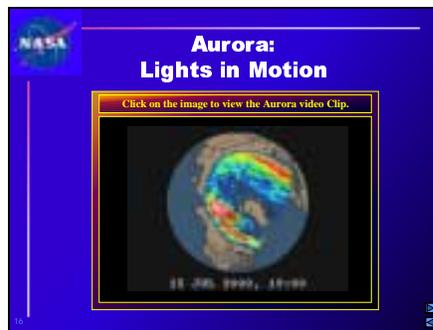
Sometimes, there can be a strong connection between a CME and the magnetic field of Earth. After traveling from the Sun in two to three days, this cloud of plasma collides with the front of the magnetosphere and can compress it on the dayside and stretch it on the nightside. This pushing and pulling acts like a great cosmic particle accelerator, exciting the plasma trapped around the Earth and snapping it down into the upper atmosphere to cause auroras and magnetic storms.

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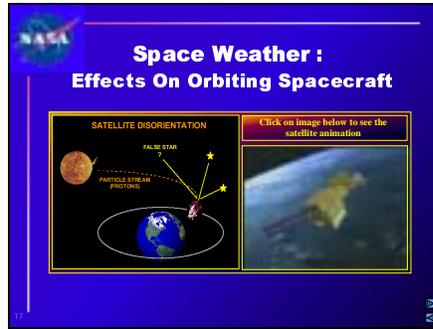
The Aurora Borealis, which occurs in the Northern Hemisphere, and the Aurora Australis, which occurs in the Southern Hemisphere, are brilliant displays of light and color. Auroras are the only visible evidence that the Sun and the Earth are connected by more than sunlight.

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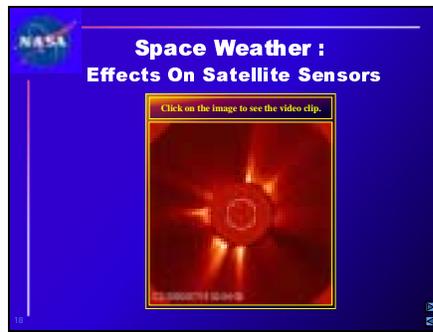
Auroras occur in ring-shaped regions centered on the magnetic poles of the Earth. Most of the time, auroras are only visited in the high northern and southern latitudes, such as Canada, Alaska, or Chile. But during the most intense storms, these auroral rings can stretch down to more populated lower latitudes in the United States or Australia.

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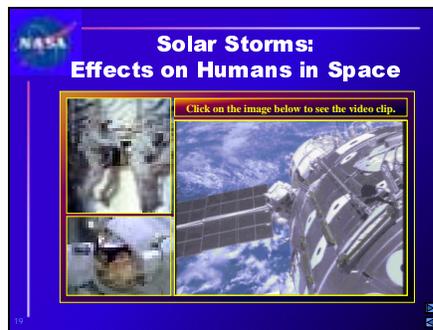
Satellites are the most common victims of storms from the Sun. Radiation and magnetic storms can distort the atmosphere of Earth, garbling communications between a satellite and its ground station. Also, increased friction in the upper atmosphere can slowly drag a satellite down from its orbit. The overall effect of space weather shortens the life of spacecraft and increases the cost of working in space.

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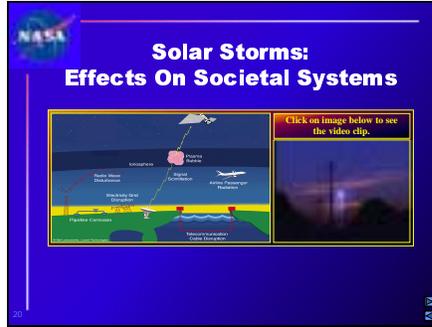
Flares and coronal mass ejections can sometimes accelerate particles to near light speed. These high-energy protons can bombard satellite cameras and saturate particle detectors. This can lead some satellites to shut down temporarily or become disoriented. High-energy particles also can destroy solar panels or pierce the skin of a satellite, causing electrical shorts and phantom commands.

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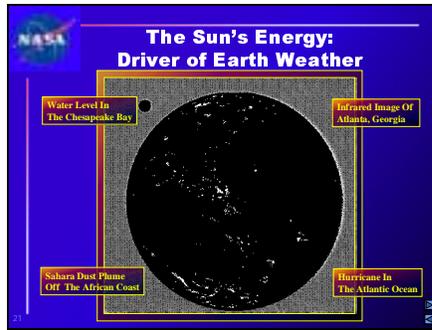
Humans are taking a risk when they travel and work in space, above our protective atmosphere. Human cells are vulnerable to the radiation from the Sun, which is why spacesuits are made with heavy insulating materials to shield the astronauts. But during the most intense storms from the Sun, spacesuits may not be enough. Astronauts sometimes need to seek shelter in special compartments of the shuttle or space station because being caught out in space could lead to radiation sickness, cancer, or even death.

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Some solar storms cause disturbances in the Earth's magnetic field. Swirling currents and changing magnetic fields in Earth's ionosphere can cause extra, damaging currents to flow in telephone cables or along pipelines. These magnetic storms also can cause surges and errors in power lines and electrical transformers, burning up power systems and causing blackouts. Finally, these disturbances cause distorted radio and satellite signals. This can create navigational problems for planes, and ships.

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The light and heat from the Sun drives the circulation of the Earth's atmosphere and helps create the seasons. Solar radiation also affects the chemistry of our atmosphere, such as the ozone layer. Scientists have reason to believe that long term changes in the Sun's activity can lead to changes in Earth's climate.

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To the naked eye, the Sun hardly changes. But a closer look reveals that we live with a dynamic, turbulent star. Using everything from high-tech spacecraft, Earth-based telescopes and computers, and old-fashioned hand drawn sketches of the Sun, scientists are unraveling the secrets of the Sun-Earth system. They scan the face of the Sun for signs of flares and CMEs. They monitor the solar wind to see if it is carrying foul weather. And they measure the energy flowing in Earth's upper atmosphere to see if a magnetic storm is brewing. What they discover will help us to someday predict the weather in space and to better understand the impact of our closest star on our lives.