National Aeronautics and
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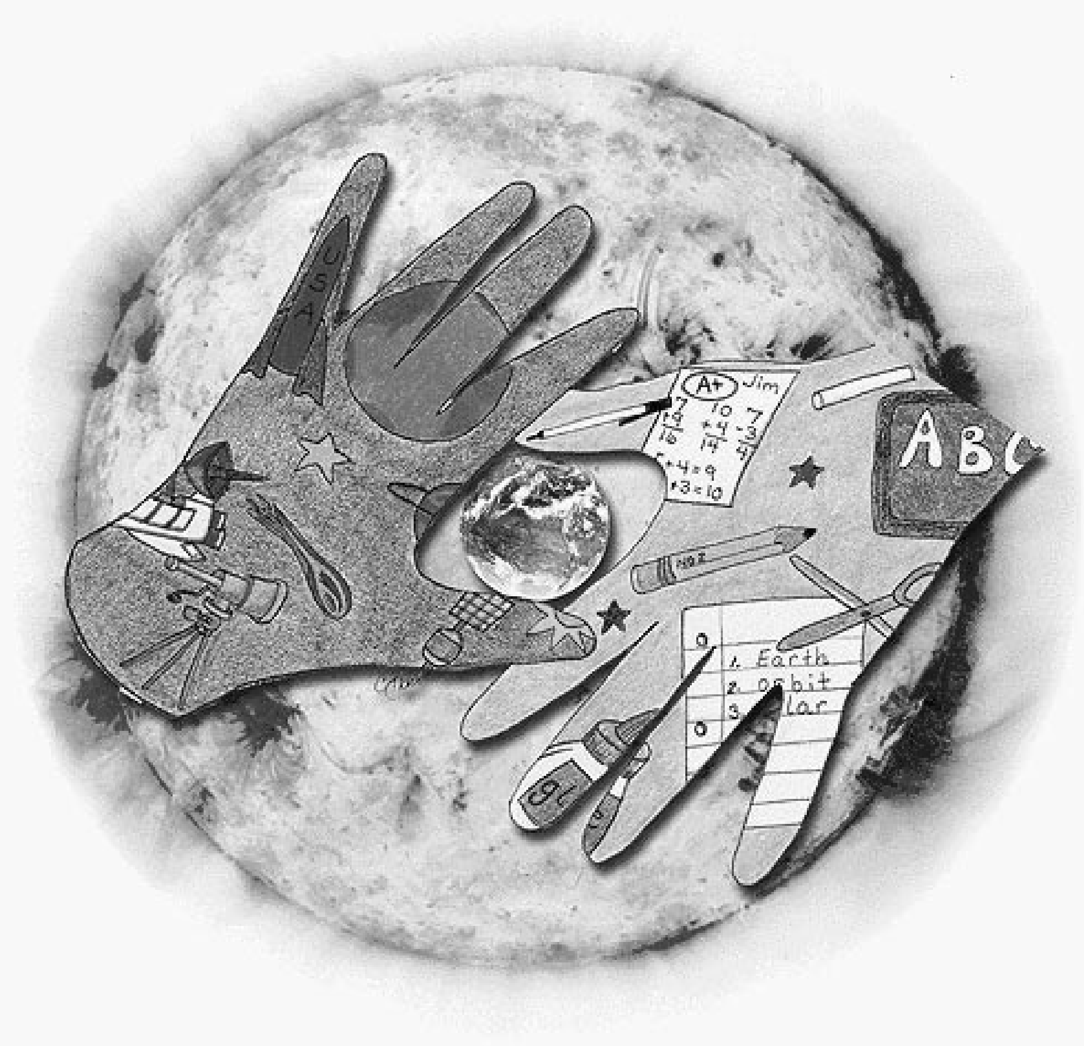
Educational Product	
Educators & Students	Grades 5-8

EG-2000-03-002-GSFC

Solar Storms and You!

Exploring the Wind from the Sun

An Educator Guide with Activities in Space Science



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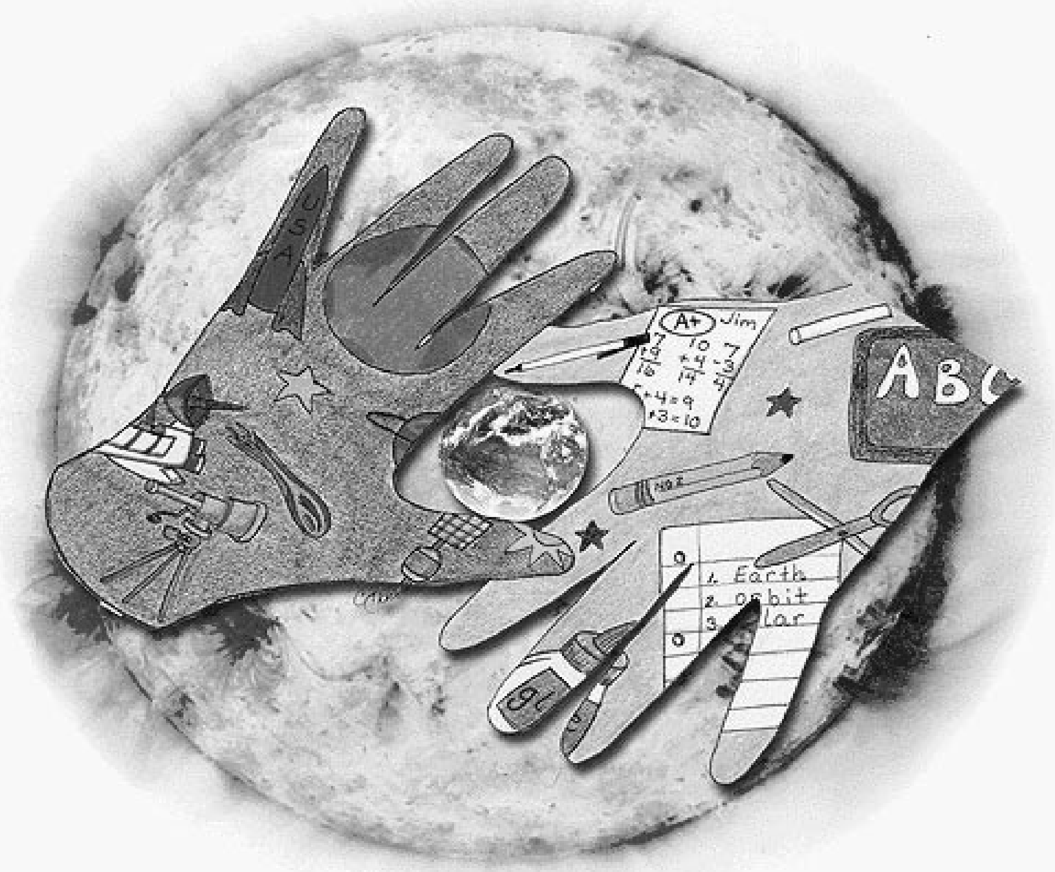

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Information about the IMAGE mission is available at:

http://image.gsfc.nasa.gov
http://pluto.space.swri.edu/IMAGE

Resources for teachers and students are available at:

http://image.gsfc.nasa.gov/poetry

National Aeronautics and
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Goddard Space Flight Center

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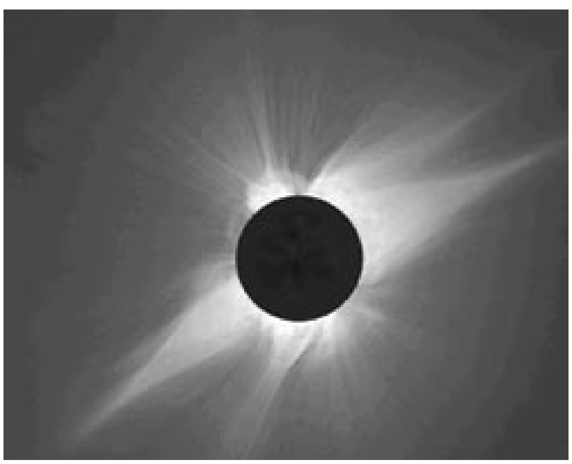
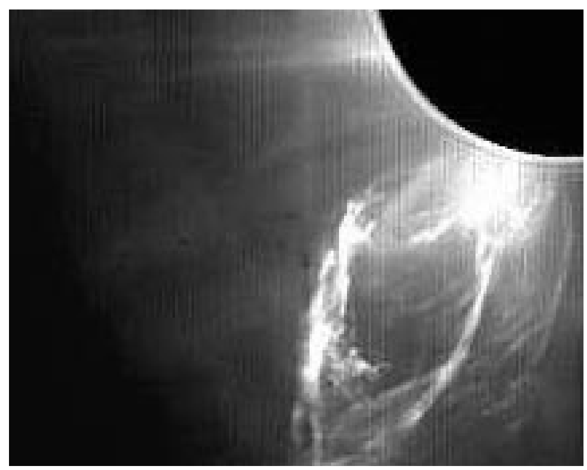




The Sun is an active star. During times of sunspot maximum, it ejects over 100 clouds every month; many of these carry over a billion tons of matter. Along with these dramatic eruptions of matter and energy, the Sun steadily emits a wind from its surface which travels at speeds up to one million kilometers an hour. This wind is very dilute and contains fewer than ten atoms in each thimble-sized volume. Eventually after traveling throughout the solar system, it collides with the gases between the stars in interstellar space outside the orbit of Pluto.

INTRODUCTION

A gas pipeline in Russia explodes
killing hundreds of people.

A satellite mysteriously falls silent
interrupting TV and cellular phone traffic.

A power blackout
throws millions of people into darkness.

These are only a few of the many things that solar storms can do when they arrive at the earth unexpected. In an age where we have increasingly come to rely upon the smooth operation of our technology, we have also made ourselves vulnerable to the ebb and flow of the solar storm cycle. Most people are not even aware of this cycle, ut long ago we used to be!

Ancient Chinese sun observers knew that, from time to time, dark spots would glide slowly across the face of the setting sun. Once seen only as portends of political upheaval, we now see them as natural phenomena that can forewarn us of impending storms that can have dire consequences for us if we ignore them.

In this activity book, your students will study five key stages in the lifecycle of a solar storm, from its emergence on the solar surface to its impact upon some aspect of our lives. The book may be used in its entirety to study solar activity and how it directly affects us, or you may use individual activities of your choice as stand-alone mini lessons as an enrichment for math and physical science courses.

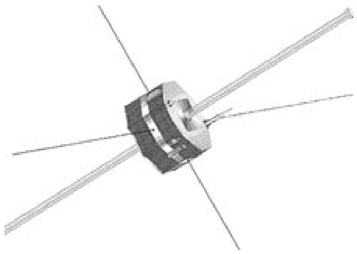
The student activities emphasize basic cognitive skills and higher-order processes such as plotting data, searching for patterns and correlations, and interpreting the results. By the end of the activity series, students will understand why we need to pay more attention to solar storms.

Visit the updated version of this workbook at:

http://image.gsfc.nasa.gov/poetry/workbook/workbook.html

Science Process Skills

for *Solar Storms and You!*

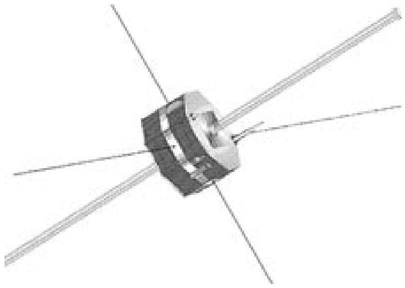


This chart is designed to assist teachers in integrating the activities contained in the guide with existing curricula.

	Lesson 1 *"CME Plotting Activity"*	**Lesson 2** *"Solar Activity and CMEs"*	**Lesson 3** *"Anatomy of a CME"*
Observing	○	○	○
Classifying			
Communicating	○	○	○
Measuring	○	○	○
Inferring		○	○
Predicting	○		
Experimental Design			
Gathering Data			
Organizing Data			
Controlling Variables			
Developing a Hypothesis	○	○	○
Extending Senses			
Researching			
Team Work			
Mathematics	○	○	○
Interdisciplinary			
Introductory Activity	○	○	○
Advanced Activity			

Science and Mathematics Standards

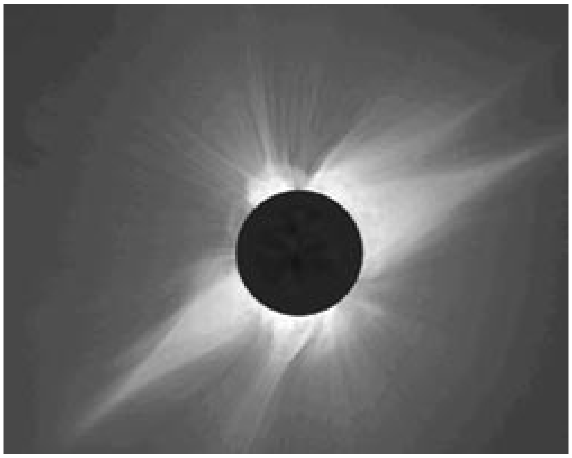
for *Solar Storms and You!*

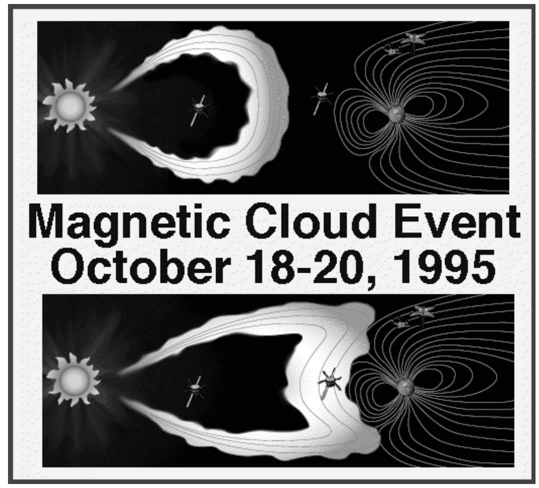


This chart is designed to assist teachers in integrating the activities contained in the guide with existing curicula.

	Lesson 1 *"CME Plotting Activity"*	**Lesson 2** *"Solar Activity and CMEs"*	**Lesson 3** *"Anatomy of a CME"*
Science as Inquiry	○	○	○
Structure and Energy of the Earth System			
Origin and History of the Earth			
Earth in the Solar System	○	○	○
Geochemical Cycles			
Physical Science	○	○	○
Populations and Ecosystems			
Understanding Science and Technology	○	○	○
Science in Personal and Social Perspectives			
History and Nature of Science			
Problem Solving	○	○	○
Measurement	○	○	○
Computation and Estimation			
Communication			
Geometry and Advanced Mathematics	○		
Statistics and Probability		○	
Number and Number Relationships			
Patterns and Functions	○	○	○

The Solar Wind





The outer layers of the Sun, called the **Corona,** are not stable but are constantly escaping into space. Although the magnetic field of the Sun 'bottles up' some of the hot gases near the solar surface to make spectacular prominences, in other regions the magnetic field opens into interplanetary space and allows the million-degree gases to escape as a **Solar Wind.**

Within the equatorial region of the Sun, the solar wind travels outwards in a pinwheel-shaped spiral pattern due to the combination of the outward gas motion, at over 400 kilometers/sec (1 million miles/hour), and the rotational motion of the Sun.

Although its normal density is less than 10 atoms per cubic centimeter, because the wind is spread out over such a vast volume of space, it amounts to over 50 billion tons of mass lost per day mostly in the form of high-speed electrons and protons - the components of the most abundant element in the Sun: hydrogen.

On occasion, and for reasons not fully understood by scientists, the magnetically trapped gases in the Sun's corona can become unstable and get ejected into space as **Coronal Mass Ejections,** or **CME**s. These clouds are carried by the solar wind. They are often as big as the Sun itself, and they contain upwards of one billion tons of matter in a single event which may last only a few hours. Traveling at speeds from 450 to 1000 kilometers/sec, the trip from the Sun to the Earth's orbit takes only a few days.

Most of these clouds dissipate quickly and merge into the solar wind while others can remain cohesive, though substantially diluted by the time they reach the Earth. Most of these CMEs never collide with the Earth, but those that do can cause satellite damage and brilliant auroral displays, so their effects are not inconsequential.

Like Stealth Bombers, it is not the ones we can detect on the limb of the Sun that pose a hazard to us here on Earth, it is the ones that are lost in the glare of the solar surface that can potentially reach Earth. NASA has stationed satellites in space between the Earth and the Sun to provide advanced warning for stealthy CME events, but even so, only about 1-2 hours of warning is possible from such distant outposts.

Teacher's Guide

CME Plotting Activity

Introduction

Coronal Mass Ejections are major storms on the Sun which can hurl billions of tons of matter into space in a matter of a few hours. Traveling at millions of kilometers per hour, some of these clouds occasionally collide with the Earth and have produced power blackouts and satellite damage. CMEs can start out with a size of only a few 100,000 kilometers, but fan out to millions of kilometers by the time they reach Earth's orbit. Only the CMEs that emerge from near the Sun's eastern limb stand a chance of traveling all the way to Earth, so this is where astronomers look for early signs that one is on its way!

Objective

Students will construct a table of values and plot the points in order to make a prediction.

Procedure

1) Plot CME1 points from the appropriate tables and draw to scale the thickness of the CME indicated in the 'Width' column of the table.

2) Plot CME2 points from the appropriate tables and draw to scale the thickness of the CME indicated in the 'Width' column.

3) By hand, sketch the path of the CME that hits Earth and complete the shape of the CME using the width information from the table.

4) Identify the location on the Sun where the sketched CME in procedure #3 will emerge so that it hits the Earth. This point is about half way between the center of the Sun and the left (eastern) edge.

5) Show that most CMEs do not hit the Earth by choosing other CME locations on the Sun, and plotting the possible shape.

6) The points in the tables were calculated for an assumed CME speed of 450 kilometers/sec, however some CMEs can travel at a speed twice this fast. Challenge your students to re-calculate the table entries for a faster speed and repeat steps 1-4 in this procedure.

The students should see the shapes of the CME trajectories become flatter. The point where the Earth-hitting CME is ejected from the Sun will shift closer to the left (eastern) edge of the sun.

Materials

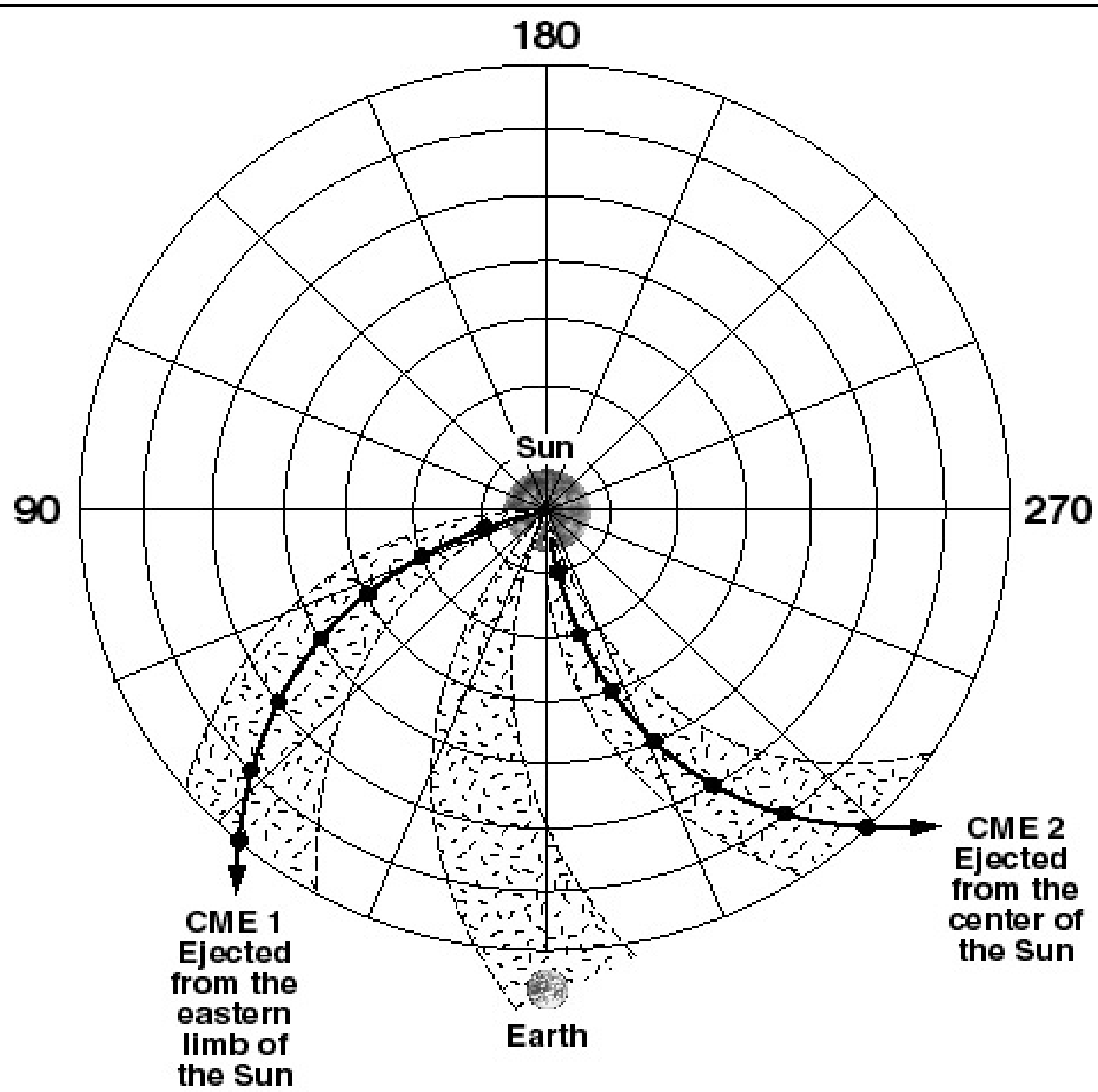
—Student work page
—Calculator
—Colored pencils

Teacher's Answer Key

Day	CME #1 Distance	CME #1 Angle	CME #2 Distance	CME #2 Angle	Width
0.0	0	90	0	360	0.5
0.5	20	83	20	353	7.0
1.0	40	76	40	346	13.5
1.5	60	69	60	339	20.0
2.0	80	62	80	332	26.5
2.5	100	55	100	325	33.0
3.0	120	48	120	318	39.5
3.5	140	41	140	311	46.0

From the table to the left, plot the path of two CMEs as they leave the Sun during its 3.5-day journey.

The distances and the widths of the CMEs are given in millions of kilometers.



Name ____________________________

Date________________

	CME #1		CME #2		
Day	Distance	Angle	Distance	Angle	**Width**
0.0	0	90	0	360	0.5
0.5	20	83	20	353	7.0
1.0	40	76	40	346	13.5
1.5	60	69	60	339	20.0
2.0	80	62	80	332	26.5
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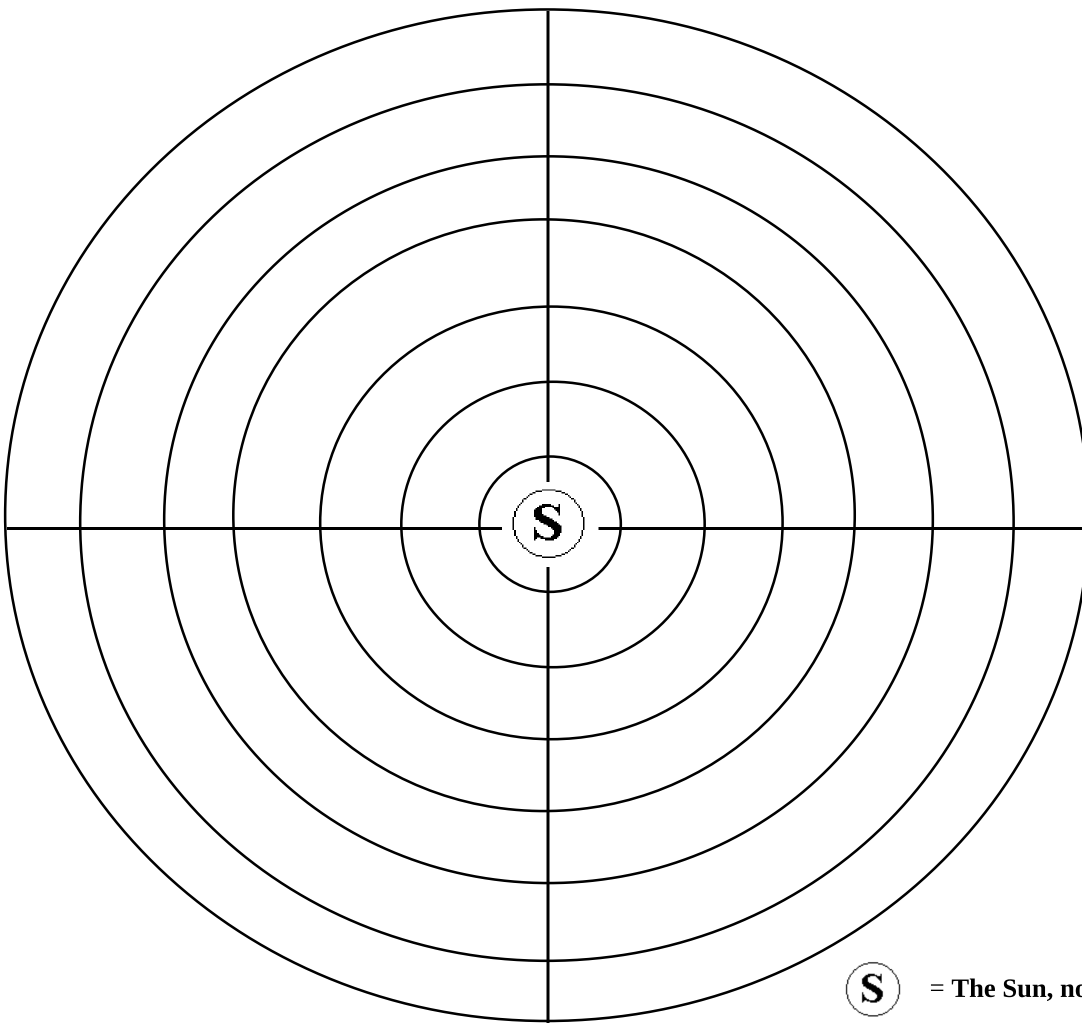


S = **The Sun, not to scale.**

Teacher's Guide

Solar Activity and Coronal Mass Ejections

Introduction

The Sun constantly emits matter into space in the form of a more or less steady solar wind. From time to time the Sun also ejects individual clouds of gas in an event called a Coronal Mass Ejection or CME. CMEs can cause storms in the environment of the earth that can have harmful impacts on humans working in space, on communication satellites, and many other aspects of our technology dependent society. For this reason, scientists look for many clues to tell when the next one may happen to provide us with an advanced warning.

Objective

Students will construct a graph to compare the sunspot cycle with Coronal Mass Ejections (CMEs).

Procedure

1) Students will use the graphing calculator to create the graphs for the sunspots and the CMEs. Students will graph the sunspots and CMEs on graph paper. **Note:** Using different colors to depict each graph will allow for ease when comparing the two graphs.

2) Students are to compare the two graphs. Location of the maximums, the minimums, and the time frames are the key components. Have students determine if there is a correlation.

3) Discuss the possible relationships that the students locate. Among other things to consider are:

—How well does the CME activity follow sunspot number?

—Do the maximums and the minimums happen at about the same time?

Some things you will find are:

—CME activity should follow rather closely to the sunspot cycle, but the correlation in exact counts may not be precise. This is probably because CMEs happen in layers of the sun that are much higher above the solar surface than the sunspots.

—The CME curve seems to have a longer, flatter minimum than the sunspot curve and its center is offset from the sunspot minimum by 2-3 years earlier. CME activity may decline to a minimum faster than sunspots after sunspot maximum.

Materials

—Graph paper
—Colored pencils
—Student worksheet

Optional:

—Teacher notes on the graphing calculator.
—Graphing Calculator
Note: TI-83 used in the examples

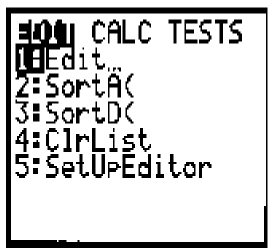
Teacher Notes for the Graphing Calculator

Reminder: Be sure to reset the calculator using the “Teacher Notes for the Graphing Calculator” included in the previous sunspot lesson .
The commands for the graphing calculator are given in bold print below the windows.

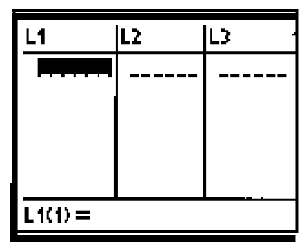
Students will enter the following data:

Year	CMEs	Sunspots	Year	CMEs	Sunspots
1980	12	154	1988	29	98
1981	26	140	1989	38	154
1982	7	116	1990	18	146
1983	8	67	1991	32	144
1984	6	46	1992	23	94
1985	2	18	1993	10	56
1986	4	14	1994	9	30
1987	5	32	1995	13	17

Entering the data into the list will consist of the following keystrokes:

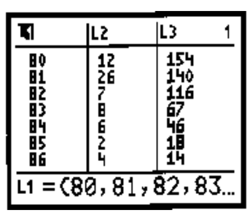


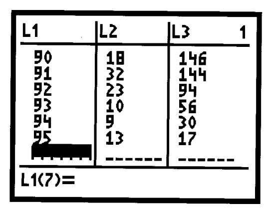
STAT



ENTER

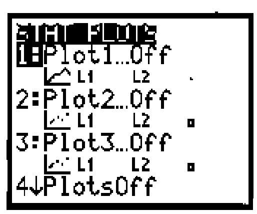
This will put you at the window to input the data for the year in List 1, CME number in List 2, and the sunspot number in List 3. Sample screen images are shown on the right:



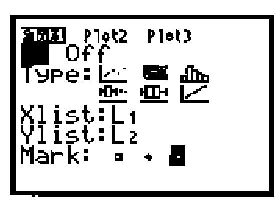


After the data has been entered into the lists, the stat plots need to be turned on. To turn the plots on, use the following keystrokes:

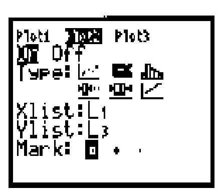
Plot 1 allows the year and CME data to be graphed. Plot 2 allows the year and sunspot number to be graphed. **Note:** To change the xlist and the ylist to L1, L2 and L3, use the **2nd 1, 2nd 2,** and **2nd 3,** commands.



2ND Y=



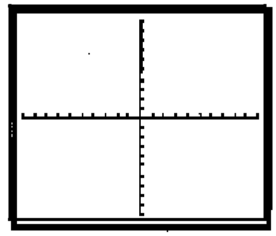
ENTER



2ND Y= 2

This would be a good time to discuss the appropriate graph for this situation. The explanation given in the sunspot lesson is consistent with this data. The data is continuous and should be displayed as such.

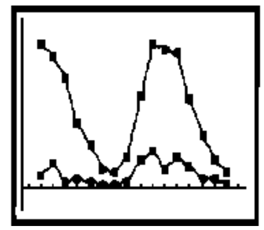
When the students push the graph key, they may not see any data. They may see a graph of four quadrants with a small display of data:



GRAPH

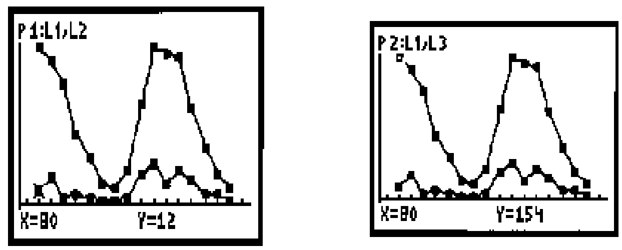
In order to get the correct window, the students need to zoom the screen:

ZOOM



9

In order to move along the values and make comparisons, use Trace. Note: The top graph is the number of sunspots and the bottom graph is the number of CMEs.



TRACE

When using the TRACE key, the students are able to see the year displayed in L1, the CMEs in L2, and the sunspot numbers in L3. By using the right and left arrow key, the students can move along a particular graph. To move to the other graph, the up and down arrow keys allow the students to move from one graph to the other.

Name ______________________________

Date________________

Teacher's Guide

Anatomy of a CME

Introduction

Coronal Mass Ejections (CMEs) are large clouds of gas ejected into space by the Sun which disable satellites, and can even cause power outages. Many of these CMEs cannot be easily detected on the solar surface so that adequate warning can be provided. NASA has begun to use satellites placed in orbit between the Earth and the Sun to provide early warning for detecting 'stealthy' CME events less than 1 hour from arrival at Earth. This exercise lets students analyze simplified data obtained from the SOHO and WIND satellites during the January 10, 1997 CME event which may have damaged Telstar 401; a $200 million AT&T satellite.

Objective

Students will compare and interpret four graphs involving the speed, temperature, magnetic field strength and density of a CME event.

Procedure

1) Because there are four different graphs for the students to analyze, this activity lends itself to a 'Four Corners'-style of execution. Divide the students into four groups in different parts of the room, and assign each group a specific graph to interpret. Have the students determine what happens to their respective graph as the CME Front passes.

2) Have individually prepared transparencies of the graphs (suggestion; make a copy and cut itapart for the groups). Have each group present their findings to the class.

3) Have prepared transparencies of all the graphs. Facilitate a discussion of the combined results using the transparency and the summary of the graph events. For a concluding event you may wish to discuss 'Combining the Clues'.

Materials

—Graph paper
—Prepared transparencies
—Graph Summaries
—Combining the Clues

Summary

The students should determine that the temperature dropped 50,000 C as the CME front passed the satellites, and then it rose sharply as the satellites were inside of the cloud. The density remained constant as the CME front passed, then it rose sharply inside the CME front, then dropped below the solar wind value before rising back to the normal solar wind level. The speed was constant at the solar wind-level until the CME passed, then the satellites were affected by the fast moving gas inside the CME cloud. The magnetic field in the CME front was three times higher than the average solar wind value which is near 5 nT. The CME front traveled at about 600 kilometers/sec (about two million miles/hour) so that for spacecraft at one million miles from Earth, the 'ETA' time is about 30 minutes.

Graph Summaries:

Temperature: This trace shows a 50,000 C dip in the temperature of the leading edge of the cloud between January 10 and January 11. This is followed by a sharp rise in the gas temperature inside the cloud , which then decreased the farther the leading edge of the CME cloud was from the satellite. The typical solar wind temperature is about 100,000 C.

Density: There was little change in the density of the gas near the satellite until January 11 . When the satellites encountered the interior of the CME, just behind the leading edge, it appears there was a ‘wall’ of high-density gas. Directly behind this wall is a low density cavity which contained nearly half the density of the gas typically detected in the solar wind.

Speed: The satellites detected the steady flow of the solar wind at about 450 kilometers/sec. Once the satellites were inside the main body of the CME cloud on January 11, they encountered the fast maving gas with speeds of 600 km/sec. This continued to be the case until the back of the cloud passed the satellites on January 12. Then, the contact with the slower-moving, normal solar wind flow was re-established.

Magnetic Field: Before January 10, the satellites were in contact with the solar wind’s magnetic field which had a strength of about 5 nT (The unit ‘nT’ means nanoTesla and is a measure of magnetic field strength. The Earth’s magnetic field is 50,000 nT at the surface). As the satellites encountered the leading edge of the CME between January 10 and January 11, the magnetic field tripled in strength. It then returned to the normal solar wind level after the back-side of the CME Front was encountered on January 11.

Combining the Clues:

Once the students have interpreted each trace, we can combine them into a simple model of the CME cloud, but not what the entire cloud looks like in three dimensions.

The solar wind, in this instance, has a temperature near 100,000 C, a density of about 10 particles per cubic centimeter, a speed near 400 kilometers/sec, and a magnetic field strength of 5 nT.

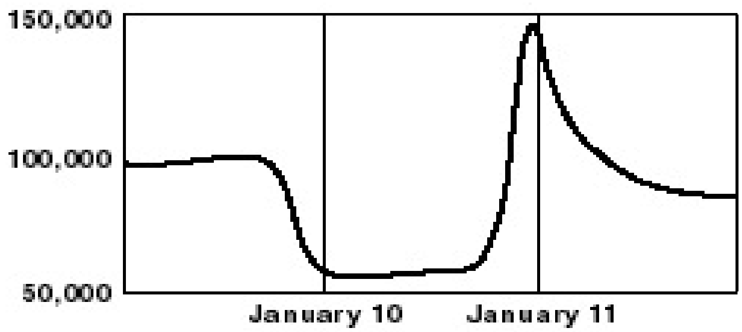
The leading edge of the CME contains a strong magnetic field. Although there is no change in the gas density and the solar wind speed , the entire magnetic field of the CME seems to be concentrated there. The magnetic field is responsible for the drop in solar wind temperature in this region. Scientists call this the CME ‘magnetic cloud’ region.

The back edge of this ‘magnetic cloud’ coincides with a sharp increase in gas density and temperature which defined the CME cloud boundary in what scientists call a ‘shock front’. Behind this shock front there is a fast-moving , but low density gas. In the interior of the CME cloud ‘bubble’ region, the gas density decreases with distance from the shock front, until it eventually returns to the temperature of the solar wind. Behind the fast-moving interior bubble is the back-side of the CME which is where the conditions have returned to those of the normal solar wind.

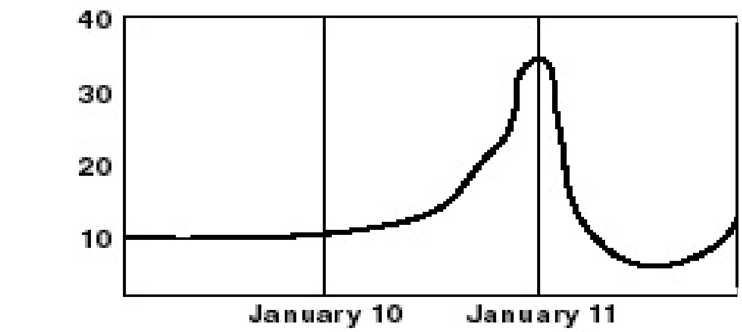
Traveling at a top speed of 500 kilometers/sec, the entire cloud took two days to pass the satellites. This means the thickness of the CME was about 86 million kilometers (500 km/sec x 2 days x 86,400 sec/day). This is about half the distance between the Sun and the Earth. Since the satellites were located about two million kilometers from the Earth, it took the cloud only about 30 minutes to reach the Earth on January 12.

Name ______________________________

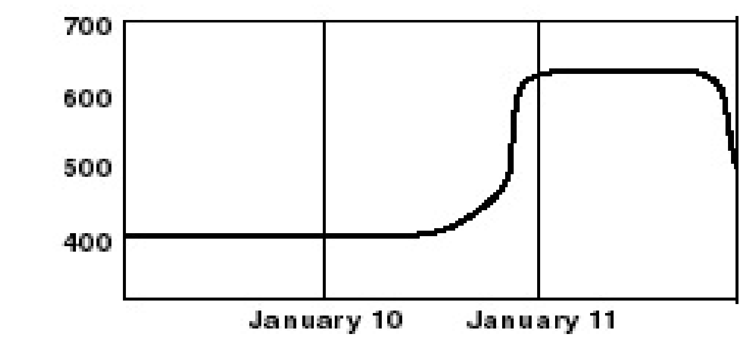
Date________________



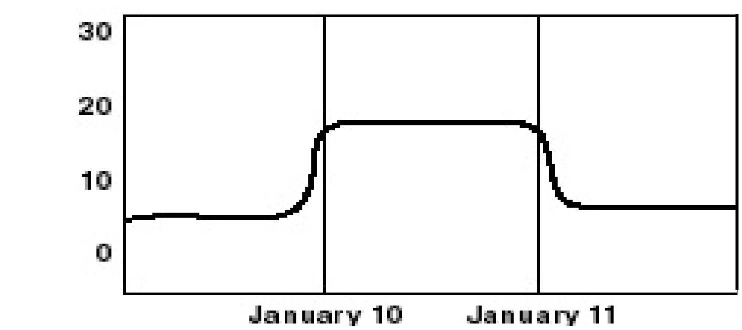
Temperature
(in degrees Celsius)



Density
(in particles per cubic centimeter)



Speed
(in kilometers/second)



Magnetic Field
(in nanoTeslas)

What is Solar Activity?

The Sun, our nearest star, provides us with warmth and light. For many civilizations, the sun was thought to be a perfect orb, free of blemishes, eternal and changeless. **Sunspots** are the most well known hints that the Sun's surface is constantly changing. Larger than the Earth, and with magnetic fields that are 10,000 times stronger than the Earth's, sunspots are the breeding grounds for some of the most violent storms in the solar system!

The number of sunspots increases and decreases in cycles that last from 6 to 17 years; the **Sunspot Cycle.** With modern technology and space satellites, this solar activity cycle can now be detected in the ebb and flow of other phenomena on the Sun and on the Earth. Among the most enigmatic storms are the **solar flares** that erupt near sunspots. In a matter of 20 minutes, magnetic fields can heat gases to tens of thousands of degrees and release more energy than a thousand atomic bombs. Some of this gas can be hurled out from the Sun at millions of kilometers per hour in what are called **coronal mass ejections.** Both solar flares and coronal mass ejections can be very disruptive to human activity on earth and in space.

The outer atmosphere of the Sun, the **corona,** is familiar to many people who have watched total eclipses of the sun. The solar wind extends billions of kilometers further out into space than the corona**.** Like invisible roadways spanning the solar system, the magnetic field from the Sun flows out from the solar surface. Matter ejected from the Sun flows radially outwards from the solar surface. From the time a solar storm is seen on the Sun, it can take 2-3 days for the gas to travel to the orbit of the Earth, and if the Earth happens to be in the wrong place at the wrong time, it will be hit by a million-kilometer wide wall of high temperature gases and magnetic fields.

Anyone can tell you that a compass points 'north' because the Earth has a magnetic field, but until the advent of the Space Age, no one understood what this field really looked like or was capable of doing. Since Gilbert proposed in the 17th century that the Earth was a giant magnet, scientists have wondered just how this field is shaped, and how it has changed with time. The geomagnetic field which gives us our familiar compass bearings, also extends thousands of kilometers out into space in a region called the **magnetosphere**. On the Sun-side, it forms a protective boundary called the **bow shock.** Stretching millions of kilometers in the opposite direction behind the Earth is the **magnetotail.**

The solar wind blows upon the magnetosphere and gives it a wind-swept shape, but when solar storms and solar wind streams reach the Earth, the magnetosphere reacts violently. On the side nearest the impact, the magnetosphere compresses like squeezing a balloon, leaving communications satellites exposed. On the opposite side, it is stretched out, past the orbit of the Moon, or Mars and even Jupiter! The geomagnetic field is remarkably stiff, and so most of the solar wind is deflected or just slips by without notice. But some of the matter leaks in and takes up residence in donut-shaped clouds of trapped particles, or can penetrate to the atmosphere to produce aurora.

For thousands of years, humans have been treated to spectacles of glowing clouds above the northern horizon at night. Reports of these mysterious Northern Lights abound in the oral histories of the northern natives. On rare occasions, even ancient Greek and Chinese texts have mentioned them. It wasn't until 1896 that the Norwegian physicist Kristian Birkeland deduced that flows of electrons from the Sun were channeled into the polar regions by the geomagnetic field, and upon colliding with the outer atmosphere, would stimulate oxygen and nitrogen atoms to cast their ghostly and inspiring curtains of light.

The **Aurora Borealis** (near the north pole) and the **Aurora Australis** (near the south pole), as the 'Northern Lights' are more formally called, are seen most often in a band located at a latitude of 70 degrees, and about 10 degrees wide in latitude. From space, the auroral zone looks like a ghostly, glowing donut of light hovering over the north and south poles. This **auroral oval** can easily be seen in images from satellites designed to detect it. Its brightness and size change with the level of solar activity. Aurora come in many shapes and colors depending on what is happening to the geomagnetic field and the flows of charged particles and plasmas trapped in this field.

Magnetic sub-storms happen when the geomagnetic field is suddenly changed because of small changes in the magnetic polarity of the solar wind as it passes the Earth. Typically, magnetic storm aurora, also called **auroral storms,** last only a few hours. They begin in the evening as arcs of colored light which slowly change into rayed-arcs and the familiar folded ribbons or bands. Expanding over the whole sky, the folded bands are colorful, with green rays and red lower borders which change from minute to minute and move rapidly across the sky like some phantasmagoric serpent. After an hour, the auroral shapes become more diffuse and less distinct.

Geomagnetic storms are more severe than magnetic sub-storms and are caused by major changes in the direction and density of the solar wind as it reaches the Earth. These events are the most remembered historically as 'Great Aurora' or as the most disruptive to radio communications. The entire geomagnetic storm can last for several days as the particles and fields around the Earth continue to readjust themselves to the passing and ebbing solar wind.They begin with an ejection of mass by the Sun, and the impact of this plasma on the magnetosphere. Fast-moving coronal mass ejections produce shock waves in the solar wind, and this compression intensifies the density of particles impacting the magnetosphere. As the solar wind shock passes across the magnetosphere and magnetotail, magnetic fields re-orient and reconnect, releasing enormous amounts of energy and accelerating trapped particles to high speeds. These charged particles then travel down the geomagnetic field in huge currents, which cause bright and long lasting auroral displays.

Solar storms and the effects they produce in the Earth's environment, have been known for decades to be responsible for many harmful effects upon human technology on the ground and in space. Solar storms are known to do far more than just paint the sky with pretty colors! The multi-billion dollar 'Global Positioning System' consists of a constellation of over a dozen navigation satellites orbiting within the Van Allen radiation belts. These satellites let humans find their position anywhere on Earth using a hand-held receiver no bigger than a pocket calculator.

During solar storms, these positions are quite a bit less accurate than under calm conditions, which in turn impacts the navigation of ships at sea and jets in the air. Solar storms have disabled multi-million dollar communication and navigation satellites such as Anik-A, Molynia, Marecs-A, and they have been implicated in many electrical problems that were experienced by other satellites.

Solar storms were responsible for causing the Skylab to burn up in the atmosphere sooner than expected, and for altering the orbits of hundreds of other satellites and even the Space Shuttle itself. A storm on March 13, 1989 knocked out the Quebec-Hydro power system, plunging 6 million people into darkness for 9 hours. Geomagnetic storms cause the magnetic field near the Earth's surface to change rapidly in just a matter of minutes or hours. These changes cause electrical currents to flow within long power transmission lines, telephone wires, and even in pipelines which makes the pipes corrode, sometimes with tragic consequences. On June 5, 1991 a natural gas pipeline in Russia was weakened by corrosion and began to leak its deadly, flammable cargo. A passenger train, loaded with 1,200 people, ignited the liquefied gas and caused an explosion equal to 10,000 tons of TNT. Over 500 people were killed, and 700 more were badly injured.

Would you believe...

Aurora can never get closer to the ground than about 60 kilometers.

A sunspot has a temperature of nearly 4000 C, and would be brighter than the full moon if placed in the night sky.

Sunspots are often several times larger than the entire earth.

The Sun rotates once every 25 days at the equator, but takes up to 36 days to rotate once around at the poles.

The corona of the Sun is over 5 million degrees hotter than the surface of the Sun.

The Earth's magnetic north pole is actually a magnetic south pole because the north end of a bar magnet is attracted to it.

The total power produced by an auroral event can exceed 1 million megawatts and produce voltages over 100,000 volts in the upper atmosphere.

Aurora are produced where the atmosphere has the same density as the vacuum inside a light bulb.

Some aurora occur at altitudes of over 1000 kilometers above the Earth's surface.

Lightning storms can eject particles into space at nearly the speed of light, and they are seen as 'sprites' on the top side of a thundercloud.

A single lightning storm can be detected on the other side of the earth because some of its radio energy travels along the local magnetic field lines that connect the pairs of points on the surface of the Earth that can be thousands of kilometers apart.

Glossary

Aurora : Also called the 'Northern Lights' in the Northern hemisphere, or the 'Southern Lights' in the Southern hemisphere. These wispy curtains of light in the sky are caused by energetic electrons which collide with atoms of oxygen and nitrogen in the air to cause these atoms to emit shades of green, red and blue light. They never descend nearer than 60 kilometers from the Earth's surface.

Corona : The very tenuous outer layers of the Sun which are seen during a total eclipse of the sun, but extending millions of miles into interplanetary space. It is heated to temperatures of over one million degrees by magnetic activity at the surface of the Sun. For decades, scientists puzzled over why the Corona could be so much hotter than the balmy 5770 degree Kelvin surface of the Sun.

Coronal Mass Ejection : The sudden expulsion of matter from the coronal regions of the sun, often involving billions of tons of plasma ejected at over one million kilometers per hour. During sunspot minimum conditions, about one 'CME' can be expelled every few days. During sunspot maximum conditions, as many as 3-5 can occur each day.

Magnetopause : A region that defines the outer edge of the magnetosphere where the pressure of the solar wind is balanced by the pressure of the earth's own magnetic field.

Magnetosphere : The region surrounding the Earth in space where its magnetic field is important in controlling the movements of charged particles. Also sometimes referred to as 'Geospace'.

Magnetotail : The solar wind pulls the magnetosphere into a comet-like shape. The long tail of this field, called the magnetotail' or also the 'geotail', extends millions of miles into space in a direction opposite to the Sun from the Earth.

Solar flare : A powerful release of energy on the surface of the sun usually lasting less than a few hours, but releasing as much energy as 1000 hydrogen bombs. These are often associated with active regions of the solar surface where magnetic fields have become badly tangled, and then snap, releasing energy and heating local gases to over 1 million degrees.

Solar storm : Although scientists prefer not to use this term because it is technically rather vague, it has come to mean any of a number of active conditions on the Sun's surface including flare activity or coronal mass ejections.

Sunspot : A dark spot on the Sun's surface that indicates a concentration of magnetic forces. They are actually about 2000 degrees cooler than the solar surface, and only look dark because they emit light faintly.

Sunspot Cycle : The change in the number of sunspots from one period of its maximum to the next, over the course of about 11 years.

Sunspot Maximum : The period during the sunspot cycle when you will see the largest number of sunspots. Also called the 'Solar Maximum'.

Sunspot Minimum: The period during the sunspot cycle when you will see the fewest number of sunspots. Also called the 'Solar Minimum'

Resources

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