National Aeronautics and
Space Administration

Educational Product	
Educators & Students	Grades 5-8

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Solar Storms and You!

Exploring the Human Impacts of Solar Activity

An Educator Guide with Activities in Space Science

Solar Storms and You! is available in electronic format through NASA Spacelink - one of the Agency's electronic resources specifically developed for use by the educational community.

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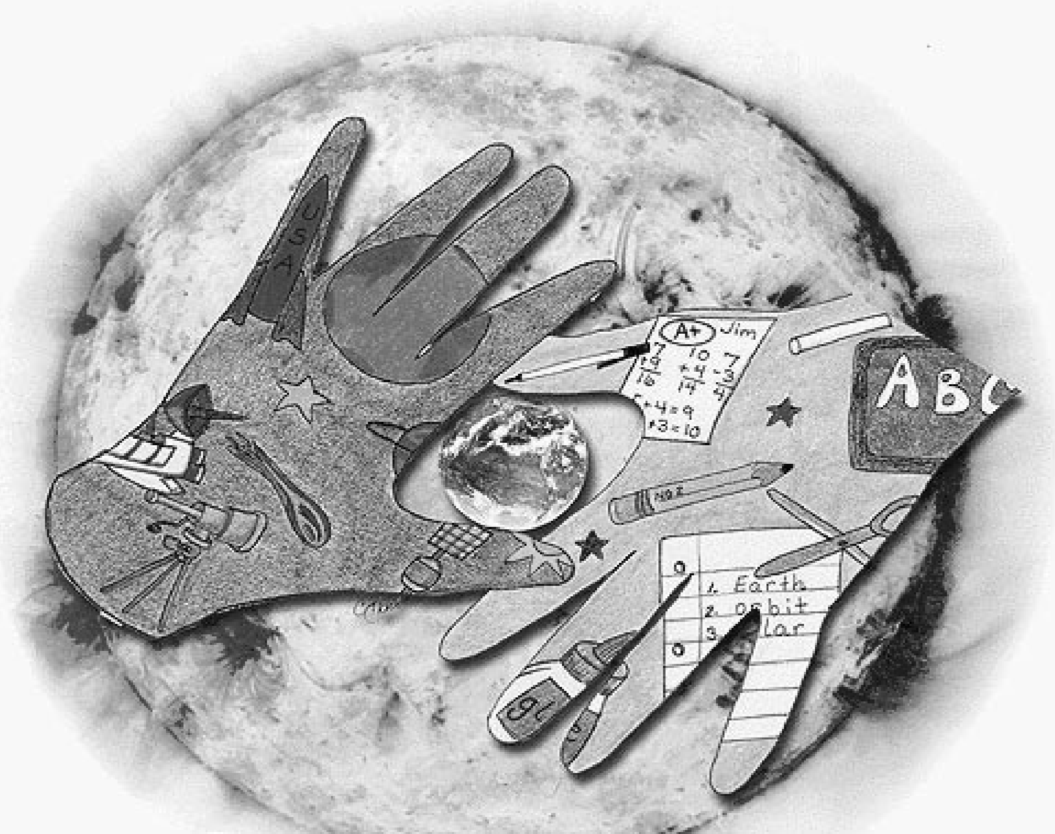

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Information about the IMAGE mission is available at:

http://image.gsfc.nasa.gov
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Resources for teachers and students are available at:

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

National Aeronautics and
Space Administration
Goddard Space Flight Center

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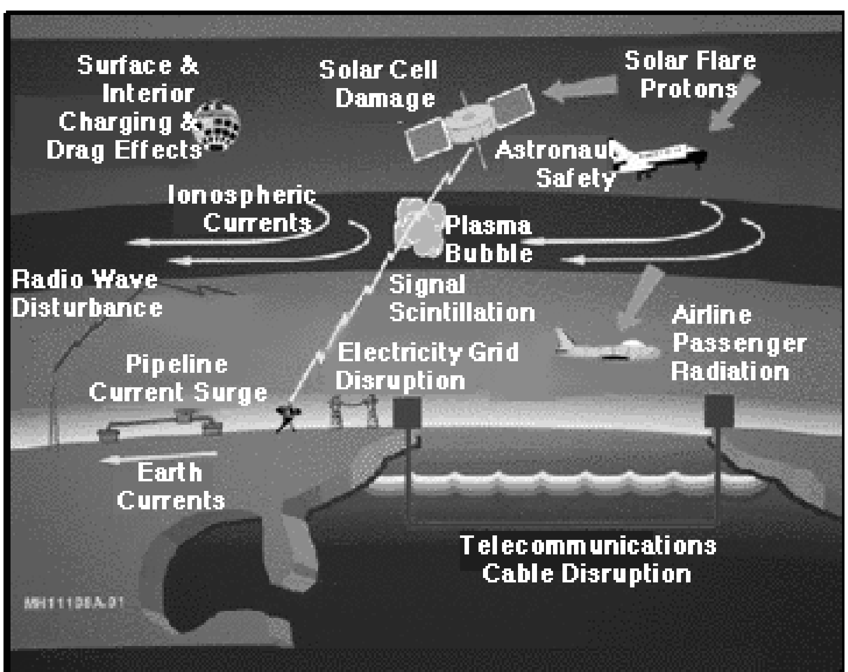


Image Credit: L. J. Lanzerotti, Bell Laboratories, Lucent Technologies, Inc.

Solar activity produces a variety of impacts upon our technology, both in space and on the ground.

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 sunspots exist, but long ago we used to be!

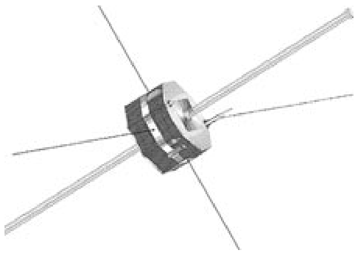
Ancient Chinese sun observers knew that, from time to time, dark spots would glide slowly across the face of the setting sun. Once seen only as portends of political upheaval, we now see them as natural phenomena that can forewarn us of impending storms that can have dire consequences for us if we ignore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

Science Process Skills

for *Solar Storms and You!*

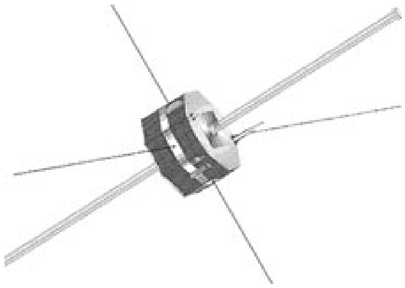


This chart is designed to assist teachers in integrating the activities contained in the guide with existing curricula.

Lesson

	1 *"Satellites*	**2** *"Air Travel"*	**3** *"Glitches"*	**4** *"Sunspot Numbers"*	**5** *"Trip to Mars"*
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.

Lessons

	1	2	3	4	5
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					

Human Impacts

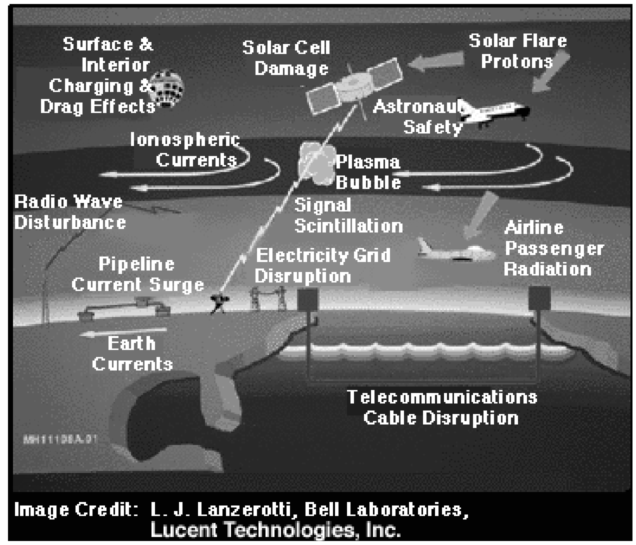


Image Credit: L. J. Lanzerotti, Bell Laboratories, Lucent Technologies, Inc.

As scientists have continued to study the sun and its many influences upon the earth, they have discovered many subtle interconnections. Apart from its obvious warmth and light, the sun produces many other dramatic impacts upon humans and their activity on the ground and in space.

Solar storms have interferred with the smooth operation of satellites in space. Sometimes satellites have been damaged because of electrical problems or false commands triggered by high energy charged particles.

The most dramatic effects involve power black outs caused by solar storms such as the one that occurred on March 10, 1989. A surge of electricity caused part of the power grid in eastern Quebec to shut down for hours.

During the early 1600s observers saw very few sunspots, and no cyclic changes in their numbers. This was also a time when Europe was affected by the so-called 'Little Ice Age'. Similar climate and solar activity correlations have also been found by studying ancient Chinese sunspot records going back thousands of years. Whenever solar activity seems to be dramatically low, or absent for a few decades, some part of the Earth seems to experience a major cooling episode.

Solar activity also affects the amount of light and heat we receive at the earth. Since the 1970s sensitive satellites have measured the power output of the sun. You would expect that when dark sunspots are present that the sun should be a little less bright. In fact the opposite is seen! This happens because sunspots are accompanied by brightenings of the surrounding solar surface far away from the darkened sunspot region, and this brightening more than compensates for the loss of light due to the sunspot itself.

Teacher's Guide

Solar Storms and Satellites

Introduction

Solar storms have long been known to affect delicate electronic circuitry in satellites orbiting the Earth. Given that the commercial, military and scientific satellite resources exceed $200 billion dollars, the issue of satellite vulnerability to solar storm damage is not only a serious consideration in satellite design, but also a highly controversial topic when specific instances are examined in detail.

Objective

Students will read to be informed.

Procedure

1) Students read "Forecasting Solar Storms" and answer the questions.

2) Discuss the answers and the article.

3) Students read "Solar Storm Eyed as Satellite Killer".

4) Construct a graphic organizer to compare and to contrast the two articles. Some of the items mentioned in both are $200 million Telstar 401 satellite, and the SOHO satellite. Both articles also mention the 1997 event, Stephen P. Maran's quote, " This is the first time a solar event has been captured from cradle to grave". It took the January 7 event, 3 3/4 days to reach the Earth, and other spacecraft that monitored the event.

5) Answer the remaining questions.

Materials

—A copy of "Forecasting Solar Storms" for each student.

—Student question sheet

—A copy of "Solar Storm Eyed as Satellite Killer"

—Student question sheet

Key Terminology:

Coronal Mass Ejection: A sudden expulsion of matter from the coronal regions of the Sun with typical speeds of millions of kilometers per hour.

Magnetic sub-storm: A rapid change in a portion of the magnetic field of the earth lasting hours to minutes.

Forecasting Solar Storms

Dr. Sten Odenwald (Raytheon ITSS and NASA Goddard Space Flight Center)

Solar storms are a problem. A big problem. Chances are you have never heard of them at all because, unlike the conventional storms that produce rain and thunder, solar storms are remote and distant. It really all depends on where you are and who you are. If you are an astronaut walking on the moon, a solar storm could give you a lethal dose of radiation in a matter of a few minutes. If you happened to be in Quebec on March 13, 1989, your entire province would have been blacked-out by a solar storm-induced power outage. If you were dialing '911' from a cellphone, the solar storm would have prevented your call from going through.

Scientists have spent a lot of time trying to predict solar storms so that, like hurricane warnings, we can have at least some forewarning of their approach. When solar storms buffet the earth's magnetic field they can, and often do, raise havoc with radio communication, power transmission, and even satellite functions. Nothing in our high-tech world seems to be entirely immune from the outfall from solar storms.

The sun and the wind from the sun are under around the clock surveillance by a network of ground-based, and satellite-based observatories such as SOHO, the Solar Heliospheric Observatory, and ACE, the Advanced Composition Experiment, to name a few. Other spacecraft orbiting the earth measure the changes in the earth's magnetic field and the populations of high-energy trapped particles which circulate within this vast magnetic bottle. Our sun has only recently begun to emerge from its lowest point in the famous 'sunspot cycle'. This ebb and flow of solar activity lasts an average of 11 years from peak to peak, with the current cycle, Number 23, destined to reach maximum in the summer of 2000.

Even though near its low point in the cycle, the sun has treated scientists to many spectacular storms which have reached earth and, in so doing, demonstrated that space weather forecasting is not an idle activity. On January 7, 1997, a region of intense activity on the sun's eastern sector launched a billion-ton gas cloud called a coronal mass ejection (CME) which, 3 3/4 days later, reached Earth. Its transit and arrival was monitored by 20 scientific research satellites as part of the International Solar-Terrestrial Physics program (ISTP). According to NASA astronomer Dr. Stephen Maran, "This is the first time a solar event has been captured from cradle to grave".

A small part of the million kilometer-wide cloud brushed by the earth, and shook the magnetic field of the earth for over 24 hours like a flame flickering in a breeze. This geomagnetic storm and the particles comprising it allegedly affected the operation of a $200 million Telstar 401 communications satellite which had to be taken out of commission on January 17 according to articles published in Sky and Telescope magazine (July, 1997 page 20) and Aviation Week and Space Technology (January 27, 1997 page 61-62).

With the upcoming 'solar maximum' approaching, and with our rapidly escalating dependence on satellite communication technology in the 21st century, additional space weather forecasting satellites will be launched so that as the older satellites reach the ends of their operating lifetimes, new generations of early-warning satellites will be on the scene to give scientists the data they need to make accurate forecasts in the next century.

Solar Storm Eyed as Satellite Killer

Dr. Sten Odenwald (Raytheon ITSS and NASA Goddard Space Flight Center)

On January 7, 1997 it seemed to be an ordinary day on the Sun. White light photographs taken at several ground-based solar observatories showed the surface to be quite ordinary. In fact, to the eye and other visible wavelength instruments, the images showed nothing at all. Not so much as a single sunspot.

But X-ray photographs taken by the YOHKOH satellite from earth orbit revealed some serious trouble brewing. High up above the solar surface in the tenuous atmosphere of the corona, invisible lines of magnetic force, like taught rubber bands, were coming undone. On January 6th, satellite images showed a coronal storm brewing from a small region of the corona, only a few hundred times the size of the Earth.

By Tuesday, January 7, solar astronomers recognized that a major Coronal Mass Ejection event was in progress, and in a sequence of daily X-ray images, the details of the event played themselves out in a deadly dance of magnetic fields, plasma and electromagnetic radiation.

The dance lasted several days, but by its end, a cloud of plasma was hurled away from the Sun at 1 million miles an hour. It crossed the orbit of Mercury in less than a day. By Wednesday it had passed Venus: An expanding cloud over 30 million miles deep, spanning the space between the orbits of Mercury and Venus. As NASA astronomer Stephen Maran noted about the 20 satellites that had monitored this event, "This is the first time a solar event has been captured from cradle to grave".

Despite the scientific excitement over this storm, it had other repercussions that were far less welcomed. The problem is that, even with detailed information about an incoming solar cloud, short of moving the earth out of the way, there was nothing we could do in the face of this looming calamity. All scientists could do was to sit back and cross their fingers that the Earth's magnetic field would repel most of the cloud like some gigantic security blanket. After all, it had done so for million of years in the past! But today, our daily sphere of activity extends off the surface of the Earth and far into space.

High up above the United States, AT&T's $200 million Telstar 401 satellite was busy relaying television programming between many destinations across the continent. Public Broadcasting Stations, ABC News and even the Home Shopping Channel were among its regular paid subscribers for the precious few channels that the satellite could re- broadcast back to our home television sets and to cable channel owners on the ground. Telstar 401 was launched from Cape Canaveral on December 13, 1993 and was the first of a fleet of modern communications satellites developed by Lockheed-Martin, and equipped with many new technologies. It was designed to last 12 years, but on Saturday, January 11 AT&T announced that it was having some communications difficulties with the satellite. Its day of reckoning had arrived, as the interplanetary coronal storm cloud, now over 30 million miles wide, slammed into the Earth's magnetosphere. Even the images from the YOHKOH satellite began to deteriorate as the plasma particles and magnetic fields invaded the delicate electronic circuitry, corrupting the images with noise.

In a report by Aviation Week and Space Technology (AWST) magazine (January 27, 1997, p. 61) the Telstar satellite "...suffered a massive power failure on Jan. 11 rendering it completely inoperative. Scientists and investigators believe the anomaly might have been triggered by an isolated but intense magnetic substorm, which in turn was caused by a coronal mass ejection...spewed from the Sun's atmosphere on Jan. 6". Some scientists were not so ready to implicate the solar storm in the damage to the satellite. Robert Hoffman, a NASA scientist, is quoted in AWST as saying that although the satellite was located in an affected area of the magnetosphere, "We have no idea what caused the failure".

Despite a number of attempts at diagnosing and repairing the problem with Telstar 401, on Saturday, January 17 AT&T had given up the effort and announced that they had lost the satellite. Paradoxically, no military satellites were apparently affected by this particular storm, and Hughes Space and Communications which manufactured over 40% of the commercial satellites now in orbit had also not received any reports of any anomalies related to the storm. According to AWST, Lockheed Martin which built the Telstar 401 satellite was investigating whether the failure could have been due to some problem in its design. Three earlier-model satellites were also disabled in 1994 by a solar storm which triggered electrical failures in these satellites: Intelsat K and two Canadian Anik television satellites. Two of them made partial recoveries but the third was lost completely. (AWST January 31, 1994 p. 28).

Satellite engineers and scientists are cautious to admit the sun was ultimately to blame when hundreds of millions of dollars are at stake and law suits could result from the wrong answers. For reasons of national security, there is also a good reason not to provide information about how vulnerable our military satellites may be to solar storm ‘attack’, perhaps emboldening an enemy to launch their own activities under the cloak of a solar storm event.

Many newspapers stories were ultimately filed about the January 1997 solar storm and its fallout, and on January 30, 1997 even George Will at the Washington Post, who normally covers political stories, wrote “Astronomy's Answer”, an anguished editorial about space calamities that can, and will, affect us.

Name ____________________________

Date________________

Reading to be Informed

"Forecasting Solar Storms"

1. **When a powerful solar wind buffets the Earth's magnetic field, what havoc can occur?**

2. **Name a satellite mentioned in the article and describe the events it photographed.**

3. **What was probably caused as a result of the power surge?**

4. **According to the article, what are the implications for future forecasting. and why do you think scientists consider forecasting to be so important?**

5. **Name some electronic gadgetry, according to the article, that is prone to disruption.**

6. **Summarize the article in your own words.**

7. **Why might a solar storm impact your life, and how might space weather forecasting be useful to you?**

Name ______________________________

Date_________________

Reading to be Informed

"Solar Storm Eyed as Satellite Killer"

1. **In your own words, describe the solar storm and its results.**

2. **What is the meaning of the quote "This is the first time a solar event has been captured from cradle to grave" ?**

3. **What was the cost of the Telstar 401 satellite?**

4. **The satellite was insured for $145 million. For what percent of the original cost was the satellite insured?**

5. **The satellite was launched in _______ and was designed to operate for _______ years. What would that cost breakdown per year be, assuming that the value of the satellite decreased by 10% the first year, 9% the second year, and 8% the third year? (Remember, the satellite was launched in 1993, therefore for this case, year one will be 1994.)**

   1994
   1995
   1996

6. **Why would we not include 1997 in the cost breakdown?**

7. **The CME cloud was traveling at a speed of 1 million kilometers/hr, how far was the cloud after Day 1, Day 2, Day 3 and Day 4? Explain what you think will happen when it reaches the Earth.**

8. **What do you think about solar storms and their impact on you in the future?**

Sample Responses For Graphic Organizer

(Students may choose an organizer such as a Venn Diagram)

"Forecasting Solar Storms"

Trying to predict when a solar storm will happen.
Why we should forecast solar storms.
Solar storms affect the earth, like blackouts.
Solar storms raise havoc with radio transmissions and satellites.
Solar cycle
Improvements being made in science
Mainly about forecasting solar storms

Common Elements to the Stories:

Solar Storms
Telestar 401 satellite
$200 million dollar
Same author
NASA
TV and radio quotes
Studying about space
ACE and SOHO
Both had the quote by Stephen Moran, "This is the first time a solar event has been captured from cradle to grave".

"Solar Storm Eyed As Satellite Killer"

Coronal mass ejections
Magnetic field
Mostly one event
Communications disruptions
Telestar - what it does, where it was launched, and who made it
Maybe solar storms are satellite killers
YOHKOH
Talks about one major event
Mainly about solar storms destroying a satellite

Selected Responses

"Solar Storm Eyed as Satellite Killer"

1. In your own words, describe the solar storm and its results.

A solar storm is a discharge of particles from the Sun that can cause the Northern Lights, blackouts, and communication problems.

A solar storm is when particles shoot from the Sun and can cause Earth a lot of trouble. It can cause a power surge and the electricity can go out.

A solar storm is where a lot of particles fly out from the Sun. One thing that they can do is interfere with communications.

The solar storm described is radiation, magnetic forces, and particles from the Sun. It's results are blackouts and non-communication. It also causes the Aurora Borealis, they are a bluish greenish color.

A solar storm is a storm on the Sun. Power surges can happen and also lots of radiation is in space.

A solar storm is when billions of particles meet the atmosphere and cause the aurora. Some results are cell phone not working and magnetic fields are disrupted.

The solar storm is when blasts of energy shoot out from the Sun. They sometimes mess with the Earth's magnetic field. They can also disrupt cell phone connections.

A solar storm is like a huge nuclear bomb, only out in space. So by the time the storm reaches the Earth, it's not so powerful. We only get our radio communications messed up and other things like power transmitters messed up.

Solar storms are ejections of particles from the Sun. They can do a lot of damage to satellites.

2. What is the meaning of the quote "This is the first time a solar event has been captured from cradle to grave" ?

It means that this is the first time a solar event has been seen from the time it starts until the time it ends.

It means that it's the first time a solar event has been captured from beginning to end.

They saw the storm from satellites when it started until it ended.

Selected Responses

"Solar Storm Eyed as Satellite Killer"

3. What was the cost of the Telstar 401 satellite?

The cost of the Telstar 401 satellite was $200 million.

The satellite cost 200 million dollars.

The satellite cost 200,000,000 dollars.

4. The satellite was insured for $145 million. For what percent of the original cost was the satellite insured?

The satellite was insured for 72.5 %.

The percentage insured for the Telstar 401 satellite was 72.5% of the original $200 million.

5. The satellite was launched in _______ and was designed to operate for _______ years. What would that cost breakdown per year be, assuming that the value of the satellite decreased by 10% the first year, 9% the second year, and 8% the third year? (Remember, the satellite was launched in 1993, therefore for this case, year one will be 1994.)

1994 $180,000,000
1995 $163,800,000
1996 $150,696,000

6. Why would we not include 1997 in the cost breakdown?

We would not include 1997 in the breakdown because the satellite suffered a massive power failure and they lost it.

The storm that disabled it was on January 7th and this is close to the beginning of the year.

We would not include 1997 in the cost breakdown because that is when the cloud messed it up.

You would not include 1997 in the cost because the satellite was disabled by a solar storm then.

Selected Responses

"Solar Storm Eyed as Satellite Killer"

7. The CME cloud was traveling at a speed of 1 million kilometers/hr, how far was the cloud after Day 1, Day 2, Day 3 and Day 4? Explain what you think will happen when it reaches the Earth.

Day one - 24 mil. km; Day two - 48 mil km; Day three - 72 mil. km; Day four - 90 mil. km

I think that when it reaches the Earth it will cause a blackout.

The CME cloud will mess up satellites.

I think that the magnetic field will block most of it, but what comes down may affect a power outage.

8. What do you think about solar storms and their impact on you in the future?

I think in the future solar storms ,I feel, will not impact us as much because we'll have better forecasting and ways of protecting us a little. I think solar storms are a very interesting thing we should continue to study.

I think that solar storms are interesting to learn about but they cause many things to go wrong on Earth, like putting out cell phones and causing satellite disruptions that take a while to repair.

I think that solar storms will cause blackouts and suspenseful moments in my life, but not much else.

I think that the storms are neat and the impact on ones life is strange. Well in the future we may have space colonies and a solar storm could be disastrous.

I think that it is weird all this stuff that is going on out in space that I don't know about. The worst thing that can happen is a blackout, I think.

I think that solar storms will not have a huge effect on me because I like power outages and I don't have a television or a phone.

Selected Responses

"Forecasting Solar Storms"

1. When a powerful solar wind buffets the Earth's magnetic field, what havoc can occur?

When a powerful solar wind buffets the Earth's magnetic field, havoc with radio communication, power transmissions, and even satellite functions can occur.

Havoc can occur with radio communication, power transmissions, and satellite functions.

When solar storms buffet the Earth's magnetic field, they can raise havoc with radios, power transmissions, or even satellite functions.

Powerful solar winds can cause radio communication trouble, power transmission trouble, and also satellite trouble. Blackouts can occur and even powerful explosions.

2. Name a satellite mentioned in the article and describe the events it photographed.

One satellite mentioned was SOHO. This photographs the Sun and detects the wind from the Sun.

SOHO is a satellite mentioned in the article, that is the Solar Heliospheric Observatory. It photographs the Sun and the wind from the Sun.

The Ace, Advanced Composition Experiment, photographed the Sun and the wind from the Sun.

Two satellites mentioned are the SOHO and ACE. They measure the changes in the magnetic field, also high energy particles which circulate past.

The satellite SOHO took pictures of gas clouds which are called coronal mass ejections.

3. What was probably caused as a result of the power surge?

On March 13, 1989, the entire province would have been blacked out.

If you lived in Quebec on March 13, 1989 your entire province would have been blacked out because of a solar storm induced power outage.

The black out in Quebec on March 13, 1989 was probably caused as a result of the power surge.

In result of the power surge, a $200 million Telstar 401 satellite was knocked out.

Selected Responses

"Forecasting Solar Storms"

4. According to the article, what are the implications for future forecasting. and why do you think scientists consider forecasting to be so important?

According to the article, the implications for future forecasting are that as the older satellites kind of die out, new satellites will already be there. I think scientists should consider forecasting so important because they will need to prepare to know when havoc and catastrophe can be prevented.

The implications for future forecasting was to launch the new and improved satellites so that as the older satellites reach the ends of their operating lifetimes, new generations of early warning satellites will be on the scene to give scientists data. They need to make accurate forecasts. I think scientists consider forecasting so important because it helps other people to know what's going on and to be ready for what comes.

The implications for future forecasting are that more satellites will be giving the scientists more accurate forecasts in the next century. Forecasting is so important so that we know when communication may go down.

According to the article, some implications for future forecasting would be to be looking for more solar storms to know when to tell us to put away our satellites and to be able to forecast when a solar maximum is coming, which means major solar storm.

Some implications for future forecasting are that additional space weather forecasting satellites will be launched so that new generations of satellites will give scientists the data needed to make more accurate forecasts in the future, thus preventing damages.

5. Name some electronic gadgetry, according to the article, that is prone to disruption.

Some electronic gadgetry that is prone to disruption are the satellites and the cell phones.

Some things that are prone to disruptions are power transmissions, satellite functions, and radio communications.

6. Summarize the article in your own words.

Solar storms have been a problem over the years. Some places in the world have been affected by these storms. Scientists have been trying to study the storms so if it was to happen again we would have some kind of warning. The satellites have brought back a lot of information about the sun and the wind from the sun which helps the scientists to keep track of what is going on. Scientists now have a new generation of early warning satellites that will be launched to take the place of the old ones. Scientists now expect to get the data they need to make better updated forecasts about solar storms.

Selected Responses

"Forecasting Solar Storms"

Solar storms are a big problem and can blackout your entire province. Scientists have been trying to predict solar storms so that we can have at least some forewarning of their approach. With the upcoming 'solar maximum' approaching, additional space weather forecasting satellites will be launched so that the new generations of satellites will give scientists the data to make accurate forecasts in the next century.

Solar storms are a big problem. This article tells how solar storms are made. They are made from the sun, a wind from the sun makes the Earth's magnetic field circulate with vast magnetic particles. Scientists are figuring out a way to get the forecast for the future that will help in the next century by replacing old satellites with new ones.

7. Why might a solar storm impact your life, and how might space weather forecasting be useful to you?

The solar storm may impact my life because we would have no way to communicate and no way to tell what would happen next because the phones and probably the television would be blacked out. Space weather forecasting is useful to me because I will have an idea of what will happen and I could be prepared.

A solar storm would impact my life because blackouts and the use of satellites and cell phones may be disrupted. Space weather forecasting would be useful so I would know when to put away supplies and so scientists know when to put away satellites.

A solar storm might impact your life because the Aurora colors are so beautiful. You would remember them forever, they might inspire you. Also if there was a blackout, you would also remember that event. You could be prepared.

A solar storm might impact me by causing a blackout. As a result, all electronics could go out and this would affect us greatly. Space weather forecasting would be useful because they could warn us when these storms would or will happen, and they can tell us what to do and how to deal with the blackouts before they happen.

Teacher's Guide

Cosmic Radiation Creates Unfriendly Skies

Introduction

On the Earth's surface, we are protected from the harmful effects of cosmic rays by the atmosphere. During a trip in a jet plane at altitudes of 30,000 feet, cosmic rays and other energetic particles pose a great problem and can lead to significant health risks, especially for airline pilots.

Objective

The student will read to be informed, and write a letter to persuade based on the article that was read.

Procedure

1) Students read the article "Cosmic radiation creates unfriendly skies".

2) Allow sufficient time for the students to complete questions #1 through #10.

3) Discuss the student responses to questions #1 through #10.

4) Allow students a sufficient amount of time to prewrite the letter.

5) Group students in pairs. Assign one member of the pair to be "A" and the other member to be "B". Student "A" reads the letter to student "B" and receives suggestions. Allow five minutes for the peer review. Then student "B" reads the letter to student "A" and receives suggestions. Allow five minutes for the peer review.

6) Separate the students for individual work.

7) Students complete the final copy of the letter.

Materials

—"Cosmic radiation creates unfriendly skies"

—Student question sheet

—Lined paper

Scoring rule: Writing to persuade.

2=Consistently addresses audience's needs by identifying a clear position and fully supporting or refuting that position with relevant information. Text is uniformly organized, and language choices often enhance the text.

1=Sometimes addresses the audience's needs by identifying a somewhat clear position and partially supporting or refuting that position with relevant information. Text is generally organized, and language choices sometimes enhance the text.

0=Rarely or never addresses audience's needs by failing to identify a clear position or failing to adequately support or refute a position that is identified. Text lacks organization and language choices seldom, if ever, enhance the text.

Cosmic Radiation Creates Unfriendly Skies

Dr. Sten Odenwald (Raytheon ITSS and NASA Goddard Space Flight Center)

A trip on a jet plane is often taken in a party-like atmosphere with passengers confident that, barring any unexpected accidents, they will return to earth safely and with no lasting physical affects. But depending on what the sun is doing, a solar storm can produce enough radiation to equal a significant fraction of a chest X-ray's dosage even at typical passenger altitudes of 35,000 feet. The situation is even worse for airline pilots and flight attendants who spend over 900 hours in the air every year. According to a report by the Department of Transportation (Science News magazine, vol. 137, p. 118), the highest dosages occur on international flights passing close to the poles where the earth's magnetic field concentrates the dosages. Estimates suggest that for such polar routes, flight crews can receive nearly 910 millirems of cosmic radiation dosage per year. The annual federally recommended limit for pregnant women is 500 millirems. Even at these levels, it has been estimated that there will be on the average four extra cases of mental retardation per 100,000 women due to this exposure between weeks 8 to 15 in the gestation cycle.

Although the dosage you receive on a single such flight per year is very small, frequent fliers who amass over 480 hours of flight per year would statistically expect to suffer from 500 extra cancer deaths per 100,000 travelers over a 20 year period. Airline crews who spend 960 hours in the air on such polar routes would have over 1000 additional cancer deaths per 100,000 crew members over a 20 year period of travel.

By comparison, the typical cancer rate is about 22,000 deaths per 100,000. This means that instead of a 22 in 100 chance of cancer, airline crews and frequent fliers would have as much as a 23 in 100 chance of cancer death. This doesn't sound like much, but for a population as large as the United States with nearly 300 million people, this means an additional 3 million people would die if they all traveled on such routes. Of course only a small number of people are this well-traveled, but nevertheless, without proper safeguards, hundreds of additional people would die from such radiation exposure.

Matthew H. Finucane, air safety and health director of the Association of Flight Attendants in Washington DC, as quoted in Science News (vol. 137, p. 118), advocates asking the FAA to monitor and regulate radiation exposure and, if possible, to warn crews of unusually intense bursts of cosmic radiation, or solar storm activity. Currently, the FAA guidelines are written in too technical a language to be readily useful to pilots and flight attendants so that they need to be re-written.

Name ______________________________ Date________________

Writing to Persuade

"Cosmic radiation creates unfriendly skies"

1. What is the central idea of the reading selection?

2. How does the central idea relate to the title of the article?

3. In regards to a crew that spends 960 hours in the air each year for 20 years, how many total hours are spent per person in the air?

4. If this crew received the highest annual dose of cosmic radiation, 910 millirems, how many total millirems do they receive in a day assuming an equal amount per day.

5. Suppose that 910 millirems are spread equally over 32 routes from New York to Athens. How many millirems do they receive per trip?

6. If the crew had flown on September 29, 1989 and they received 110 millirems from the solar event, how might they have received the remaining dosage of the 910 millirems?

7. What is the expected cancer rate for a frequent flier over a 20 year period according to the article?

8. What is the percentage for the overall cancer rate in the general population, and how does it compare to the cancer rate for frequent fliers?

9. Determine the percentage for the typical cancer rate, and compare this to the cancer rate for the airline crews. Is this a significant threat to them? If so, explain your reasoning.

10. What could be the implications for solar weather forecasting?

11. Write a letter to the Federal Aviation Administration or the Department of Transportation why, or why not, it is important to educate, to predict, and to notify the public, about the effects of solar radiation. Be sure to include details from the text that support your reasoning.

Teacher's Guide

Satellite Glitches and Cosmic Rays

Introduction

Electronic problems with orbiting satellites are more frequent when the environment has been bombarded with energetic particles called cosmic rays. These high energy, charged particles impact sensitive electronic circuits and causes 'glitches', which can alter the operation of a satellite in an unpredictable manner. This activity shows the correlation between cosmic ray hits and the electronic errors in the NASA TDRS-1 communication satellite which is used for keeping in touch with the Space Shuttle crew while in space.

Objective

Students will construct a graph from a data table. Students will look for correlations and patterns between the frequency of cosmic rays and glitches.

Procedure

1) Arrange the students into four groups.

2) Give each group a data table for an assigned year.

3) Students will create a double line graph with the months on the horizontal axis. Using two different colored pencils, plot the glitches and the cosmic ray counts.

4) Permit time for the students to analyze the graphs and look for a correlation.

5) Have the groups combine the graphs into a single graph in the proper time order from 1987 to 1990 to detect any long-term trends.

6) Provide each group with a transparency. Have each group prepare a presentation of their findings.They should note any correlation or discrepancy that they have found.

7) Have a prepared transparency of the four tables and graphs, and the combined four-year graph. Provide a concluding summary using the class results. Possible student conclusions include that when the cosmic ray hits are high, glitches are more common. There is a correlation between the two sets of data. Was there a year where there was a particularly high number of both, and did that relate to a solar storm event, sunspot number increase, or coronal mass ejection?

Materials

—Table of cosmic ray counts and TDRS-1 glitches.

—Graph paper

Extra Credit:

If you compare the cosmic ray hits against the sunspot cycle, you will note that when the solar cycle is near maximum, the number of cosmic ray hits is lowest. This is because cosmic rays come from interstellar space and not the sun. When the sunspot activity is highest, the sun's magnetic field is much stronger out near the Earth, and this helps to shield us from cosmic rays. When solar activity is lowest, the sun's magnetic field is weaker near the Earth and so the cosmic rays have an easier time reaching the Earth and affecting our satellites.

Conclusion:

Students should have correlated the data for the electronic glitches with the cosmic ray hits to the satellite. From the real data in the tables, the students have plotted, analyzed and have drawn a conclusion.

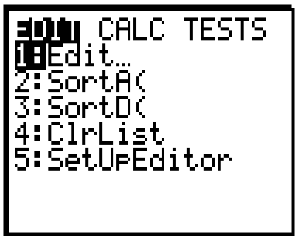
TEACHER NOTES FOR THE TI-83 GRAPHING CALCULATOR

Reminder: Be sure to reset the calculator using "Teacher Notes for the Graphing Calculator" included in the previous sunspot lesson.

The commands for the graphing calculator are given in bold print.

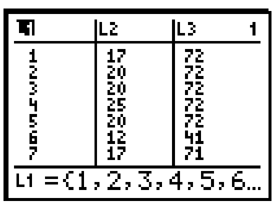
Students will enter the data for the years into list one, the data for the glitches in list two, and the cosmic ray hits (Cr hits) in list three. NOTE: Be sure to list the years as the numbers 1 through 48.

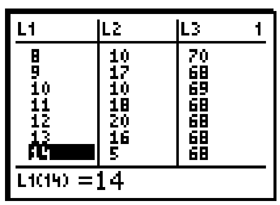
Entering the data into the list will consist of the following keystrokes:

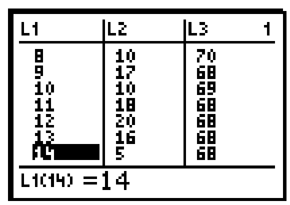


STAT **ENTER**

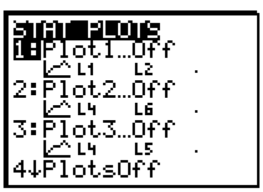
This will put you at the window to input the data for the year into your selected lists. Sample screen images are shown below.







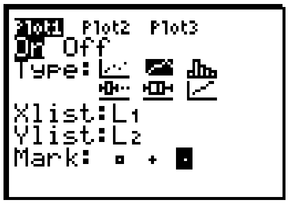
The next step is to turn on the appropriate graph and to use the correct lists. Since the data is in List 1, List 2, and List 3, those are the ones that we shall select. To turn the plots on, use the following keystrokes:

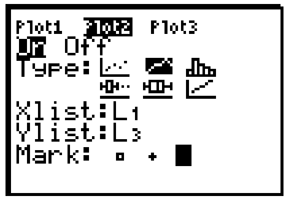


2ND **Y=** **ENTER**

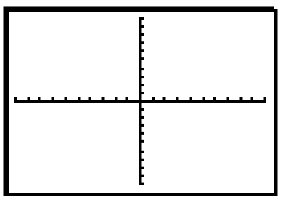
To turn the plot on, make sure that the cursor is blinking over the **ON** and push **ENTER**. Next arrow down and over to select the second graph. Once the cursor is flashing over it, push **ENTER**. Arrow down to the X list and push **2ND 1**, arrow down to the Y list and push **2ND 2**. To turn on the second plot, **2ND Y= ENTER**. Arrow down and select 2. Again, make sure that the cursor is flashing over the **ON** and push **ENTER**. Then arrow down and over to the second graph, and **ENTER**. Arrow down to the X list and push **2ND 1**, and arrow down to the Y list and push **2ND 3**.

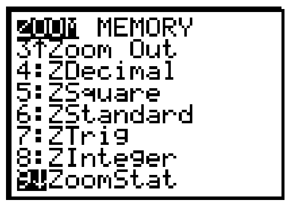
The correct windows are displayed below.



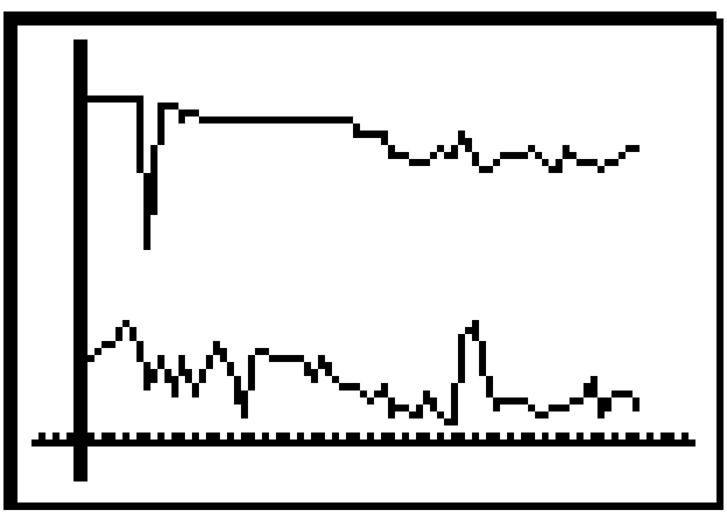


The next step is to graph the data. When the students push the graph key, they may or may not see a part of the graph. If the calculator was reset prior to the beginning of the lesson, the students would see the following blank display. It is necessary to adjust the viewing window using **ZOOM 9**. The window display for the zoom is shown below.





In order to move along the graphs and to display the values, push **TRACE**. The up and down arrow keys allow movement between the two graphs, and the right and left arrow keys allow movement along a particular graph.The appropriate graph display will appear as follows:



Students will probably say that there is no relationship evident between these two graphs, and they are right.There is a correlation between these two, it is just not evident with the small sampling of data that is presented. The overall slopes are similar in that there is a downward slant to both. Students need to be aware that in the scientific world, answers are not always readily apparent and that there may be a need to explore a relationship further. However, students can draw conclusions based on the given data.The discussion can also focus on the need to possibly scale one set of data to see if this allows for more concise results, or to collect more data to analyze.

Name ______________________________

Date________________

1987

Month	Glitches	CR Hits
January	17	72
February	20	72
March	20	72
April	25	72
May	20	72
June	12	71
July	17	71
August	10	70
September	17	68
October	10	69
November	18	68
December	20	68

1988

Month	Glitches	CR Hits
January	16	68
February	5	68
March	17	67
April	19	68
May	18	67
June	17	67
July	17	67
August	13	67
September	18	67
October	13	67
November	12	67
December	12	65

1989

Month	Glitches	CR Hits
January	9	64
February	12	64
March	5	60
April	7	60
May	5	59
June	10	59
July	6	62
August	4	60
September	22	65
October	25	58
November	10	57
December	7	59

1990

Month	Glitches	CR Hits
January	8	60
February	9	60
March	7	61
April	6	58
May	7	57
June	7	61
July	9	58
August	13	58
September	5	57
October	10	58
November	10	61
December	7	62

Name ______________________________

Date__________________

Name ______________________________

Date_________________

Teacher's Guide

Planning a Trip to Mars

Introduction

In the 21st century, NASA is planning a mission to Mars. You and a group of your peers are about to set off on this mission. The trip will take 240 days to get to Mars. Once there, you will explore the surface for fossils for 3 years. The return trip to Earth will take another 240 days. A concern exists for how the crew will be protected from radiation over-exposure during the 4-year expedition in space. You will assume during the trip that your shielding is the same as NASA uses on the Space Shuttle.

Objective

Students will calculate the cumulative radiation dosage for a trip to Mars, and participate in a probability-based exposure simulation.

Procedure

1) Read the introductory paragraph to the students.

2) Allow sufficient time for the students to complete questions #1 and 2 on the Student Worksheet. Discuss student results and answers.

3) Group the students into either pairs or groups of four.

4) Provide each group with a dice. Conduct the simulation and complete the remaining activities.

5) Discuss the outcome of the simulation, and review possible responses to the remaining exercises.

For a possible extension:

Have the students use the graph created in the first activity in this book **"The Sunspot Cycle"** to determine when would be the best opportunities in the next century to leave for the trip.

Materials

—A dice

—Student Worksheets

—Graph paper

—Calculator

Key Terminology:

SPE: Solar Proton Event. An unpredictable, major burst of high-energy particles from the sun which take less than 20 minutes to reach the orbit of the Earth.

Rad: The amount of radiation needed to deliver a specific amount of energy into a fixed mass of biological tissue. 100 rads equals one Joule of energy per kilogram of mass. One Joule is the amount of energy a 1 Watt bulb produces in a second.

Rem: A number that tells the actual damage done per rad of dosage which accounts for the fact that charged particles are 10 times more damaging than electromagnetic radiation.

Name ______________________________ Date_________________

1. NASA is concerned about the amount of radiation that your crew will be exposed to while on your trip. The table below shows the minimum and maximum dosages (in rems) that were received for different Space Shuttle flights, and at different altitudes given in Nautical Miles (NM). Find the combined average dosage.

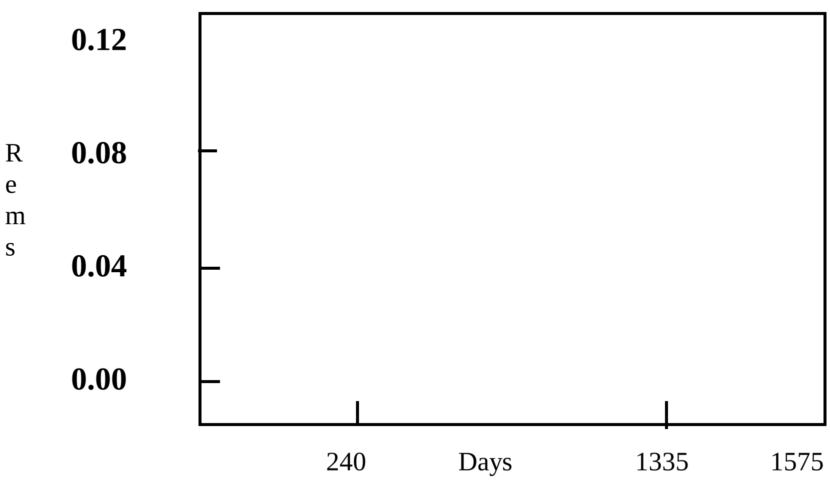
Mission	Altitude	Minimum	Maximum
STS-38	**125 NM**	**0.003**	**0.004**
STS-51G	**200 NM**	**0.015**	**0.020**
STS-37	**245 NM**	**0.040**	**0.070**
STS-31	**330 NM**	**0.140**	**0.220**

Average combined dosage in rems = ___________________

2. **Suppose that NASA decides to send the expedition at a time near solar maximum. By the time you return, the conditions in space will be near those at solar minimum during the solar cycle which occurs about 5.5 years after solar maximum. During solar maximum, the sun is very active and effectively shields the inner solar system from most of the galactic cosmic rays (GCRs) which contain very high energy particles. During solar minimum, the Sun is relatively inactive and allows GCRs to reach the inner solar system in greater numbers. The integrated dose of GCRs is about 2.5 times higher at solar minimum than at solar maximum. Using the data in the table above during conditions of solar maximum, calculate the average dosage in rads/day during solar minimum.**

Average dosage in rems during solar minimum = ____________

3. **The next step in the process is to determine the number of rems for the crew. Also, you will need to calculate the total exposure over the entire 4.3 year trip. Total exposure is measured in units of rems. Your trip begins during solar maximum and ends during solar minimum. On the graph below, calculate the number of rems for each time period. Assume that while on Mars that you are adequately shielded with a natural background dose of 15 rem per year (or 0.04 rems/day). To calculate rems: Rems per day multiplied by the number of days of exposure = number of rems of total radiation dosage.**



Number of rems on trip to Mars:

= ____________

Number of rems on Mars:

= ____________

Number of rems on trip to Earth:

= ____________

Name ___________________________ Date_______________

4. **There is an event that occurs in space known as a Solar Proton Event (SPE). SPEs are the most dangerous to astronauts because of our inability to predict them. They occur about once every month during solar maximum, and once every eight months during solar minimum. Typical radiation dosages are about 0.4 rems inside a spacecraft or similar shelter. The amount of rems varies due to the intensity of the SPE. During your trip, assume that you will encounter 3 SPEs on your way to Mars, 10 SPEs while on Mars, and 1 SPE on your trip home. To simulate the random amount of rems received from SPEs, toss a dice and using the chart below, the number on the dice equals the corresponding dosage. Example, a roll of 5 gives you a dosage of 2.0 rems. Repeat for each SPE and add the amount of the total SPE rems for each part of the trip.**

Dice	Dose
1	0.1
2	0.3
3	0.4
4	0.8
5	2.0
6	10.0

Trip to Mars:

SPE	Dose
1	
2	
3	

On Mars:

SPE	Dose
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

Trip to Earth:

SPE	Dose
1	

Total Rems..... ______________ ______________ ______________

7. Calculate the mission's total dose by filling in the numbers below:

Amount of rems on trip to Mars + total SPE on trip to Mars = _____________

Amount of rems while on Mars + Total SPE while on Mars = ______________

Amount of rems on trip to Earth + Total SPE on trip to Earth = _____________

Total dosage for entire trip = __________

Name ____________________________ Date_________________

8. NASA's career equivalent doseages for astronauts is computed as follows:

200 + 7.5 (age - 30) rems (males up to 400 maximum rems)
200 + 7.5(age - 38) rems (females up to 400 maximum rems)

Using these formulas, answer the following questions:

How many trips to Mars could a 40 year old man take before reaching the maximum amount of 'career' radiation exposure recommended by NASA?

How many trips to Mars could a 40 year old woman take before reaching the maximum amount of 'career' radiation exposure recommended by NASA?

Name some ways that the amount of radiation you received on this trip could vary.

Which of the two sources of radiation, cosmic rays and SPEs, are the most hazerdous and how would you try to minimize its risk to the crew?

Based on what you have learned, what are some things you could do to minimize the amount of radiation that you would receive on a trip to Mars?

Teacher's Answer Key

1. NASA is concerned about the amount of radiation that your crew will be exposed to while on your trip. The table below shows the minimum and maximum dosages (in rems) that were received for different Space Shuttle flights, and at different altitudes given in Nautical Miles (NM). Find the combined average dosage.

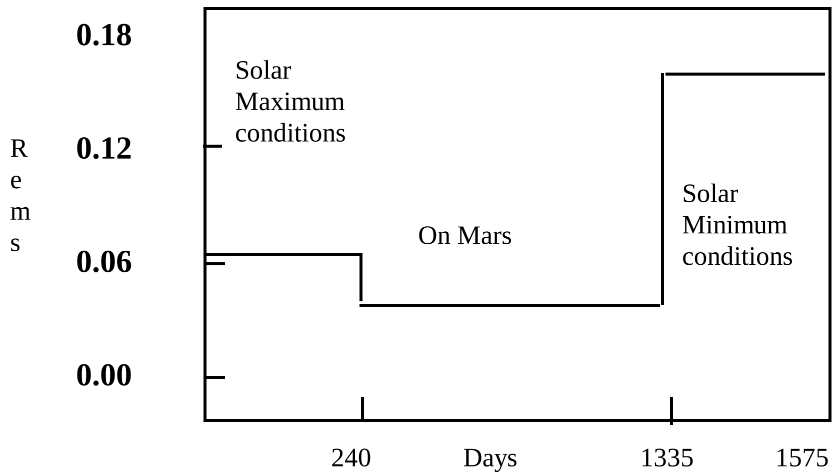
Mission	Altitude	Maximum	Minimum
STS-38	**125 NM**	**0.003**	**0.004**
STS-51G	**200 NM**	**0.015**	**0.020**
STS-37	**245 NM**	**0.040**	**0.070**
STS-31	**330 NM**	**0.140**	**0.220**

Average combined dosage in rems = **0.064**

2. Suppose that NASA decides to send the expedition at a time near solar maximum. By the time you return, the conditions in space will be near those at solar minimum during the solar cycle which occurs about 5.5 years after solar maximum. During solar maximum, the sun is very active and effectively shields the inner solar system from most of the galactic cosmic rays (GCRs) which contain very high energy particles. During solar minimum, the Sun is relatively inactive and allows GCRs to reach the inner solar system in greater numbers. The integrated dose of GCRs is about 2.5 times higher at solar minimum than at solar maximum. Using the data in the table above during conditions of solar maximum, calculate the average dosage in rems during solar minimum.

Dosage in rems during solar minimum = **0.064 x 2.5 = 0.16 rems**

3. The next step in the process is to determine the amount of rems for the crew. Also, you will need to calculate the total exposure over the entire 4.3 year trip. Total exposure is measured in units of rems. Your trip begins during solar maximum and ends during the solar minimum. On the graph below, calculate the number of rems/day for each time period. Assume that while on Mars that you are adequately shielded with a natural background dose of 15 rem per year (or 0.04 rems). To calculate rems: Rems per day multiplied by the number of days of exposure = number of rems of total radiation dosage.



Number of rems on trip to Mars:

= 0.064x240 = 15.4 rems

Number of rems on Mars:

= 0.04x(1335-240) = 43.8 rems

Number of rems on trip to Earth:

= 0.16x240 = 38.4 rems

Teacher's Answer Key

4. There is an event that occurs in space known as a Solar Proton Event (SPE). SPEs are the most dangerous to astronauts because of our inability to predict them. They occur about once every month during solar maximum, and once every eight months during solar minimum. Typical radiation dosages are about 0.4 rems inside a spacecraft or s similar shelter. The amount of rems varies due to the intensity of the SPE. During your trip, assume that you will encounter 3 SPEs on your way to Mars, 10 SPEs while on Mars, and 1 SPE on your trip home. To simulate the random amount of rems received from SPEs, toss a dice and using the chart below, the number on the dice equals the corresponding dosage. Example, a roll of 5 gives you a dosage of 2.0 rems. Repeat for each SPE and add the amount of the total SPE rems for each part of the trip. Here is a sample result of the dice tossing outcomes:

Dice	Dose
1	0.1
2	0.3
3	0.4
4	0.8
5	2.0
6	10.0

Trip to Mars:

SPE	Dose
1	0.4
2	2.0
3	0.1

On Mars:

SPE	Dose
1	0.3
2	2.0
3	0.4
4	0.3
5	10.0
6	0.4
7	0.1
8	2.0
9	0.3
10	0.3

Trip to Earth:

SPE	Dose
1	0.8

	Trip to Mars	On Mars	Trip to Earth
Total Rems.....	**2.5**	**16.1**	**0.8**

7. Calculate the mission's total dose by filling in the numbers below:

Amount of rems on trip to Mars + total SPE on trip to Mars = 15.4+2.5 = 17.9

Amount of rems while on Mars + Total SPE while on Mars = 43.8+16.1 = 59.9

Amount of rems on trip to Earth + Total SPE on trip to Earth = 38.4+0.8=39.2

Total dosage for entire trip = 117.0

NOTE: The values for the SPE contribution will vary depending on the dice tosses that come up for each group, but you may combine the results for all groups to get a 'class average' SPE dosage! These SPE doses assume the astronaut is shielded inside a spacecraft. If they are caught outside a shelter, the dosages from the SPEs are about 8-10 times higher!

Teacher's Answer Key

8. NASA's career equivalent doseages for astronauts is computed as follows:

200 + 7.5 (age - 30) rems (males up to 400 maximum rems)

200 + 7.5(age - 38) rems (females up to 400 maximum rems)

Using these formulas, answer the following questions:

How many trips to Mars could a 40 year old man take before reaching the maximum amount of 'career' radiation exposure recommended by NASA?

Total recommended dose = 200 + 7.5(40-30) = 275.0
Mars trip dose = 117.0 so number of trips is 2

How many trips to Mars could a 40 year old woman take before reaching the maximum amount of 'career' radiation exposure recommended by NASA?

Total recommended dose = 200 + 7.5(40-38) = 215.
Total trips = 215/117 = 1.8. This could either be stated as 1 or 2 trips.

Name some ways that the amount of radiation you received on this trip could vary.

Higher SPE exposure; more solar storms; defective shielding; less solar activity; better shielding. These are all possible answers.

Which of the two sources of radiation, cosmic rays and SPEs, are the most hazerdous and how would you try to minimize its risk to the crew?

SPEs are unpredictable and can deliver significant doses, especially if an astronaut is 'spacewalking' during which time little shielding is available. Some type of early warning system is required to anticipate when these storms may be starting on the solar surface. Either constant telescopic monitoring is needed, or some other method to sense the buildup of SPE conditions.

Based on what you have learned, what are some things you could do to minimize the amount of radiation that you would receive on a trip to Mars?

Stay in the spacecraft. Staying on Mars less than 2 years is not an option because you can only return when Mars and Earth are closest to each other every 2.1 years. It is not the stay on Mars that hurts you, it is the changing cosmic ray conditions during solar maximum and solar minimum. One possibility is to start and end your trip during the time that the sun is near its maximum in the solar cycle. This would reduce your non-SPE cumulative dose, which is the factor that dominates the total dosage. Start the trip 2 years before solar maximum, and end it 2 years after solar maximum would be a better strategy, provided you can reduce your risk for SPE events.

Teacher's Guide

Cosmic Rays And Sunspot Number

Introduction

Cosmic rays are very energetic particles, mostly protons and electrons, that enter the solar system from the depths of interstellar space. Although the Earth's magnetic field partially shields us from these particles, so too does the much more extended solar wind with its own magnetic field. When the sun is most active, the solar magnetic field is more intense, and so it provides additional sheilding from cosmic rays near the Earth. When the sun is less active, the wind is weaker and the shielding is less effective.

Objective

The student will analyze and compare two or more graphs to determine if there is a correlation between Sunspot Number and the variation of Cosmic Ray Flux.

Procedure

1. Divide the students into either pairs or groups of four. Read the introduction to the students.

2. Review with the students an example of how graphs may be similar and different. Be sure to include shape, distribution,highs, lows,scale, axis. and the time frame.

3. Provide students with a copy of the Student Activity # 1. Allow a sufficient amount of time for the students to complete the activities. Discuss their results and their conclusions.

4. Provide students with a copy of Student Activity #2 and provide them with appropriate time to complete the exercises.

Have the groups present their findings to the class. Some of the groups will argue that there is an almost perfect inverse relationship between the two graphs. Other groups may see the inverse pattern, but be unable to explain it in correct terminology. Finally, other students may take their explanations to a higher level by discussing the maxima and the minima and the actual fit of the data.

5. Provide students with a copy of Student Activity #3. Allow a sufficient amount of time to complete the activities. Discuss the results.

6. Provide students with the technology aspect using the TI - 83 graphing calculator and the magnification of the graphs.

Materials

Student Activity #1
Student Activity #2
Student Activity #3
Ruler
Transparencies (optional)
TI -83 Graphing Calculator (optional)

Have the groups present their findings to the class. Some of the groups will argue that there is an almost perfect inverse relationship between the two graphs. Other groups may see the inverse pattern, but be unable to explain it in correct terminology. Finally, other students may take their explanations to a higher level by discussing the maxima and the minima and the actual fit of the data.

Conclusions

Students will determine that the relationship between Sunspot Number and Cosmic Ray Flux is an inverse correlation. This may not be readily apparent to some students since the scales are so diverse. The activities introduce the students to the concept of magnifying a graph in order to better see the fit of the data. Students will also see that regardless of the location of the observatory, be it northern hemisphere or southern hemisphere, there is still an inverse correlation between the Sunspot Number and the Cosmic Ray Flux. Students will see that the data from the Huancayo, Peru observatory and the Climax, Colorado observatory are almost a perfect fit. Students can further investigate the relationship of Cosmic Ray Flux and Sunspot Number if they so choose. In order to do so, they may wish to check out more observatories and their data. For reference purposes:

Calgary, Canada	N51	W114	Altitude...1128m
Climax, Colorado	N39	W106	Altitude...3400m
Deep River, Canada	N46	W77	Altitude.....145m
Moscow, Russia	N55	E37	Altitude.....200m

Key Terminology:

Maxima: The locations on a curve where the y-axis values are largest.

Minima: The locations on a curve where the y-axis values are smallest.

Inverse Correlation: When one quantity increases, the other quantity decreases

Cosmic Ray Flux: The flow of particles through a region of space in a given amount of time.

Cosmic Rays: Particles, usually electrons or protons or even light atomic nuclei, which travel at high speed through interstellar space.

Flux: A term used to describe the flow of particles or radiation through space given in units of particles per second per square centimeter, or watts per square centimeter.

Name ____________________________ Date_________________

Student Activity # 1

The following table contains the data for the variation of Cosmic Ray Flux. From these averages, use the table to create an appropriate graph for Huancayo's observations of the measurement of Cosmic Ray Flux, and then answer the following questions. Please use a scale from 2 to -2 in increments of tenths.

Huancayo Observatory's Measurement Of Cosmic Ray Flux Over Time

Year	Cosmic Ray Flux	Year	Cosmic Ray Flux
1954	1.35	1976	1.10
1956	0.00	1978	.600
1958	-1.3	1980	-.20
1960	-1.2	1982	-.90
1962	.400	1984	-.40
1964	1.00	1986	1.25
1966	1.20	1988	.100
1968	.100	1990	-.70
1970	0.00	1992	-.10
1972	.600	1994	0.00
1974	.400		

1. Describe any patterns that may be evident. Be sure to include the years that span maxima or minima.

2. Why do you think that a scale using tenths was selected?

3. Would the shape and distribution of the graph change if we were to magnify the graph by a factor of ten?

Name ______________________________

Date________________

Name ______________________________   Date________________

Student Activity #2

Construct the appropriate graph based on the following table and determine if there is a correlation with the graph of the variation of Cosmic Ray Flux from Huancayo. Communicate your analysis in the space beside the graph. Be sure to include supporting evidence.

Recorded Sunspot Number

YEAR	Sunspot Number	YEAR	Sunspot Number
1950	84	1973	38
1951	69	1974	34
1952	31	1975	16
1953	14	1976	13
1954	4	1977	27
1955	38	1978	92
1956	142	1979	155
1957	190	1980	154
1958	185	1981	140
1959	159	1982	116
1960	112	1983	67
1961	54	1984	46
1962	38	1985	18
1963	28	1986	14
1964	10	1987	32
1965	15	1988	98
1966	47	1989	154
1967	94	1990	146
1968	106	1991	144
1969	106	1992	94
1970	104	1993	56
1971	67	1994	30
1972	69		

Name ______________________________

Date________________

Name ___________________________ Date_________________

Student Activity #3

The observatory in Huancayo, Peru is in the southern hemisphere.After completing the prior activities, it should seem evident that certain events in our universe affect one another. In order to investigate this connection further, more data will need to be analyzed.

Suppose we were to make a hypothesis that is based on the results from Huancayo. It is assumed that an observatory in the north may also experience some sort of a correlation. Based on the previous data analysis, state a hypothesis about an observatory in the northern hemisphere that would be observing the same events.

It just so happens that there is an observatory located in Climax, Colorado. Please construct the appropriate graph to display the given data. Please use a scale from 2 to -2 with increments of tenths.

Climax Observatory's Measurement Of Cosmic Ray Flux Over Time

Year	**Cosmic Ray Flux**	**YEAR**	**Cosmic Ray Flux**
1954	1.30	1976	1.20
1956	0.70	1978	.800
1958	-1.7	1980	-.50
1960	-1.1	1982	-1.2
1962	.100	1984	-.40
1964	0.90	1986	1.20
1966	0.80	1988	.100
1968	-.40	1990	-1.8
1970	-.40	1992	-.70
1972	.900	1994	0.60
1974	.900		

Using the graphs for Huancayo and Climax, what conclusion can be drawn about the effects of the northern and southern hemisphere in regards to the variation of Cosmic Ray Flux. In addition, how does this conclusion relate with the Sunspot Number?

Suppose data from the observatories in Deep River and Calgary, Canada, as well as Moscow, Russia were given. What would be the expected correlation to both the variation of Cosmic Ray Flux as well as the Sunspot Number? Justify your reasoning.

Name ______________________________

Date________________

Teacher Notes For The Graphing Calculator

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

Students will enter the following estimated table of values taken from the measurement of Cosmic Ray Flux for Huancayo. The year will be entered into list 4, the Cosmic Ray Flux intensity will be entered in list 5, and the Sunspot Number for the corresponding years will be entered in list 6.

Directions For Activity #1 and Activity #2

Cosmic Ray Flux For Huancayo Versus The Sunspot Number

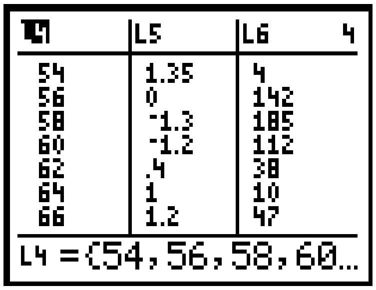
Year	Cosmic Ray Flux	Sunspot Number	YEAR	Cosmic Ray Flux	Sunspot Number
1954	1.35	4	1976	1.1	13
1956	0	142	1978	.6	92
1958	-1.3	185	1980	-.2	154
1960	-1.2	112	1982	-.9	116
1962	.4	38	1984	-.4	46
1964	1.0	10	1986	1.25	14
1966	1.2	47	1988	.1	98
1968	.1	106	1990	-.7	146
1970	0	104	1992	-.1	94
1972	.6	69	1994	0	30
1974	.4	34			

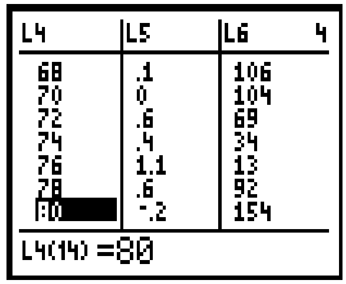
Entering the data into the list will consist of the following keystrokes:

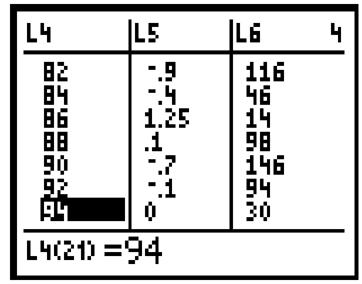
STAT **ENTER**

When entering data, enter the value and then **ENTER**, until the list is complete. Then arrow to the right, and enter the value for that list.

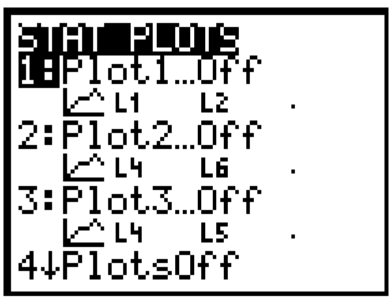
This will put you at the window to input the data for the year into your selected lists. **Note**: I selected to use lists 4, 5, and 6. When entering data, type the value and then push **ENTER**, until the list 4 is complete. Next arrow to the right, and enter the values for list 5 by typing the data value and pushing **ENTER**. Finally, arrow to the right, and enter the values for list 6 by typing the data value and pushing **ENTER**. Sample screen images shown below.





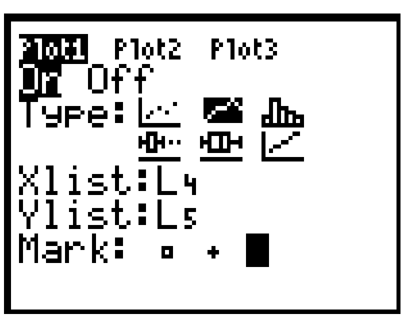


After the data has been entered into the lists, the stat plot needs to be turned on. To turn the plots on, use the following keystrokes:



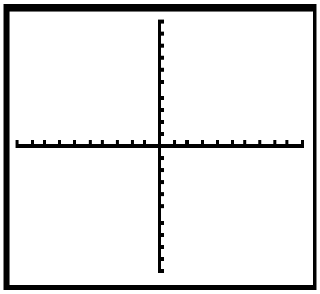
2ND Y = ENTER

The next step is to turn on the appropriate graph and to use the correct data lists.
Since the data is in List 4, List 5, and List 6, those are the ones we shall select. To turn the plot on, make sure that the cursor is blinking over the **ON** and push **ENTER**. Next arrow down and over to select the second graph. Once the cursor is flashing over it , push **ENTER**. Arrow down to the X list and push **2ND 4,** arrow down to the Y list and push **2ND 5.** These steps have allowed for the data in lists four and five to be graphed. The appropriate windows would appear as follows:

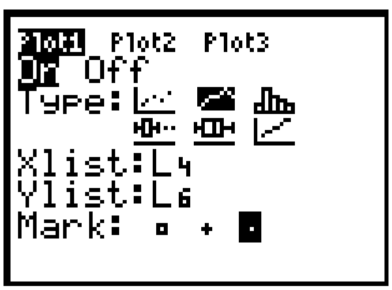


GRAPH

The next step is to graph the data. When the students push the graph key, they may or may not see a part of the graph. If the calculator was reset prior to beginning the lesson, the students would see the following blank display. It is necessary to adjust the viewing window using **ZOOM 9**. The window that the student should see is shown below.



To turn the second plot on, push **2ND Y =**. Next arrow down and select the second plot, **ENTER**. Make sure that the cursor is blinking over the **ON** and push **ENTER.** Next arrow down and over to select the second graph Once the cursor is flashing over it , push **ENTER**. Arrow down to the X list and push **2ND 4**, arrow down to the Y list and push **2ND 6**. These steps have allowed for the data in lists four and six to be graphed. Students may wish to see the graph at this point.

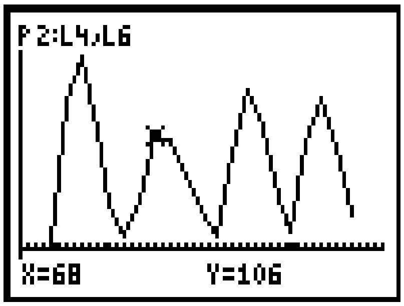


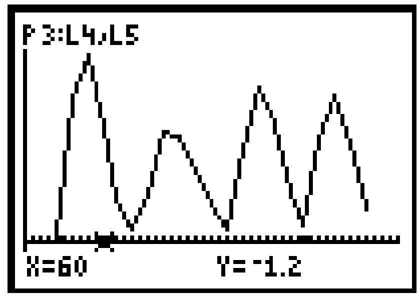
GRAPH

NOTE: The first time that the students did a zoom 9, they saw the data in list 4 and list 5, which is the Cosmic Ray Flux (ONE GRAPH!). When they push the graph button again they will see one graph, the Sunspot Number data in list 4 and list 6. It will not be until they use the **ZOOM 9** to fit the data that they will view both graphs. Even then, most students will believe that there is only one graph because the values in list 5 are so minimal. At this point, to help the students to understand that there are two graphs, it is necessary to move along the graphs and to look at the values displayed. In order to move along the values and to compare the two graphs, push **TRACE**.

The up and down arrow keys allow movement between the two graphs, and the right and left arrow keys allow movement along a graph.

This is a good time to discuss the appropriate graph for this data and why it should be a line graph. Students are aware that a line graph is appropriate for time. However, be sure to include the fact that the data is continuous and needs to be displayed as such.



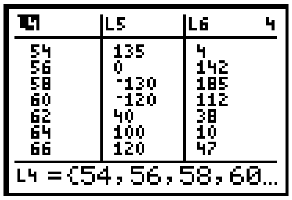


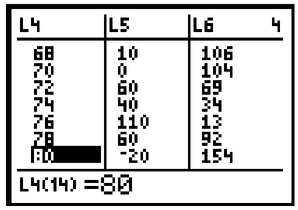
Students will have a very difficult time visualizing these two graphs, especially since the one for cosmic ray flux (L5) appears to not be there. If you look at the windows given above and note that the second window does display the values in the table, the students can start to understand that there really is a second graph. Explain to them that there are really two graphs displayed. This leads to a discussion about the scales and values needed to compare these two sets of data.

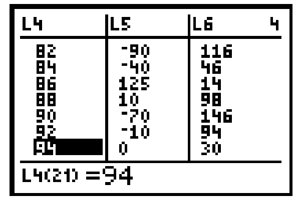
In the study of science, scientists need to sometimes magnify a certain set of data in order to visualize the correlation. In doing this exercise,and depending on your time available for exploration, a magnification of ten may be selected and applied to the values for Huancayo in list 5. The graph is still not readily apparent. This will lead the students to think that maybe they need to increase the magnification. Be aware that the magnification of 100 seems to be a nice visual representation. Have the students multiply the data for the Cosmic Ray Flux by 100, and then enter the data into list 5 . Follow the same procedures for entering and displaying the data.

Directions For Magnification

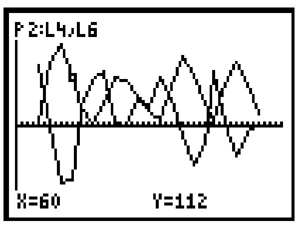
Have the students begin with a magnification of ten, and then view the data. After discussing that further magnification is necessary, magnify the data to 100 times the original. Display the results and discuss the conclusions.The windows for magnification of 100 times are:







The graph display then appears as the following:



TRACE

This allows the students to use the trace function, and to determine that there is an inverse relationship. That is, when the Sunspot Number is high, the Cosmic Ray Flux is low.

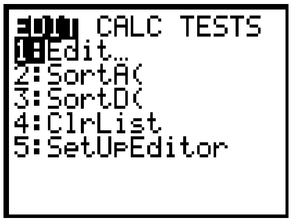
The same procedures can be followed for each of the remaining four stations. The results should be the same.

A variation may be to have the students decrease the scale on the Sunspot Number by a certain value.

Directions For Activity # 3

The data table for Huancayo and Climax will be needed. The year will be entered into list 1, Huancayo data in list 2, and Climax data in list 3.

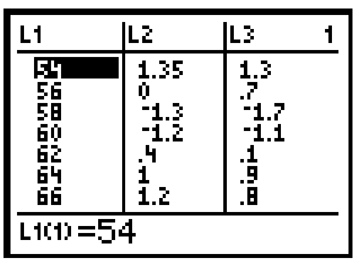
Entering the data into the list will consist of the following keystrokes:

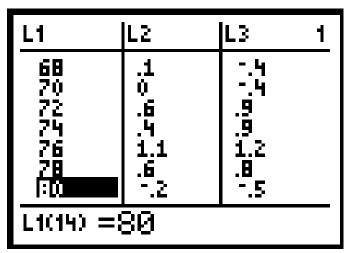


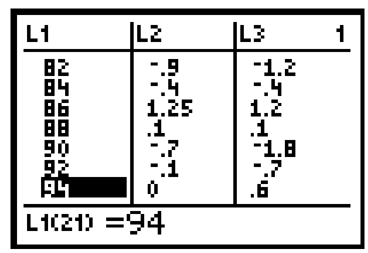
STAT ENTER

This will put you at the window to input the data for the year into your selected lists. When entering data, enter the value and then **ENTER,** until the list is complete. then arrow to the right, and enter the values for that list.

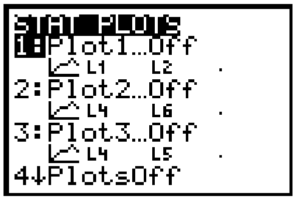
Sample screen images shown below.





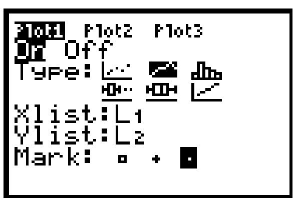


After the data has been entered into the lists, the stat plot needs to be turned on. To turn the plots on, use the following keystrokes:

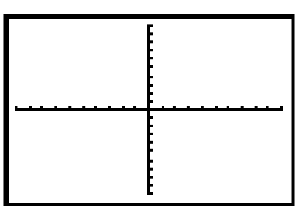


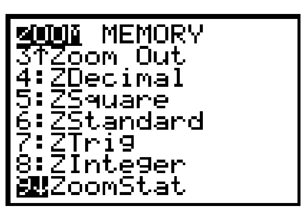
2ND Y = ENTER

The next step is to turn on the appropriate graph and to use the correct data lists.
Since the data is in List 1, List 2, and List 3, those are the ones we shall select. To turn the plot on, make sure that the cursor is blinking over the **ON** and push **ENTER**. Next arrow down and over to select the second graph. Once the cursor is flashing over it , push ENTER. Arrow down to the X list and push **2ND 1,** arrow down to the Y list and push **2ND 2.** These steps have allowed for the data in lists one and two to be graphed. Students may wish to see the graph at this point. The window is displayed below.

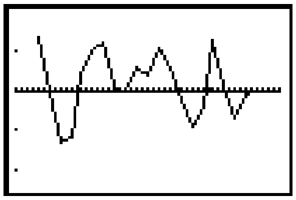


The next step is to graph the data. When the students push the graph key, they may or may not see a part of the graph. If the calculator was reset prior to beginning the lesson, the students would see the following blank display. It is necessary to adjust the viewing window using **ZOOM 9**. The window that the student should see is shown below.

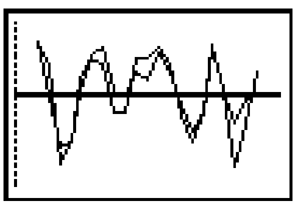




The students will be viewing the data for Huancayo only. The graph for Huancayo is as follows:



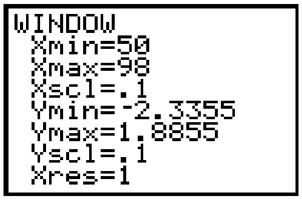
It is important that they realize that the second plot needs to be turned on to view Climax data.To turn the second plot on, push **2ND Y =.** Next arrow down and select the second plot, **ENTER**. Make sure that the cursor is blinking over the **ON** and push **ENTER.** Next arrow down and over to select the second graph Once the cursor is flashing over it , push **ENTER**. Arrow down to the X list and push **2ND 1**, arrow down to the Y list and push **2ND 3**. These steps have allowed for the data in lists one and three to be graphed. Students may wish to see the graph at this point. The graph is displayed below.



TRACE

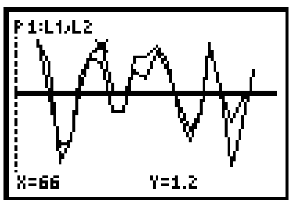
It is necessary to move along the graphs and to look at the values displayed.In order to move along the values and to compare the two graphs, push **TRACE**.The up and down arrow keys allow movement between the two graphs, and the right and left arrow keys allow movement along a graph.

Discuss with students the scale involved on the graphs. The calculator has used a scale, possibly of one. In order to more fully appreciate the graphs, the students will need to adjust their scale to tenths. Push the **WINDOW** key. Change the Xscl to .1 and the Yscl to.1. Return to the graph. A sample window is shown below.



GRAPH

Students can **TRACE** the graphs and see that they are almost exactly alike. The differences occur at the maxima and the minima, which are the inverse of the Sunspot Number's maxima and minima. The graph is displayed below.



This may be a good time to ask the students what they think will happen if the magnification is changed to .001, and then explore the effects on the graph by changing the window values. They should determine that it is the same graph with a different scale.

EXTENSION:

Have the students find or develop two sets of data that show a nice fit and correlation, a set of data that has an inverse correlation, and a set of data that appears to have no correlation. Next, have the students interpret that data and justify their results. Ask the students how they feel about manipulating data in this way to 'bring out detail'. Some students may not like to tamper with the data to be able to draw conclusions.

NOTE: This is a really nice activity and opportunity for students to explore and use real data on the internet.

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 kilometers 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

IMAGE	http://image.gsfc.nasa.gov
POETRY	http://image.gsfc.nasa.gov/poetry
SOHO	http://sohowww.nascom.nasa.gov
NASA Sun-Earth Connection Resources	http://sunearth.gsfc.nasa.gov
The Earth's Magnetic Field	http://image.gsfc.nasa.gov/poetry/magneto.html
Satellite Glitches -Space Environment Info	http://envnet.gsfc.nasa.gov
Magnetic North Pole	http://www.nrcan.gc.ca/gsc/cpdnew/magnet.html
Solar Sounds	http://soi.stanford.edu/results/sounds.html
Sunspot Number Archives / Resources	http://image.gsfc.nasa.gov/poetry/sunspots.html
CME Archives at MLSO	http://www.hao.ucar.edu/public/research/mlso/movies.html
Stellar Activity Cycles at Mt. Wilson	http://www.mtwilson.edu/Science/HK_Project/
Satellite Data	http://cdaweb.gsfc.nasa.gov
Space Weather Resources	http://image.gsfc.nasa.gov/poetry/weather.html
Magnetic Observatories and Data	http://image.gsfc.nasa.gov/poetry/maglab/magobs.html
Space Environments and Effects	http://see.msfc.nasa.gov/sparkman/Section_Docs/sparkman.html
Sun-Earth Classroom Activities Archive	http://sunearth.gsfc.nasa.gov/educators/class.html
Storms from the Sun	http://www.istp.gsfc.nasa.gov/istp/outreach/learn.html
The Aurora Page	http://www.geo.mtu.edu/weather/aurora/
Space Weather Human Impacts	http://image.gsfc.nasa.gov/poetry/storm/storms.html
Ionosphere density and sunspot numbers	http://julius.ngdc.noaa.gov:8080/production/html/IONO/ionocontour_90.html
Space Weather Daily Reports	http://windows.engin.umich.edu/spaceweather/index.html
Solar wind density and speed	http://www.sel.noaa.gov/wind/rtwind.html

Teacher Reply Card