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NASA CONNECT

Data Analysis and Measurement:
Having a Solar Blast!

A Lesson Guide with Activities in Mathematics, Science, and Technology

Data Analysis and Measurement: Having a Solar Blast! is available in electronic format through NASA Spacelink - one of NASA's electronic resources specifically developed for the educational community. This publication and other educational products may be accessed at the following address: **http://spacelink.nasa.gov/products**

A PDF version of the lesson guide for NASA CONNECT can be found at the NASA CONNECT web site: **http://connect.larc.nasa.gov**

NASA CONNECT

Data Analysis and Measurement: Having a Solar Blast!

A Lesson Guide with Activities in Mathematics, Science, and Technology

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Acknowledgments: Special thanks to Michelle Larson, the NOAA GOES Satellite, Chris Giersch, Bill Williams, and NCTM.

Program Overview

SUMMARY AND OBJECTIVES

In *Data Analysis and Measurement: Having a Solar Blast!*, students will learn how NASA researchers study the Sun. They will learn how satellite technology plays a pivotal role in helping NASA researchers understand the Sun-Earth connection. Students will learn about three current satellites that monitor the Sun: SOHO, ACE, and IMAGE. They will also receive information about HESSI, a satellite that will study solar flares. Students will observe NASA researchers using data analysis and measurement to determine the solar cycle of the Sun. By conducting hands-on and web activities, students will make connections between NASA research and the mathematics, science, and technology they learn in their classrooms.

STUDENT INVOLVEMENT

Cue Card Questions

Norbert, NASA CONNECT's animated cohost, poses questions throughout the broadcast. These questions direct the instruction and encourage students to think about the concepts being presented. When viewing a videotaped version of NASA CONNECT, educators have the option to use Norbert's Pause, which gives students an opportunity to reflect and record their answers on the Cue Cards (p. 13). Norbert appears with a remote to indicate an appropriate time to pause the videotape and discuss the answers to the questions.

Hands-On Activity

The teacher-created, hands-on activity is aligned with the National Council of Teachers of Mathematics (NCTM) standards, the National Science Education (NSE) standards, the International Technology Education Association (ITEA) standards, and the National Education Technology (NET) standards. Students will discover the solar cycle through an investigation of solar X-ray flares. They will use data analysis and measurement to plot their findings to help them identify the long-term pattern of flare activity on the Sun.

Instructional Technology Activity

PBL: Space Weather is aligned with the National Council of Teachers of Mathematics (NCTM) standards, the National Science Education (NSE) standards, the International Technology Education Association (ITEA) standards, and the National Education Technology (NET) standards. This online Problem-Based Learning (PBL) activity will engage and motivate students to solve a real world problem. Students will use the Internet to learn more about the Sun and to develop possible solutions to the problem. To access PBL: Space Weather, go to Dan's Domain on NASA CONNECT's web site at **http://connect.larc.nasa.gov/dansdomain.html**.

RESOURCES

Teacher and student resources (p. 16) support, enhance, and extend the NASA CONNECT program. Books, periodicals, pamphlets, and web sites provide teachers and students with background information and extensions. In addition to the resources listed in this lesson guide, the NASA CONNECT web site, **http://connect.larc.nasa.gov**, offers online resources for teachers, students, and parents. Teachers who would like to get the most from the NASA CONNECT web site can visit the "Lab Manager," located in "Dan's Domain," **http://connect.larc.nasa.gov/dansdomain.html**.

Hands-On Activity

BACKGROUND

The Sun is the nearest star to Earth and our proximity to it allows us to study it in great detail. Observations reveal that the Sun is extremely dynamic, with changes taking place on many timescales. Solar flares are among the fastest and most energetic events on the Sun.

Solar flares are the biggest explosions in the solar system! A solar flare occurs when magnetic energy that builds up in the solar atmosphere is suddenly released. Charged particles, such as electrons, protons, and heavier ions, are accelerated to such high energies that some are traveling at almost the speed of light. Some of these charged particles travel away from the Sun along magnetic field lines. Others move towards the surface of the Sun and emit X-rays and gamma rays as they slow down. Also, gas in the solar atmosphere is heated to temperatures as high as 100 million degrees Celsius. This heated gas emits X-rays as well. Flares produce all forms of electromagnetic radiation from radio waves and visible light to X-rays and gamma rays.

Solar Flares occur in the solar atmosphere. The solar atmosphere starts at the photosphere, where the visible light from the Sun originates. It extends through the intermediate layer called the chromosphere to the outermost layer called the corona. The gas in the corona normally has a temperature of a few million degrees. Inside a flare, the temperature typically reaches 10 to 20 million degrees and can be as high as 100 million degrees Celsius. The frequency of solar flares varies with the Sun's 11-year cycle. When the solar cycle is at a minimum, very few flares occur. As the Sun approaches the maximum part of its cycle, they begin to occur more and more frequently.

The biggest flares are as powerful as billions of hydrogen bombs exploding at the same time! We still don't know what triggers them or how they release so much energy in such a short time. Solar flares have a direct effect on the Earth's upper atmosphere. For instance, long distance radio communications can be disrupted by the effect the flares have on the Earth's ionosphere. In addition, energetic particles accelerated in solar flares that escape into interplanetary space are dangerous to astronauts outside the protection of the Earth's magnetic field and to electronic instruments in space. Understanding solar flares can aid in understanding energetic events throughout the Universe.

In the hands-on activity, "X-ray Candles: Solar Flares on Your Birthday", students will discover the solar cycle through an investigation of solar X-ray flares. Using the Geostationary Operational Environmental Satellite (GOES) X-ray data, students will record the total number of solar flares in their birth month over 11 years and will compute the percentage of high class flares which occur for each year. Students will graph their findings to help them identify the long-term pattern of flare activity on the Sun.

NATIONAL STANDARDS

Mathematics (NCTM) Standards

- Understand numbers, ways of representing numbers, relationships among numbers, and number systems.
- Compute fluently and make reasonable estimates.
- Use mathematical models to represent and understand quantitative relationships.
- Apply appropriate techniques, tools, and formulas to determine measurements.
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them.
- Develop and evaluate inferences and predictions that are based on data.
- Build new mathematical knowledge through problem solving.
- Communicate mathematical thinking coherently and clearly to peers, teachers, and others.
- Create and use representations to organize, record, and communicate mathematical ideas.

Science (NSE) Standards

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry
- Earth in the solar system
- Understandings about science and technology
- Science as a human endeavor

Technology (ITEA) Standards

- Develop an understanding of the relationships among technologies and the connections between technology and other fields of study.
- Develop an understanding of the role of society in the development and use of technology.

Technology (NET) Standards

- Select and use appropriate tools and technology resources to accomplish a variety of tasks and solve problems.

INSTRUCTIONAL OBJECTIVES

The students will

- discover the solar cycle through an investigation of solar X-ray flares.
- record the total number of flares in their birth month over 11 years.
- compute the percentage of high class flares which occur.
- graph their findings to help them identify the long-term pattern of flare activity on the Sun.
- incorporate collaborative problem-solving strategies in a real-life application.

VOCABULARY

chromosphere - the layer of the Sun, pinkish in color and composed of hydrogen, that lies between the visible surface (the photosphere) and the corona

corona - the outermost layer of the Sun's atmosphere that begins immediately above the chromosphere and that contains gas at temperatures of 1 to 2 million degrees kelvin

electromagnetic spectrum - contains every frequency and wavelength of electromagnetic radiation that exists

gamma ray - extremely high-energy radiation observed during large, very energetic solar flares. Gamma rays are more energetic and have shorter wavelengths than all other types of electromagnetic radiation.

magnetic field - a field of magnetic force lines, usually referred to as the pattern of magnetic force emanating from and surrounding the Sun or any of the planets

photosphere – the lowest layer of the solar atmosphere, where the Sun's visible spectrum of light (electromagnetic radiation) is released. It is the visible "surface" we see in white-light images of the Sun.

radio waves – energy waves produced by charged particles naturally emitted by the Sun and other stars

solar flare – a sudden eruption in the vicinity of a sunspot, lasting minutes to hours and caused by the release of large amounts of magnetic energy in small volume above the solar surface

Solar Maximum - the month(s) during the Solar Cycle when the 12-month mean (average) of monthly average sunspot numbers reaches a maximum

Solar Minimum - the month(s) during the Solar Cycle when the 12-month mean (average) of monthly average sunspot numbers reaches a minimum

sunspot – a dark, cooler area on the Sun's surface. Charged particles are emitted from these areas. The average sunspot is about the same diameter as the Earth.

visible light – the region of the electromagnetic spectrum that can be perceived by human vision

X-ray - electromagnetic radiation of very short wavelength and very high energy

PREPARING FOR THE ACTIVITY

Student Materials (per 4-student group)

Calculator
Graph Paper (p. 12)
Student Data Charts (p. 10 - 11)

Teacher Materials

Solar flare data from the Internet
Summary Flare Counts (p.15)

Time

Discussion of the activity................................10 minutes
Performing the activity...................................30 minutes

Focus Questions

1. What is a solar flare?
2. Where do solar flares occur?
3. How often do solar flares occur?
4. Why do NASA researchers and engineers study solar flares?

Advance Preparation

A. Solar flare data for each month of the year from 1990 – 2001 can be accessed at **http://connect.larc.nasa.gov/solarflaredata.html**. The data are broken down into six columns: date, #B Flares, #C Flares, #M Flares, #X Flares, and Total Flares. Scientists use a series of letters to classify the energy level of an X-ray flare. The letters used are A, B, C, M, and X, with A being the weakest and X being the strongest. X-ray flare intensity is measured in units of power per area or W/m^2. Each letter represents a certain numeric value. For this activity, the teacher will only use the X-ray classification letter. There are very few A-class flares in the data because satellites can only record flares which are above the normal X-ray level of the Sun and A-class flares are normally below this level.

B. Print out a copy of the solar flare data for each month from 1990-2001. There are 12 pages of data for each month.

THE ACTIVITY

Step 1: Introducing the Activity

A. Organize students into groups according to their birth month. If there is a month for which no one has a birthday, the teacher can use the Summary Flare Count (p. 15) to fill in data for the months where the teacher has no one to perform the activity. Also, if the teacher sees that a group is too big, he or she can ask students to pick a birth month not being used.

B. Provide each group with the solar flare data for the corresponding birth month.

C. Provide each student with a calculator, graph paper, and student data charts.

Step 2: Conducting the Activity

A. Have students add the total number of flares that occurred in their birth month for each year. To do this, first add together the numbers across the row for each day. Have students record that number in the last column of each row.

B. Have students add together all the numbers in the last column to determine the total number of flares in their birth month for each year. Have students record the total number of flares for each year in the box at the bottom right of each page.

C. Have students add the total number of M-class flares in their birth month for each year. Students can do this by adding together all the numbers in the M-class column.

D. Have students record the total number of M-class flares for each year in the box at the bottom middle of each page.

Note: M-class flares are singled out because they are always strong enough to show up above normal X-ray levels of the Sun. X-class flares are the most energetic and are strong enough to be visible, but they do not occur very often; therefore, it would not be interesting to count them.

E. Have students obtain the total number of flares for all months in each year. Groups will need to collaborate with each other to obtain the information. Have students record the data on Data Chart A (p. 10).

F. Have students obtain the total number of M-class flares for all months in each year.

G. Groups will need to collaborate with each other to obtain the information. Have students record the data on Data Chart B (p. 10).

H. Have students calculate the total number of flares and M-class flares for each year.

I. Record the data on Data Chart C (p. 11).

J. Have students compute the percentage of M class flares for each year. This is done by dividing the number of M-class flares by the total number of flares and multiplying that number by 100. Record the percentage of M-class flares for each year on Data Chart C.

K. Have students use graph paper to plot the percentage of M-class flares versus year.

L. The year should be along the horizontal axis, and the percentage of M-class flares along the vertical axis.

Step 3: Discussion

A. In analyzing the graph, what can you conclude about the percentage of high-energy solar flares from the Sun?

B. What year had the lowest percentage of M-class flares and the highest percentage of M-class flares? What is the difference in years between those two percentages?

C. In general, the Sun goes through a regular solar cycle approximately every 11 years. Based on the graph, predict when the next solar maximum and solar minimum will occur.

D. When you reach your 30th birthday, at what stage in the solar cycle will the Sun be?

E. In analyzing the data, what are some other ways to graphically represent the length of the solar cycle?

F. Why is it important for researchers and engineers to know when solar maximums and solar minimums will occur?

Extensions

A. Have the students research the relationship between solar flares and sunspots. Have students determine if the solar cycle can be calculated based on the number of sunspots on the Sun.

B. Have students research Native American folklore concerning the Sun. Students can write a research paper, develop a web page, or give an oral presentation on why Native Americans worshiped the Sun.

C. Have students use a graphing calculator to plot total number of flares vs. time.

D. Students can determine if this plot is more accurate in determining the solar cycle of the Sun.

Student Worksheets

Name: ______________________________ Date: ______________________

Data Chart A

Total Number of Flares by Month

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1990												
1991												
1992												
1993												
1994												
1995												
1996												
1997												
1998												
1999												
2000												
2001												

Data Chart B

Total Number of M-Class Flares by Month

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1990												
1991												
1992												
1993												
1994												
1995												
1996												
1997												
1998												
1999												
2000												
2001												

Name: ______________________________ Date: ______________________

Data Chart C

	Total Number of Flares	Total Number of M-Class Flares	Percentage of M-Class Flares
1990			
1991			
1992			
1993			
1994			
1995			
1996			
1997			
1998			
1999			
2000			
2001			

Name:

Date:

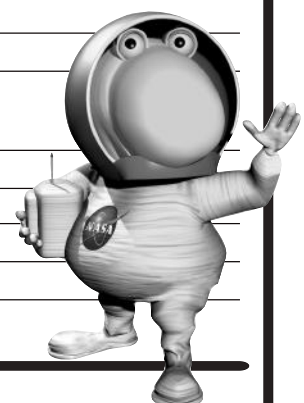
Cue Cards

Dr. Sten Odenwald, Astronomer,
IMAGE Satellite Program, NASA Goddard Space Flight Center

1. What are some forms of electromagnetic radiation?

2. How can satellites help researchers monitor the Sun?

3. Why is it important to track solar storms as they approach Earth?



Dr. Michelle Larson, Astrophysicist, University of California at Berkeley

1. What is the goal of the HESSI satellite?

2. When do solar flares occur on the Sun?

3. How do solar flares have a direct effect on the Earth's atmosphere?

Teacher Materials

Cue Cards

Dr. Sten Odenwald, Astronomer, IMAGE Satellite Program, NASA Goddard Space Flight Center

1 What are some forms of electromagnetic radiation?

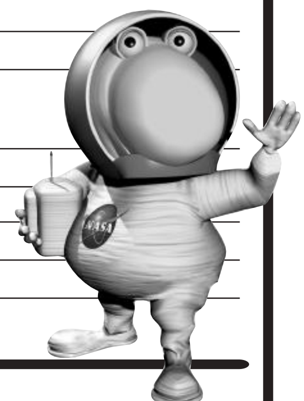
Possible Answers: visible light, radio waves, microwaves, infrared light, ultraviolet light, X-rays, gamma rays

2 How can satellites help researchers monitor the Sun?

Possible Answers: Satellites can be positioned outside of Earth's atmosphere to collect valuable data from the Sun and to act as early warning devices against solar storms.

3 Why is it important to track solar storms as they approach Earth?

Possible Answers: Solar storms have caused billions of dollars of satellite damage in the last 10 years. They have caused blackouts and will always be a hazard for astronauts working in space.



Dr. Michelle Larson, Astrophysicist, University of California at Berkeley

1 What is the goal of the HESSI satellite?

Possible Answers: The HESSI satellite is designed to learn more about the basic physical processes that occur in solar flares.

2 When do solar flares occur on the Sun?

Possible Answers: A solar flare occurs when magnetic energy that builds up in the solar atmosphere is suddenly released. Particles are accelerated to such high energies that some are traveling at almost the speed of light.

3 How do solar flares have a direct effect on the Earth's atmosphere?

Possible Answers: Long distance radio communications can be disrupted by the effect of flares on the Earth's ionosphere, which is a part of Earth's atmosphere.

SUMMARY FLARE COUNTS

This information can be used to shorten the activity or to fill in data for months that have no one available to participate in the full activity.

Date	Total # Flares	# M Class Flares
Jan 2001	197	10
Feb 2001	107	1
Mar 2001	253	37
Apr 2001	212	38
May 2001	181	11
Jun 2001	241	13
Jul 2001	149	3
Aug 2001	325	22
Sep 2001	262	50
Oct 2001	264	32
Nov 2001	310	46
Dec 2001	205	47
Jan 2000	149	9
Feb 2000	202	14
Mar 2000	343	37
Apr 2000	210	11
May 2000	235	20
Jun 2000	222	21
Jul 2000	273	51
Aug 2000	168	3
Sep 2000	232	14
Oct 2000	174	11
Nov 2000	200	17
Dec 2000	253	7
Jan 1999	243	10
Feb 1999	152	6
Mar 1999	200	11
Apr 1999	165	5
May 1999	199	16
Jun 1999	202	17
Jul 1999	249	23
Aug 1999	225	23
Sep 1999	135	2
Oct 1999	212	8
Nov 1999	250	40
Dec 1999	192	9
Jan 1998	176	5
Feb 1998	144	0
Mar 1998	235	10
Apr 1998	143	4
May 1998	236	15
Jun 1998	155	4
Jul 1998	159	3
Aug 1998	187	14
Sep 1998	170	9
Oct 1998	177	3
Nov 1998	241	15
Dec 1998	225	12
Jan 1997	10	0

Date	Total # Flares	# M Class Flares
Feb 1997	55	0
Mar 1997	46	0
Apr 1997	88	1
May 1997	76	1
Jun 1997	14	0
Jul 1997	56	0
Aug 1997	94	1
Sep 1997	202	6
Oct 1997	86	0
Nov 1997	267	11
Dec 1997	147	1
Jan 1996	72	0
Feb 1996	10	0
Mar 1996	32	0
Apr 1996	41	1
May 1996	49	0
Jun 1996	12	0
Jul 1996	68	2
Aug 1996	75	0
Sep 1996	2	0
Oct 1996	2	0
Nov 1996	70	1
Dec 1996	77	0
Jan 1995	169	0
Feb 1995	157	5
Mar 1995	208	1
Apr 1995	100	2
May 1995	120	0
Jun 1995	102	0
Jul 1995	40	0
Aug 1995	43	0
Sep 1995	46	0
Oct 1995	106	3
Nov 1995	25	0
Dec 1995	8	0
Jan 1994	279	11
Feb 1994	104	2
Mar 1994	178	0
Apr 1994	100	0
May 1994	77	0
Jun 1994	75	1
Jul 1994	140	1
Aug 1994	158	8
Sep 1994	106	0
Oct 1994	160	1
Nov 1994	77	0
Dec 1994	154	1
Jan 1993	135	2
Feb 1993	281	17

Date	Total # Flares	# M Class Flares
Mar 1993	256	13
Apr 1993	220	3
May 1993	204	5
Jun 1993	211	13
Jul 1993	152	4
Aug 1993	139	1
Sep 1993	116	2
Oct 1993	233	3
Nov 1993	197	3
Dec 1993	284	8
Jan 1992	235	39
Feb 1992	290	47
Mar 1992	176	4
Apr 1992	197	8
May 1992	161	5
Jun 1992	193	7
Jul 1992	255	12
Aug 1992	309	12
Sep 1992	273	33
Oct 1992	300	24
Nov 1992	216	7
Dec 1992	210	4
Jan 1991	277	32
Feb 1991	254	52
Mar 1991	367	103
Apr 1991	218	41
May 1991	252	39
Jun 1991	308	66
Jul 1991	266	29
Aug 1991	217	33
Sep 1991	272	24
Oct 1991	314	53
Nov 1991	238	27
Dec 1991	341	91
Jan 1990	168	25
Feb 1990	175	10
Mar 1990	261	28
Apr 1990	195	21
May 1990	205	28
Jun 1990	174	21
Jul 1990	161	13
Aug 1990	186	25
Sep 1990	172	16
Oct 1990	244	11
Nov 1990	358	25
Dec 1990	331	50

Resources

BOOKS, PAMPHLETS, AND PERIODICALS

Campbell, Wallace H. (1997). *Introduction to Geomagnetic Fields.* New York: Cambridge University Press.

Friel, Susan; Rachlin, Sid; and Doyle, Dot: *Navigating through Algebra in Grades 6-8* (with CD-ROM), NCTM, 2001. (This book is also available for purchase on **http://nctm.org/publications** under new books.)

WEB SITES

Sun Science

http://cse.ssl.berkeley.edu/hessi_epo/html/cur.html
http://www.exploratorium.edu/spectra_from_space/xray_activity.html
http://imagine.gsfc.nasa.gov/docs/science/know_l1/emspectrum.html
http://www.hao.ucar.edu/public/education/slides/slides.html
http://hesperia.gsfc.nasa.gov/sftheory/index.htm
http://www.lmsal.com/YPOP/Classroom/Lessons/Cycles/
http://image.gsfc.nasa.gov/poetry/sunspot/sunspot.html
http://www.spaceweather.com/

Satellites and Science

http://wwwssl.msfc.nasa.gov/msl1/ground_lab/aroundtheworld.htm
http://octopus.gma.org/surfing/satellites/index.html
http://observe.ivv.nasa.gov/nasa/exhibits/learning/learning_0.html
http://deepspace.jpl.nasa.gov/dsn/tutor/

The HESSI Mission

http://cse.ssl.berkeley.edu/hessi_epo/html/cur.html
http://hesperia.gsfc.nasa.gov/hessi/hessi_model.pdf
http://hesperia.gsfc.nasa.gov/hessi/

Figure This!
Offers Mathematics Challenges that middle school students can do at home with their families to emphasize the importance of a high-quality mathematics education for all.

http://www.figurethis.org

Engineer Girl

Part of the National Academy of Engineering's Celebration of Women in the Engineering project. The project brings national attention to the opportunity that engineering represents to people of all ages, particularly to women and girls.

http://www.engineergirl.org

GetTech

Through its web site and collateral materials, GetTech helps prepare students in fun ways for tomorrow's great jobs.

http://gettech.org

Event-Based Science

Event-Based Science is a new way to teach science at the middle school level. Newsworthy events establish the relevance of science topics; authentic tasks create the need-to-know more about those topics; and lively interviews, photographs, web pages, and inquiry-based science activities create a desire to know more about those topics.

http://www.mcps.k12.md.us/departments/eventscience

7 Steps for Teachers Using Television in the Classroom

TV programs can add a new dimension to your classroom and promote active learning among your students. The following steps can guide you in preparing a lesson using instructional television:

http://www.qued.org/erc/teachers/mediatips.html