# Heliophysics: What are the Impacts of Space Weather on Humanity? Lessons for 7th Grade

Prepared by: The Institute for the Integration of Technology into Teaching and Learning (IITTL) in collaboration with the NASA HEAT Project

Authors: Rhonda Christensen, Gerald Knezek, Fred Hobbs and Jenna Kelley
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UNT UNIVERSITY OF NORTH TEXAS®

HEAT HELIOPHYSICS EDUCATION ACTIVATION TEAM

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This set of lessons is focused on the one of three essential questions highlighted in the heliophysics topic found at https://science.nasa.gov/heliophysics.

**Essential Question: What are the impacts [of space weather] on humanity?**
https://science.nasa.gov/heliophysics/big-questions/how-does-solar-variability-affect-human-society-technological-systems-and-the-habitability-of-planets

The lessons are intended to engage learners in the concepts described. The lessons included are:

Lesson 1: What is Space Weather?
Lesson 2: Predicting Space Weather
Lesson 3: Sunspots
Lesson 4: Phases of the Moon

In many lessons there are activities that require technology apps and equipment. The following list contains the different apps and equipment needed for the activities. Each lesson includes several activities so if you don't have one of the needed tools, there are other ways to teach the concepts.

| Lesson | Hardware and Software Requirements |
|---|---|
| Lesson 1 | Computer with projection system and Internet access for videos; *NASA Space Weather* app (Android) |
| Lesson 2 | Internet access; *DIY Sun Science* app on iPad (iOS device) |
| Lesson 3 | Access to the internet and browser; computer to show ppt |
| Lesson 4 | Computer with projection system and Internet access for videos; *My Moon Phase* app |


**Concept:**
What is space weather? Space weather is caused by the Sun's constant outflow of radiation and solar wind, caused by magnetic storms on the surface of the Sun.

**Objectives:**
Students will be able to describe the scientific term, "space weather" and be able to distinguish it from weather on Earth, which is also caused by the Sun.

**Standards Addressed (Grades 5-8)**

- TEKS (D)(9) (B) identify the accommodations, considering the characteristics of our solar system, that enabled manned space exploration
- NGSS The solar system consists of the sun and a collection of objects, including planets their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. (MS-ESS1-2), (MS-ESS1-3); Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and law s that describe the natural world operate today as they did in the past and will continue to do so in the future.(MS-ESS1-4)

**Materials:**
Computer with projection system and Internet access for videos; NASA Space Weather app (Android only)

**Activities:**
Background information: https://science.nasa.gov/heliophysics/space-weather

1. Predicting Space Weather
   - Watch video *An Introduction to Space Weather and the Space Weather Prediction Center* (4m 56s)
     https://www.youtube.com/watch?v=JncTCE2NWgc&feature=emb_logo
   - Concepts addressed:
     - The sun is our main energy source and is in a chaotic state
     - Space weather impacts the earth and our technology (power, GPS data, air traffic, astronauts, space station)
     - Eruptions can be forecasted early (Space Weather Prediction Center)

2. Storms in Space

- On Sept. 1-2, 1859 the largest geomagnetic storm ever recorded hit the earth. Can you find the name of this event, and some of the effects it caused? (Go to: https://www.nasaspaceflight.com/2020/08/carrington-event-warning/).
- On July 23, 2012 NASA's STEREO spacecraft recorded a storm of similar strength to the one in 1859, ejected from the surface of the sun. Can you explain why it didn't hit the earth? If it had, would the impact be greater or less than in 1859? Do you think such a storm will hit the Earth in the future? What measures are in place to predict these storms?
- Play the game to see how much you recognize about the different solar topics such as coronal mass ejection, coronal loop, sunspots, corona, and aurora. https://scied.ucar.edu/interactive/sun-space-weather-memory-game
  Once you master the first level, try more difficult levels until you are a sun expert!

**3.** Space Weather Index
- The **Kp index** measures changes in the Earth's magnetic field due to the relative strength of a magnetic storm reaching the Earth. The Kp index uses a 0-9 scale, with zero being very quiet and 9 indicating a major geomagnetic storm. The letters Kp come from 'K' as is 'Kennziffer' ('index' in German) and 'p' as in planetary.
- Download the NASA Space Weather app (Android). Scroll through the different views for today given by several NASA satellites and other monitoring systems. Near the end are displays called the Solar Flare Monitor and the Planetary KP. What is the likelihood of a solar flare erupting from the surface of the sun today? How large is the KP index today? Are you worried that your cell phone communications or electric power grid systems might be disrupted by a geomagnetic storm originated on the sun today?

**4.** Finding Recent Geomagnetic Storms
- Access the National Oceanic and Atmospheric Administration Space Weather Prediction Center (NOAA) website at: https://www.swpc.noaa.gov/products/real-time-solar-wind. Slide your cursor across the top graph to see the intensity of current solar storms. Is there any point in the graph higher than a Kp Index of 5 (bottom of the two numbers displayed)? If not, change the display setting in the lower left corner of the screen from one day (default) to one month, one year, or five years (as needed) so that you can view Feb. 13, 2021. What is the highest Kp index you find by sliding across part of Feb. 13 and Feb. 14?
- Access the story found at https://www.space.com/10862-sun-erupts-powerful-solar-flare.html to find out what happened that day.
- Then access https://www.nationalgeographic.com/science/article/110302-solar-flares-sun-storms-earth-danger-carrington-event-science to compare Feb. 13-14, 2021 to Sept. 1-2 1859. Was the effect of the solar flare that erupted toward the Earth in Feb. 2021 small or large compared to the one in Sept. 1859?

**Assessment:**
Why is it important for humans to monitor space weather?
What was the name of the most powerful geomagnetic storm known to strike the Earth?
What year did it occur?
Evidence for understanding could include having students comparing and contrasting space weather and weather on Earth.


**Concept:**
The best way to protect against **space weather** hazards is to accurately predict them so that we can determine what precautions need to be taken. **Prediction of space weather** helps to protect human space exploration, technological assets, communications systems, and Earth-based power systems

**Objectives:**
Students will be able to explain that accurate prediction is the best protection against space weather.

**Standards Addressed (Grades 5-8)**

- TEKS (D)(9) (A) analyze the characteristics of objects in our solar system that allow life to exist such as the proximity of the Sun, presence of water, and composition of the atmosphere;
- NGSS Analyze and interpret data to determine similarities and differences in findings. (MS-ESS1-3)

**Materials:**
DIY sun science app (iOS only);

**Activities:**

1. Exploring the sun and its dynamic weather
   - Download the "DIY Sun science" app
   - Click on "Observatory" that includes high resolution images of the sun take from NASA's Solar Dynamics Observatory (SDO)
   - Learn about sunspots, solar flares, coronal mass ejections, solar prominence and coronal loops noting the characteristics of each
   - Go to the "puzzle" to match the image with the term
   - Under the "images+videos" gallery, explore the most recent 48-hours of the sun; explore four large flares that have occurred over a 48-hour period of time; explore a "big blast"
   - When these actions occur, what impact do they have on the earth?
   - Go to "Views from the SOHO satellite" that shows changes over time from 1996 to 2005; in which year(s) did the most activity occur? Was it during a solar minimum or solar maximum?
2. Predicting space weather
   - Scientists use information from satellites to predict the solar weather forecast. Watch video at https://scijinks.gov/space-weather-snap/ (2m 16s)
   - View the videos about space weather and how it impacts us (4m 56s) https://www.youtube.com/watch?v=JncTCE2NWgc

Video on how space weather impacts GPS (3m 13s)
https://www.youtube.com/watch?v=V4rSC6Hje0E

- There is a center focused on predicting space weather. Visit the Space Weather Prediction Center https://www.swpc.noaa.gov/content/education-and-outreach Explore the data that is supplied by satellites in space such as the solar sunspot progression at https://www.swpc.noaa.gov/products/solar-cycle-progression.
- What patterns do you see in the data?

**Assessment:**
How do we protect ourselves from space weather?
Analyze the effectiveness of space weather prediction methods.
Evidence for understanding could include having students analyze space weather prediction methods.


**Concept:**
The Sun has dark spots, called "**sunspots**." Sunspots are slightly cooler regions on the Sun's surface.

**Objectives:**
Students will be able to identify that there are cooler regions on the surface of the Sun that are called "sunspots."

**Standards Addressed (Grades 5-8)**

- TEKS (D)(9) (B) identify the accommodations, considering the characteristics of our solar system, that enabled manned space exploration
- NGSS Analyze and interpret data to determine similarities and differences in findings. (MS-ESS1-3)

**Materials:**
Access to the internet and browser; computer to show ppt

**Activities:**
Background info**:** Sunspots are areas that appear dark on the surface of the Sun. They appear dark because they are cooler than other parts of the Sun's surface. The temperature of a sunspot is still very hot though—around 6,500 degrees Fahrenheit! The sunspots are relatively cool because they form at areas where magnetic fields are particularly strong. These magnetic fields are so strong that they keep some of the heat within the Sun from reaching the surface.

1. Exploring sunspots
   - View Sunspot ppt (from Cal Berkeley[1])
     https://www.weather.gov/fsd/sunspots
   - Concepts addressed:
     - Size and distance of sun
     - Different parts of the sun
     - Sunspots
     - Sun changing its spots
     - Solar cycle

2. Solar Cycle

[1] http://cse.ssl.berkeley.edu/SEGwayed/lessons/exploring_magnetism/in_Solar_Flares/s4.html#act1

- View video *NASA: Solar Cycle*
  https://www.youtube.com/watch?v=sASbVkK-p0w
- Concepts addressed:
  - Solar cycle is typically 11 years (range 8-14)
  - Solar minimum
  - Solar maximum
  - Location of sunspots during cycle
  - Powerful magnetic fields
  - Solar flares
  - Coronal mass ejection
  - Sun poles flip
- Describe the different between a solar minimum and a solar maximum.
- How long are the solar cycles typically?
- Go to https://spaceplace.nasa.gov/solar-cycles/en/ to explore topics related to the solar cycle. How many years does it typically take to complete the solar cycle?

3. Solar Minimum is coming 2020 (3m 55s)
   https://www.youtube.com/watch?v=NhhV2dgGS-o
   - Where are we currently in the cycle – closer to max or min?
   - Concepts addressed:
     - Sunspots
     - Solar cycle
     - Solar activity
     - Coronal holes
     - Solar wind
     - Earth's magnetic field
     - UV radiation and the weakening of sun's magnetic field/shield
     - Impact on earth, astronauts and spacecraft

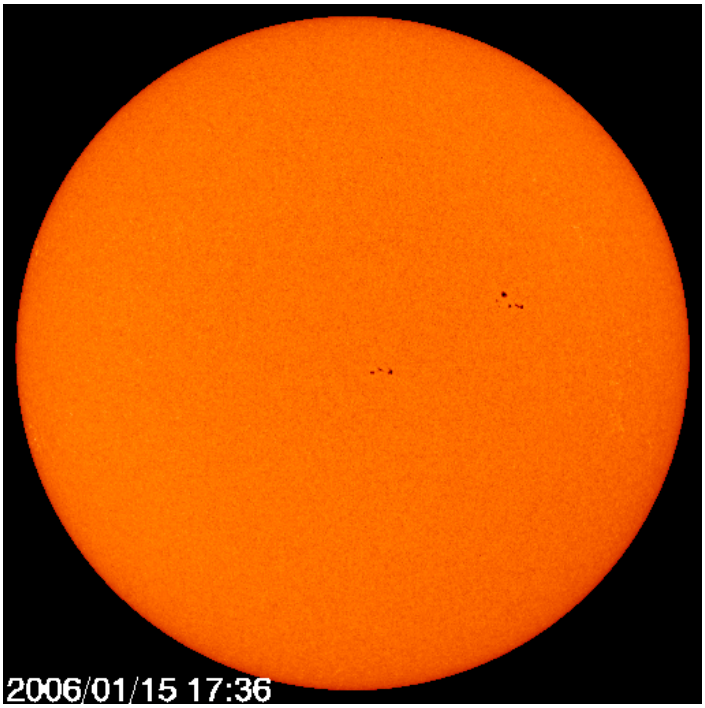
4. Galileo's sunspot drawings – in the 1600s, Galileo was observing and drawing images of the sun that revealed sunspots.
   - View the images of the sunspots drawn daily over a period of 5 weeks in 1613
     http://galileo.rice.edu/sci/observations/sunspot_drawings.html
   - What observations can you make regarding the number of sunspots over time?

5. Helioviewer Activity to Explore Sunspots and the Solar Cycle
   - Go to https://student.helioviewer.org/
   - Start with today's date. Set the "Time Step" to 1 Year. Go backwards each year for 11 years to see the changes in the number of sunspots. Which years have the most? Least? Does there appear to be a cycle? Where is the cycle now?

6. Using sunspots to help predict space weather
   - Ultraviolet radiation increases dramatically during high sunspot activity, which can have a large effect on the Earth's atmosphere.

- To create a simplified calculation of the sunspot contribution to space weather, calculate the Relative Spot Number (RSN) index (R= 10g+s)
- R = the Relative Spot Number, g = number of sunspot groups and s = total number of individual sunspots (both in groups and alone)
- View 5 images of the sun taken from different days (better if spread over a period of days or weeks).
- Calculate the RSN index for each of the images.

Example of calculation of RSN based on image from SOHO:
There are 2 sunspot groups and approximately 11 individual spots so plugging numbers into equation, R = 10g + s would be R = 10(2) + 11 = 31




Predicted sunspot forecast https://www.swpc.noaa.gov/products/predicted-sunspot-number-and-radio-flux
http://www.sidc.be/silso/datafiles

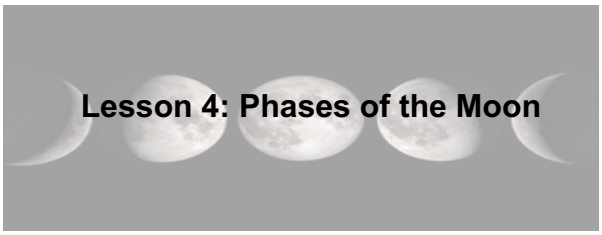
7. Sunspot cycle
   - Use the following resources to understand what sunspots look like, when they appear and what cycle they follow.
     - Sunspot cycle by year https://solarscience.msfc.nasa.gov/SunspotCycle.shtml
     - Viewing sunspots https://www.exploratorium.edu/sunspots/
     - Graph of predicted solar cycle https://solarscience.msfc.nasa.gov/images/ssn_predict_l.gif
     - Play the game in which you categorize the images of the sun into solar max or solar min. When you categorize the images, you will see more

information about the sun. https://scied.ucar.edu/interactive/sun-sorting-game

- Another game allows you to compare multi-spectral sun images at different times and in different colors https://scied.ucar.edu/interactive/sun-compare-multispectral

**Assessment:**

Why does the Sun (when seen up close with special telescopes) have dark spots? The Sun's surface has varying temperatures. What are some other examples of things you have observed on Earth or in the Universe that have varying temperatures? Evidence for understanding could include having students analyze various images of the Sun with temperature data.




**Concept:**
The phases of the moon are determined by its position in its orbit around the Earth and the Sun. We view different phases from the earth because we see the side of the moon illuminated by the sun.

**Objectives:**
The students will be able to understand why we see the moon in different phases and what those phases are called.

**Standards Addressed (Grades 5-8)**

- TEKS (1) (D) Earth and space. Earth and space phenomena can be observed in a variety of settings. Both natural events and human activities can impact Earth systems. There are characteristics of Earth and relationships to objects in our solar system that allow life to exist.
- NGSS Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models. (MS-ESS1-1)

**Materials:**
*My Moon Phase* app**,** internet access on a device

**Activities:**

1. Moon Phases
   - Go to https://spaceplace.nasa.gov/moon-phases/en/
   - Explore the different phases of the moon. Go to the “what the moon looks like right now from earth” and move the slider to see what it will look like tomorrow and the next day. How many days ago was the “New Moon”?
2. Download “My Moon Phase” app. Note there two versions. Choose the one that is free.

   **Use the calendar feature to find out when the next full moon will occur using your current location.**
   - Install the app and note that it shows today's date and data across the top, with an illustration of the current phase of the moon in the middle of the screen. It may ask to use your location and you should indicate "yes."
   - Scroll through the dates at the top of your screen and note the changes in the moon illustration as you get closer to a full moon.
   - Stop scrolling when you see the moon is full and read the projected date as the answer to the question.

   **How long is one complete cycle of the phases of the moon?**

- With the App open, click the button in the upper right hand corner of your screen that looks like a calendar.
- Choose the month after the one you are currently viewing, on the calendar.
- Click on several days to find out which one gives you 98% or 99% full moon image.
- Count the number of days between the full moon you identified for the previous question, and the full moon that will come after that.

3. Simulating the moon phases
   - Go the link that allows you to see the phases of the moon simulated. https://kera.pbslearningmedia.org/resource/buac19-35-sci-ess-earthsunmoon35model/moon-phases-simulation-viewed-from-earth-and-space/
   - Note the relationship of the moon to the earth and the sun. What is happening? Can you explain why the moon appears to be different sizes?

**Assessment:**

Students can keep a moon journal for one month making observations of the Moon with adequate detail and notes.

Students should be able to explain that the Moon goes through phases and appears in the sky at different times of day and night, depending on its phase.

Teachers' guide to moon phases
http://solar-center.stanford.edu/activities/MoonPhases/