Space Weather (Sunspots and Solar Flares

By Raphael Lucas

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# Lesson Overview

Level: Middle School Time: Ten 50-minute class periods

This lesson begins with students watching the video, [Chasing Sunspots](https://www.youtube.com/watch?v=Y8eCcebGiN4%20s). Students will then complete a T-chart (I Wonder/I Notice) and describe the direction of the Sun’s rotation in the video. Then students will watch the video: [The Carrington event of 1859 — the largest solar flare ever recorded.](https://youtu.be/9cNf8xK67JA) to learn of a real world problem which occurred in 1859. Students will then use current data from NASA about sunspot activity starting from 1950 until present day (2022), to look for trends in sunspot activity over the last 70 years.

Using an Evidence Gradient Chart, students will learn about the evidence criterion for data, long-term trends vs. short-term fluctuations, determine which evidence card is more convincing, and learn about maximum and minimum value points in the data.

Students will observe sunspots to estimate their size and the rate at which they move across the face of the Sun. They will hypothesize about sunspot movement on the opposite side of the hemisphere they observed.

Finally, students will research space weather phenomena and its impact on Earth’s changing climate, on technology, communications and daily life, and engage in scientific argument, using evidence and reasoning, to convince others about the effects of climate change.

**Educator Background Knowledge**

Space weather is defined as the flow of particles and radiation from the Sun in the form of the solar wind, CMEs, and solar flares. Sunspots are caused by intense magnetic storms on the Sun. As the Sun rotates, lines of magnetic force wrap around it. These lines dip into the Sun’s interior and then back out, forming sunspots. This explains why many sunspots occur in pairs and why the members of the pair have opposite magnetic polarity. The Sun’s magnetic field goes through a cycle, called the Solar Cycle, every 11 years, during which the Sun’s North and South poles switch every 11 years. It takes another 11 years for these poles to flip back.

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**Learning Goals**

To introduce students to the idea of space weather, and to help them become familiar with phenomena associated with space weather.

**Learning Objectives**

1. Students will describe the impacts of space weather on Earth’s climate.
2. Students will research phenomena associated with space weather and present their findings.
3. Students will use the NOAA [Solar Cycle Progression Chart](https://www.swpc.noaa.gov/products/solar-cycle-progression) to observe differences between Solar Cycle 23 and 24 and to evaluate predictions made by scientists for Solar Cycle 25.
4. Students will list the impacts of space weather on technology and daily life.
5. Students will be able to differentiate between a trend and a fluctuation using NASA sunspot activity data from as early as 1950 to 2022, and from students’ birth dates.

**Framework for Heliophysics Education**

NASA Question: What are the impacts of the Sun on humanity? Big Idea: [The Sun is really big and its gravity influences all objects in the solar system.](https://solarsystem.nasa.gov/heat/big-ideas/big-idea-1-1/)

**NGSS Performance Expectations**

* MS-ESS1-2: Earth’s Place in the Universe: Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.
* MS-PS2-3: Motion and Stability: Forces and Interactions: Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.

**Disciplinary Core Ideas**

* MS-ESS1.A: The Universe and Its Stars: 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-PS2.B: Types of Interactions: Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively).

**Crosscutting Concepts**

* MS-ESS1: Patterns: Patterns can be used to identify cause-and-effect relationships.

**Common Core Standards for Mathematical Practice**

* Use graphs to analyze and display data: Standards require middle school students to create graphs and analyze data from their graphs.
* Estimation: Compute fluently and make reasonable estimates.

**Targeted STEM Skills**

* Analyzing and Interpreting Data: Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis. Analyze and interpret data to determine similarities and differences in findings.
* Using Mathematics and Computational Thinking: Mathematical and computational thinking in 6–8 builds on K–5 experiences and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments. Use mathematical representations to support scientific conclusions and design solutions.

# **Materials**

Refracting telescope, drawing paper, clipboard, tripod, graph paper, cardboard, scissors.

**Handouts**

* KWL Chart
* Carrington Event Worksheet
* For Project Ideas: Tales From Stanford Solar (Light, Energy, and the EM Spectrum):

<https://solarsystem.nasa.gov/resources/2288/the-solar-wind-across-our-solar-system/>

* Pre-post Assessment for a Heliophysics Unit that includes three lessons by Raphael Lucas: 1) Characteristics of the Sun; 2) EM (Electromagnetic) Spectrum; and 3) Space Weather. See lesson: **Characteristics of the Sun.**

**Links to Digital Resources for Students**

* NOAA Solar Cycle Progression: <https://www.swpc.noaa.gov/products/solar-cycle-progression>
* Make Sun Paper: <https://spaceplace.nasa.gov/sun-paper/en/>
* Chasing Sunspots: <https://www.youtube.com/watch?v=Y8eCcebGiN4>
* The Carrington event of 1859: The Largest Solar Flare Ever Recorded:

<https://www.youtube.com/watch?v=9cNf8xK67JA>

* What is Space Weather?: <https://svs.gsfc.nasa.gov/20192>
* SDO Spots X8.2 Class Solar Flare, September 10, 2017: <https://www.youtube.com/watch?v=ybfAvEVpBMo>.
* Student Helioviewer: <https://student.helioviewer.org>
* Explore Light — NASA: <https://www.nasa.gov/content/explore-light>
* Artemis Animations: <https://space.rice.edu/artemis/artemis_animations.html>

**Key Vocabulary**

Solar cycle, solar flares, coronal mass ejections (cme), solar wind, Earth’s magnetosphere, ionosphere, auroras

# 5E Steps

**Engage**

Use a K-W-L Chart with students to determine what they already know about space weather. Then watch the video [Chasing Sunspots](https://www.youtube.com/watch?v=Y8eCcebGiN4%20s) and discuss the Guiding Question.

* How is the Sun’s rotation described in the video?

**Explore**

Watch the [Carrington event of 1859: The Largest Solar Flare Ever Recorded](https://www.youtube.com/watch?v=9cNf8xK67JA) video to learn some of the real world effects of features of solar flares. Discuss the questions with students who should put the answers on their worksheet.

Questions:

1. In which year did humans begin recording storm activity on the Sun?
2. Solar Cycle 10 lasted from …………………….to ………………………
3. The eruption of the most powerful Sun storm lasted from……………………………………………………..
4. The Solar flares of 1859 took just over ………. hours to travel from the Sun to Earth.
5. The Northern lights produced from the Carrington event reached as far as the…………………., …………………. and …………………….
6. List two (2) effects the Carrington event had on life in 1859 and four (4) effects the Carrington event would have had on daily life today.

Watch the NASA video, What is Space Weather? <https://svs.gsfc.nasa.gov/20192> and the video SDO Spots X8.2 Class Solar Flare, September 10, 2017: <https://www.youtube.com/watch?v=ybfAvEVpBMo>.

**Explain**

Have students use the data provided in the NOAA [Solar Cycle Progression Chart](https://www.swpc.noaa.gov/products/solar-cycle-progression) to obtain data of sunspot activity for the first year of their lives. Each student should make a bar chart graph of sunspot activity during their birth date month.

Place students in small groups of four. The bar charts can help students to determine “Fluctuations vs Trends” in the data for the time periods. Have each group describe any observed trends and fluctuations over a 11-year period.

Students should be able to answer the following two questions:

1. Describe how the number of sunspots change from month to month during the year (fluctuations).
2. Describe how the number of sunspots changed from the year of your birth to the next year.

**Extend**

**A. Teacher-led real-world investigation: Can sunspot motion be used to determine the Sun’s period of rotation?**

***Learning Goals:***

1. Observe sunspots and estimate their size.
2. Estimate the rate at which sunspots move across the face of the Sun.

***Teacher Procedure***

1. Find a location where the Sun can be viewed at the same time of day for a minimum of five days. **WARNING**: ***Do not look directly at the Sun. Do not look through the telescope at the telescope at the Sun. You could damage your eyes.***
2. If the telescope has a small finder scope attached, remove it or keep it covered.
3. Set up the telescope with the eyepiece facing away from the Sun. Align the telescope so that the shadow it casts on the ground is the smallest size possible. Cut and attach the cardboard.
4. Trace any sunspots that appear as dark areas on the Sun’s image. Repeat this step at the same time each day for five days.
5. Have students answer these questions:
	1. Using the Sun’s diameter (approximately 1,390,000 Km), estimate the size of the largest sunspots you observed.
	2. Calculatehow many kilometers the sunspots move each day.
	3. Predict how many days it will take for the same group of sunspots to return to the same position in which they appeared on day 1.

***Conclusion and Analysis***

Have students answer these two questions:

1. What was the estimated size and rate of motion of the largest sunspots?
2. Infer how sunspots can be used to determine that the Sun’s surface is not solid like Earth’s surface.

**B. Research Activity**

Students will research the following question about space weather phenomenon and its impacts on Earth’s changing climate in *groups of three* and present their findings. **Question: Can sunspot activity be used to determine the Sun’s period of rotation?**

Students will be required to use the provided NASA resources on space weather provided by the teacher.

***Teacher Information:*** The Sun doesn’t behave the same way all the time. It goes through phases of high and low activity which make up the solar cycle. Approximately every 11 years, the Sun’s geographic poles change their magnetic polarity. The north and south magnetic poles swap. During this cycle, the Sun’s photosphere, chromosphere, and corona change from quiet and calm to violently active. The height of the Sun’s activity cycle, known as solar maximum, is a time of greatly increased solar activity. These include large eruptive events such as solar flares and/or coronal mass ejections. The latest solar Cycle-Solar Cycle 25-started in December 2019 when the minimum occurred. Scientists now expect the Sun’s activity to ramp up toward the next predicted maximum in July 2025.

**Additional Activities:**

Space Weather Math Activity: How Common are X-Class Solar Flares? <https://spacemath.gsfc.nasa.gov/sun/8Page44.pdf>

Art Activity: Make Sun Paper: <https://spaceplace.nasa.gov/sun-paper/en/>

**Evaluate**

Have students hypothesize about sunspot movement on the hemisphere they did not observe. Guiding Question:

* How might sunspots on the opposite hemisphere move compared to those plotted in this activity?

Revisit the KWL Chart with the class.

# Resources

* KWL Chart
* Carrington Event Worksheet and Answer Key
* Evidence Gradient Chart
* Solar Cycle Progression: <https://www.swpc.noaa.gov/products/solar-cycle-progression>
* Make Sun Paper: <https://spaceplace.nasa.gov/sun-paper/en/>
* Chasing Sunspots: <https://www.youtube.com/watch?v=Y8eCcebGiN4>
* The Carrington event of 1859: The Largest Solar Flare Ever Recorded:

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* What is Space Weather: <https://svs.gsfc.nasa.gov/20192>
* SDO Spots X8.2 Class Solar Flare, September 10, 2017: <https://www.youtube.com/watch?v=ybfAvEVpBMo>.
* Student Helioviewer: <https://student.helioviewer.org>
* Explore Light — NASA: <https://www.nasa.gov/content/explore-light>
* Artemis Animations: <https://space.rice.edu/artemis/artemis_animations.html>
* Pre-post Assessment for a Heliophysics Unit that includes three lessons by Raphael Lucas: 1) Characteristics of the Sun; 2) EM (Electromagnetic) Spectrum; and 3) Space Weather. See lesson: **Characteristics of the Sun.**

# Handouts

These begin on the next page.

**K-W-L Chart**

**TOPIC:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

| What I **K**now | What I **W**ant to Know | What I **L**earned |
| --- | --- | --- |
|  |  |  |

**Carrington Event Student Worksheet**

Watch the [Carrington event of 1859: The Largest Solar Flare Ever Recorded](https://www.youtube.com/watch?v=9cNf8xK67JA) video to learn some of the real world effects of features of solar flares.

**Questions:**

1. In which year did humans begin recording storm activity on the Sun?

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1. Solar Cycle 10 lasted from \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_to \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
2. The eruption of the most powerful Sun storm lasted from: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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1. The Solar flares of 1859 took just over \_\_\_\_\_\_\_\_ hours to travel from the Sun to Earth.
2. The Northern lights produced from the Carrington event reached as far south as

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

1. List two (2) effects the Carrington event had on life in 1859 and four (4) effects the Carrington event would have had on daily life today.

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**Carrington Event Student Worksheet Answer Key**

**Questions:**

1. In which year did humans begin recording storm activity on the Sun?

**1755.**

1. Solar Cycle 10 lasted from **December, 1855 to March, 1867.**
2. The eruption of the most powerful Sun storm lasted from: **August, 28th 1859 until September, 2nd, 1859.**
3. The Solar flares of 1859 took just over **18** hours to travel from the Sun to Earth.
4. The Northern lights produced from the Carrington event reached as far south as **Cuba, Bahamas and Jamaica.**
5. List two (2) effects the Carrington event had on life in 1859 and four (4) effects the Carrington event would have had on daily life today.

**In 1859 two effects were: (i) telegraph operators were shocked and (ii) telegraph paper was burned.**

**Present day: (i) Billions of dollars of damage to satellites, (ii) Radio communications, (iii) Cell phone communications, (iv) aircraft and ship navigation systems.**

**Evidence Gradient Chart**

 **STRONG**

………………………………………………………………………………………..

**MEDIUM**

…………………………………………………………………………………….

**WEAK**

 ……………………………………………………………………………………

