Pretty Lights, Pesky Problems: The Science of Solar Storms

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Authors

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SUBJECT/GRADE LEVEL

Subject Area: Science Research, AP Research

Grade Level: 9-12 (advanced/honors)

Materials

- 8-11 Class Periods
- Access to **analysis software** such as Microsoft Excel, Google Sheets, Codap, DataClassroom, Python, etc.
- **Resource Folder**: Pretty Lights, Pesky Problems Lesson Resources
    - Articles
    - Student Handouts
    - Teacher Notes & Resources
    - Rubrics
    - Data Sets
    - Google Slides Presentation

STANDARDS

Next Generation Science Standards

Earth and Space Sciences

- HS-ESS1-1: Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation.
- HS-ESS1-4: Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.
- HS-ESS2-4: Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.

Physical Sciences

- HS-PS4-5: Communicate technical information about how some technological devices use the principles of wave behavior and properties of electromagnetic radiation to transmit and capture information and energy.

Science and Engineering Practices

- SEP 4: Analyzing and Interpreting Data
- SEP 6: Constructing Explanations

Crosscutting Concepts

- CCC 2: Cause and Effect
- CCC 4: Systems and System Models
- CCC 7: Stability and Change

Mathematics Standards | Common Core State Standards

- CCSS.MATH.CONTENT.HSS.ID.B.6: Represent data on two quantitative variables on a scatter plot, and describe how the variables are related.
- MP1: Make sense of problems and persevere in solving them.
- MP3: Construct viable arguments and critique the reasoning of others.

English Language Arts Standards | Common Core State Standards

Reading Informational Text

- CCSS.ELA-LITERACY.RI.9-10.1 / RI.11-12.1: Cite strong and thorough textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text.
- CCSS.ELA-LITERACY.RI.9-10.2 / RI.11-12.2: Determine a central idea of a text and analyze its development over the course of the text.
- CCSS.ELA-LITERACY.RI.9-10.4 / RI.11-12.4: Determine the meaning of words and phrases as they are used in a text, including technical meanings in a scientific context.

Writing

- CCSS.ELA-LITERACY.W.9-10.1 / W.11-12.1: Write arguments to support claims with clear reasons and relevant evidence.
- CCSS.ELA-LITERACY.W.9-10.2 / W.11-12.2: Write informative/explanatory texts to examine and convey complex ideas clearly and accurately.
- CCSS.ELA-LITERACY.W.9-10.4 / W.11-12.4: Produce clear and coherent writing appropriate to task, purpose, and audience.
- CCSS.ELA-LITERACY.W.9-10.6 / W.11-12.6: Use technology to produce and publish writing and to interact and collaborate with others.
- CCSS.ELA-LITERACY.W.9-10.8 / W.11-12.8: Gather relevant information from authoritative sources and integrate the information selectively.

Speaking and Listening

- CCSS.ELA-LITERACY.SL.9-10.1 / SL.11-12.1: Initiate and participate effectively in a range of collaborative discussions.
    - CCSS.ELA-LITERACY.SL.11-12.1.A: Come to discussions prepared, having read and researched material under study; explicitly draw on that preparation by referring to evidence from texts and other research on the topic or issue to stimulate a thoughtful, well-reasoned exchange of ideas.

- CCSS.ELA-LITERACY.SL.9-10.2 / SL.11-12.2: Integrate multiple sources of information presented in diverse media or formats.
- CCSS.ELA-LITERACY.SL.9-10.4 / SL.11-12.4: Present information clearly, concisely, and logically so listeners can follow the line of reasoning.
- CCSS.ELA-LITERACY.SL.9-10.5 / SL.11-12.5: Make strategic use of digital media in presentations.

AP Research | College Board

- LO 2.1A: Summarize, explain, and evaluate the main idea and reasoning in a text or performance.
- LO 2.3B: Evaluate the relevance and credibility of source information.
- LO 4.2A: Interpret data or information.
- LO 5.1B: Communicate information clearly and effectively using an appropriate medium.

LESSON OBJECTIVE(S)

Students will be able to (SWBAT):

- Identify the visible and unseen impacts of geomagnetic storms on Earth and its technology.
- Define and explain key vocabulary terms related to solar activity, Earth's space environment, and GPS technology.
- Explain the cause-and-effect relationship between solar events (flares, CMEs) and geomagnetic storms.
- Analyze scientific data sets (e.g., Kp index, Dst index, Bz component) to identify patterns and correlations during space weather events.
- Interpret graphical data to provide evidence that supports scientific explanations of GPS signal disruption.
- Construct evidence-based explanations for how geomagnetic storms disrupt GPS signals.
- Communicate complex scientific information about space weather impacts to a public audience through various media.
- Evaluate the importance of space weather forecasting and mitigation strategies for modern society.

CAREER CONNECTION(S)

Mentor Background: Colonel Diana C. Loucks, PhD. https://www.westpoint.edu/diana-c-loucks

Colonel Diana Loucks is an Academy Professor and the Director of Advanced Physics in the Department of Physics and Nuclear Engineering at West Point Military Academy. She holds both a master's and a doctoral degree in Aerospace Engineering Sciences from the University of Colorado, Boulder, and a Bachelor of Science in Mathematics from Texas Christian University.

STEM Careers: Physics, Astrophysics, Aerospace Engineering, Mathematics

ENGAGEMENT (1 Class Period)

Brief Description: Capture student interest and introduce a real-world problem related to space weather and GPS. Students will use Claim, Evidence, Reasoning to demonstrate their understanding.

Procedures:

Objectives (SWBAT):

- Identify the visible and unseen impacts of geomagnetic storms on Earth and its technology.
- Define and explain key vocabulary terms related to solar activity, Earth's space environment, and GPS technology.

Engagement Slides

- **Hook:** Begin by showing students captivating images or a short video clip of the May 2024 aurora event (or the October 10, 2024 aurora). Ask students if they saw or heard about these spectacular lights.
    - *Teacher Note:* You can find many high-quality images and short time-lapse videos of the May 2024 aurora by searching "May 2024 aurora borealis photos" or "May 2024 aurora time-lapse."
    - *Additional Photos*: https://www.npr.org/sections/pictureshow/2024/05/11/1250750303/photos-see-northern-lights-from-rare-solar-storm
    - *Additional Video*: https://youtu.be/c4l-iaMEn5M?si=4DR292TRhMmhoQ-M (Time lapse video of aurora in Montana, May 10, 2024)
- **Article Reading & Questions:** Distribute an article focusing on the financial cost and practical disruptions experienced by farmers due to GPS malfunctions during a geomagnetic storm (e.g., the May 2024 event).
    - *Suggested Article*: Space.com: "May 2024 solar storm cost $500 million in damages to farmers, new study reveals" (https://www.space.com/astronomy/sun/may-2024-solar-storm-cost-usd500-million-in-damages-to-farmers-new-study-reveals)
    - Students will answer questions about their understanding using the CER framework. Students will share their responses in a pair-share format and prepare to discuss with the whole class.
        - Engagement Activity Article.docx
        - Discussion Prompts:
            - "What was the surprising impact of the solar storm described in the article?"
            - "Why is precise GPS so critical for modern activities like farming, and what was the cost of its disruption?"
            - "What questions do you have about how something happening on the Sun can affect technology on Earth?"
        - Engage Article Questions - Sample Responses

EXPLORATION (2-3 Class Periods)

Brief Description: Students will collaboratively research key vocabulary to build foundational knowledge.

Procedures:
Objective (SWBAT):

- Identify the visible and unseen impacts of geomagnetic storms on Earth and its technology.
- Define and explain key vocabulary terms related to solar activity, Earth's space environment, and GPS technology.
- Explain the cause-and-effect relationship between solar events (flares, CMEs) and geomagnetic storms.

Jigsaw Activity: Students form groups to become an expert on different key concepts/terms related to space weather and GPS.

  - Exploration Jigsaw Directions
  - Exploration Jigsaw Teacher Answer Key

EXPLANATION (1-2 Class Periods)

Brief Description: Students will construct and present scientific explanations for how geomagnetic storms work and how they affect GPS signals, teaching their peers based on their vocabulary research.

Procedures:
Objective (SWBAT):

- Construct evidence-based explanations for how geomagnetic storms disrupt GPS signals.

Jigsaw Activity continued: Students return to their home groups, share their expert knowledge, and then collaboratively create a slides presentation.

- Explanation Jigsaw cont. Directions
- Explain Group Presentation Rubric
  - *Note*: You may consider giving the same score to the whole team or you may choose to make rows 1-4 a team score and row 5 of the rubric be an individual score.

ELABORATE (1 Class Period)

Brief Description: Students will analyze provided data to deepen their understanding of space weather phenomena and their impacts.

Procedures:
Objective (SWBAT):

- Analyze scientific data sets (e.g., Kp index, Dst index, Bz component) to identify patterns and correlations during space weather events.

- Interpret graphical data to provide evidence that supports scientific explanations of GPS signal disruption.

Students are given the data set below surrounding a space weather event from October 2024 and asked to graph and interpret three sets of data.

- Data for October 2024.xlsx
  - **Kp Index:** a measure of Earth's geomagnetic disturbance
  - **Dst Index**: a measure of Earth's ring current
  - **Bz Componen**t: Interplanetary Magnetic Field - North/South Direction
- Elaborate Student Handout
- Elaborate Teacher Resources

Statistics Extension Activity: Students can also be asked to do more statistics with the provided data set. Below are some examples of mathematics students can engage in. Here is also a linked Excel spreadsheet with the requested calculations. Stats Extension Solutions for October 2024.xlsx

- Identify the maximum and minimum values for Kp Index, Dst Index, and Bz Component.
- Calculate the mean, median, and range for Kp Index, Dst Index, and Bz Component.
  - Interpret the meaning of those values.
  - Compare and contrast them.
    - *The minimum for the Kp is 0 while Dst and Bz can be negative values. The maximum for Dst is much larger than the maximum for Kp and Bz. The range for Dst is also much larger.*
- Calculate the standard deviation for each and interpret the meaning of those values.
  - Compare the three different standard deviations.
    - *The standard deviation for Dst is much larger than the standard deviation for Kp and Bz.*
- Graph a scatterplot of Kp vs. Bz and Dst vs. Bz.
  - Is there a linear relationship between each set of variables?
    - *Kp vs. Bz → expect a scatterplot with a negative trend, but some variability.*
    - *Dst vs. Bz → expect a stronger negative slope, possibly closer to a linear fit.*
  - Determine the correlation coefficient and describe the relationship.
    - *There appears to be no correlation based on the correlation coefficient. However, the geomagnetic storm may be affecting this value. The data sets are also not a perfect match in terms of elements so this affects the answer as well.*
  - How would your answer differ if you removed the data where the geomagnetic storm occurred?
    - *You may be able to see the linear relationship better.*
  - Write an equation for the line of best fit.
  - Use the line of best fit to predict Bz values.

EVALUATION (3-4 Class Periods)

Brief Description: Students will communicate complex scientific information about space weather impacts to a public audience through a PSA.

Procedures:

Objective (SWBAT):

- Communicate complex scientific information about space weather impacts to a public audience through various media.

Assessments:

- **Vocabulary Check (Kahoot!)**: Use a Kahoot! quiz to quickly assess student understanding of the key vocabulary terms from the jigsaw activity ("Explore").

- **Data Analysis Report**: Students submit their graphs, data interpretations, and conclusions from the "Elaborate" phase as a written report or presentation.

- **PSA Directions for Students (2-3 Class Periods)**: Students will work individually or in small groups to create a Public Service Announcement (PSA) aimed at informing the general public about the impact of auroras (and the underlying geomagnetic storms) on daily life and technology, incorporating data insights.
    - PSA Rubric
    - PSA Teacher Resources
    - **Gallery Walk & Peer Feedback (1 Class Period):** After completing their PSAs, students will participate in a gallery walk to observe their peers' work. Have students evaluate 2-3 other groups' PSAs using this Gallery Walk Peer Feedback.
    - **Self-Reflection Activity (1 Class Period-same day as Gallery Walk):** After the gallery walk and receiving peer feedback, students will complete a short self-reflection. Responses can be collected using a Google Form.

REFERENCES

- Gross, T. (2024, May 11). *Photos: See the Northern Lights from rare solar storm*. NPR. https://www.npr.org/sections/pictureshow/2024/05/11/1250750303/photos-see-northern-lights-from-rare-solar-storm
- OpenAI. (2025). *ChatGPT (July 25 version)* [Large language model]. https://chat.openai.com/