# Citizen Science Training Modules

## The Radio JOVE Project

radiojove.gsfc.nasa.gov

A Partnership Between

SUNRISE GROUND RADIO LAB

NASA Partner

UNIVERSITY OF MICHIGAN

Welcome to The Radio JOVE Project Citizen Science Training Modules.


These training modules are a partnership between the SunRISE mission team and The Radio JOVE Project. We acknowledge contributors to these modules as well as our funding sources of support.


This is Training Module 0.4 – Space Weather

# Prerequisites for Training Modules

1. High School Reading Comprehension and General Science
2. Electromagnetic Spectrum
3. Speed, Wavelength, Frequency, and Energy of Waves
4. Graphical Interpretation of Data
5. Training Modules 0.0, 0.1, 0.2, 0.3

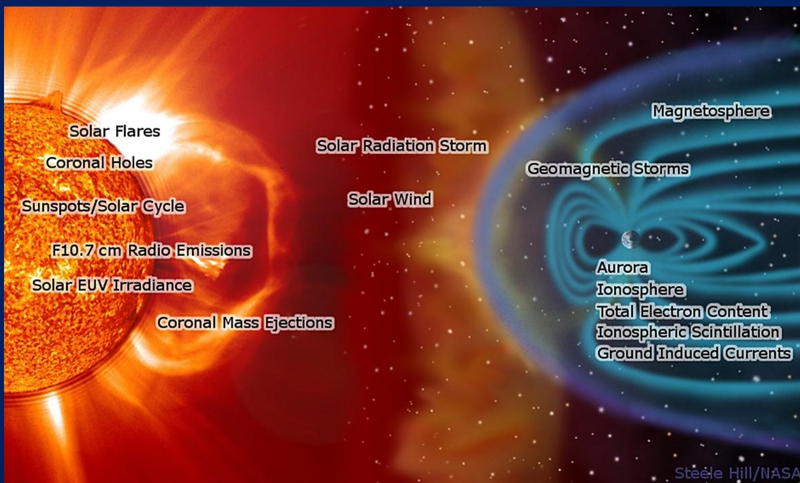
This is a list of prerequisites needed to be able to understand the material in this module.

# Learning Objectives

1. Define space weather
2. Types of space weather storms
3. Learn the impacts of space weather

This is a brief summary of the learning objectives for this presentation.
After a brief definition of space weather, we discuss the types of space weather storms and the impacts they have.

# Space Weather




Credit: SOHO (ESA & NASA)

https://www.swpc.noaa.gov/phenomena

Space Weather

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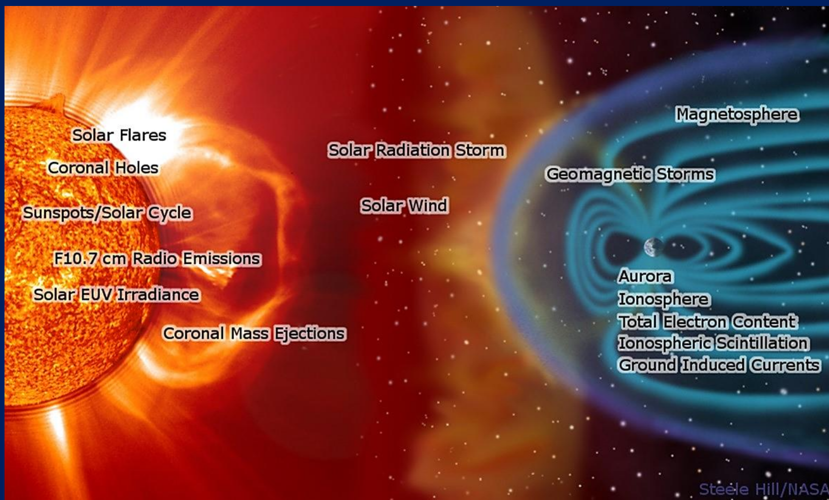
- emphasizes the conditions between the Sun and Earth
- describes the phenomena that impact systems and technologies in orbit and on Earth

Space Weather, a branch of space physics, describes the variations in the space environment in the solar system. According to NOAA, Space Weather describes the variations in the space environment between the sun and Earth. In particular, space weather describes the phenomena that impact systems and technologies in orbit and on Earth.

The figure shows various solar components and processes and the effects it has on Earth's space environment.

https://www.swpc.noaa.gov/phenomena

# Space Weather

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When a solar storm reaches Earth, it energizes Earth's magnetosphere causing a multitude of effects.

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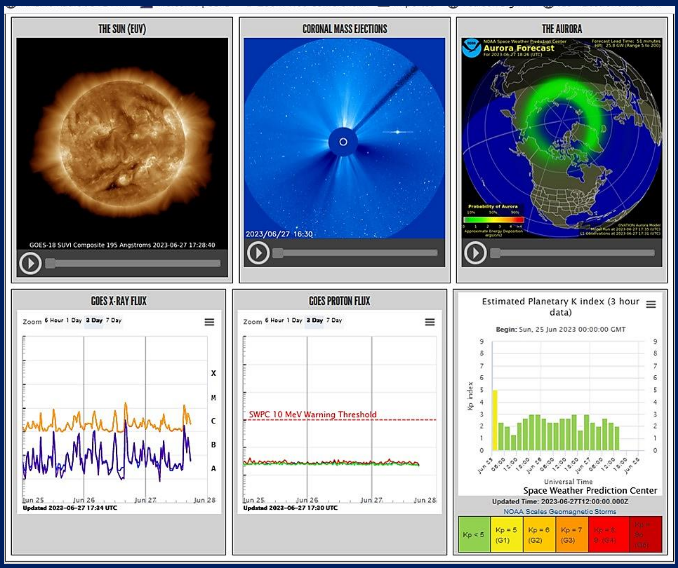


Different types of space weather can affect different technologies at Earth.

Potential impacts include:

- Degraded or blocked radio communication
- Electrical failure in satellite electronics
- Degraded power grid operations
- Loss of accuracy from radio navigation systems (GPS and GNSS)
- Aurora
- Astronaut safety

Current Space Weather Conditions: https://www.swpc.noaa.gov

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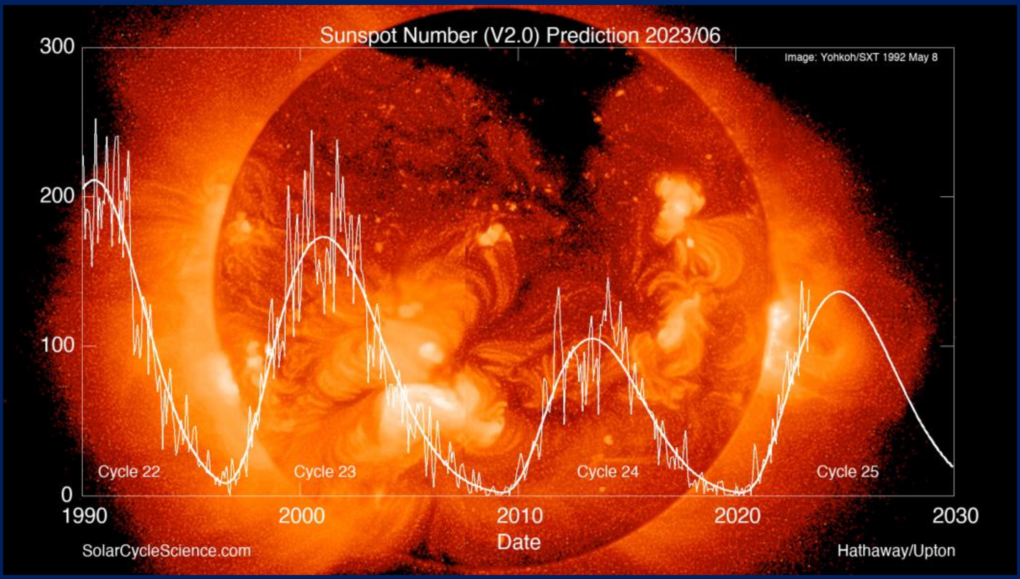
Current views of space weather are found in several places:
https://spaceweather.com/
https://swe.ssa.esa.int/current-space-weather
https://www.swpc.noaa.gov/

# Space Weather and the Solar Cycle




http://solarcyclescience.com/forecasts.html#Cycle24Prediction

Space weather is directly related to the solar cycle. Near solar maximum, the Sun has more energetic events like flares and CMEs. The graph shows the most recent sunspot cycle data and predictions for Cycle 25. from Hathaway/Upton, http://solarcyclescience.com/forecasts.html#Cycle24Prediction.

# Sun – Coronal Mass Ejection (CME)


Note the steady solar wind in between the CMEs.

https://soho.nascom.nasa.gov/gallery/Movies/flares.html

A SOHO movie from near the time of solar maximum in 1999 showing several CMEs released over several days. This coronograph instrument creates an artificial eclipse, with the Sun indicated by the white circle. Note the steady stream of solar wind. That's the planet Jupiter moving in the sky behind the Sun.
Tremendous movies of flares and CMEs are found on the NASA Solar and Heliospheric Observatory (SOHO) site: https://soho.nascom.nasa.gov/gallery/Movies/flares.html

## Space Weather Storms

1. Geomagnetic Storms – fluctuations in the Earth's magnetic field, caused by changes in the solar wind and interplanetary magnetic field. These storms may cause aurora, satellite failure, and/or electrical and communication disruptions.
2. Solar Radiation Storms – caused by flares and CMEs, these storms can be a danger to the health of astronauts and to people flying at high altitudes, and cause problems for satellites and radio systems.
3. Radio Blackouts – solar flares can cause communication and GPS outages.

Aurora as seen from Talkeetna, Alaska, on Nov. 3, 2015. Image credit: Copyright Dora Miller

NASA Aurora Gallery
https://www.nasa.gov/mission_pages/sunearth/aurora-image-gallery/index.html

There are three types of space weather storms
1. Geomagnetic Storms – fluctuations in the Earth's magnetic field, caused by changes in the solar wind and interplanetary magnetic field. These storms may cause aurora, satellite failure, and/or electrical and communication disruptions.
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# Space Weather Storm Scales

SPACE WEATHER PREDICTION CENTER
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Geomagnetic Storms

| Scale | Description | Effect | Physical measure | Average Frequency (1 cycle = 11 years) |
|---|---|---|---|---|
| G 5 | Extreme | **Power systems:** Widespread voltage control problems and protective system problems can occur, some grid systems may experience complete collapse or blackouts. Transformers may experience damage. **Spacecraft operations:** May experience extensive surface charging, problems with orientation, uplink/downlink and tracking satellites. **Other systems:** Pipeline currents can reach hundreds of amps, HF (high frequency) radio propagation may be impossible in many areas for one to two days, satellite navigation may be degraded for days, low-frequency radio navigation can be out for hours, and aurora has been seen as low as Florida and southern Texas (typically 40° geomagnetic lat.). | Kp = 9 | 4 per cycle (4 days per cycle) |
| G 4 | Severe | **Power systems:** Possible widespread voltage control problems and some protective systems will mistakenly trip out key assets from the grid. **Spacecraft operations:** May experience surface charging and tracking problems, corrections may be needed for orientation problems. **Other systems:** Induced pipeline currents affect preventive measures, HF radio propagation sporadic, satellite navigation degraded for hours, low-frequency radio navigation disrupted, and aurora has been seen as low as Alabama and northern California (typically 45° geomagnetic lat.). | Kp = 8, including a 9- | 100 per cycle (60 days per cycle) |
| G 3 | Strong | **Power systems:** Voltage corrections may be required, false alarms triggered on some protection devices. **Spacecraft operations:** Surface charging may occur on satellite components, drag may increase on low-Earth-orbit satellites, and corrections may be needed for orientation problems. **Other systems:** Intermittent satellite navigation and low-frequency radio navigation problems may occur, HF radio may be intermittent, and aurora has been seen as low as Illinois and Oregon (typically 50° geomagnetic lat.). | Kp = 7 | 200 per cycle (130 days per cycle) |
| G 2 | Moderate | **Power systems:** High-latitude power systems may experience voltage alarms, long-duration storms may cause transformer damage. **Spacecraft operations:** Corrective actions to orientation may be required by ground control; possible changes in drag affect orbit predictions. **Other systems:** HF radio propagation can fade at higher latitudes, and aurora has been seen as low as New York and Idaho (typically 55° geomagnetic lat.). | Kp = 6 | 600 per cycle (360 days per cycle) |
| G 1 | Minor | **Power systems:** Weak power grid fluctuations can occur. **Spacecraft operations:** Minor impact on satellite operations possible. **Other systems:** Migratory animals are affected at this and higher levels; aurora is commonly visible at high latitudes (northern Michigan and Maine). | Kp = 5 | 1700 per cycle (900 days per cycle) |

Solar Radiation Storms

Radio Blackouts

NOAA Space Weather Scales
https://www.swpc.noaa.gov/noaa-scales-explanation

NOAA has created space weather scales. The scales describe the environmental disturbances for three event types: geomagnetic storms, solar radiation storms, and radio blackouts on a 1-5 scale of severity. Listed in each table are the possible effects at each level, how often such events happen, and a measure of the intensity of the physical causes.

As humans do more in space, understanding and predicting the space weather will become increasingly important.

## Resources

NASA Marshall Space Flight Center Solar Physics https://solarscience.msfc.nasa.gov/

NASA Solar and Heliospheric Observatory (SOHO) https://soho.nascom.nasa.gov/home.html

National Solar Observatory: https://nso.edu/

NOAA Space Weather Prediction Center: https://www.swpc.noaa.gov/
Australian Space Weather Forecasting Center https://www.sws.bom.gov.au/Educational/2/1

Current views of space weather:
https://spaceweather.com/
https://swe.ssa.esa.int/current-space-weather
https://www.swpc.noaa.gov/
https://www.spaceweatherlive.com/

This is a short list of good resources on the Sun and Space Weather.

# Thanks for watching!

Next, you will learn some background about radio astronomy …

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