SPACE WEEK

Our Planet • Our Space • Our Time

Resource Book for Teachers
TOPIC: **Space Weather Forecast**

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Forecast Space Weather and then check your prediction by looking for Aurora. This guide will review how to make space weather predictions from live data collected from spacecraft.

Curricular links

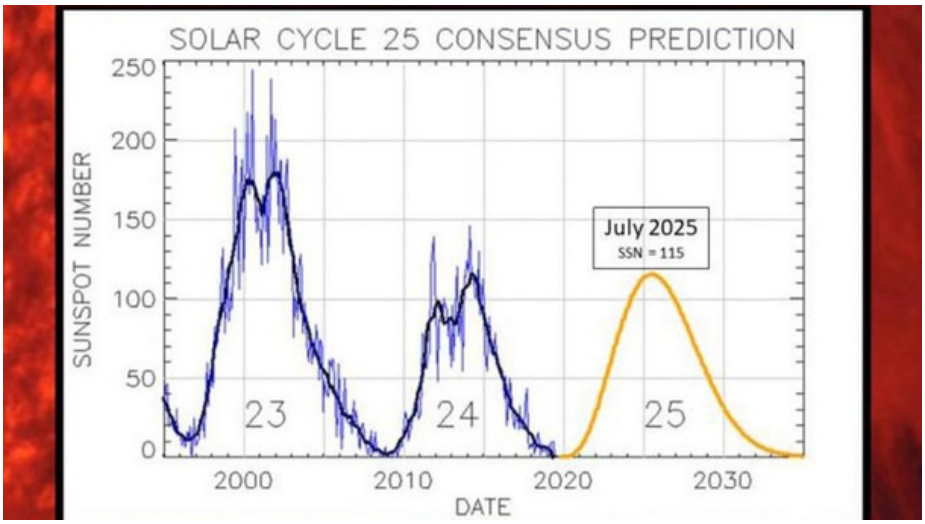
Earth and Space 1 ... describe the relationships between various celestial objects including ... planets, stars, solar systems...
Earth and Space 8 ... examine some of the hazards ... of space exploration

Physical World 2 ... calculate time (from distance and speed)

Physical World 3 ... investigate patterns and relationships between physical observables
Physical World 4 ... discuss a technological application of physics in terms of scientific and societal impact

Background Information:

Just like we experience weather on Earth, there's weather in space! The Sun may look very constant and quiet from Earth, but it's constantly spewing out a stream of particles called the solar wind. Space weather is activity on the Sun that can affect Earth and interact with our technology. Changes in the activity of the Sun occur in eleven-year cycles and the Sun itself rotates every 27 days.



Sunspots can appear and disappear over days or weeks. Flares and large ejections of mass (coronal mass ejections or CMEs) occur over timespans of minutes to hours.

The energy of the Sun constantly blows out a 'solar wind' of electrified particles. Earth is surrounded by a magnetic field (our magnetosphere) that protects us from the worst effects of solar storms. However, solar storms can cause fluctuations in the magnetosphere called geomagnetic storms. Geomagnetic storms have disabled satellites and burned-out transformers. This shuts down power grids. These storms can endanger astronauts and make more intense auroras that can be seen from more places on the Earth.

Solar flares and CMEs are both solar events. They are not the same thing but can sometimes happen together. Most solar flares and CMEs start in sunspots or groups of sunspots. Active regions are areas of the Sun's surface that typically contain strong magnetic fields and sunspots. Solar flares are bright flashes of light. That light travels to us at the speed of light, so we see a solar flare a little over 8 minutes after it happens. Solar flares might also send high energy particles into space, which can make the solar wind stronger (like a "gust" in the wind). These can take between 30 minutes (for very high energy particles) to several days to reach the Earth. These particles might cause aurora.

An excellent introduction to Space Weather is this video from Space Weather Public Dialogue: https://youtu.be/ykf9G34RfnY. See also the Space Weather Glossary.

To predict space weather from solar flares or CMEs we can ask:

1. are there sunspots?
2. have X-ray signals from the Sun arrived at the Earth?
3. has the Earth's magnetic field changed?

And then verify our prediction by checking:

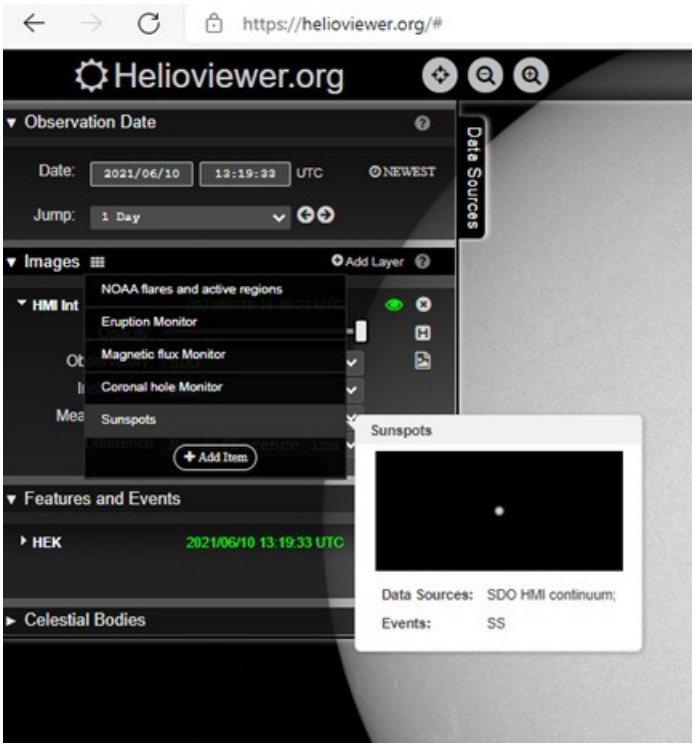
4. were aurora visible?

1. SUNSPOTS

"Do sunspot regions exist today that could be a source of solar storms?"

Let's look for any visible signs of sunspots.
Sunspots are cooler areas of the Sun's surface, so they appear dark. Sunspots are often as big as the Earth.
Use Helioviewer.org or Solarmonitor.org and choose different instruments from different spacecraft to look at the Sun's surface and the area of space near the Sun.
Sketch what you can see in the circle (or record your findings in another suitable way).

Hand drawn sketches have been made for centuries and are still made at observatories around the world.

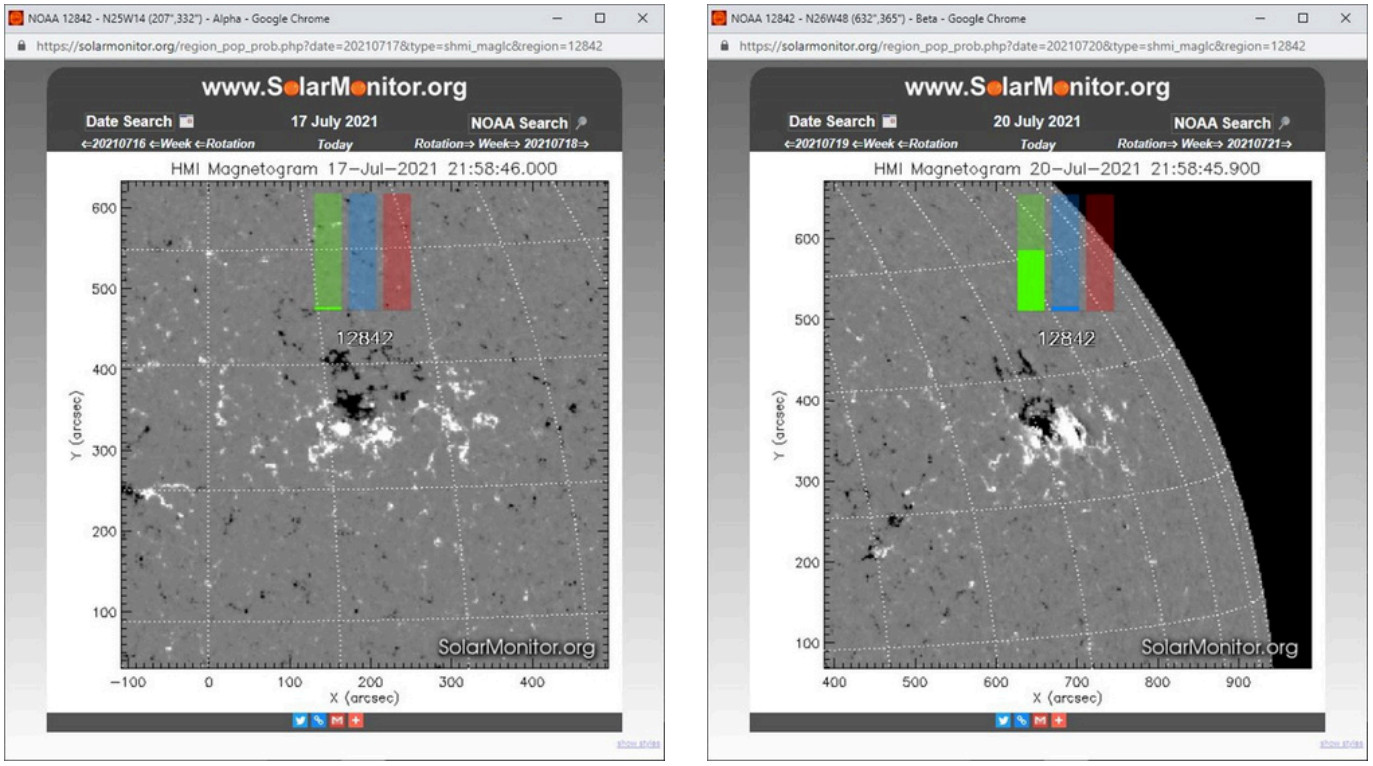


On Helioviewer.org choose "Sunspots" from the menu next to Images
OR select the following:
Observatory: SDO
Instrument: HMI
Measurement: continuum
OR Use SolarMonitor.org and look at the SDO image HMI 6173Å.
Are there any sunspots? How big are they compared to the Earth? On Helioviewer you can zoom in and out of the image and drag the Earth Scale around. On SolarMonitor you can click to zoom in.

a) Where are the sunspots compared to the Sun's equator?

b) Do you see clusters of sunspots (sunspots that are grouped together)? Sunspots are considered a group if they are at about the same latitude of the Sun and fall within 10 degrees longitude.

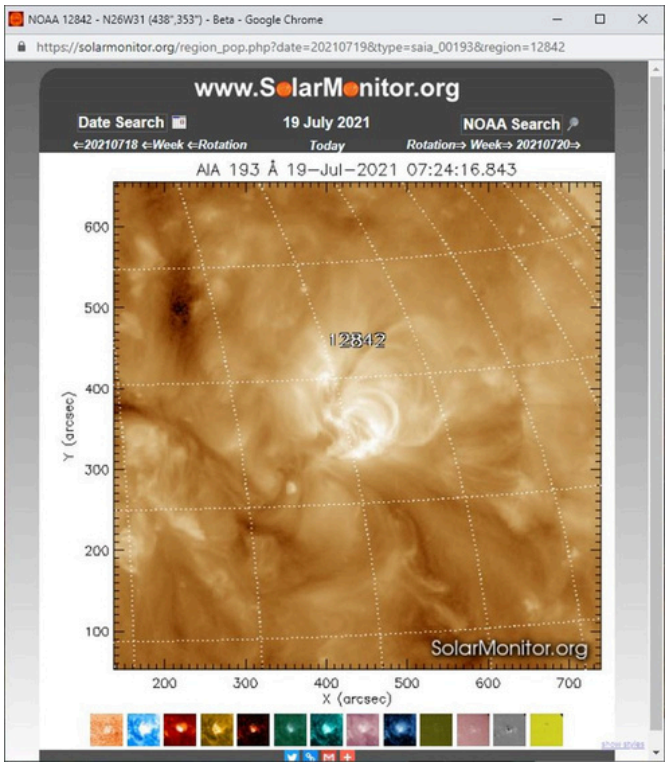
B. Helioviewer: +Add Layer to look at Magnetic flux. Set this to:
Observatory: SDO
Instrument: HMI,
Measurement: magnetogram.
Or
Use SolarMonitor and look at the HMI Mag image.
Do you observe any black and white areas on the magnetogram? If so, do those areas seem mixed together or clearly separated? When they are clearly separated, there is less chance of a solar eruption. When they are mixed, there is a better chance for a solar eruption from that location.



Compare separated (lower chance of flare) on the left vs mixed (higher chance of flare) on the right. Flare forecast shown from SolarMonitor.org.

On Helioviewer: Adjust the opacity sliders to see if these areas match the sunspots.

Sunspots can last 30 days, but the active regions associated with them might only last a few days.



C.Helioviewer: +Add Layer to look at SDO AIA 193Å Observatory SDO Instrument: AIA Measurement 193

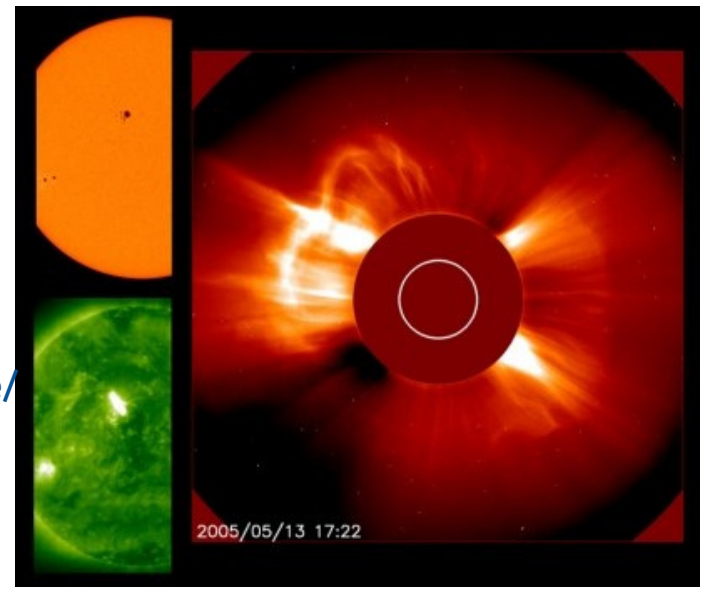
Or SolarMonitor: AIA 193Å

This shows the hot plasma (temperature about 1 million K). Magnetic fields themselves are invisible; but by making pictures of the plasma, we can see where the mag- netic "pipes" are, and what direction they are oriented. By watching these images, we can see how the magnetic field is structured in such regions, and we can monitor how it gets twisted and stretched, and how it sometimes erupts in a solar flare.
(How does the shape of the magnetic field lines compare to that of a bar magnet?)
Do these regions match the sunspots? If so, this is an area where a solar eruption might happen.

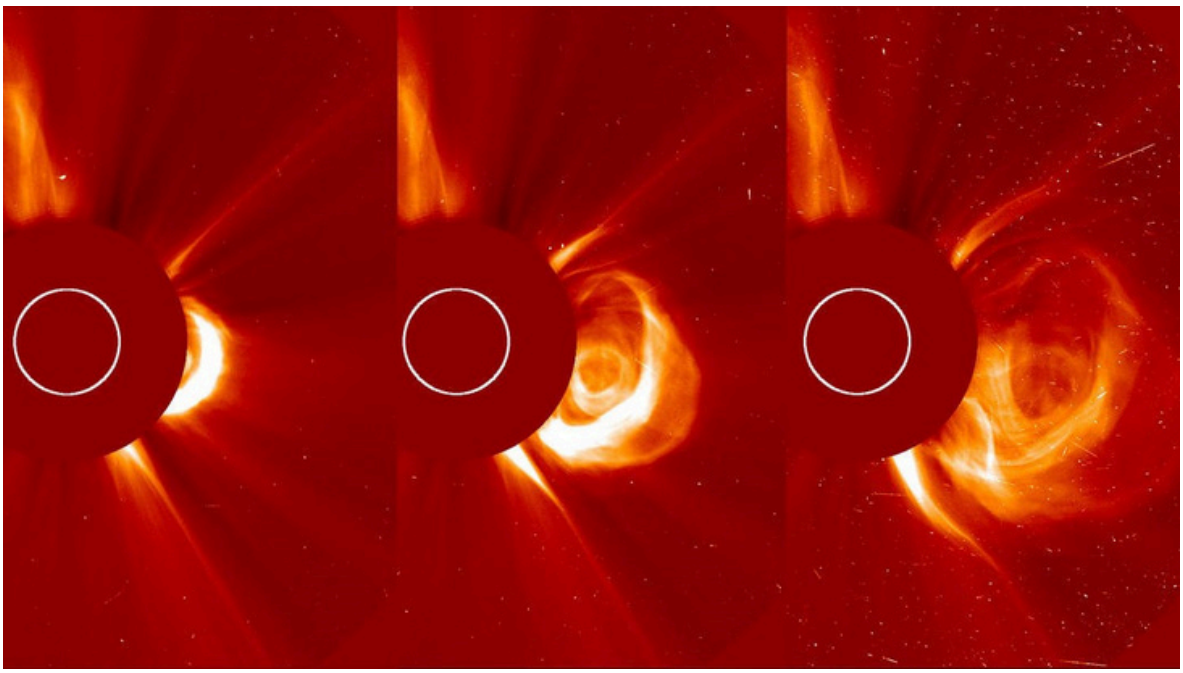
D.Is the corona of the Sun active?
Helioviewer: +Add Layer
Observatory: SOHO,
Instrument: LASCO,
Detector: C2 or C3, (you can open two layers, one for C2, one for C3)

Or SOHO, the Sun now: https://sohowww.nascom.nasa.gov/data/realtime/realtime-update.html
View LASCO C2 or C3

Do you observe any CMEs leaving the surface of the Sun? Where? Do you see a halo effect (signs of a CME on more than one side of the Sun image)? This could indicate that a storm is coming directly toward Earth.



Date: 13 May 2005 Satellite: SOHO
Depicts: Composite of SOHO observations of the 13 May 2005 Halo CME
Copyright: ESA/NASA

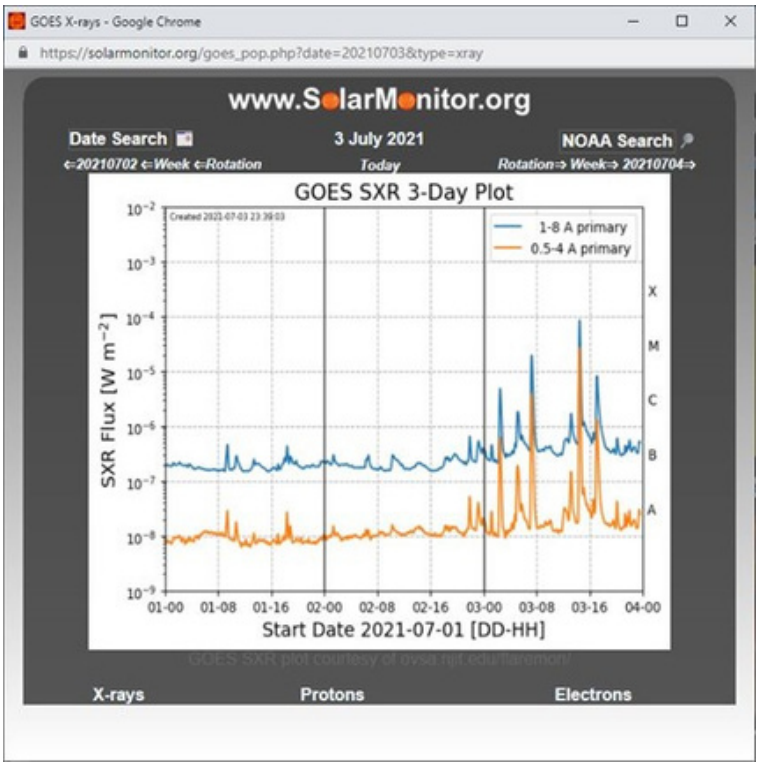


On May 16, 2012 at 9:47 PM EDT, the sun erupted with a coronal mass ejection. Credit: ESA & NASA/SOHO

Jump a day or more back in time. On Helioviewer, if you find an event, you can make a movie of it with the icons at the top right. See the YouTube icon for movies that have been made from Helioviewer.

2. X-ray Signals

"Have X-ray signals from the Sun arrived at the Earth?"



Solar flares can give out X-rays as well as or instead of visible light. An X-ray flare may affect radio communications on Earth. If the X-rays were accompanied by particles, those charged particles will arrive a little bit later and we might see aurora.

Look at the GOES X-ray Flux (1-minute data) at Space Weather Prediction Center https://www.swpc.noaa.gov/products/goes-x-ray-flux or at SolarMonitor: GOES X-ray

Observe the upper line on the graph, the GOES-16 Long data (1-8A).
This line indicates the level of solar activity that will affect Earth. A flare will be revealed in this data as a sudden increase, or "spike," in the X-ray brightness, followed by a more gradual fall-off to the normal X-ray levels as the heated gases cool. The time on the horizontal axis is Universal Time which is the same as GMT.

Use the X-ray flare class scale (A, B, C, M, and X) along the right side of the graph to determine the power of the solar storm. Each level is 10 times more powerful than the previous level.

It is important to find out if these flares were on the side of the Sun facing us. Flares from the side of the Sun facing us are more likely to disturb Earth's magnetosphere than flares that erupt from the edges. You can use images from the previous step: Sunspots, for the appropriate day to evaluate the location of the emissions from the Sun.

Levels A and B are very minor storms. They will have little effect on Earth and aurora sightings are only possible in higher latitudes.

Level C is a more powerful, but still minor storm. It indicates that aurora sightings are possible further south.
Level M is 10 times more powerful than C. M-class flares can cause brief radio blackouts at the poles and minor radiation storms that might endanger astronauts.
Level X is the most powerful solar flare.

The X-rays from a flare travel to us at the speed of light. If there are particles from that same storm, they usually take 2-3 days to reach the Earth.
(What does this tell us about the speed of the particles?)

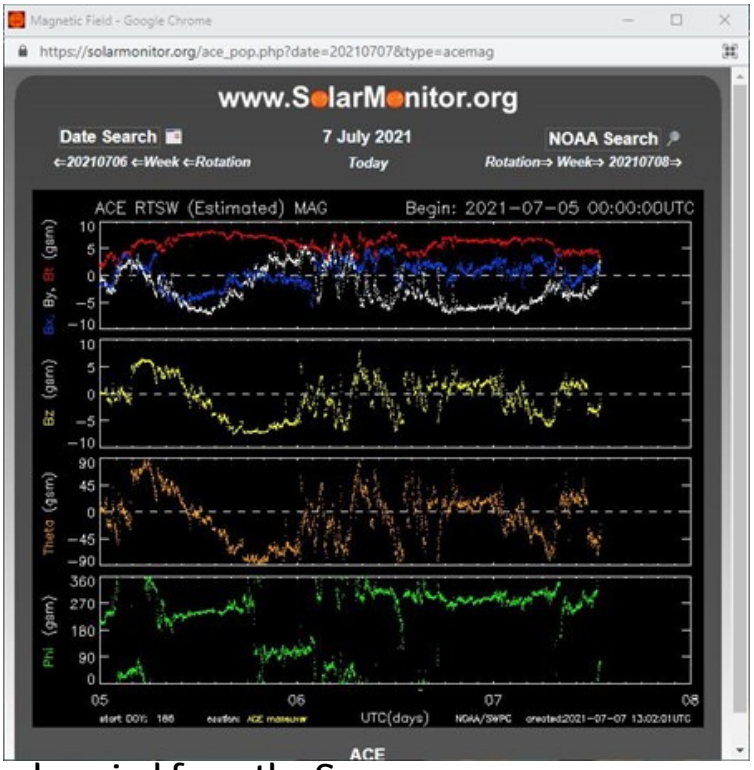
Did the intensity of X-ray emissions from the Sun increase over the last few days? If yes, record the dates and levels (A, B, C, M or X). On the website of the Space Weather Prediction Center there may be an X-ray event recorded in the box below the graph.

On which date(s) might we expect to see a solar storm at Earth? (What factors does this depend on?)

3. Earth's Magnetic Field

Has there been a measurable disturbance in the Earth's magnetic field? Look at the planetary K index at https://www.swpc.noaa.gov/products/planetary-k-index or at https://isdc.gfz-potsdam.de/kp-index/. K-indices of 5 or higher indicate 'storm-level' geomagnetic activity. Values of 7 or higher indicate a severe geomagnetic storm.

Check the real time solar wind magnetic field at: https://www.swpc.noaa.gov/products/ace-real-time-solar-wind
or at SolarMonitor: ACE B field.



Look for the line marked Bz. This graph shows the solar wind's effects on Earth's magnetosphere. When the solar wind magnetic field is opposite the Earth's, it is called a southward field and is negative in sign. You can monitor the ACE data in this graph to identify times when this happens. Each time that line falls below zero, our planet's magnetic field has been affected by the solar wind from the Sun.

You can use the following levels to determine the intensity of the storm:

Low (0 to -2) Medium (-2 to -4) High (-4 to -6)

Decide if the data shows a change in the Earth's magnetic field that may indicate a solar storm.

MAKE YOUR PREDICTION:

I predict that aurora are (likely/unlikely) on (date) because....
(refer to presence of sunspots, mixing of magnetic regions, appearance of CMEs, X-ray flares, the planetary K-index, disturbances in the Earth's magnetic field)

4. Aurora

The effect of this space weather may be visible as auroras. Check if aurora have been seen on the date(s) you expected.

Note that aurora viewing is affected by a variety of other factors, such as cloud cover, moonlight, urban light pollution and time of the year.

- During the northern summer, sunlight prevents viewing of the aurora at high northern latitudes. The nights are too bright to see the aurora.
- The most active auroras form near local midnight and come in waves, these are referred to as sub-storms. It is not unusual even during an active storm to have a lull in activity that then becomes more intense within an hour.
- Check the list of webcams (https://seetheaurora.com/webcams, http://www.aurora-service.eu/) and choose a suitable location for the time of year. Use Southern hemisphere cameras during northern summer - National Institute for Polar Research's Syowa Station in Antarctica: http://polaris.nipr.ac.jp/~acaurora/aurora/Syowa/latest.jpg or Dunedin, New Zealand: http://dunedinaurora.nz/index.php; and Northern hemisphere cameras only during northern winter, to see if aurora were visible.

Compare your forecast to a published forecast, such as https://www.magie.ie/aurora/.
Is your prediction the same?
This is an active area of research. You might consider how to improve your forecast by starting with known geomagnetic events and working backwards to find out when and where they started and how they were measured.

See also https://spaceweathergallery.com/aurora_gallery.html

https://www.met.ie/education/the-northern-lights

Review the introductory video from the Space Weather Public Dialogue. The Sun changes over an 11-year cycle and we are currently heading towards solar maximum, when space weather events are more likely.

What should our priorities be? Who should be in charge of letting people know about potentially dangerous space weather?