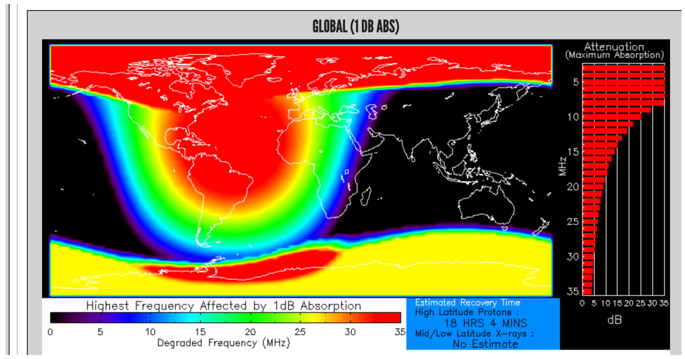
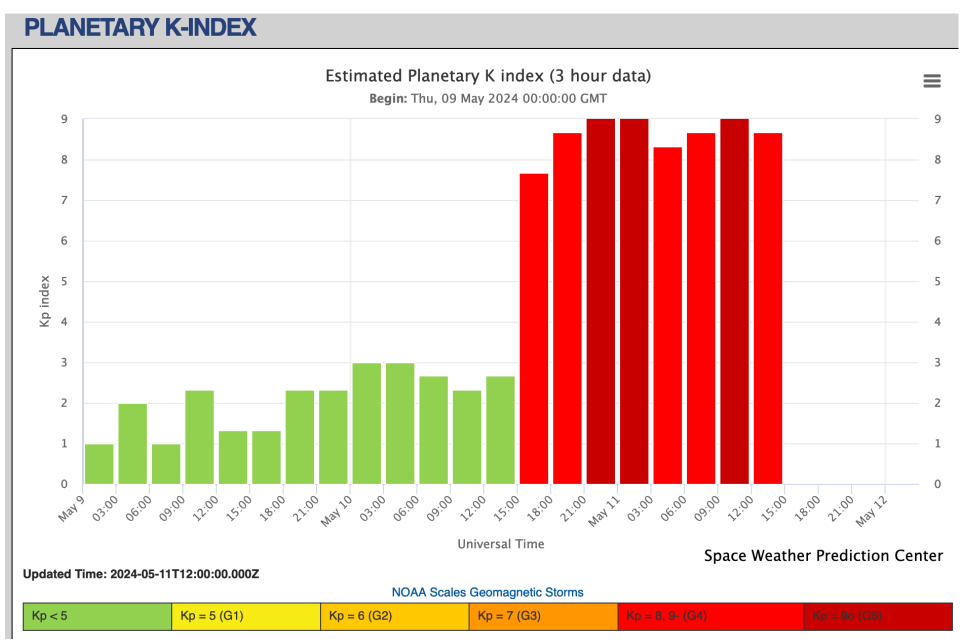



# Severe May 2024 Geomagnetic and Ionospheric Storms

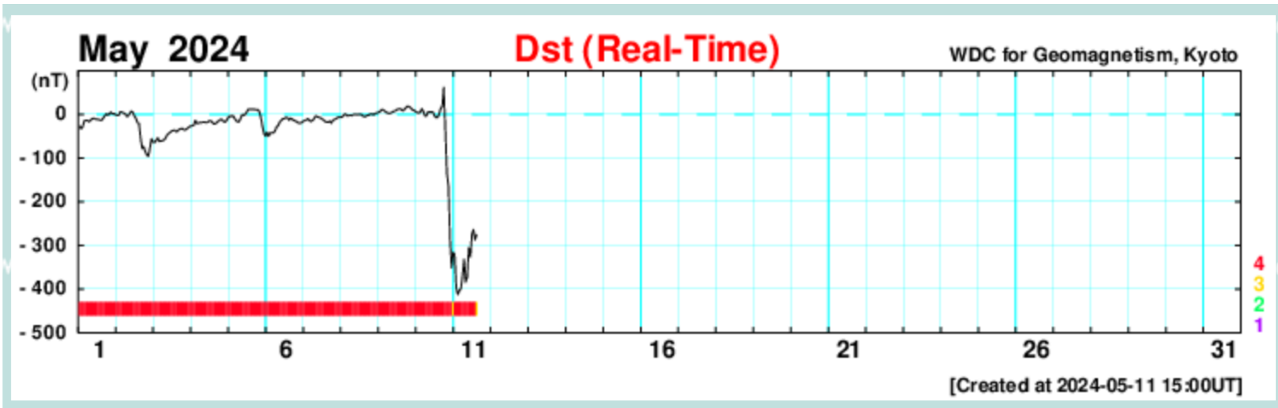
The last several days has seen intense solar activity with very large solar flares and Coronal Mass Ejections (CMEs) occurring every day. The intense solar activity has caused severe geomagnetic and ionospheric storms here on Earth. It appears that this extensive activity could last another couple of days.

### Geomagnetic Storms

Geomagnetic storm is the name given to a large fluctuation in Earth's magnetic field caused by a coronal mass ejection impacting Earth. The severity of a storm is measured by the planetary Kp index and the Dst index. The Kp index for the current storm has been running between 8 and 9 with a Kp value of 9 being the most severe class of geomagnetic storm.



The Dst index measures the fluctuation in Earth's magnetic field strength. Normally the fluctuations appear as small ripples around the 0 nano-Teslas (nT) level. On May 11th the magnetic field strength spiked down – 400 nT.




The most severe geomagnetic storm on record occurred in 1859. The storm disrupted telegraph communications, caused telegraph operators to receive severe electrical shocks, and in some cases started fires. It is estimated that a storm of that magnitude occurring today would cause over $2 trillion dollars in damage to our technological infrastructure and economy. For this reason, fleets of spacecraft are in orbit around the Earth and Sun continuously monitoring solar activity. These spacecraft provide us with an early warning system of impending geomagnetic storms, allowing us time to put critical systems into a "safe mode".

The most severe geomagnetic storm experienced in recent decades occurred in March 1989. This storm was the result of a coronal mass ejection from the Sun on March 9 th. The storm was so intense that it knocked out the Hydro Quebec electric power distribution system causing over 6 million people to lose electricity. The March 1989 Dst index spiked down – 600 nT. The Dst index for the current geomagnetic storm spiked down – 400 nT, almost as far as the March 1989 event. We are encountering a severe storm.

A geomagnetic storm is caused by charged particles from an intense solar wind event becoming trapped in the Earth's Van Allen radiation belts. The particles drift westward approximately 10,000 miles above Earth's equator creating the equatorial ring current. The magnetic field from this ring current opposes Earth's magnetic field producing the negative spike in the Dst index and the incurring geomagnetic storm with its high Kp values.

**Ionospheric Storms**

Ionospheric storms are completely different from geomagnetic storms. While geomagnetic storms can be catastrophic for our technological society, they have relatively little effect on HF communications. It is the ionospheric storms that are so disruptive to HF communications.

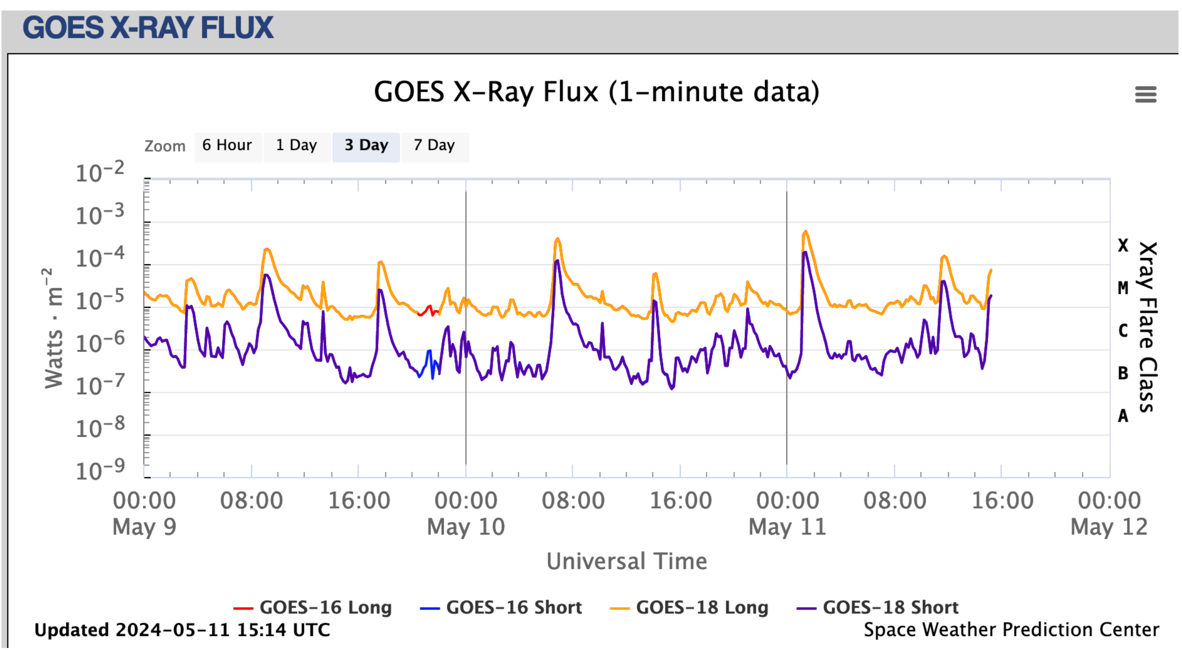
There are three types of ionospheric storms:

- X-ray radiation storms,
- High energy particle storms, and
- Solar wind storms.

We are currently being hit by all three types of storms considerably disrupting most global HF communications.

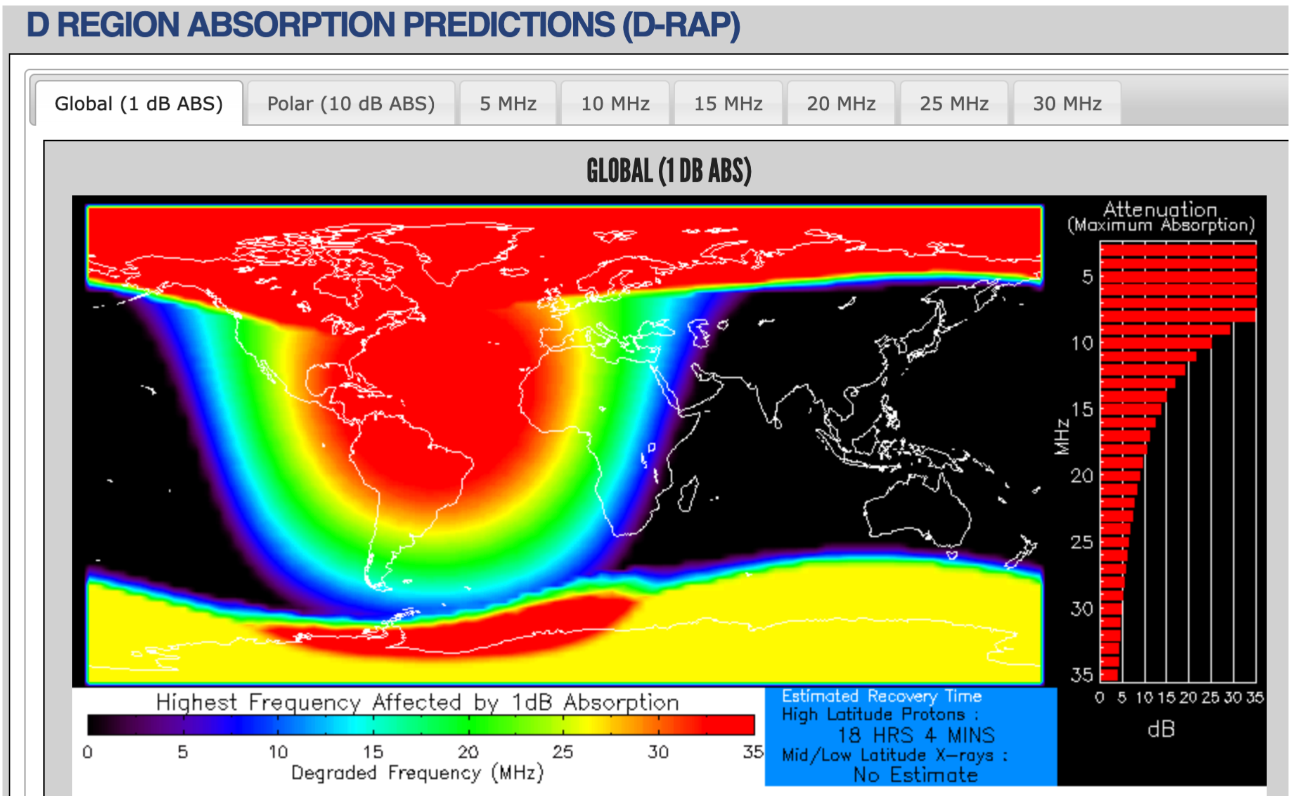
**X-ray Radiation Storms**

X-ray radiation from a solar flare causes a radiation storm. The x-ray radiation reaches Earth in a little over 8 minutes following the onset of a solar flare. X-class solar flares (the most severe) occurred on May 9 th, 10 th, and 11 th, with the intensity increasing each day.



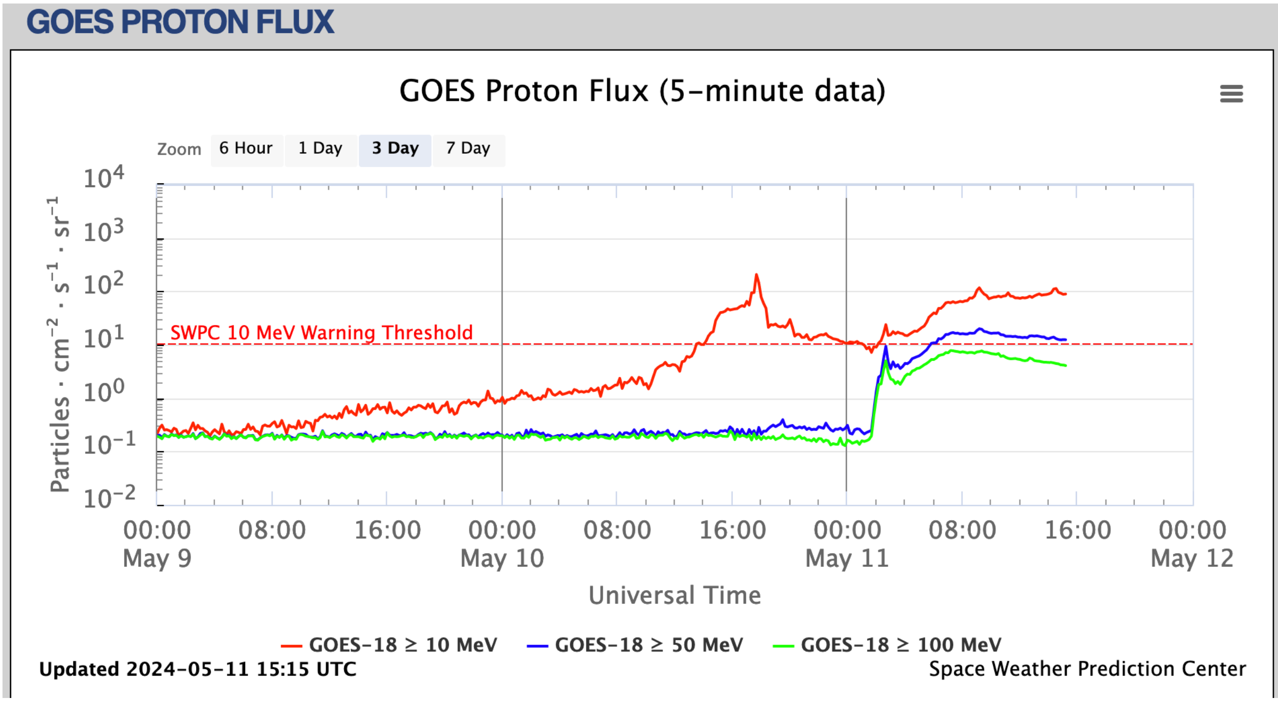

The x-ray radiation heavily ionizes the D-layer of the ionosphere on the sun-lit side of the Earth, in most cases absorbing all HF radio waves below 20 MHz. On May 11 th all HF signals up through

35 MHz were being absorbed. This absorption occurred throughout North and South America in addition to western Europe and Africa, as shown in the chart below, creating a radio blackout throughout the entire region. The disturbance moved westward toward Asia later in the day as the Earth rotated eastward.




### High Energy Particle Storms

High energy particles from a solar flare, traveling at nearly the speed of light, reach Earth in 20 minutes to an hour following the onset of a solar flare. If the energy level of the particles is high enough, they will heavily ionize the D-layer of the polar ionosphere causing a Polar Cap Absorption event (PCA). To create a PCA the energy of the incoming particles must be greater than the 10 MeV (million electron volt) threshold warning level. The proton flux (shown below) was considerably above threshold level from the afternoon of May 10 through May 11 th creating an intense PCA. The PCA event was so complete that at all transpolar HF radio communications up through 35 MHz were absorbed, creating a full transpolar radio blackout between the United States and Europe. In the D Region Absorption chart the entire artic region is in the red. A PCA was also occurring in the Antarctic region but it was not as intense.

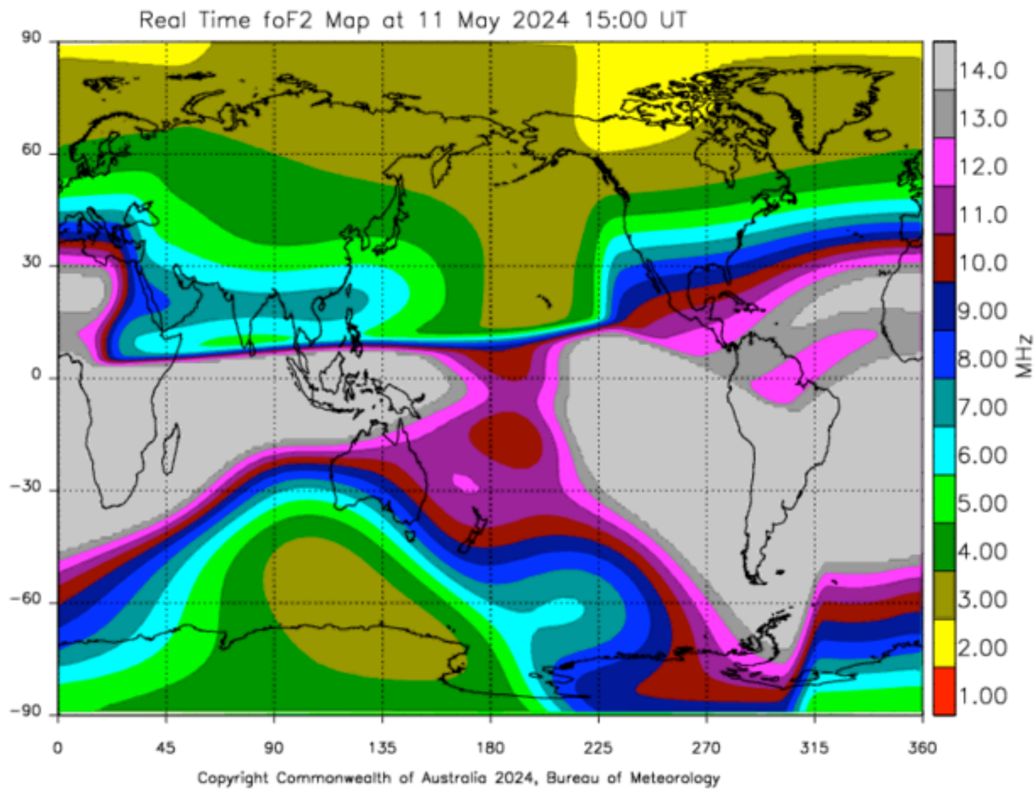



Proton flux above the threshold warning level can cause other serious problems, including damaging spacecraft, altering the accuracy of GPS navigational systems, and causing biological DNA damage to passengers and crew in aircraft flying over the poles. Airlines must avoid transpolar routes during a high energy particle storm. Following a lower latitude route avoids the risks cause by high energy particles but significantly lengthens the trip, disrupts schedules, consumes more fuel, etc.

**Solar Wind Ionospheric Storm**

A magnetic field, called an interplanetary magnetic field (IMF), is embedded in the solar wind. If the IMF happens to be pointed southward as the wind impacts the Earth, the IMF will couple to Earth's northward magnetic field. The two intertwined fields are dragged across Earth's polar region by the solar wind ripping open Earth's magnetic field. This allows solar wind particles to stream down into the ionosphere. The incoming particles modify the chemical composition of the ionosphere causing electron – ion recombination to occur twice as fast. This is known as a solar wind ionospheric storm.

A solar wind storm causes the ionosphere's critical frequency (responsible for most skywave propagation phenomenon) to drop by a factor of 2 knocking out most 20 through 10 meter communications for days. The critical frequency map below shows that the critical frequency through the center part of the United States was 5 to 6 MHz at 1500 UT on May 11. Prior to the storm critical frequencies were running between 10 to 11 MHz. Critical frequencies should return to this level a few days after the storm subsides.




You can watch all of these events unfold by monitoring the "Current Conditions" section of the www.skywave-radio.org website. The "Ionospheric Storms" presentation under the Presentations tab of the website (Presentations > Skywave Propagation > Ionospheric Storms) provides an overview of ionospheric storms. For those interested, Chapter 21 of the "Book" provides a more detail explanation of ionospheric storms.

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