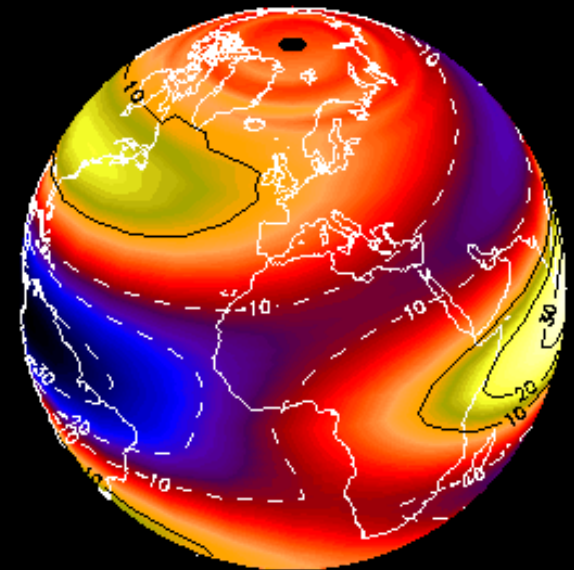
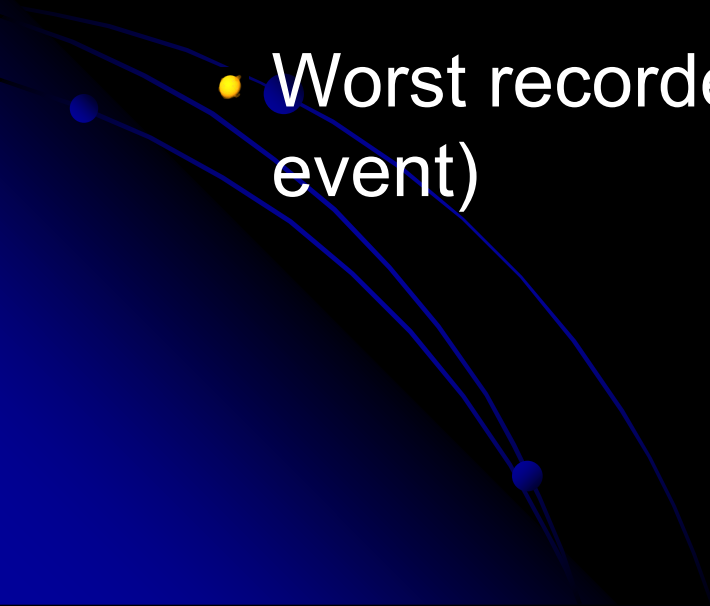


Geomagnetic Storm Threat to the Electrical System

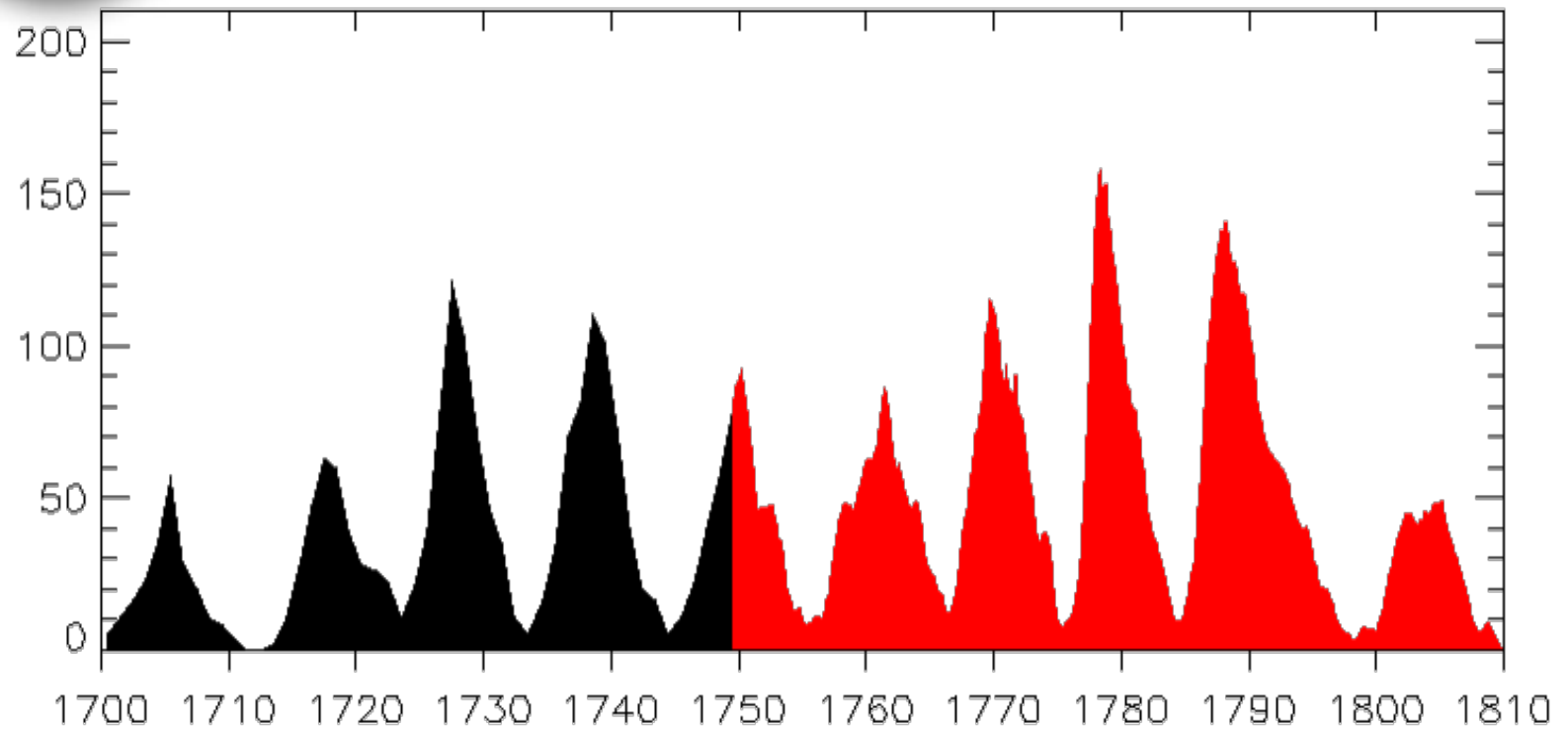


GIC and The Solar Cycle

- Geomagnetic Induced Current (GIC) is the product of solar activity and is strongly tied to the peak of solar cycles.
 - Average 11 year cycle (9-14), now in cycle #24
 - Worst recorded GIC event in 1859 (Carrington event)
- 

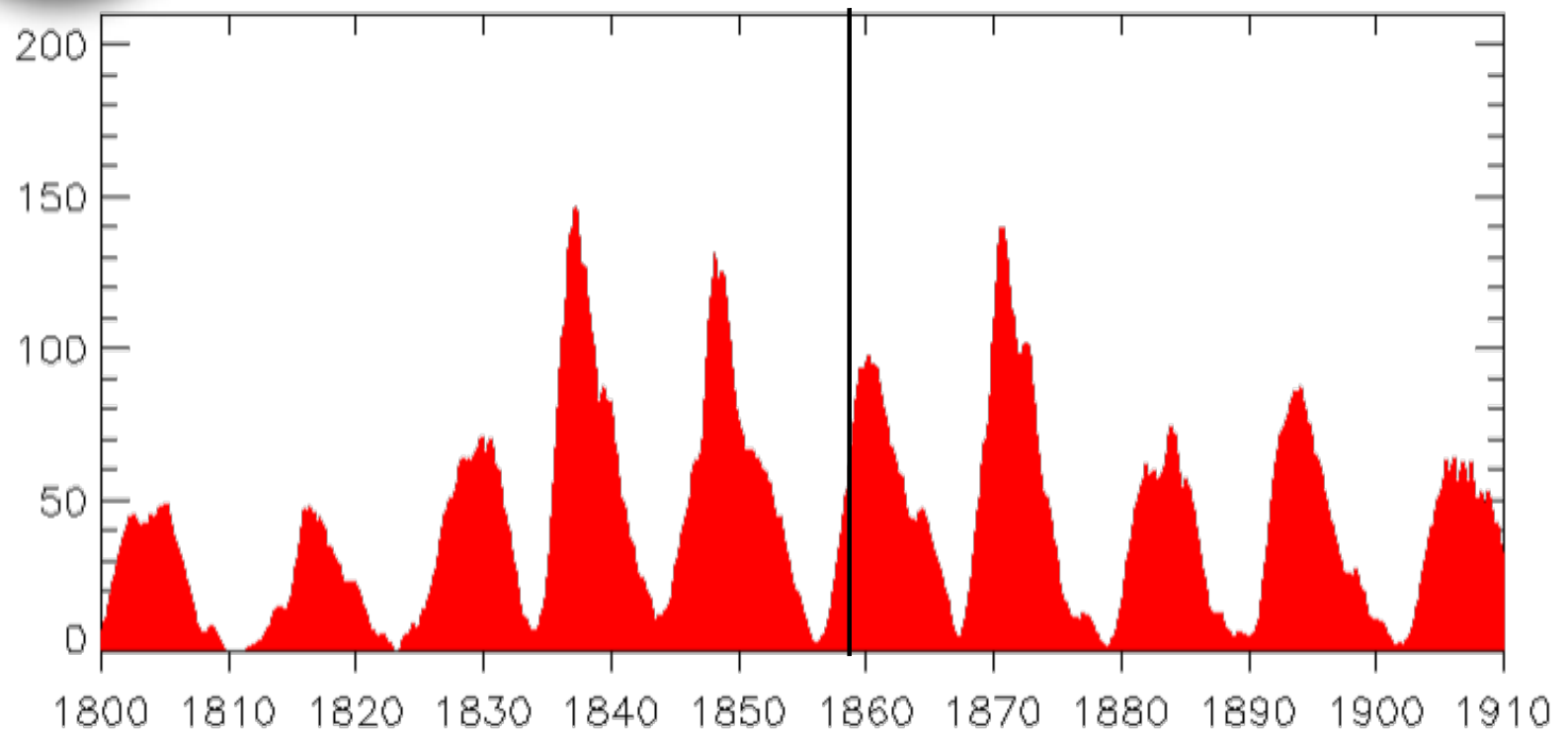


Recorded Solar Cycles





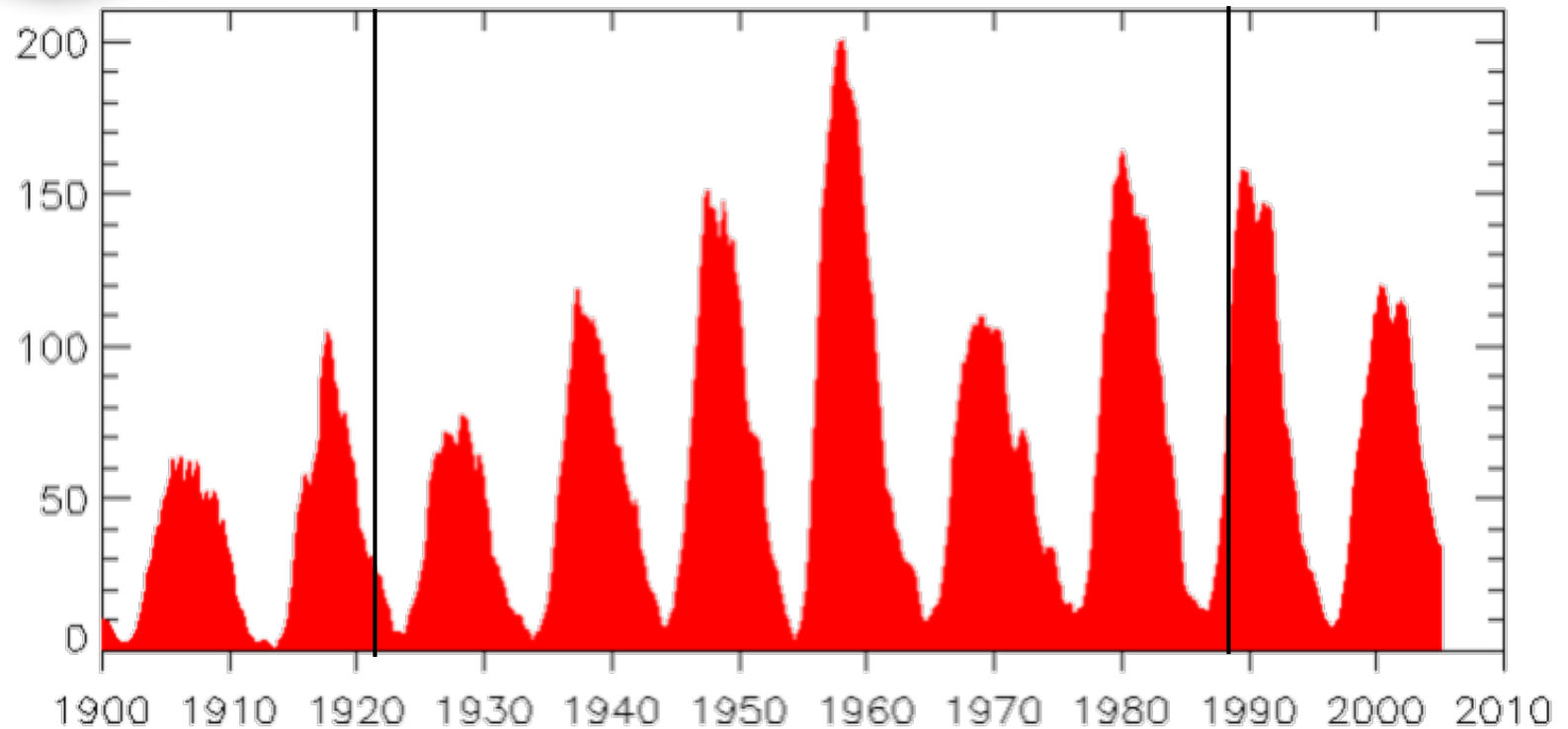
Recorded Solar Cycles



1859

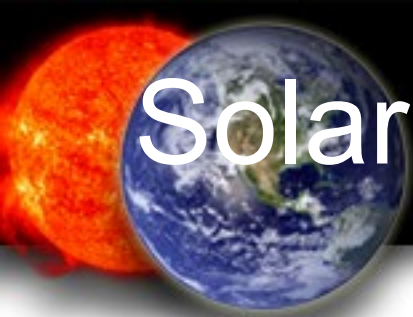


Recorded Solar Cycles



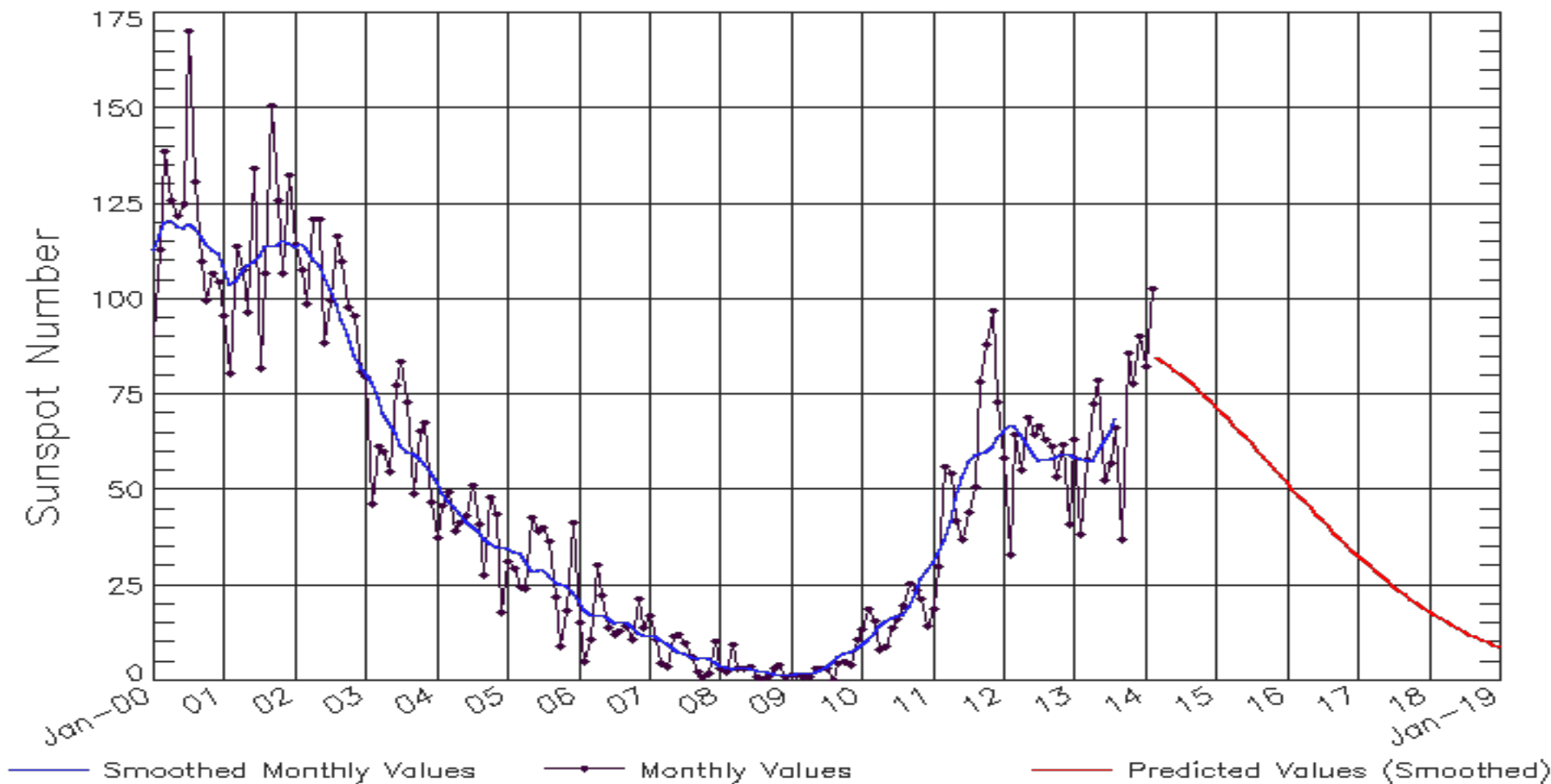
1921

1989



Solar Cycle 24 Prediction Panel

ISES Solar Cycle Sunspot Number Progression
Observed data through Feb 2014



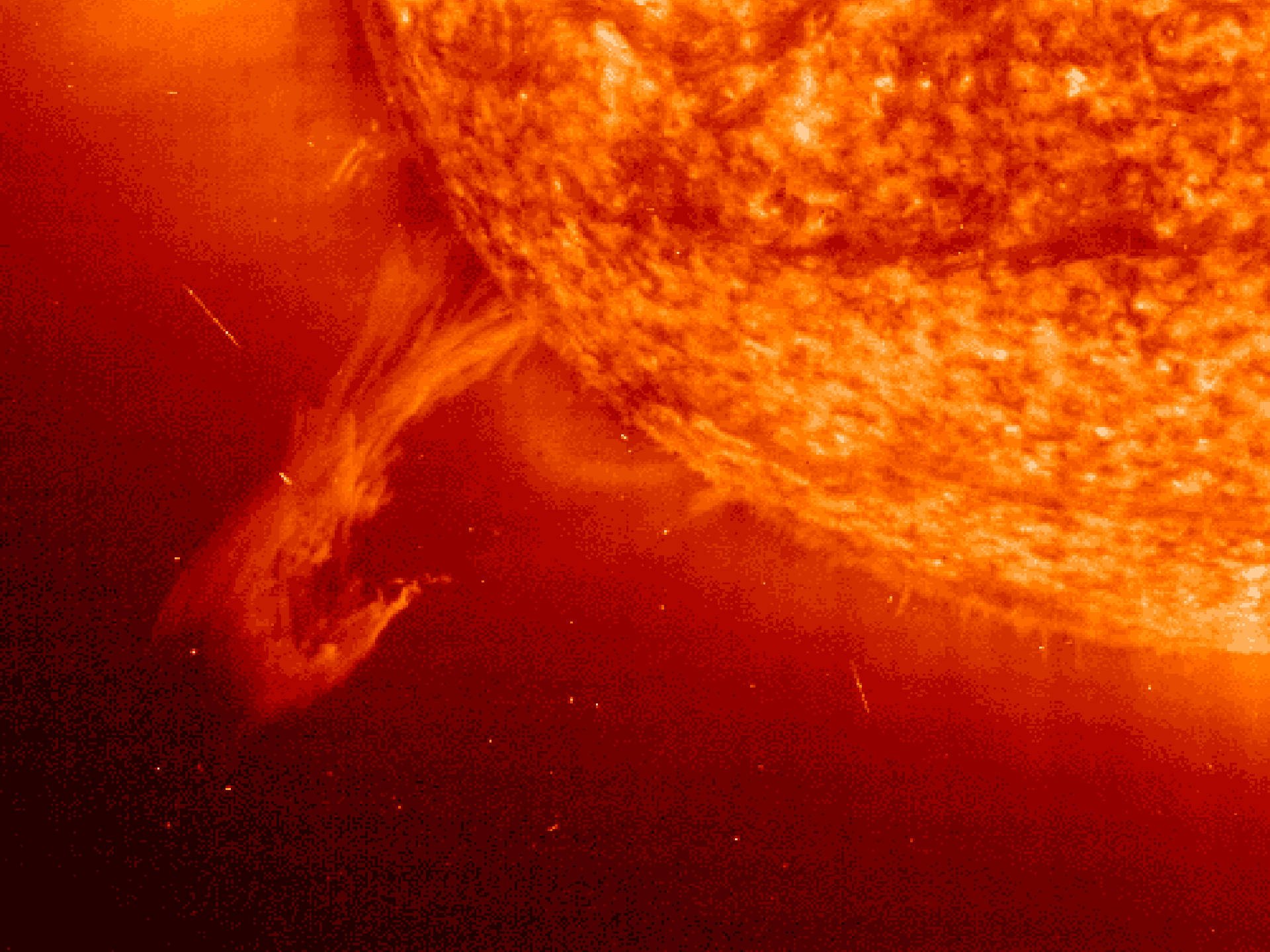
GIC and The Solar Cycle

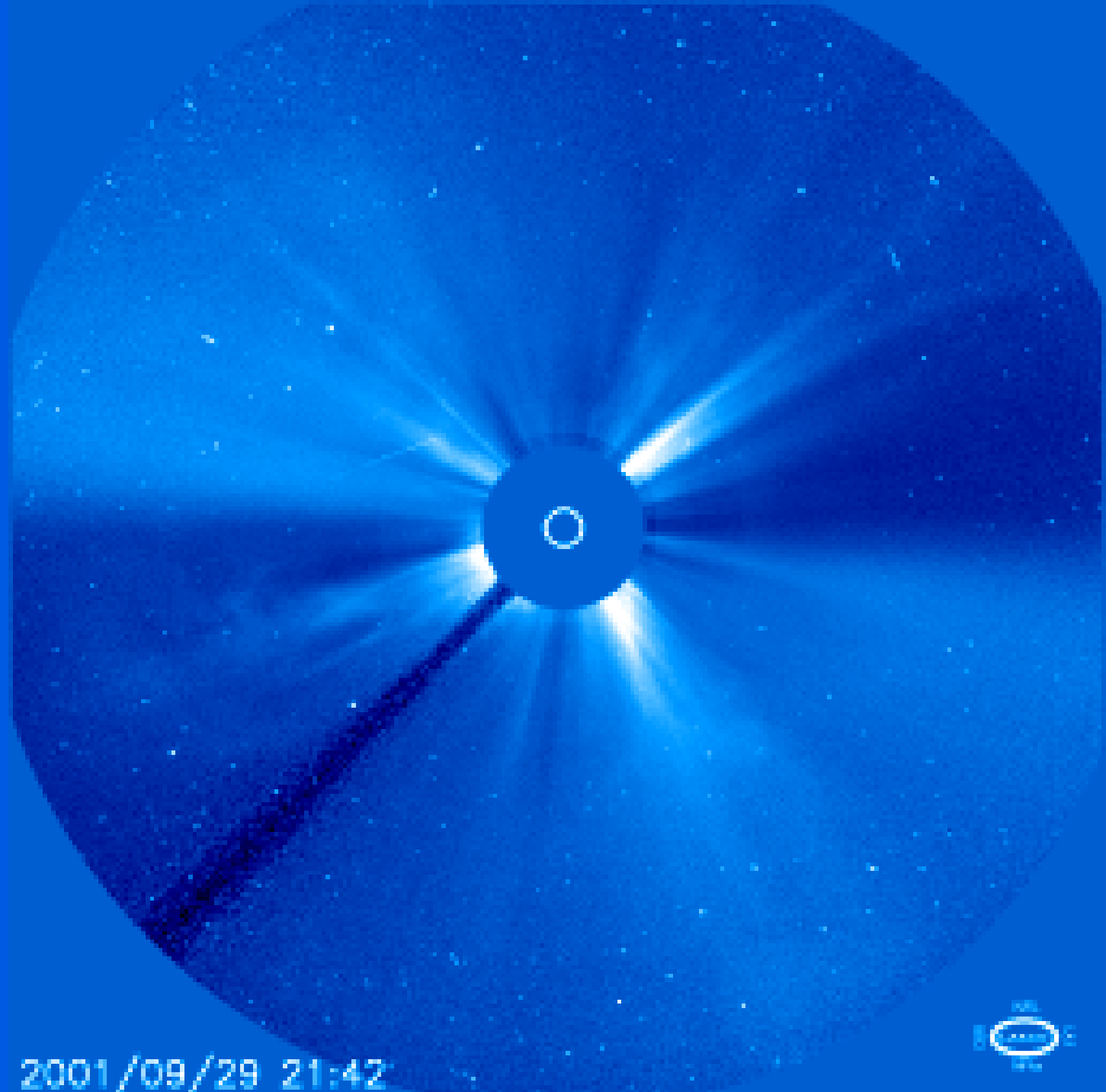
- During peak solar activity large solar flares / coronal mass ejections eject matter from the sun which travels on the solar wind towards earth and interacts with its magnetic field
 - Visually seen as auroras at the earth's poles
 - Impacts to radio, satellites, pipelines, power systems, and power transformers

Solar Flares

- **Flares** are short term brightenings that last for minutes or hours.
- They usually occur near active regions on the Sun where abrupt changes in magnetic field are taking place.
- When a flare begins, plasma is accelerated out from the Sun.
- This plasma usually returns in an arching fashion but in more eruptive flares, plasma is thrown completely away from the Sun.





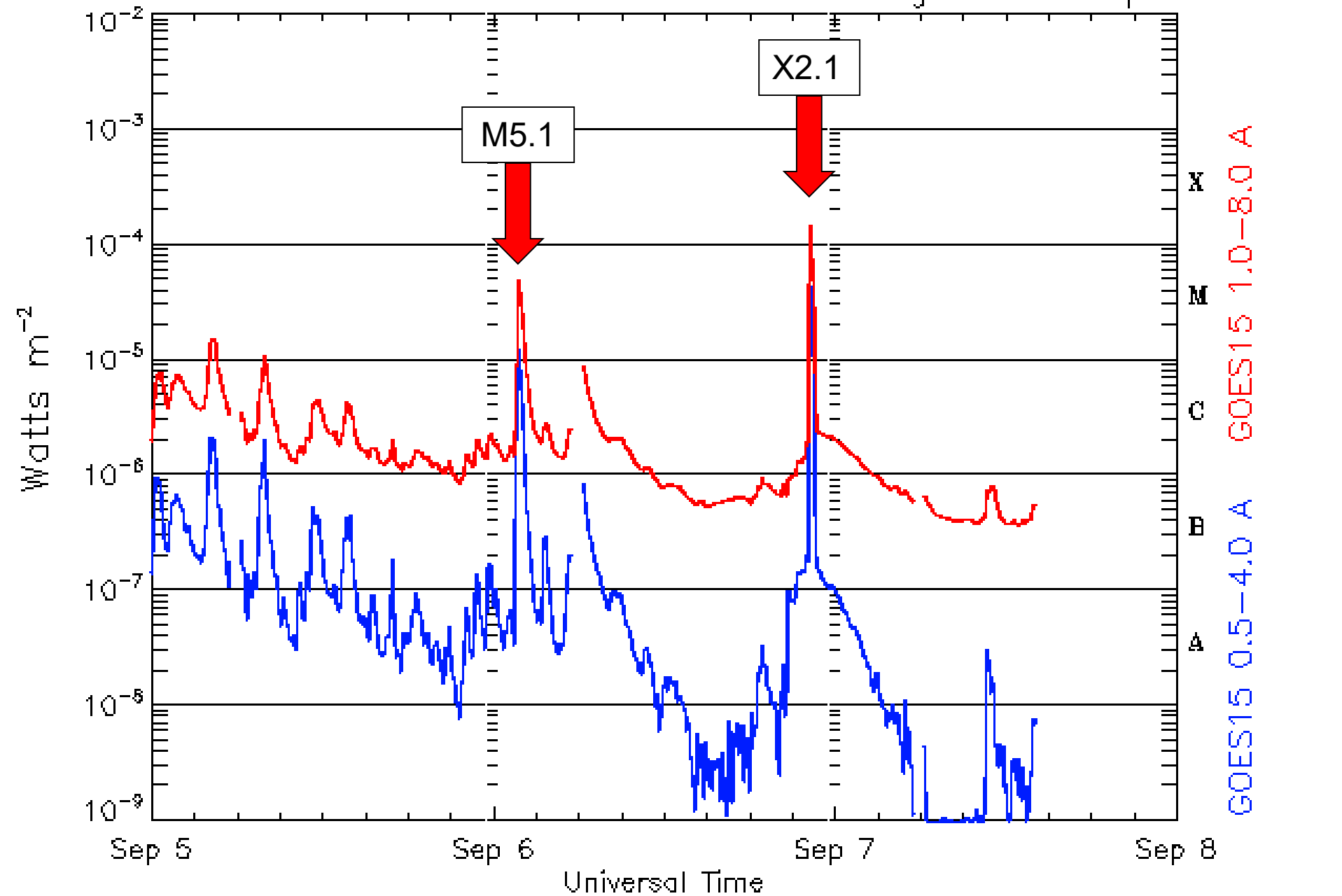


2001/09/29 21:42



GOES Xray Flux (5 minute data)

Begin: 2011 Sep 5 0000 UTC



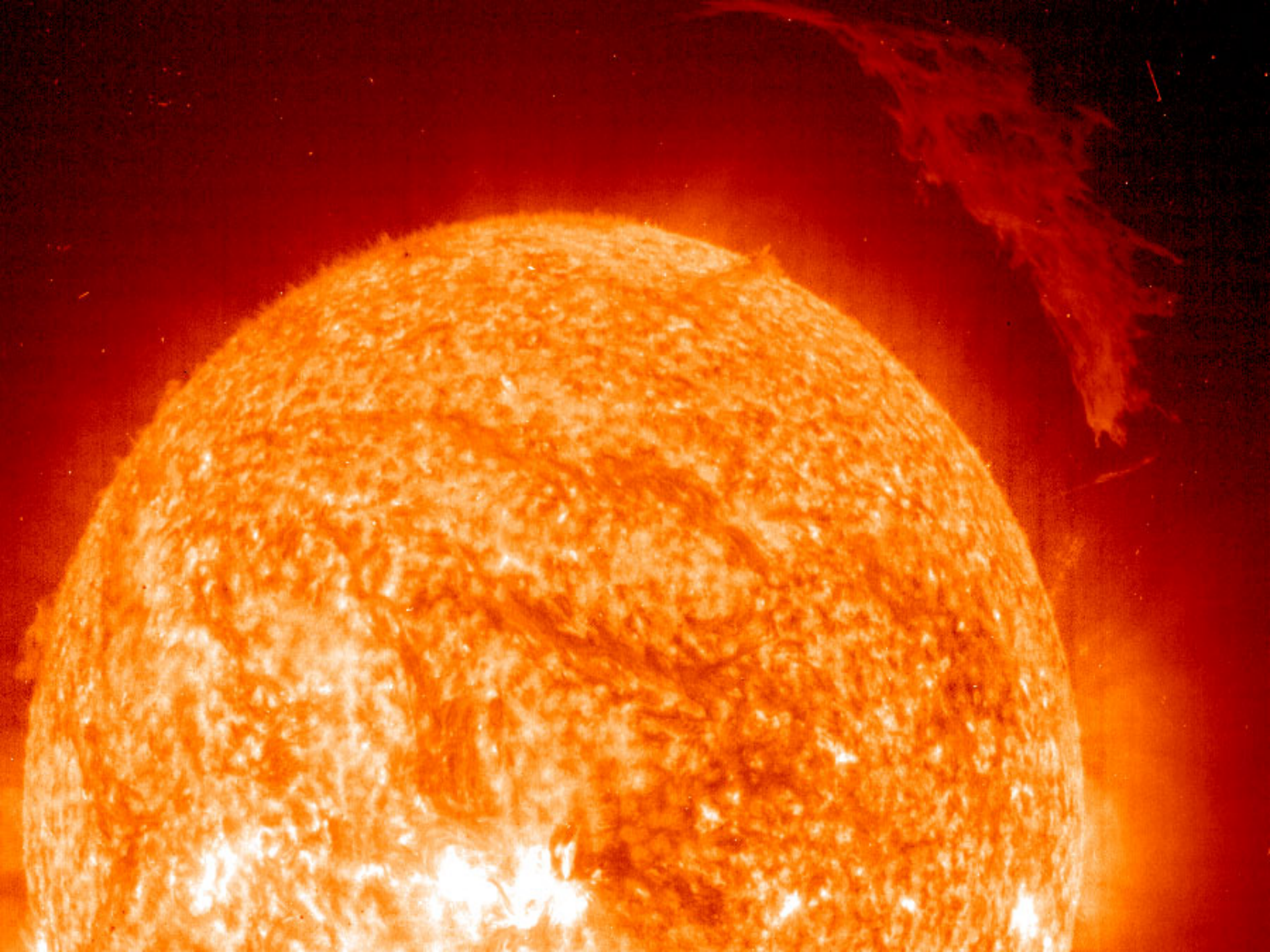
Updated 2011 Sep 7 14:20:11 UTC

NOAA/SWPC Boulder, CO USA

Filaments

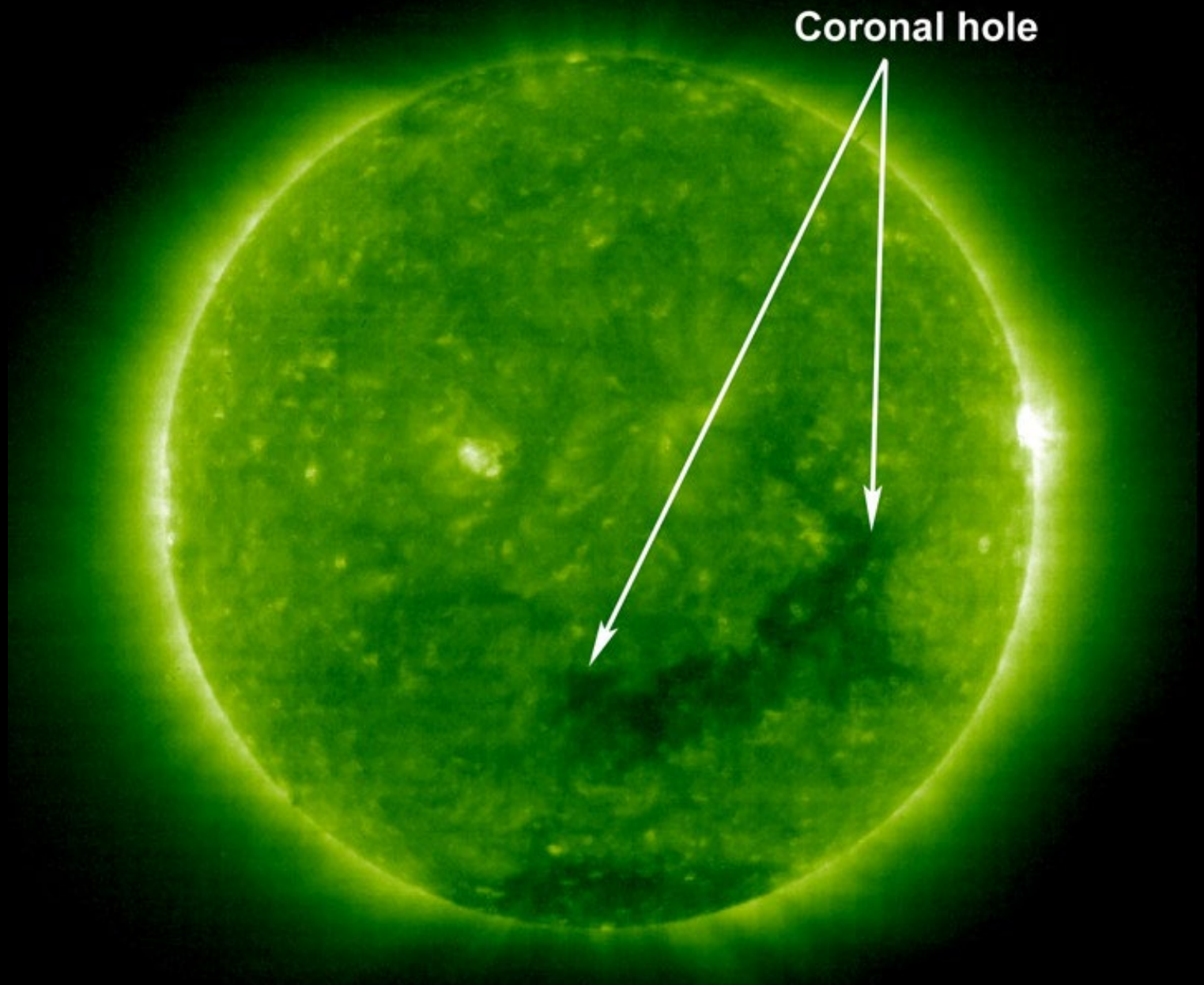
- Filaments are the long, string-like features which appear prominently in photos of the Sun.
- They hang like clouds for days or weeks then disappear, in most cases by dissipating, much like Earth clouds “burn off.”
- In other cases, though, filaments disappear by rising up, away from the Sun



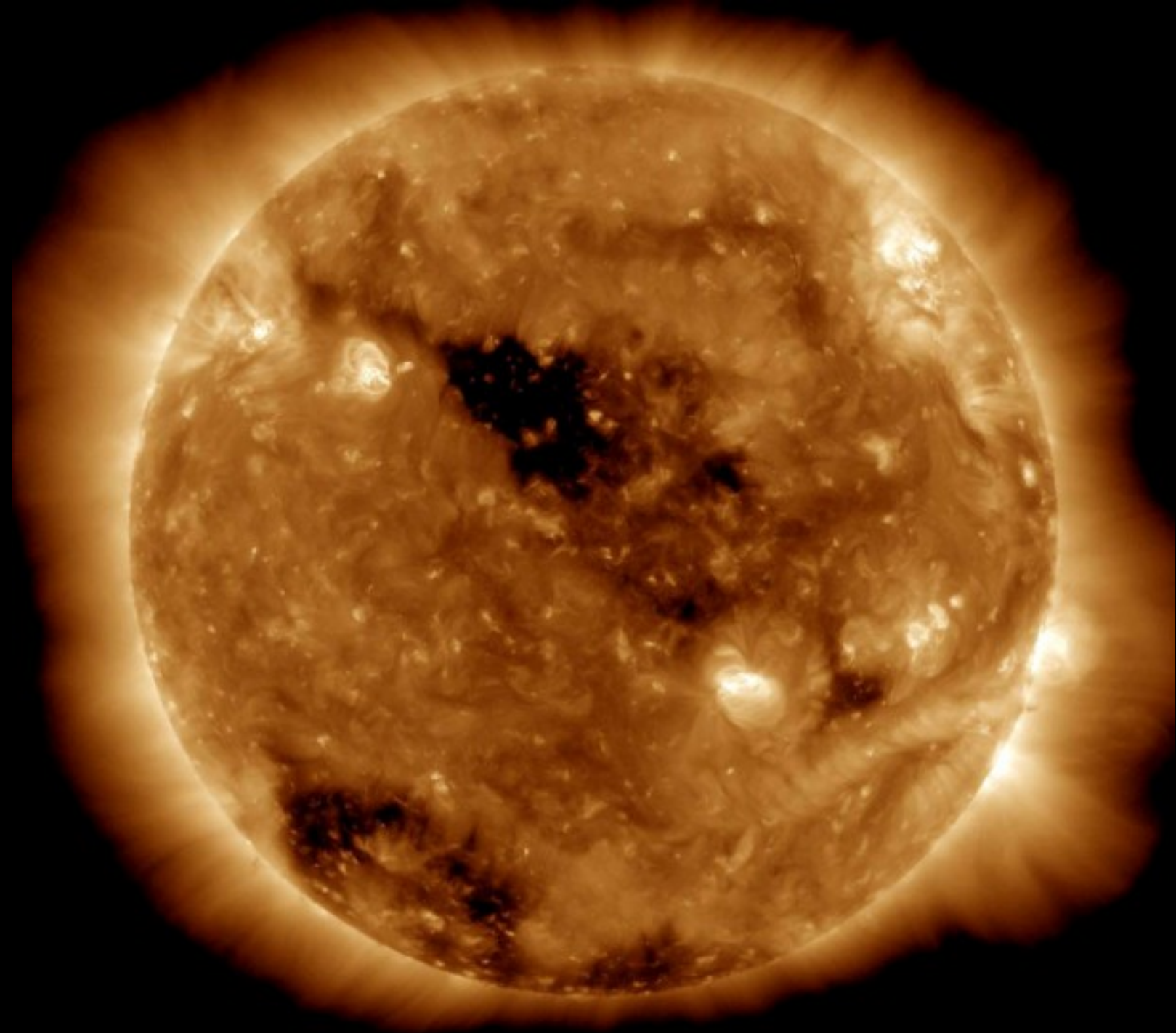


Coronal Hole

- The third source of mass traveling out from the Sun is the ***coronal hole***, easily seen as a dark region in an x-ray photo of the Sun.
- Coronal holes reside permanently near the poles of the Sun, and the solar wind streaming out from these generally does not reach the Earth.
- But during some rotations of the Sun, coronal holes form at lower latitudes, facing the Earth, and these act like a broadly focused fire hose spraying the Earth with a high intensity of charged particles.



Coronal hole



Plasma: From the Sun to Earth

- Speed of plasma: 400 km/s - 1500 km/s
- Time to hit earth atmosphere: 28 – 100 hours
(150,000,000 kilometers)
- Time for an alarm from satellites located around the first Lagrange point: 17 minutes – 1 hour
(1,500,000 kilometers)

Geomagnetic Storm

- When an intense surge of solar wind reaches Earth, there are many changes which occur in the magnetosphere.
- The day side of the magnetosphere is compressed closer to the surface of Earth and the geomagnetic field fluctuates wildly.
- This type of event is generally called a ***geomagnetic storm***

Geomagnetic Induced Current

- Geomagnetic induced currents often flow through the ground unnoticed by humans.
- But when good conductors are present, like pipelines and electrical power transmission lines, the currents travel through these as well.
- Voltages as high as 10 volts per mile have been measured.

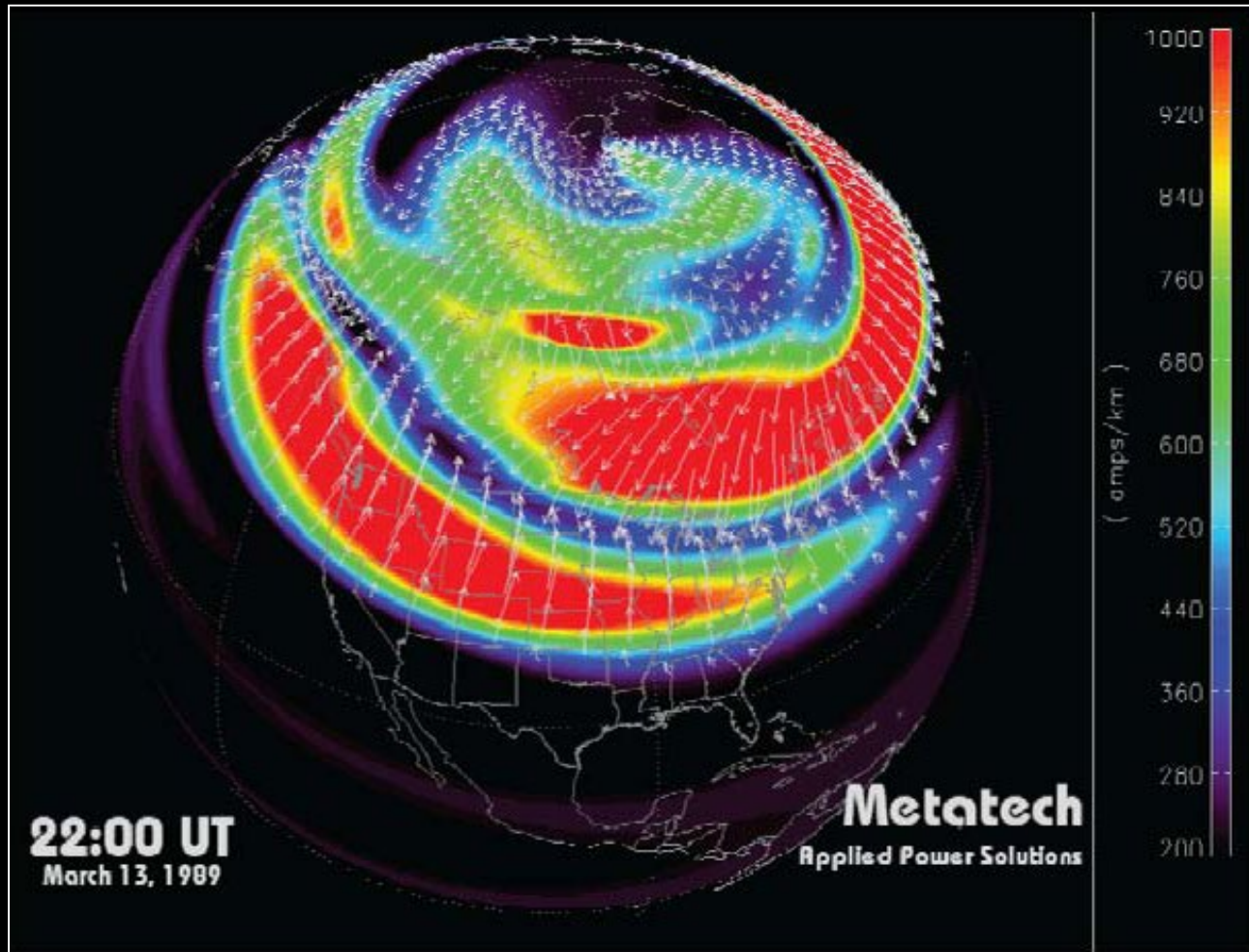
The HydroQuebec Blackout of March 1989

- On March 13, 1989, at 2:44 am, a transformer failure on one of the main power transmission lines in the HydroQuebec system precipitated a catastrophic collapse of the entire power grid. The string of events that produced the collapse took only 92 seconds from start to finish. 6 million people lost electrical power for 9 or more hours.

The HydroQuebec Blackout of March 1989



The HydroQuebec Blackout of March 1989



The HydroQuebec Blackout of March 1989



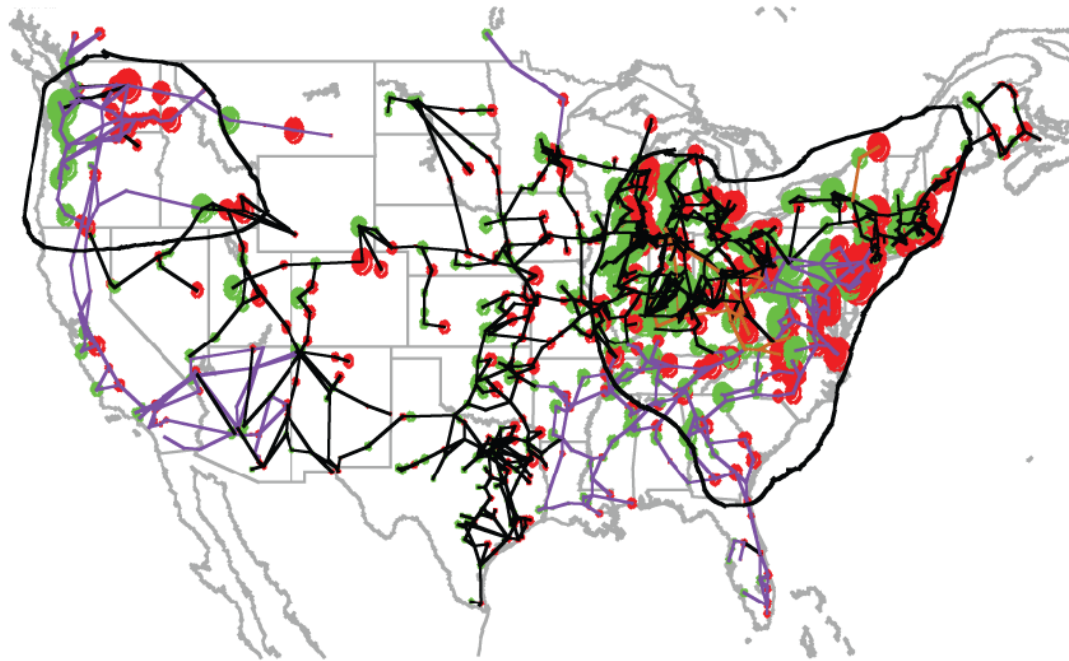
The HydroQuebec Blackout of March 1989



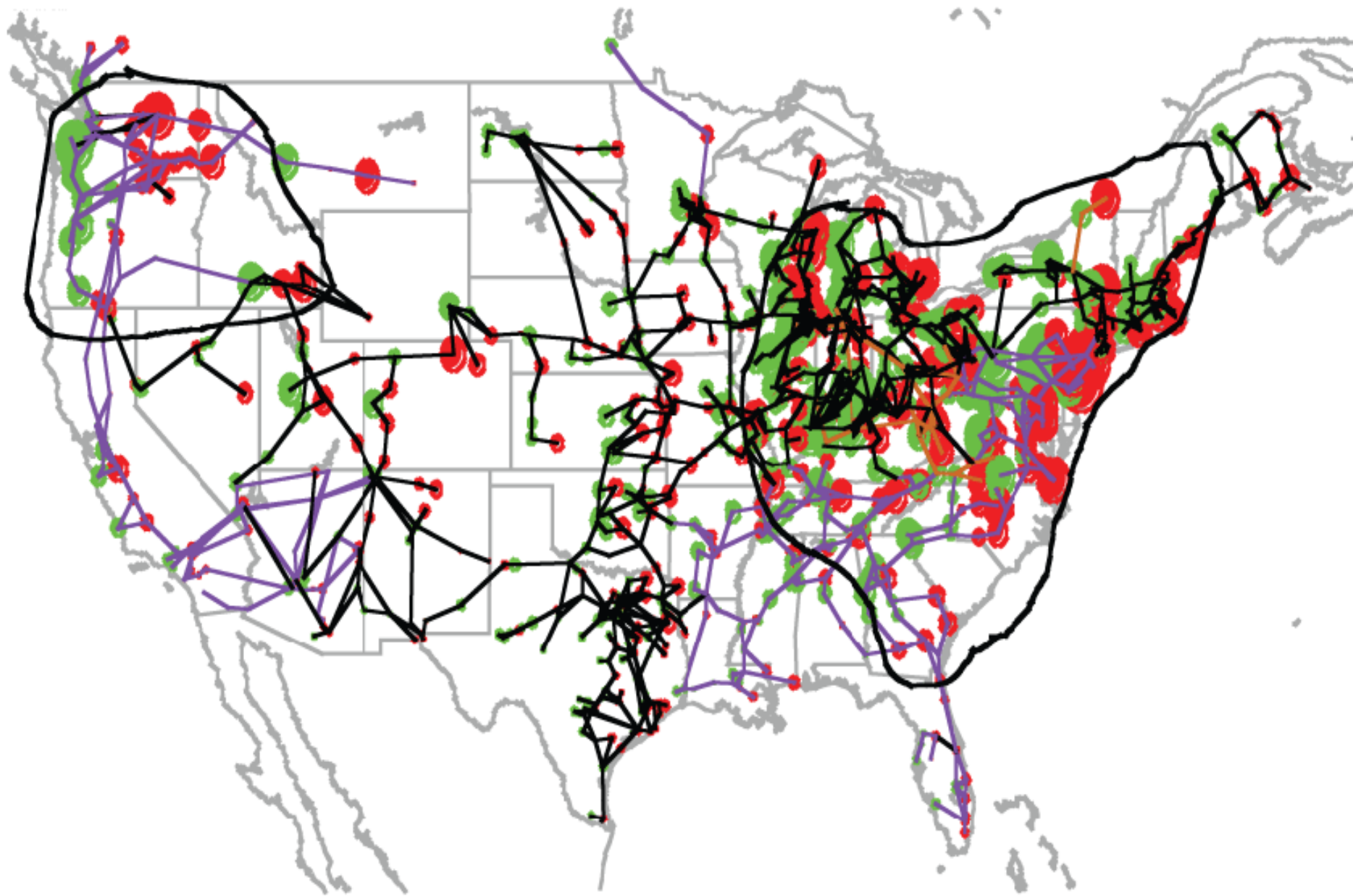


May 1921 Super Storm

Produced ground currents as much as ten times stronger than the 1989 Quebec storm

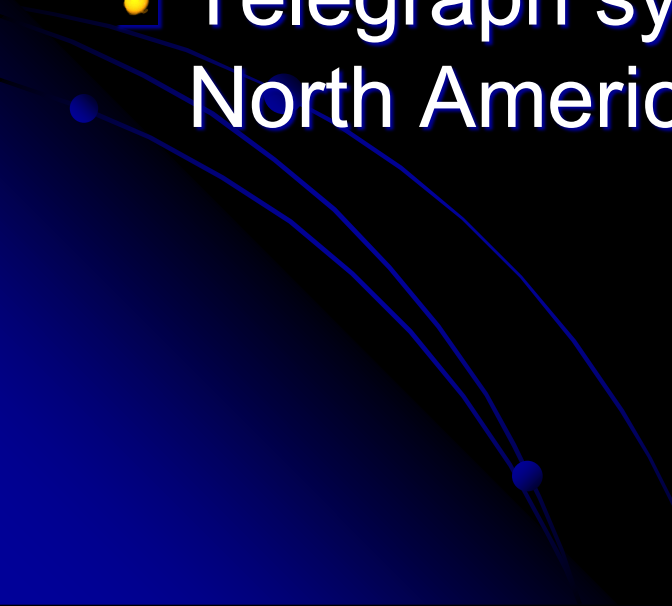


100 Year Geomagnetic Storm $\tilde{G}50$ Degree Geomagnetic Disturbance Scenario



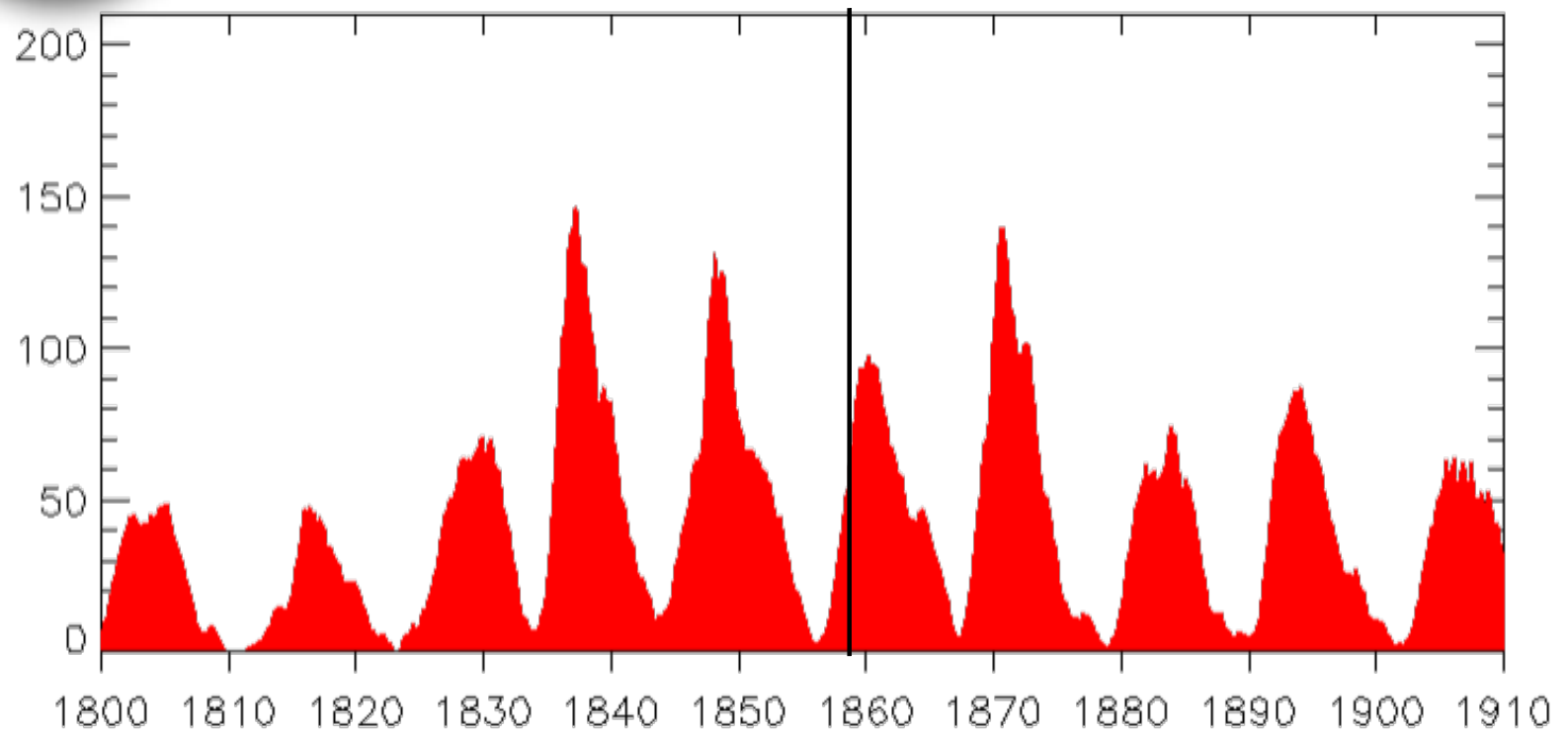
100 Year Geomagnetic Storm G50 Degree Geomagnetic Disturbance Scenario

1859 Carrington Event

- On September 1–2, 1859, the largest recorded geomagnetic storm occurred. Aurora were seen around the world, most notably over the Caribbean.
 - Telegraph systems all over Europe and North America failed.
- 



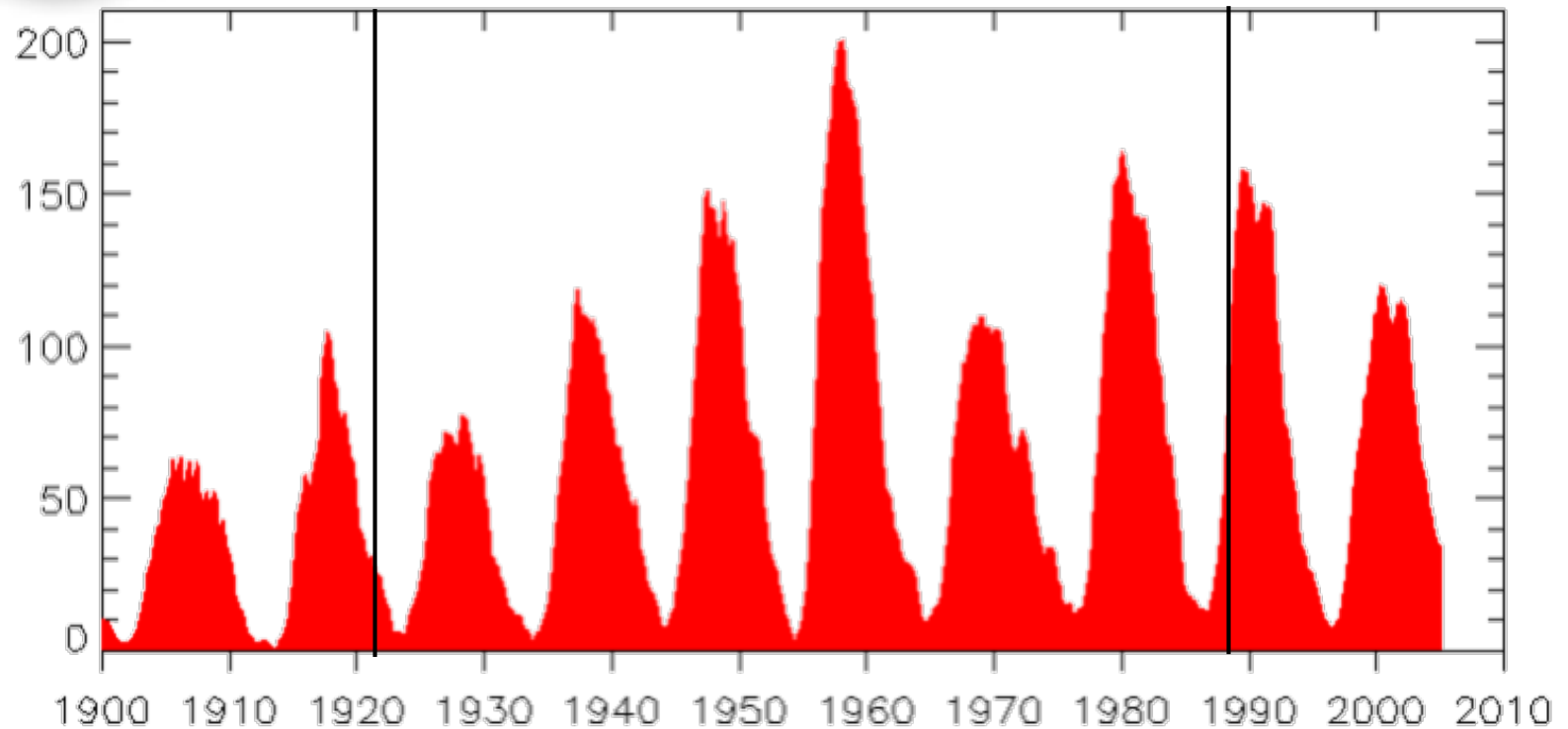
Recorded Solar Cycles



1859



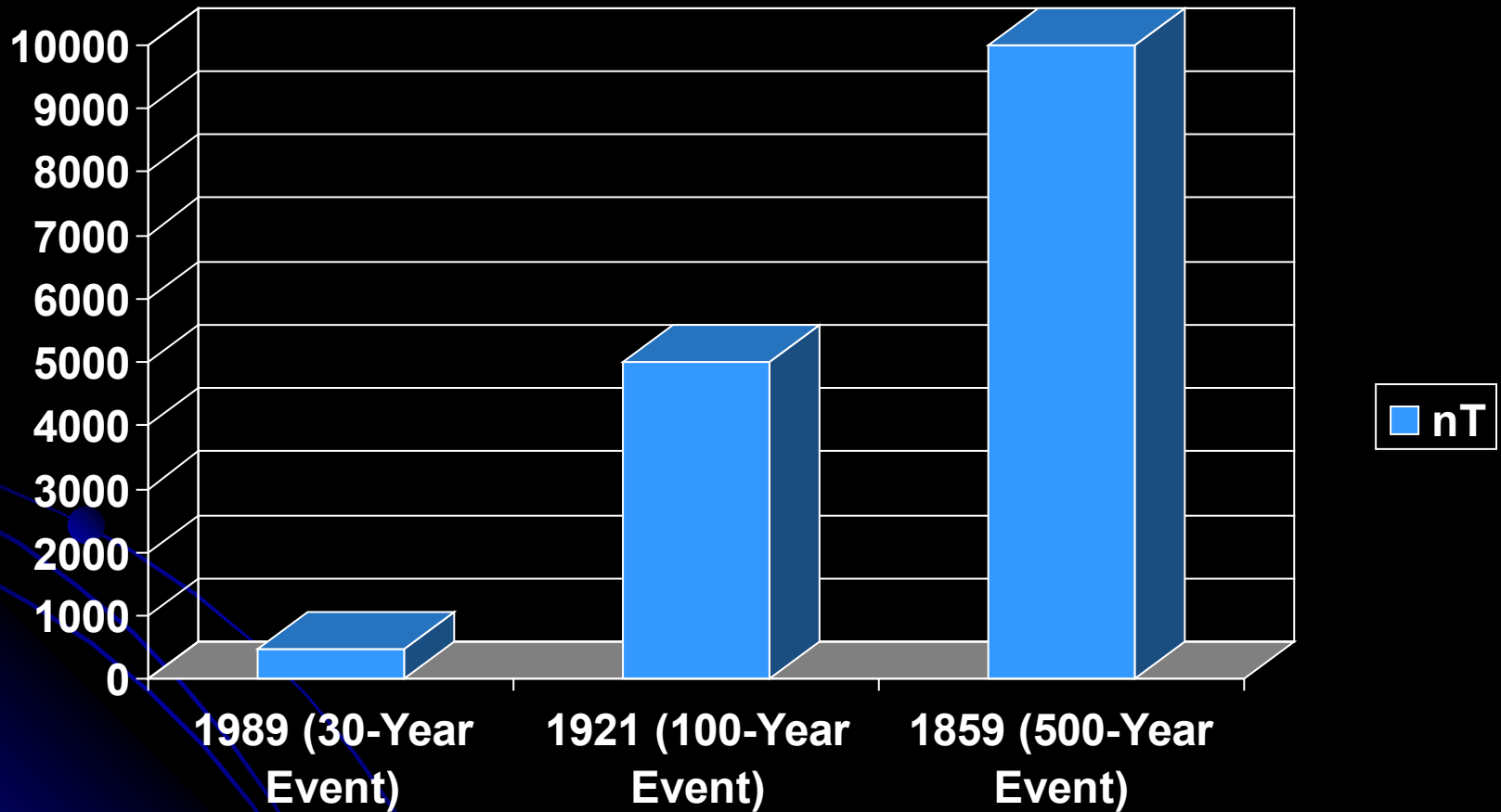
Recorded Solar Cycles



1921

1989

Comparison



NOAA Scales Activity

- Geomagnetic Storms
 - Power Systems
 - Spacecraft Operations
 - Others (pipelines, radio, satellites, auroras)
- Solar Radiation Storms
 - Biological
 - Satellite Operations
 - HF Radio
- Radio Blackouts
 - HF Radio
 - Navigation





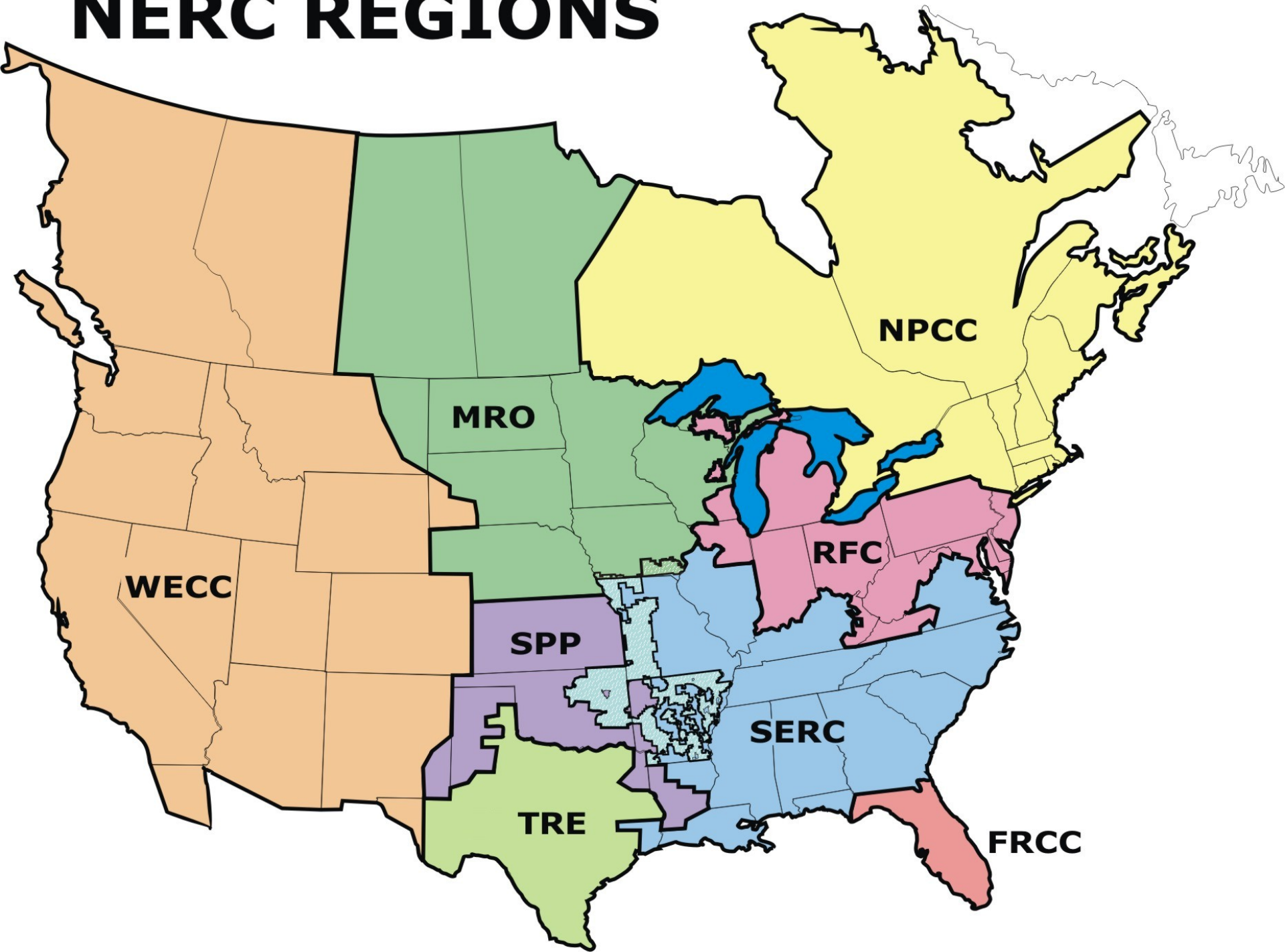
K Index Hourly Range in Nanoteslas (nT)

K	G	nT	
9	G 5	750+	Extreme
8	G 4	500-749	Severe
7	G 3	300-499	Strong
6	G 2	180-299	Moderate
5	G 1	105-179	Minor
4		60-104	Active
3		30-59	Unsettled
2		15-29	Quiet
1		8-14	Quiet
0		0-7	Quiet

Electrical Grid

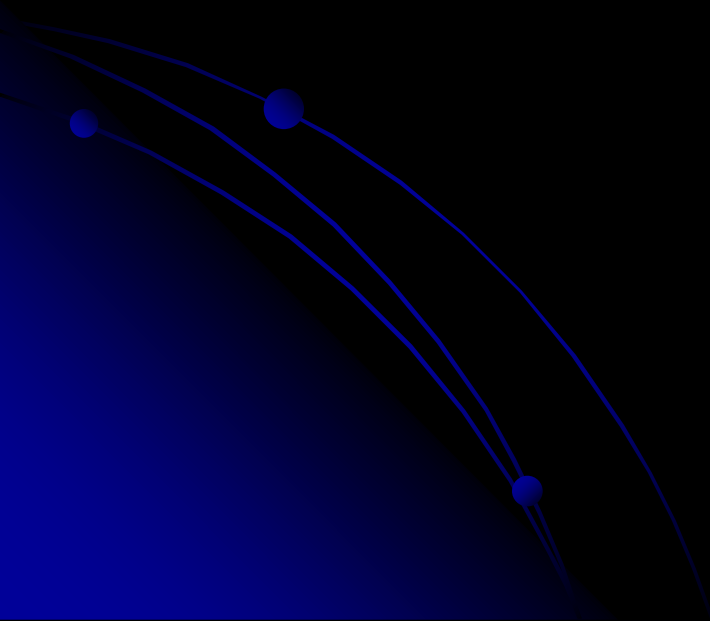
- North America's bulk power system is one of our most critical infrastructures; it underpins our government, economy and society in many important ways.
- Comprised of over 200,000 miles of transmission lines and thousands of generating plants.

NERC REGIONS



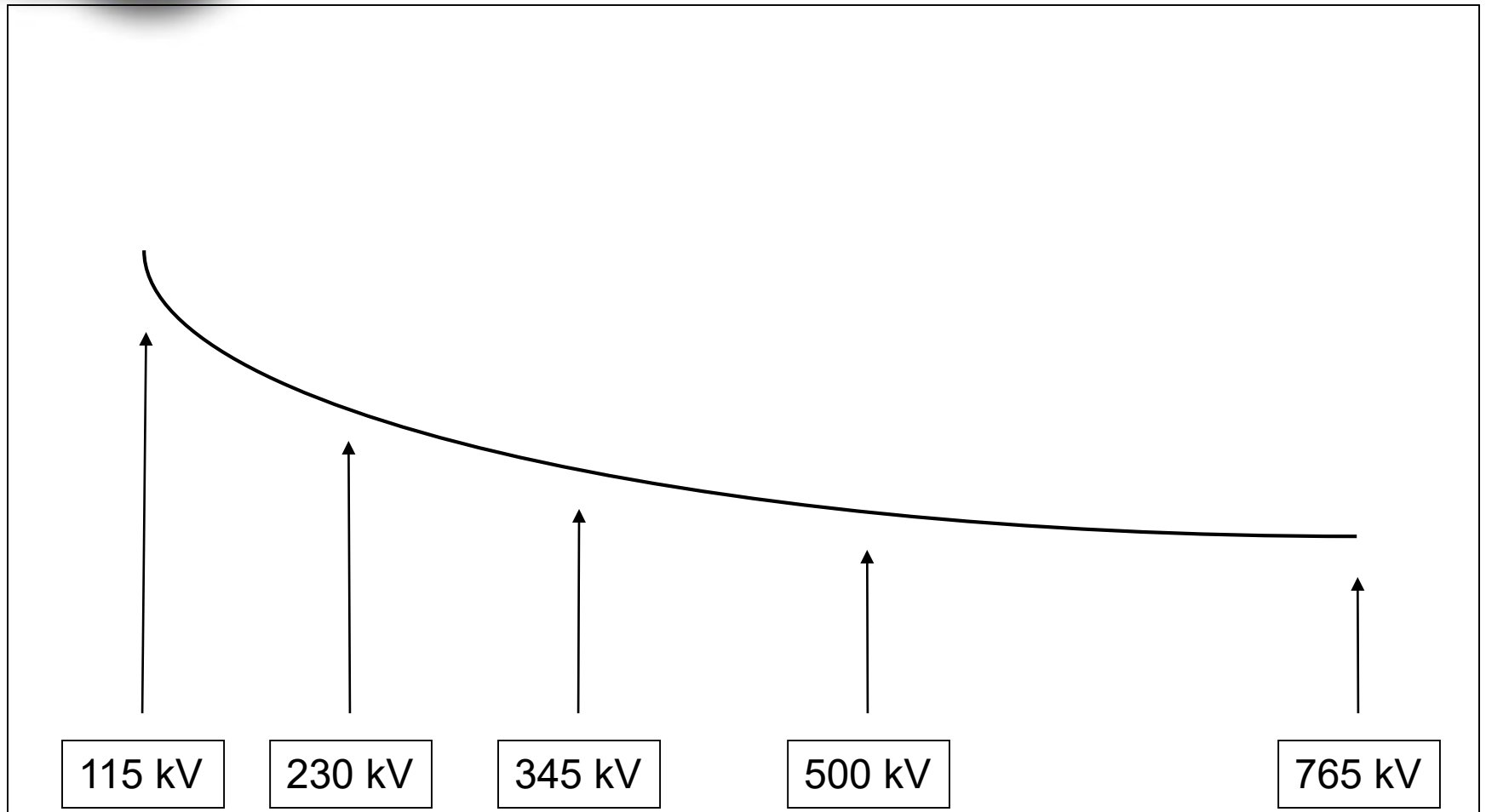
Vulnerability Factors

- Electrical line voltage
- High magnetic latitudes
- Direct current
- Soil type





Transmission Line Resistance



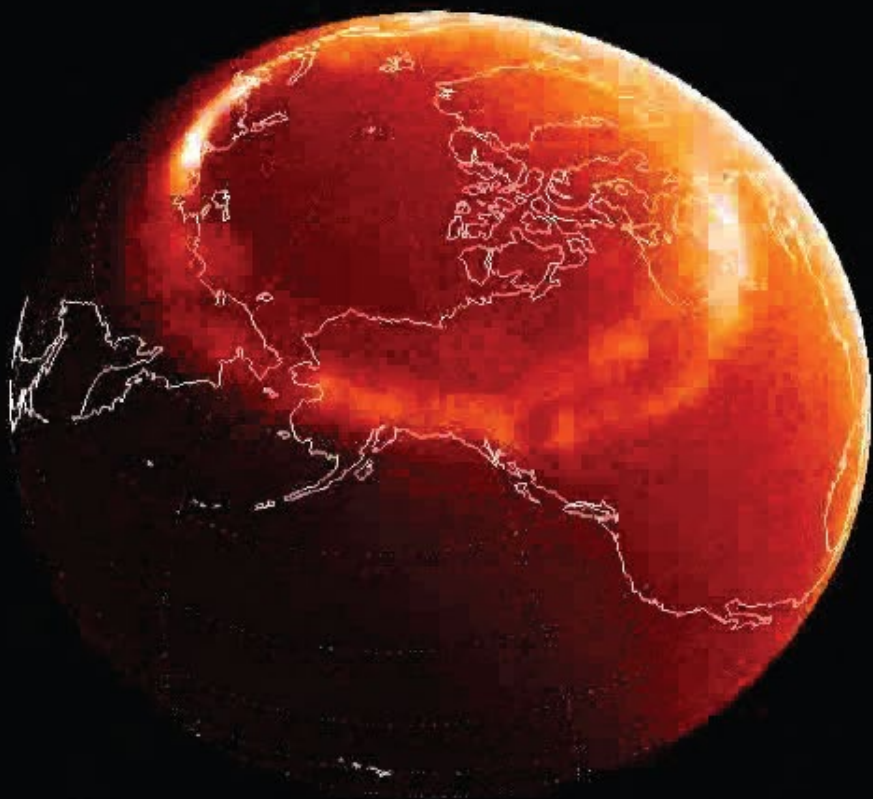


IMAGE-FUV-WIC. 2000-07-15-14:37:27

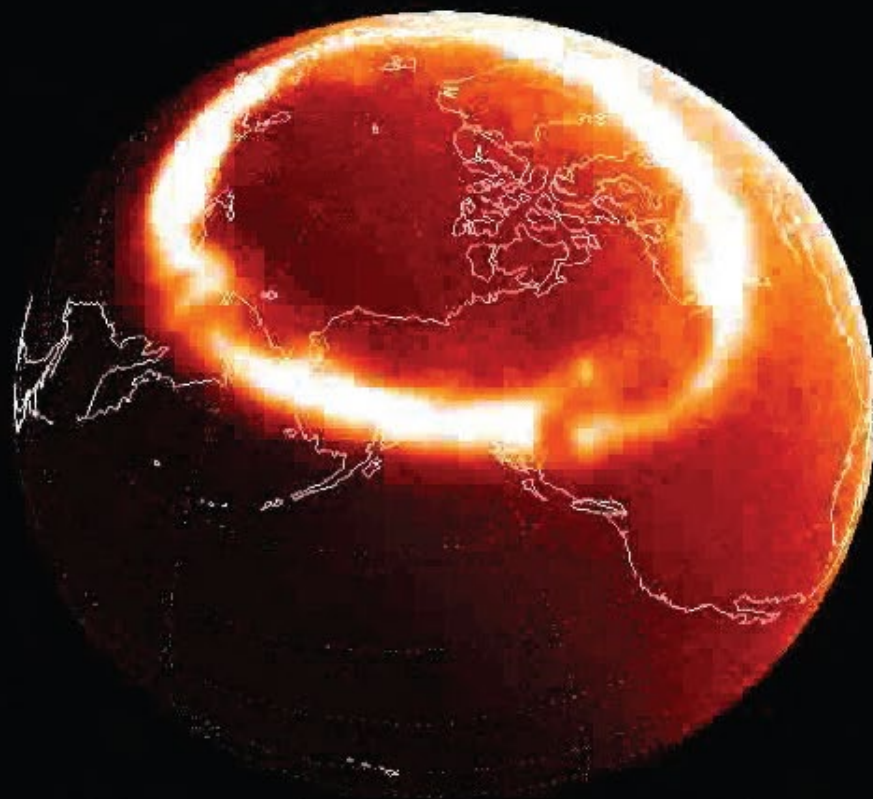


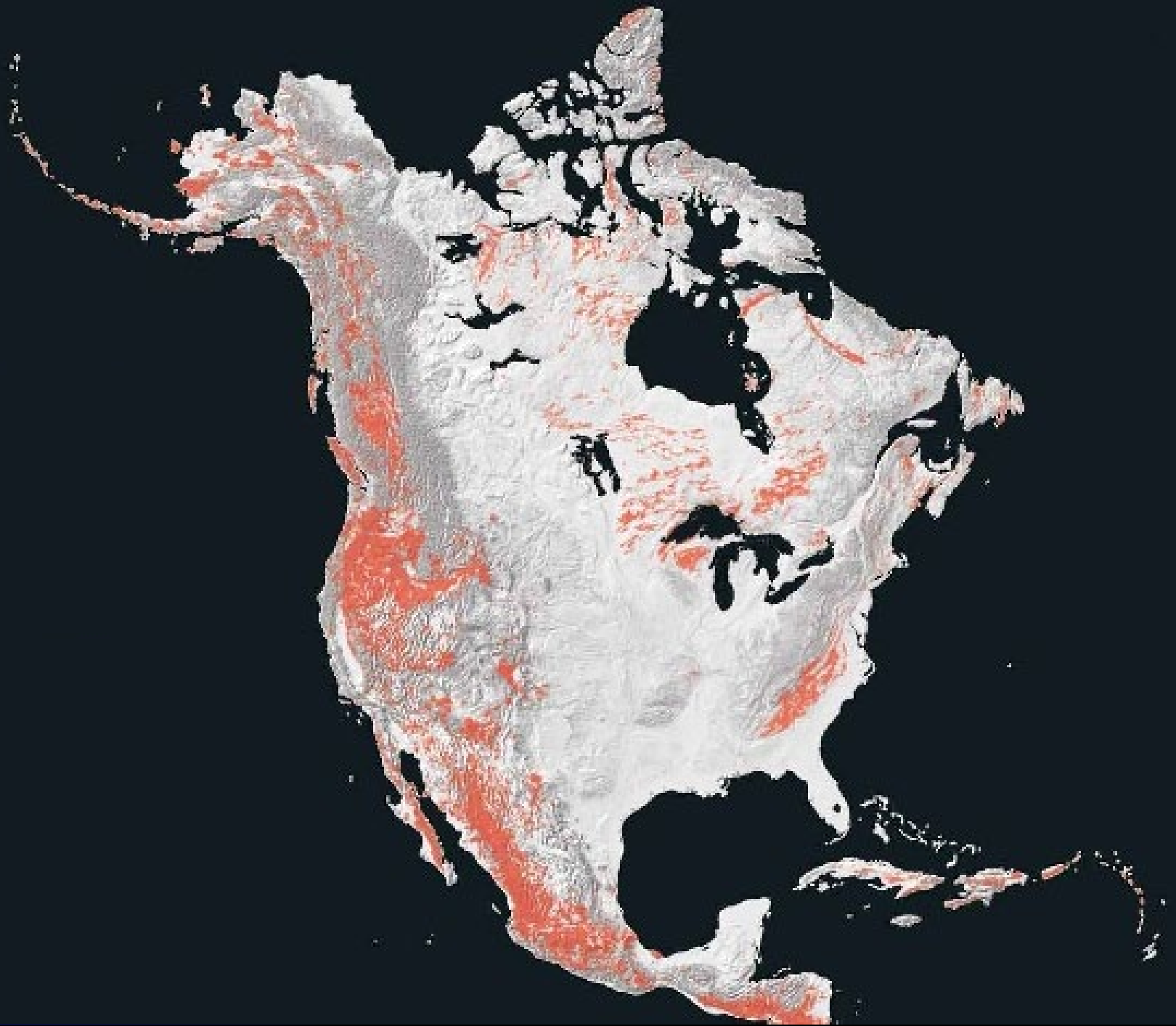
IMAGE-FUV-WIC. 2000-07-15-14:39:29



Igneous Rock

Because igneous rock has a low conductivity, the induced currents tend to take a path through man-made conductors







Protective Measures

GIC risk can, to some extent, be reduced by capacitor blocking systems, maintenance schedule changes, additional on-demand generating capacity, and ultimately, load shedding.

These options are expensive and sometimes impractical.

Seattle City Light

- ~30% of power comes directly to Seattle from the Skagit Project.
- All of the rest, including Boundary Dam, comes through BPA transmission lines.
- All of Seattle City Light's equipment is 230 kV or less.

Monitoring

Space Weather Prediction Center

www.swpc.noaa.gov/

National Weather Service
Space Weather Prediction Center

Site Map News Organizational Chart

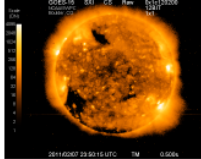
Top News of the Day: January 10, 2011 -- GOES 15 will Replace GOES 11 as Secondary SWPC GOES Proton, Electron and Magnetometer Satellite the end of February.

February 4 -- SWPC webmaster retiring after four solar cycles.

Current Space Weather Conditions

----- Satellite Displays ----- Popular Pages -----

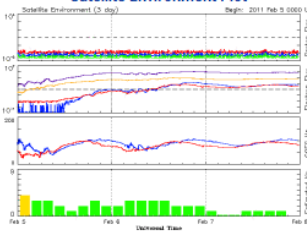
Latest GOES Solar X-ray Image



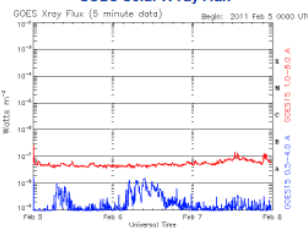
NOAA Scale Range 1 (minor) to 5 (extreme)

NOAA Scale	Past 24 hours	Current
Geomagnetic Storms	none	none
Solar Radiation Storms	none	none
Radio Blackouts	none	none

Satellite Environment Plot



GOES Solar X-ray Flux





Space Weather Topics:
Alerts / Warnings, Space Weather Now, Today's Space Wx, Data and Products, About Us, Email Products, Space Wx Workshop, Education/Outreach, Customer Services, Contact Us


Monitoring

Space Weather Canada

www.spaceweather.gc.ca

 Government of Canada / Gouvernement du Canada





Space Weather Canada

www.spaceweather.gc.ca

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[NRCan](#)

[CSA](#)

[ISES](#)

[Proactive disclosure](#)

Space Weather Canada

ISES Regional Warning Centre for Canada

Geomagnetic Field - CURRENT STATUS 2011 02 07 23:45 UT

Polar	Quiet
Auroral	Quiet
Sub-Auroral	Quiet

The Canadian Space Weather Forecast Centre in Ottawa is operated by [Natural Resources Canada \(NRCan\)](#), with support from the [Canadian Space Agency \(CSA\)](#). It is a Regional Warning Centre (RWC) of the [International Space Environment Service \(ISES\)](#), formerly IUWDS). The ISES global network monitors a variety of parameters that help to characterize the conditions on the Sun, in space between the Sun and Earth, and on the Earth. The data are used by Regional Warning Centres and others to develop Space Weather warnings and alerts.

Information

[What is Space Weather ?](#)

[Space Weather Research in Canada](#)

[Space Weather Links](#)

Regional Warning Centres

[More information](#)

[Beijing](#)

[Boulder](#)

[Brussels](#)

[Delhi](#)

[Hermanus](#)

[Lund](#)

[Moscow](#)

[Ottawa](#)

[Prague](#)

[São José dos Campos](#)

[Sydney](#)

[Tokyo](#)

[Warsaw](#)

Date Modified: 2010-02-11

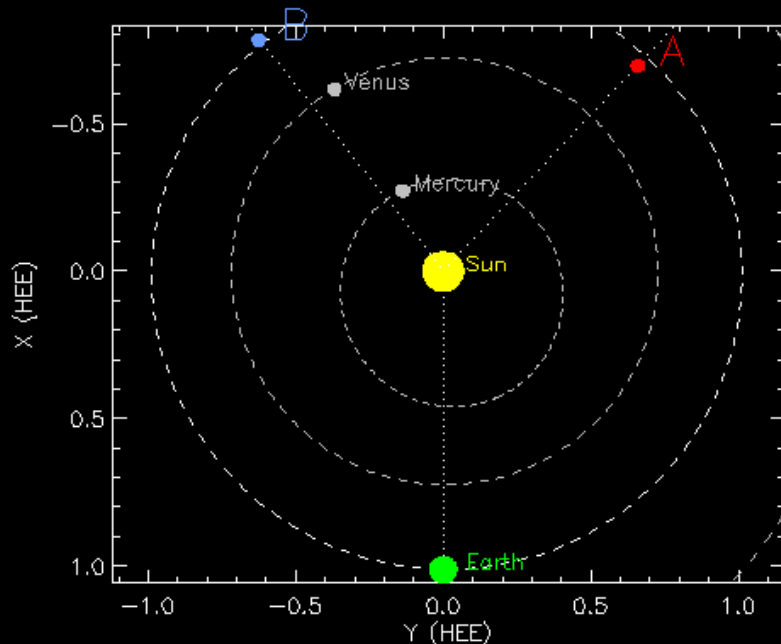
[Top of Page](#)

[Important Notices](#)

Monitoring

STEREO – Solar Terrestrial Relations Observatory

www.stereo.gsfc.nasa.gov/



3-D VIEW OF THE SUN AND HELIOSPHERE

HOME CONTACT SITE MAP

Welcome to the STEREO website!

STEREO consists of two space-based observatories - one ahead of Earth in its orbit, the other trailing behind. With this new pair of viewpoints, scientists will be able to see the structure and evolution of solar storms as they blast from the Sun and move out through space.

MISSION
Mission
Spacecraft
Launch
Instruments
Where is STEREO?

IN THE NEWS
What's New?
Current Status
Newsroom

SCIENCE
Space Weather
Science Center
(Data)

RESOURCES
Latest Images
Galleries
Learning Center
Links

This movie shows a spherical map of the Sun as it currently appears, formed from a combination of the latest STEREO Ahead and Behind beacon images, along with an SDO/AIA image in between. The movie starts with the view of the Sun as seen from Earth, with the 0 degree meridian line in the middle. The map then rotates through 360 degrees to show the part of the Sun not visible from Earth. The black wedge shows the part of the Sun not yet visible to the STEREO spacecraft.

Latest EUVI Images

STEREO Behind EUVI 195

STEREO Ahead EUVI 195

Questions?

