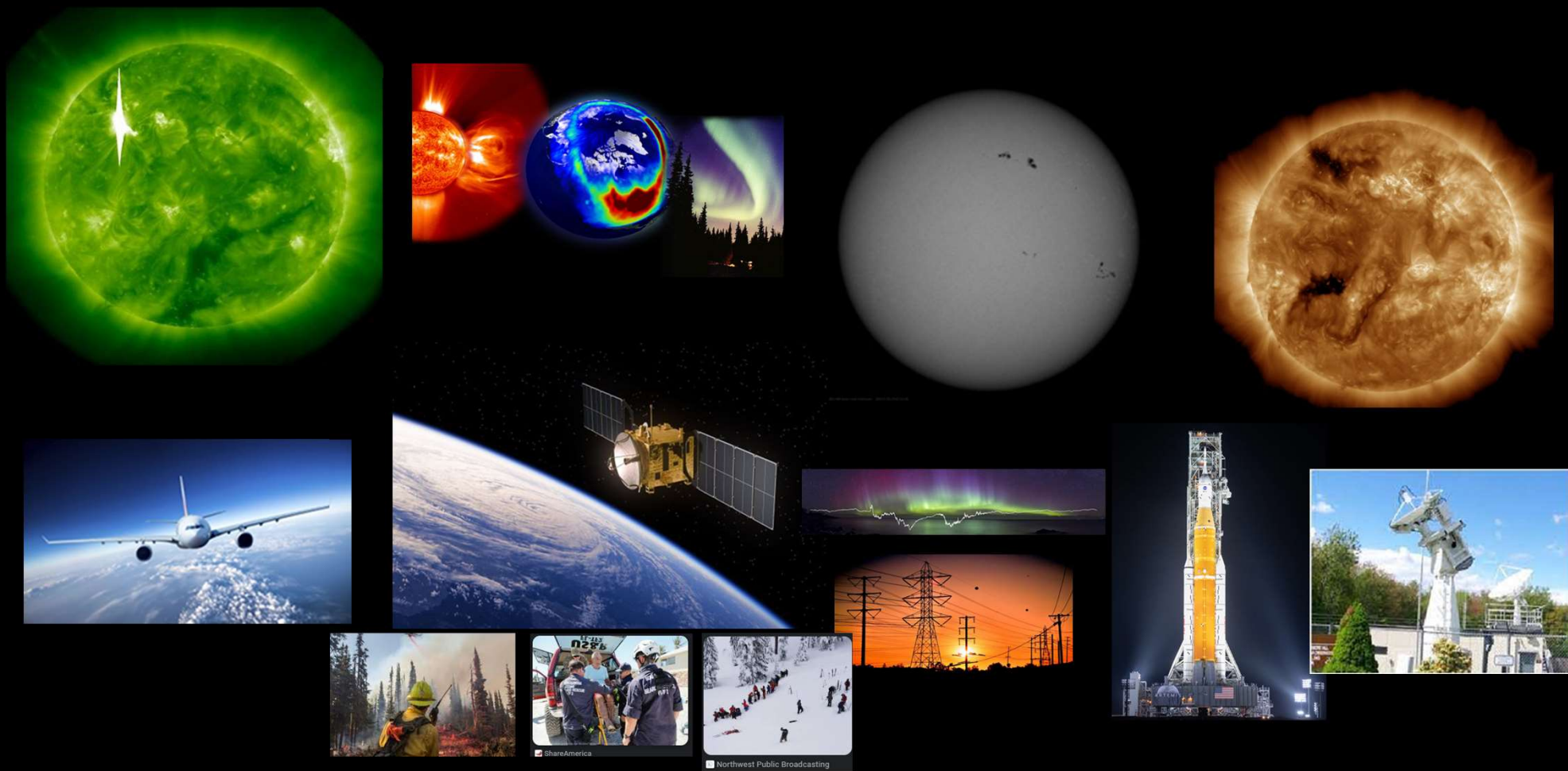
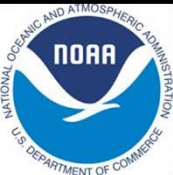


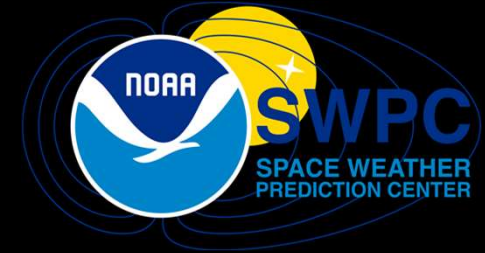
# Space Weather Introduction for EM Preparedness



***SWPC: "Safeguarding Society with  
Actionable Space Weather Information"***

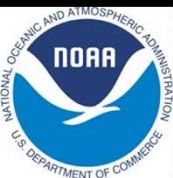


# Space Weather Prediction Center (SWPC) Boulder, CO



*“Safeguarding Society with Actionable Space Weather Information”*

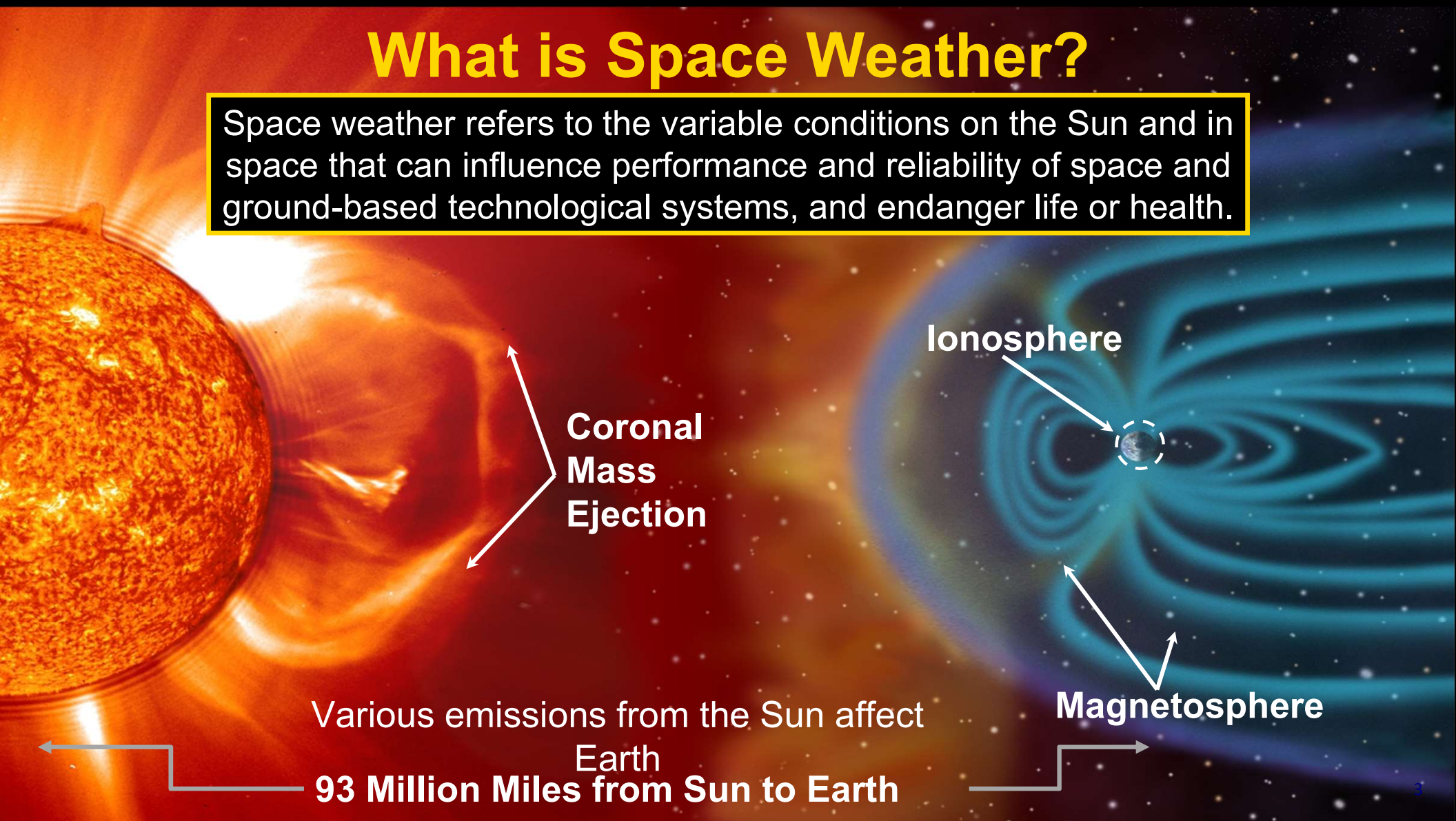
We are the NWS and proud to be part of the mission to protect lives & property – thus a key relationship with EM community





# What is Space Weather?

Space weather refers to the variable conditions on the Sun and in space that can influence performance and reliability of space and ground-based technological systems, and endanger life or health.




Coronal  
Mass  
Ejection

Ionosphere

Magnetosphere

Various emissions from the Sun affect  
Earth  
93 Million Miles from Sun to Earth

# Space Weather Importance recognized by the Federal Government



**NATIONAL SPACE WEATHER STRATEGY AND ACTION PLAN**

Product of the  
SPACE WEATHER OPERATIONS, RESEARCH, and MITIGATION WORKING GROUP  
SPACE WEATHER, SECURITY, and HAZARDS SUBCOMMITTEE  
COMMITTEE ON HOMELAND and NATIONAL SECURITY  
of the  
ADVISORY COUNCIL

One Hundred Sixteenth Congress  
of the  
United States of America

AT THE SECOND SESSION

Begun and held at the City of Washington on Friday,  
the third day of January, two thousand and twenty

An Act

To improve understanding and forecasting of space weather events, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

**SECTION 1. SHORT TITLE.**

This Act may be cited as the "Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow Act" or the "PROSWIFT Act".

**SEC. 2. SPACE WEATHER.**

(a) **POLICY.**—It shall be the policy of the United States to prepare and protect against the social and economic impacts of space weather phenomena by supporting actions to improve space weather forecasts and predictions including: sustaining and enhancing critical observations, identifying research needs and pro-



Space Weather Advisory Group (SWAG) Meeting at the Department of Commerce



(b) AMENDMENT TO TITLE 51, UNITED STATES CODE.—Subtitle VI of 51, United States Code, is amended by adding after chapter 605 the following:

**“CHAPTER 606—SPACE WEATHER**

“Sec.

- “60601. [Space weather.](#)
- “60602. [Integrated strategy.](#)
- “60603. [Sustaining and advancing critical space weather observations.](#)
- “60604. [Research activities.](#)
- “60605. [Space weather data.](#)
- “60606. [Space weather knowledge transfer and information exchange.](#)
- “60607. [Pilot program for obtaining commercial sector space weather data.](#)
- “60608. [Space weather benchmarks.](#)



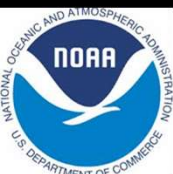
EXECUTIVE ORDERS

**Executive Order on Coordinating National Resilience to Electromagnetic Pulses**

Whitehouse.gov  
Issued on: March 26, 2019

INFRASTRUCTURE & TECHNOLOGY

## As a Concerning Risk





# Space Weather Impacts are wide ranging

## Infrastructure and Activities Vital to National Security and the Economy

Satellite Malfunctions; SATCOM Interference/Disruption; Satellite Drag; Pipeline Corrosion  
Radiation Exposure; Power Outages; HF Comm Dropouts; GNSS Degradations



**Space weather-induced electricity blackout: Daily domestic economic loss in the U.S. = \$41.5 billion plus an additional \$7 billion loss through the international supply chain.**

*"Quantifying the daily economic impact of extreme space weather due to failure in electricity transmission infrastructure," Centre for Risk Studies, University of Cambridge, Jan 2017*

# SWPC Forecast Operations (SWFO)

Operations, systems & data monitoring, forecasting, warning, & Alerts, IDSS, etc.

Core partnerships with USAF, NASA, FEMA, NERC


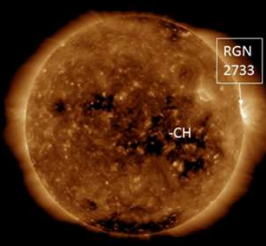



Staffed 24 hours 7 days a week – just like your supporting forecast office

G1

Minor geomagnetic storm watch in effect:  
31 January and 1 February, 2019

**Most likely area of Aurora Extent:** to the vicinity of the green line (Kp=5)

For updating aurora visibility information go to the SWPC aurora (OVATION-Prime) model:  
<http://www.swpc.noaa.gov/products/aurora-30-minute-forecast>

**SPACE WEATHER CONDITIONS** on NOAA Scales

24-hour Observed Maximum	Level Observed	Predicted 2019-07-15 UTC
R S G	R S G	R1-42 1% S1 or greater 1% G

Solar Wind Speed: 479 km/sec      Solar Wind Magnetic Fields: Bz 6 nT, Bz -3 nT      Noon 10.7cm Radio Flux: 67 sfu

**Solar Cycle 25 Preliminary Forecast**

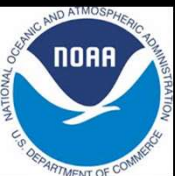
WSA-Enlil v2.0 now operational  
published: Tuesday, June 15, 2019 19:53 UTC  
SWPC is pleased to announce the successful implementation of the upgraded WSA-Enlil heliospheric model v2.0 (the first upgrade since the initial im)

HW5 Summer 2019 Safety Campaign  
published: Tuesday, June 11, 2019 04:03 UTC  
Get ready for summer weather hazards by visiting our Summer Safety website at <https://www.weather.gov>

Solar Cycle 25 Preliminary Forecast  
published: Tuesday, June 11, 2019 04:02 UTC  
The NOAA/NASA co-chaired international panel to forecast Solar Cycle 25 released a preliminary forecast for Solar Cycle 25 on April 5, 2019.

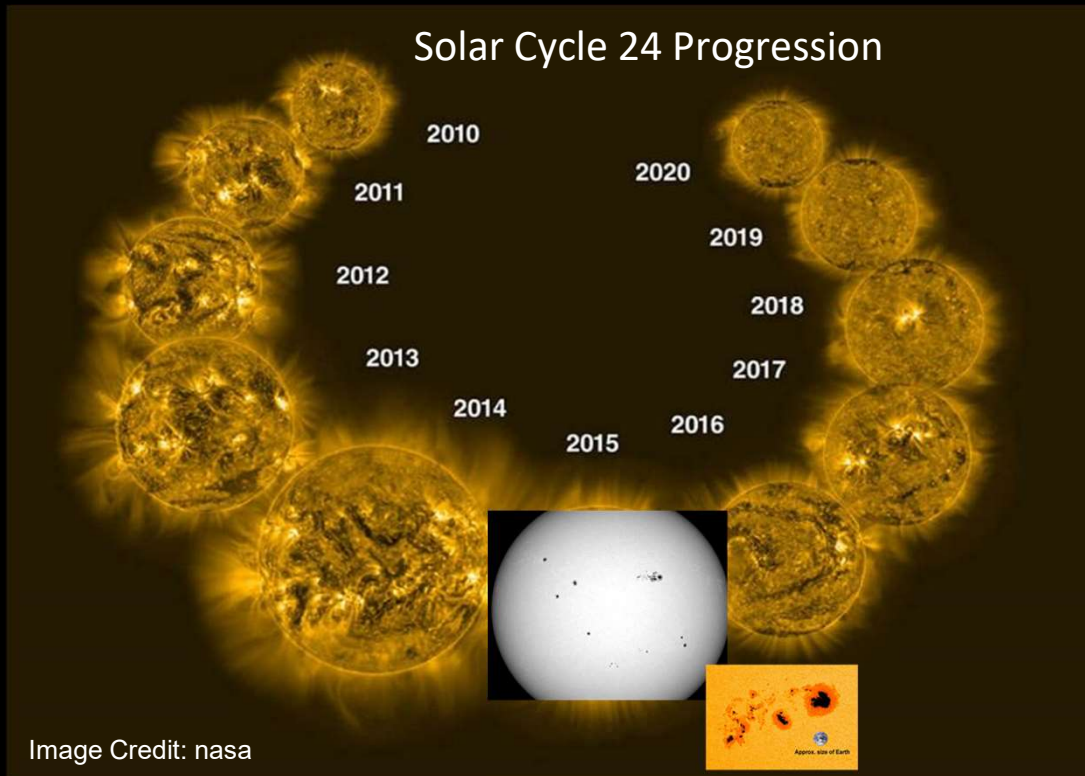
Save the Date - June 26, 2019 - Space Weather Enterprise Forum  
published: Tuesday, June 11, 2019 04:02 UTC  
The 2019 Space Weather Enterprise Forum will be held June 26, 2019

SERVING ESSENTIAL SPACE WEATHER COMMUNITIES

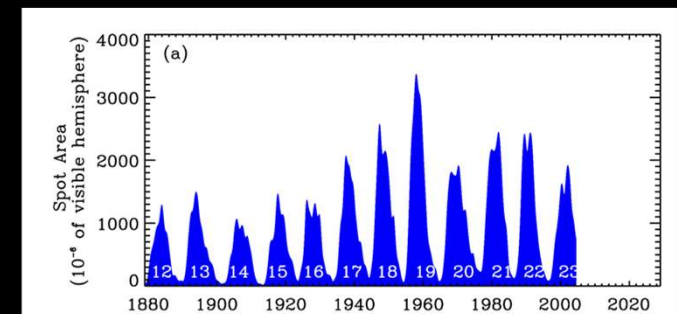
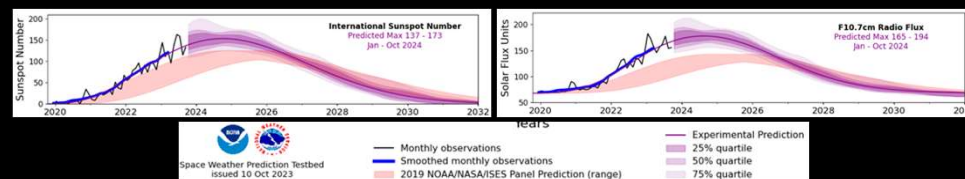




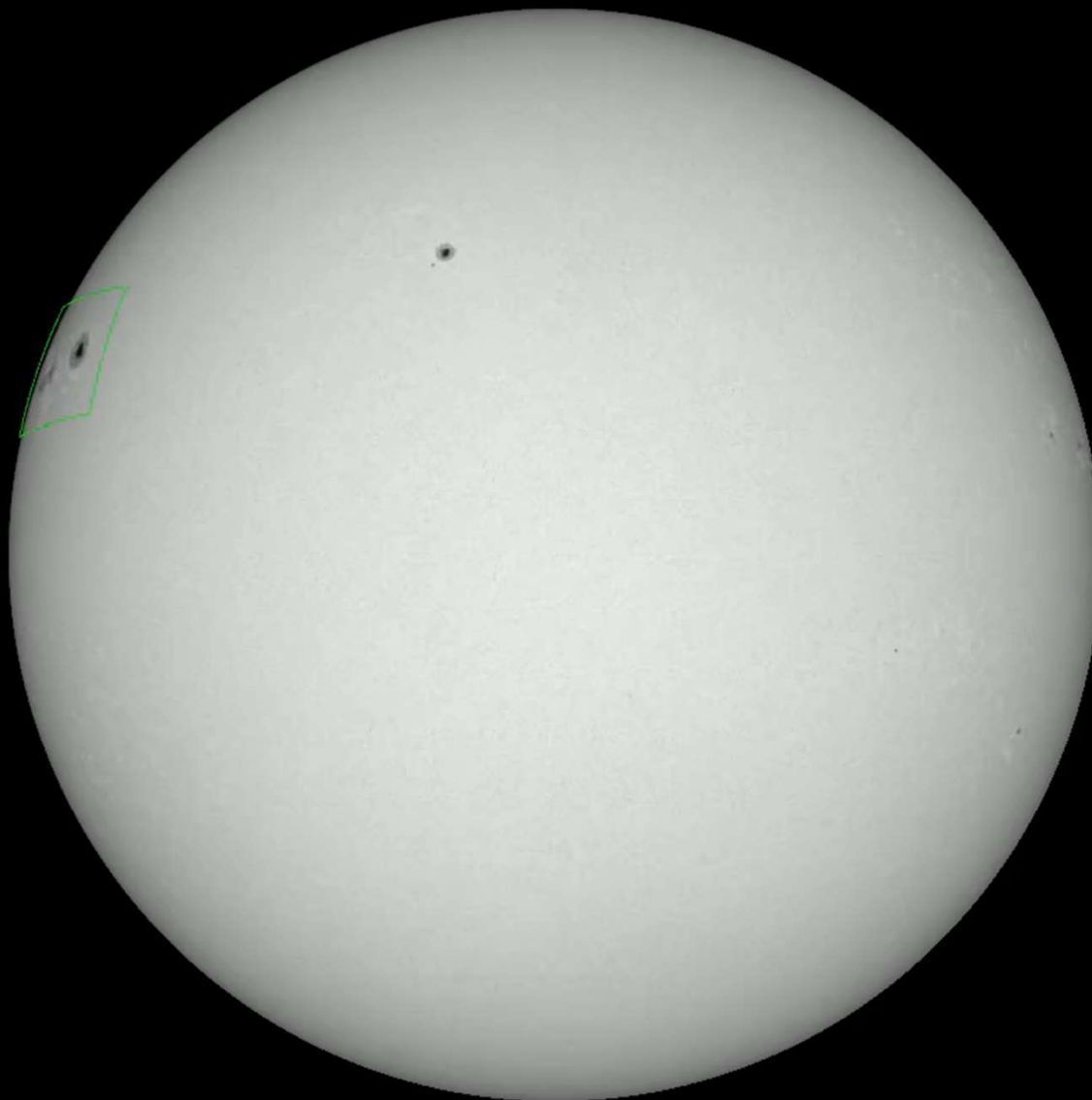
# Solar Cycle and Sunspots



The most sunspots are correlated with solar maximum. This is part of the **11-year Solar Cycle (SC)**. We are now well on pace to reach solar maximum peak of Solar Cycle 25 in **2024** (this year); but **2025** will also be active!



# Sunspot Region 3590 (Feb 19-27<sup>th</sup>)



2024-02-19T14:19:09.700



# Focus areas

(3 main activity types SWPC forecasts)

## Impacts & Phenomena Based Forecasts

**Solar Radiation Storms (S-scale)** : related to Solar Proton Events

Solar Radiation Storm Warnings and Alerts

**HF Radio Blackouts (R-scale)**: as related to Solar Flares

Solar Flare Alerts

**Geomagnetic Storms (G-scale)**: as related to origin source

Coronal Mass Ejection (CME), Coronal Hole (CH)

Geomagnetic Storm Watches, Warnings, and Alerts

S 1	Minor
R 1	
G 1	

S 2	Moderate
R 2	
G 2	

S 3	Strong
R 3	
G 3	

S 4	Severe
R 4	
G 4	

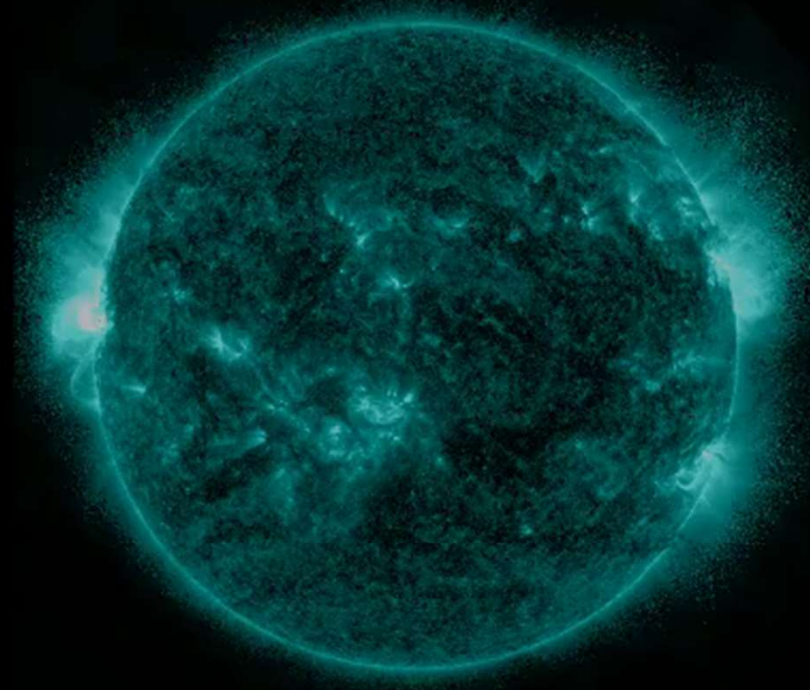
S 5	Extreme
R 5	
G 5	

# Solar Flares

**R3** Dec 31st: X5 flare from the east limb of the Sun - largest flare of SC25 to that point

Location of a flare on the Earth-facing disk does not matter.

The impact on our sunlit side of Earth's ionosphere is immediate.

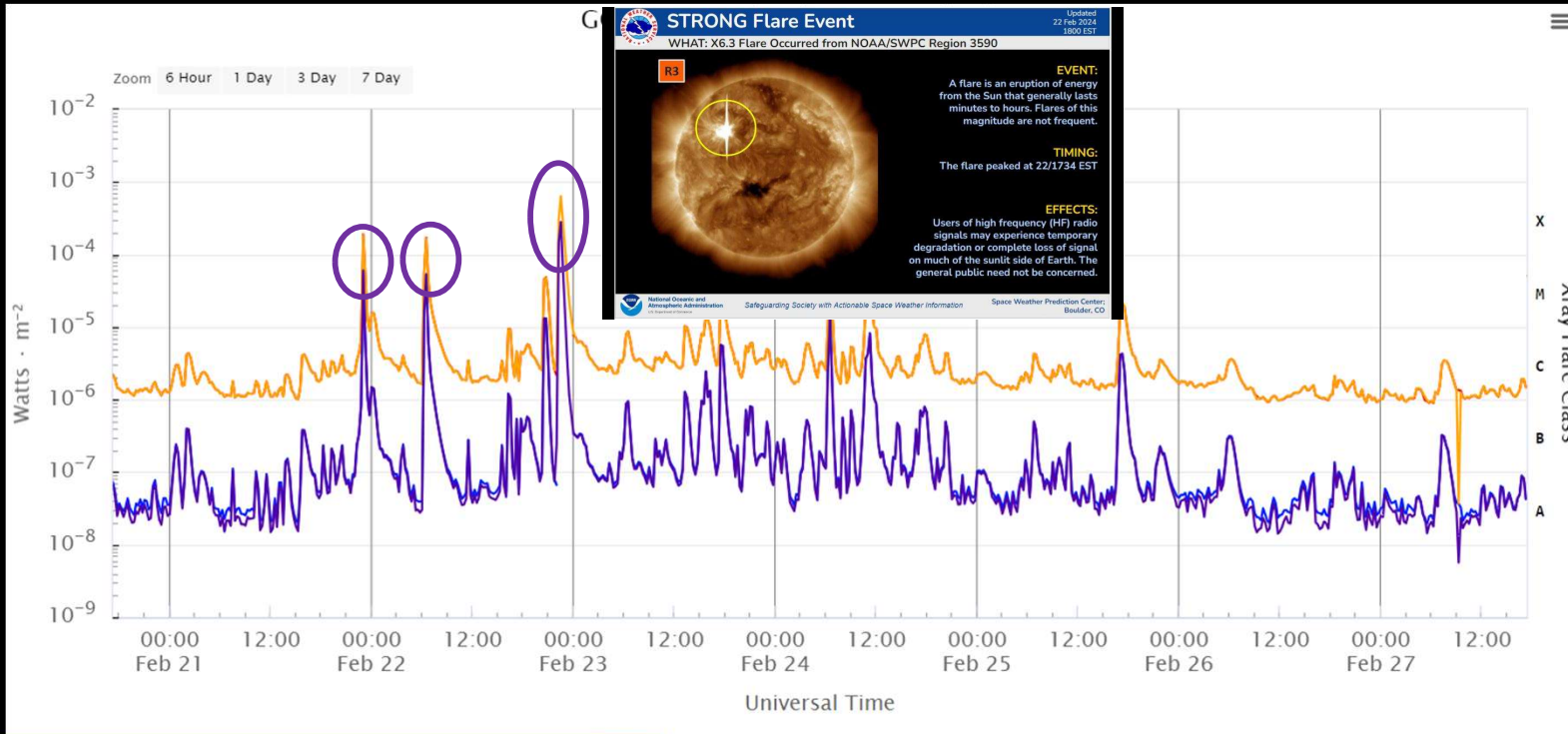


Their X-ray energy strength correlates to the likelihood of certain types of HF radio interference or signal absorption on the **sunlit** side of Earth; and relates to geographic area of impact.

A concern for Ham radio users and other types of HF communications (usually voice modulation and skywave); mainly 3 – 30 Mhz



# Trio of R3 Solar Flares 21-22 February

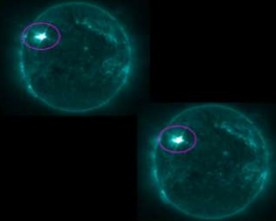


All three flares were quite impulsive (quick to rise and decrease).

So, this would have lessened their impact in duration as well.

**Two Major Solar Flares; Effects on Cellular Networks Unlikely**  
WHAT: R3 Events Occurred late on Feb 21st into early Feb 22nd  
Updated 2024 Feb 22 1429 EST

ES-16 Short — GOES-18 Long — GOES-18 Short  
Space Weather Prediction Center



**EVENT:**  
Two notable flares erupted from the Sun beginning the late afternoon of 21 Feb through the overnight hours into early 22 Feb. Levels reached were R3 (Strong) as seen in these images from GOES-16.

**TIMING:**  
The events peaked at 6:07 p.m. EST on Feb 21st and the second peak was at 1:32 a.m. EST on Feb 22nd.

**EFFECTS:**  
While solar flares can affect communication systems, radar, and the Global Positioning System, based on the intensity of these eruptions and associated phenomena, it is unlikely that these flares contributed to the widely reported cellular network outage.

**All these flares took place when most of North America was not on the direct daylight side of our planet. So, any impacts were felt elsewhere**

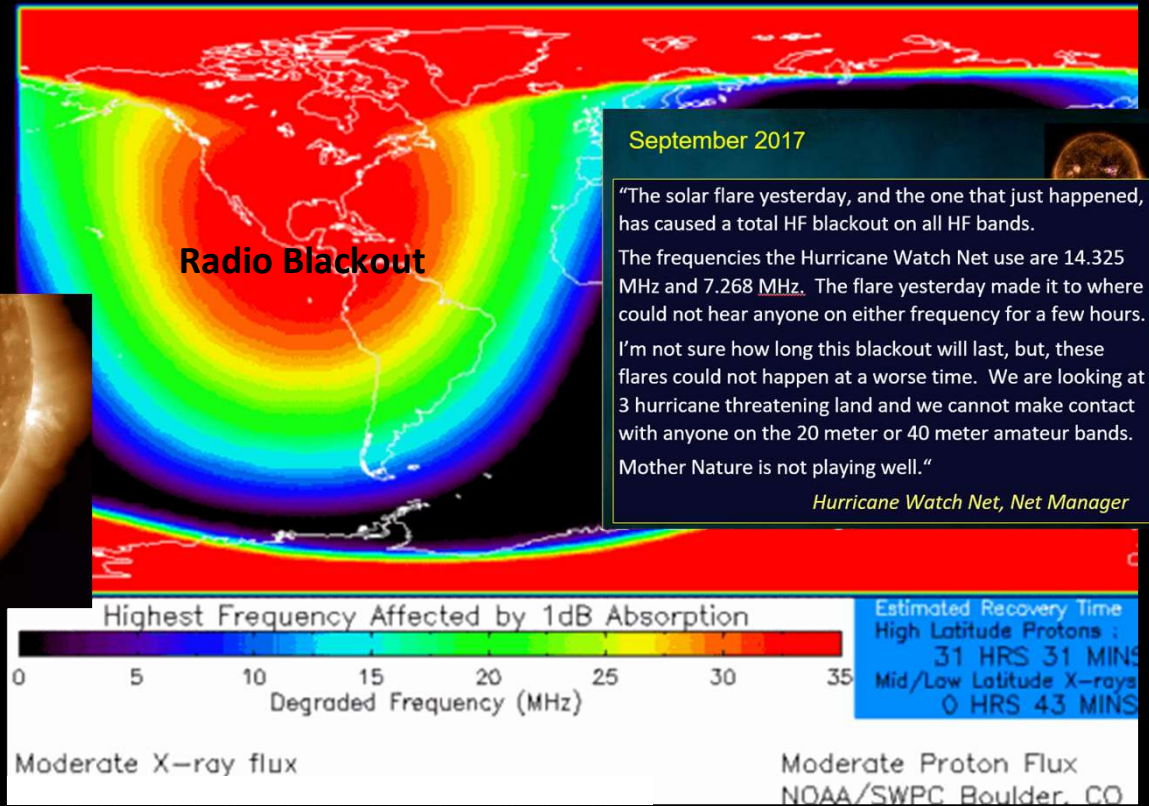
# When Extreme Space Weather and Catastrophic Terrestrial Weather come together September 2017

EOS NEWS NEWS FROM AGU JOURNALS TOPICS & DISCIPLINES OPINIONS BLOGS AGU'S CENTENNIAL

SPACE SCIENCE & SPACE PHYSICS Scientific Press Releases

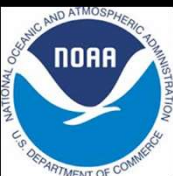
Solar Flares Disrupted Radio During 2017 Hurricane Irma

On 6 September 2017, as Category 5 Hurricane Irma hit the Caribbean's Leeward Islands, and Tropical Storm Jose hovered in the wings, another storm erupted on the Sun.



**This flare and it's effects lasted a few hours**

**HF Radio Comm from the Caribbean Islands (Ham Radio in particular) was nearly impossible during the hurricane disasters & crisis response for several hours. Hurricane Watch Net & Aviation Communication notably impacted.**





# Frequency (Radio) Bursts

We cannot forecast these; but we do monitor for them thanks to the USAF Solar Electro-Optical Network (SEON)

 **Strongest Solar Flare of this Solar Cycle** Updated  
2023 Dec 14  
1900 EST  
 WHAT: Multiple Aviation Communication Impacts Associated with this Event

Amazing Event - likely one of the largest solar radio events ever recorded

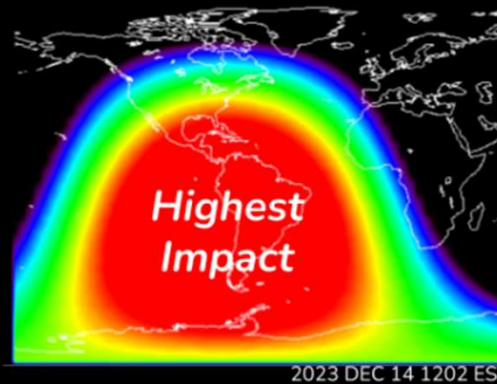
Radio communication impacts between approximately 1200 - 1400 EST Thu

CWSUs report degraded communications across Nation

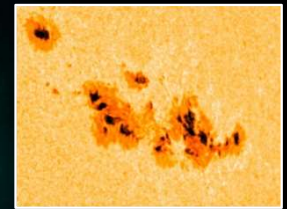
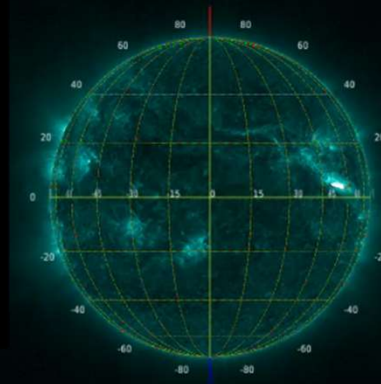
- ZKC, ZMP, ZAU, ZNY, ZOB
- "... Never seen anything like this..." - ZOB

Possible Earth-directed Coronal Mass Ejection (CME) being analyzed

Dec 14th

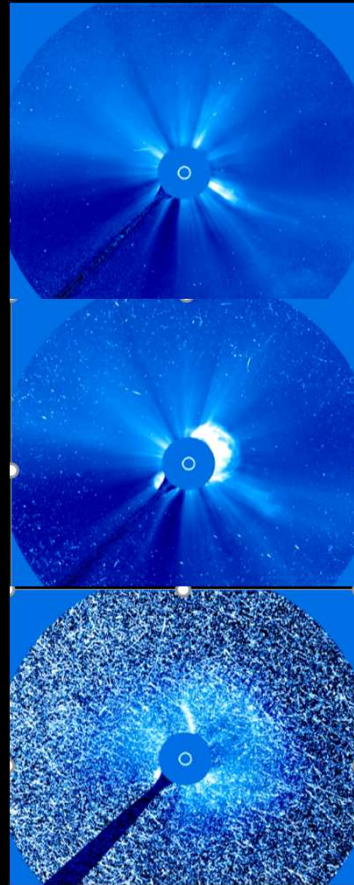
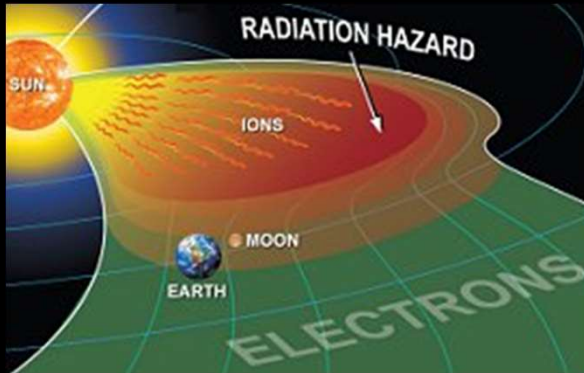


10,000 times normal background!



Can make radio communication difficult or unclear on frequencies other than HF bands. Additional Air Traffic Control (ATC) channels impacted dramatically on higher communication bands over U.S. in VHF-UHF on Dec 14<sup>th</sup> (8 minutes)  
 Could also be issue for urban environment communication repeater systems.  
 Also, concern for military assets and interests.

# Solar Radiation Storms



Feb 9-13th

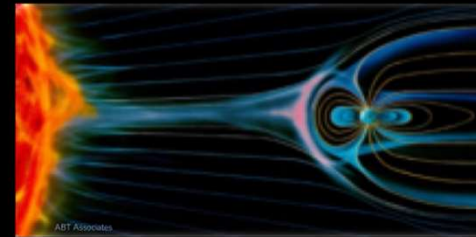


## Solar Radiation Storm Event

S1 S2

Updated  
2024 Feb 09  
1435 EST

WHAT: A Solar Energetic Particle Event is in Progress



### EVENT:

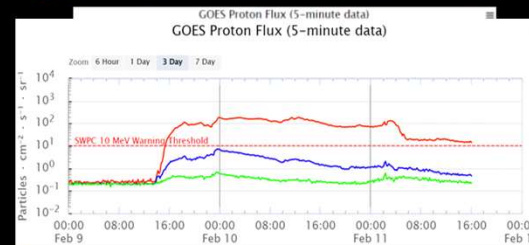
A solar radiation storm occurs when charged particles are accelerated by processes at or near the Sun and arrive in enough quantity at Earth. S2 levels are less common, while S1 storms are not uncommon

### TIMING:

The S1 event first began at 09/1530 EST and is expected to last to at least 10/0100 EST. The event reached an initial peak at S2 levels at 09/1325 EST

### EFFECTS:

Degradation to HF communications in the polar regions; possible risk to space launch and satellites; high flying interests along polar routes should monitor the situation for updates. The general public need not be concerned.



National Oceanic and Atmospheric Administration  
U.S. Department of Commerce

Safeguarding Society with Actionable Space Weather Information

Space Weather Prediction Center;  
Boulder, CO

These storms are measured not only by the amount of solar energetic particles (protons), but also by their energy levels (MeV).

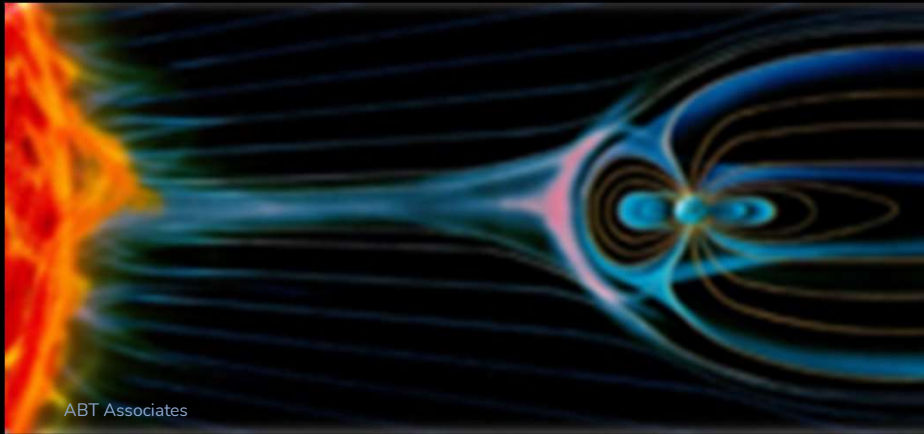
Can adversely affect aviation – increased radiation exposure risk to astronauts and aircrews at high altitudes near polar regions; relates to HF communication outages extending from polar regions; can delay space launch and cause increased risk of anomalies to satellites

We communicate with NASA everyday about the threat and risk of these events.

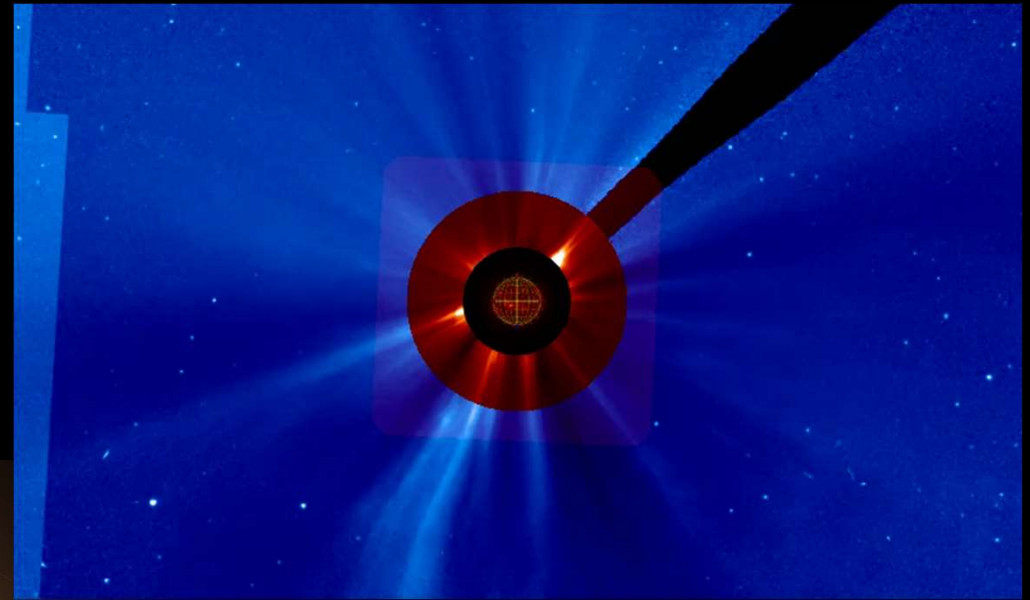


# Solar Radiation Storms

And the underlying cause: Solar Energetic Particles (Primarily Protons)



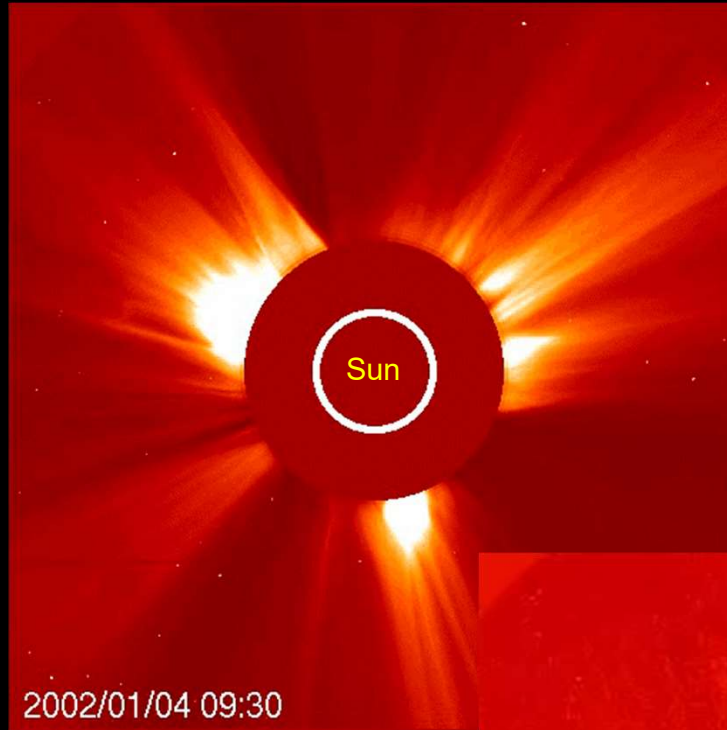
Feb 9th



**Impact potential increases with higher flux and energy levels: 10 MeV (some space operations)  
Different energy levels: 30 MeV (launch); 50 MeV (USAF); 100 MeV (NASA/SRAG)  
\* Higher energy levels (500 MeV) are of particular concern to aviation \***

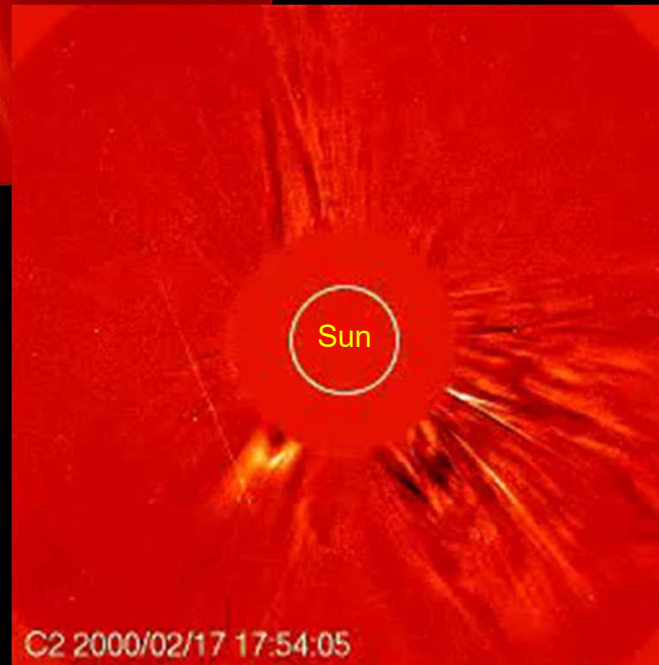
# Coronal Mass Ejections (CME)

Tremendous expulsions of solar material from or through the solar corona, carrying embedded magnetic fields.



Fastest Earth-directed CMEs can get here in 15 hours. Usually, they are slower and take 2 to 4 days.

Their impact to our magnetosphere can cause major changes resulting in **Geomagnetic Storms.**

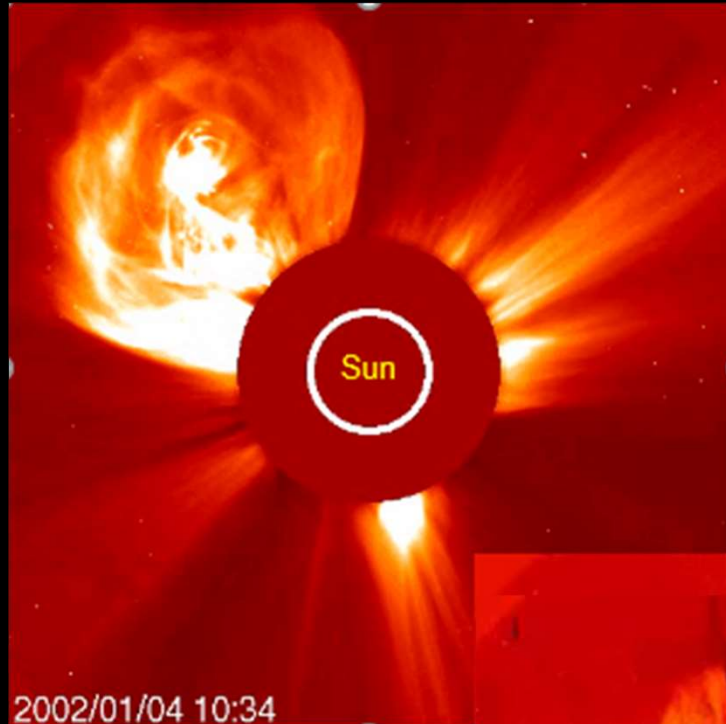


We analyze and parametrize any CME for model submission in order to determine possibility of any Earth directed component.



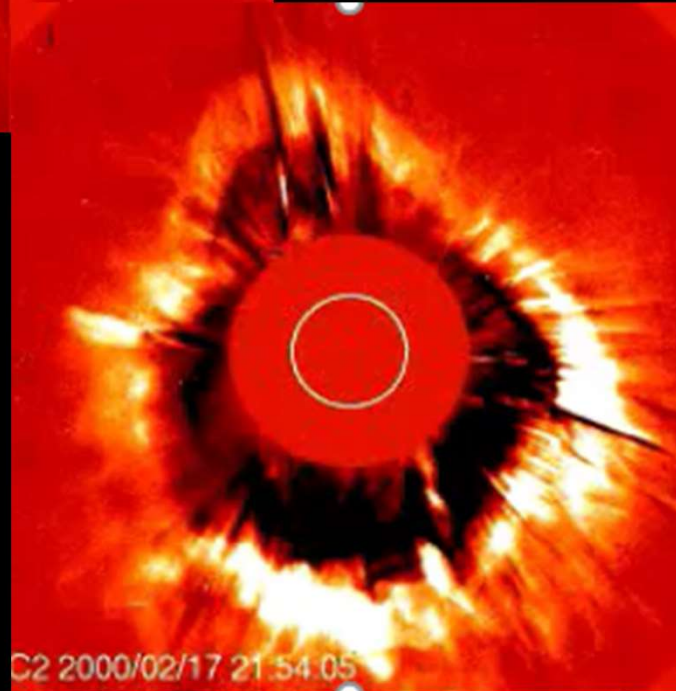
# Coronal Mass Ejections (CME)

CMEs expand quite rapidly as they move outward from the Sun.

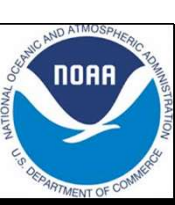


93 million miles is lots of travel time and thus plenty of expansion as the CME transits interstellar space

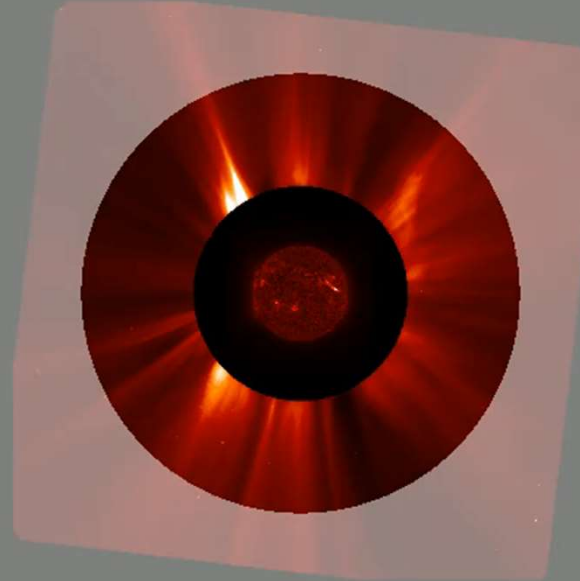
Even those near the solar limb can still reach Earth and result in **Geomagnetic Storms.**



Fastest, historical CMEs could be observed earlier on the same day of potential arrival



# December 14<sup>th</sup> Flare and associated CME





# Geomagnetic Storms

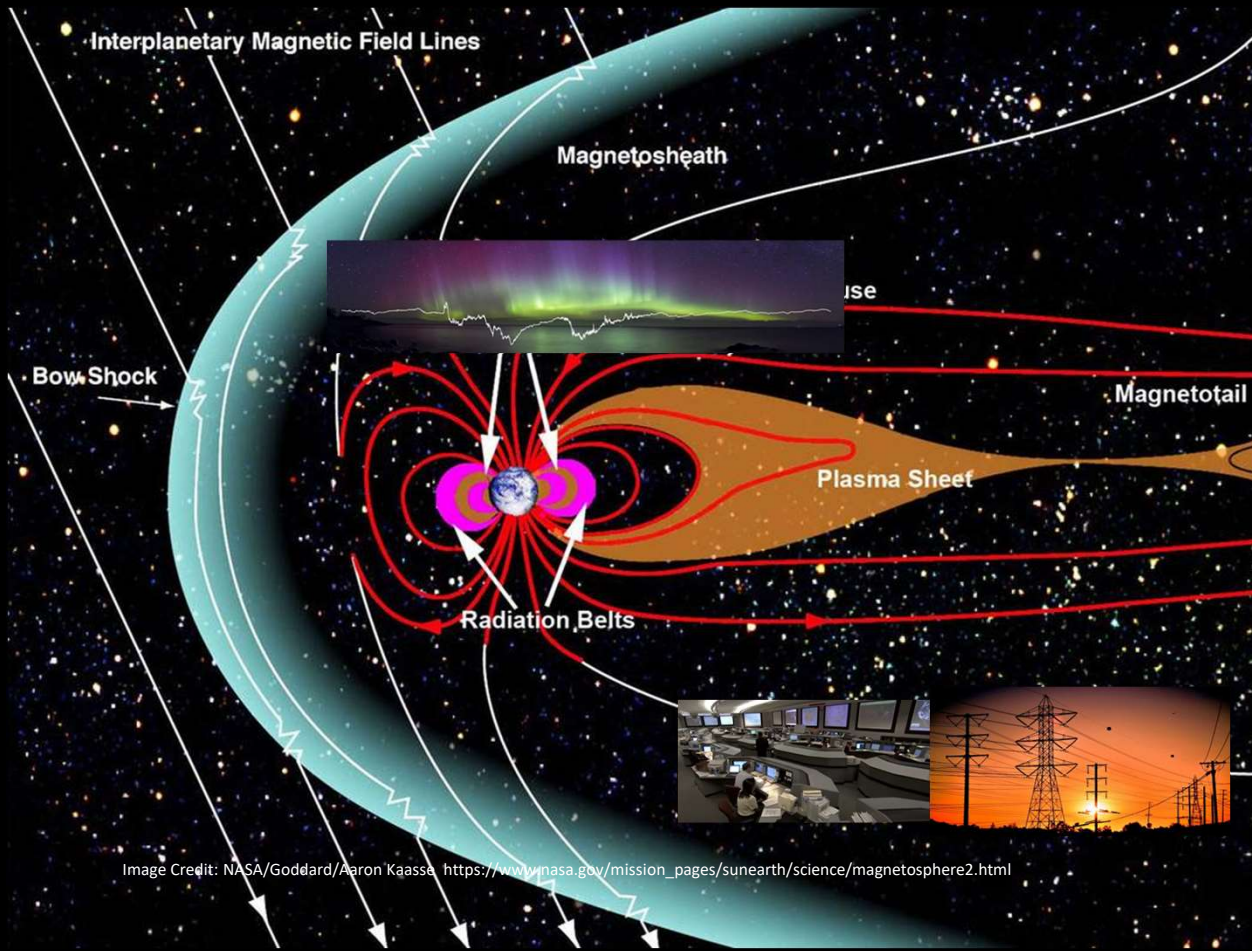
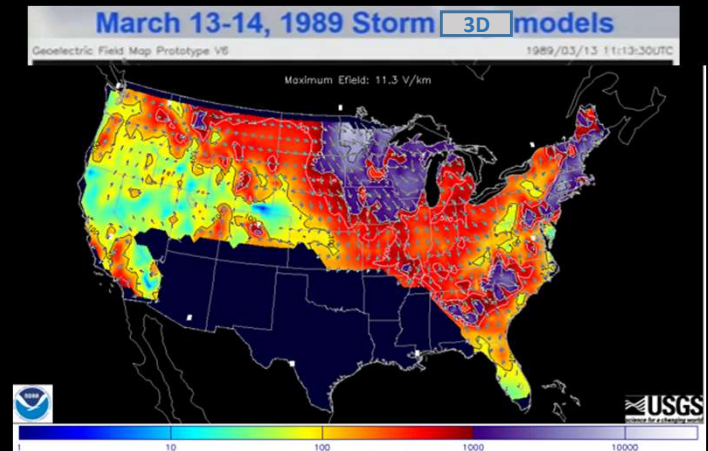


Image Credit: NASA/Goddard/Aaron Kaassa [https://www.nasa.gov/mission\\_pages/sunearth/science/magnetosphere2.html](https://www.nasa.gov/mission_pages/sunearth/science/magnetosphere2.html)

When a CME strikes and envelopes Earth's magnetic field, storms may begin. In particular, if the CME mag field connects with Earth's.



**Can produce problematic induced currents on the power grid systems and can lead to upper atmospheric conditions that can cause variety of communication (SATCOM included) & navigation accuracy problems**



# G1-G4 Events already in 2023

## Geomagnetic Storm WATCH for 27-28 February (UTC days) G3 G2

**WHAT:** Two eruptions from the sun

**EVENT:** Eruptions from the sun on 24 and 25 Feb are expected to cause geomagnetic storms

**TIMING:** Strong storms are expected on the 27th and moderate storms on the 28th.

**EFFECTS:** Aurora visible in some northern tier states with disturbances on HF radio bands. See the NOAA [space wx scales](#) for more information

Image credit: [SIDC Belgium CACTus](#)

National Oceanic and Atmospheric Administration | Safeguarding Society with Actionable Space Weather Information | Space Weather Prediction Center | Boulder, CO

## STRONG Geomagnetic Storm ALERT G3

**WHAT:** Geomagnetic responses increased and G3 levels first reached 27 Feb at 1:00 am EST

**What is a strong geomagnetic storm?**  
A stronger disturbance in Earth's magnetic field

**What you or your agency should do?**  
The general public need not be concerned. Those under or near the 30-minute predicted auroral extent may look for the aurora if at night and should weather conditions permit

**Possible Technology Effects**

- Power Grid: some risk for controllable voltage fluctuations
- Spacecraft Operations: possible surface charging; atmospheric drag increase on Low Earth Orbiting (LEO) satellites
- Other: Intermittent GNSS (i.e. GPS) degradation possible

National Oceanic and Atmospheric Administration | Safeguarding Society with Actionable Space Weather Information | Space Weather Prediction Center | Boulder, CO

**The Washington Post**  
Dazzling aurora lit up Sunday night sky and may shine again Monday

**Feb 27th**  
the best aurora sightings across much of the U.S. in some time

## SEVERE Geomagnetic Storm ALERT – 24 March UTC-Day G4

**WHAT:** Geomagnetic responses increased and G4 levels first reached 24 March at 12:04 am EDT

**What is a severe geomagnetic storm?**  
A severe disturbance in Earth's magnetic field

**What you or your agency should do?**  
Keep updated about storm status and progression. Those under or near the 30-minute predicted auroral extent may look for the aurora if at night and should weather conditions permit

National Oceanic and Atmospheric Administration | Safeguarding Society with Actionable Space Weather Information | Space Weather Prediction Center | Boulder, CO

## STRONG (or higher) Geomagnetic Storm WARNING G3+

**WHAT:** Strong G3 (or higher) conditions may be ending soon

**Why does it matter?**  
The storm is beginning to show signs of weakening. As the storm weakens, some impacts will diminish and the aurora will begin to retreat.

**When will it end?**  
Warning continues until 2:00 AM EDT.

**G4 Conditions occurred at 3:45 PM EDT  
G3 Conditions were recently observed**

**How Far South Can Aurora Be Observed?**  
G is the NOAA Geomagnetic Storm Index (0-5)  
Kp is the Planetary K Index (0-9)

**What you or your agency should do?**  
Expect adverse impacts. Notify the Public. Operators have been notified to take possible impacts. Technology Effects: voltage control problems; Intermittent GNSS (i.e., GPS) degradation possible

National Oceanic and Atmospheric Administration | Safeguarding Society with Actionable Space Weather Information | Space Weather Prediction Center | Boulder, CO

# Continuing Chances of NOAA Space Weather Scale Activity in 2024 and on into 2025



# Geomagnetic Storms:

Forecast probabilities and intensities out 3 days

More Calls & Queries

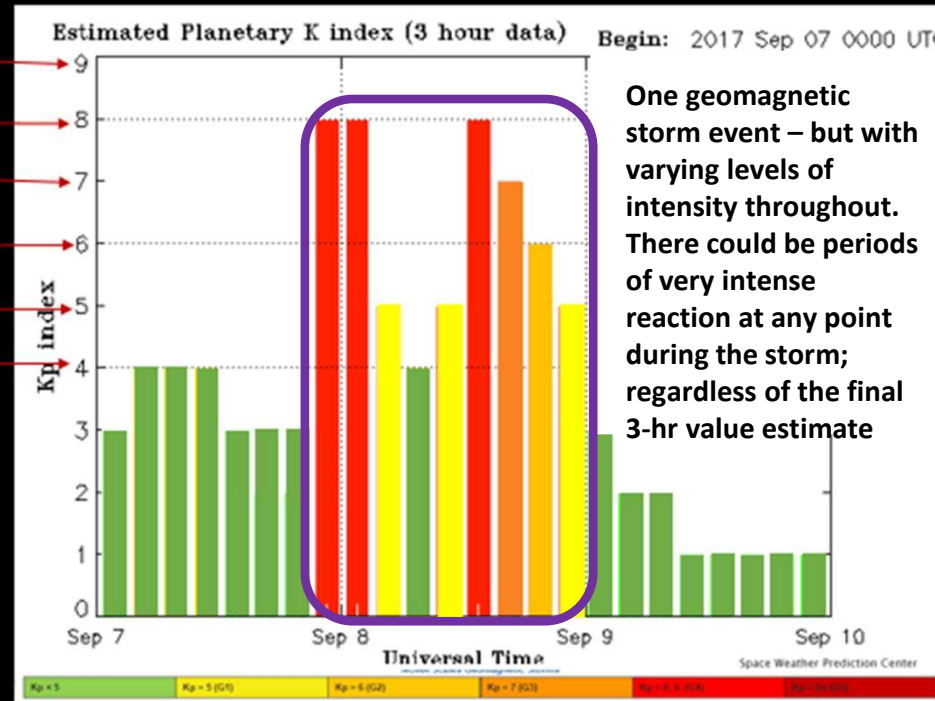
FEMA Call

NERC Hotline Call

ATC Pacific / NASA Call

K5/G1 Warning

1<sup>st</sup> Warning Issued



Warnings issued for Kp 4 up to Kp 7 and greater

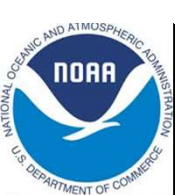
Alerts issued at each Kp level

Estimated in real-time; with a final value attributed at the end of each 3-hour period. This can cause confusion, because we may not reach expected levels every 3 hours. Think of it like a rain gauge being emptied every 3 hours – but the heavy rain event continues, with varying amounts of precipitation rates

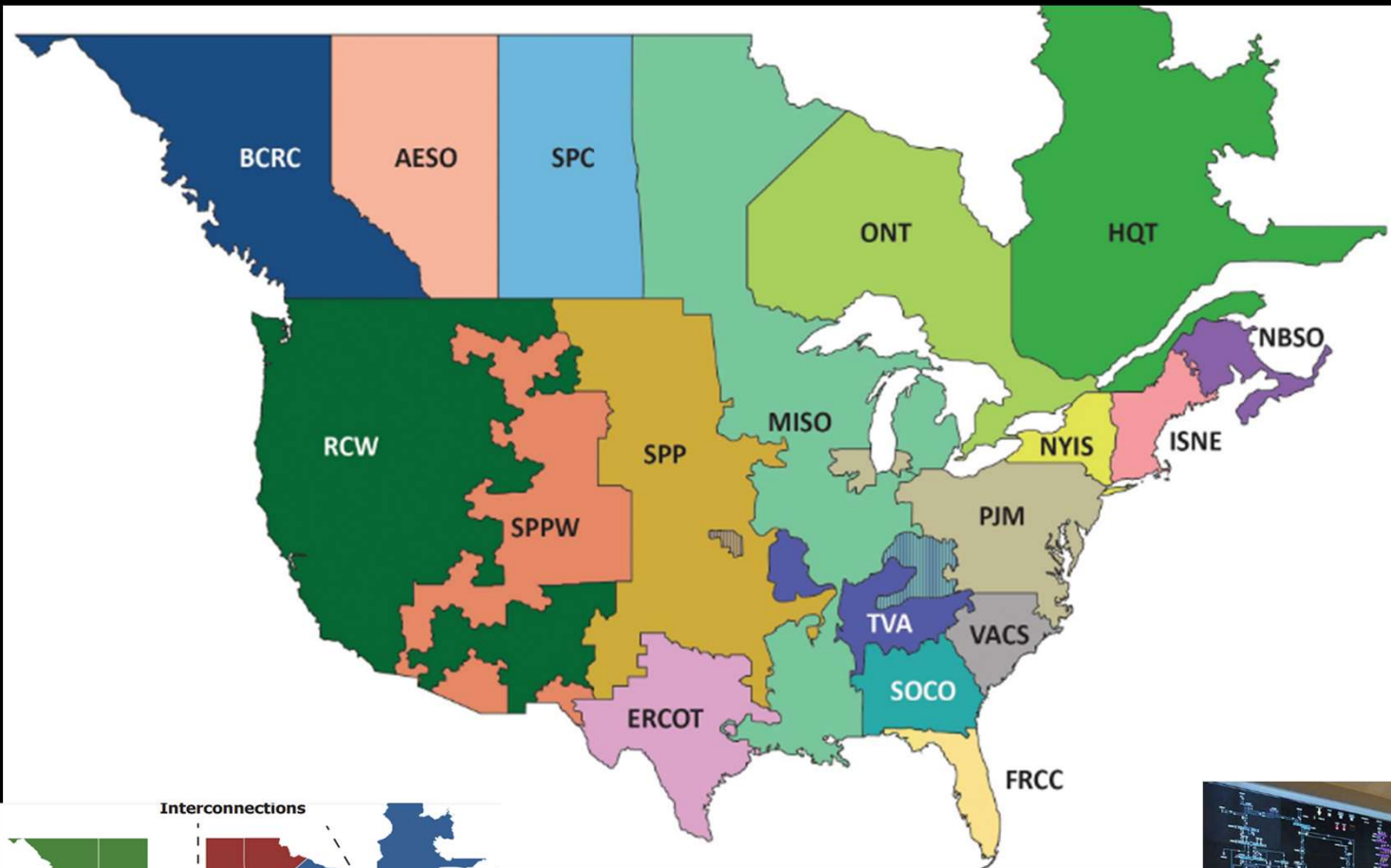
Based on Estimated Planetary K-index (8 magnetometer stations).

Kp5 = G1 Kp6 = G2 Kp7 = G3 Kp8-K9m = G4 Kp9z = G5

\*each Kp level divided into three levels: m (-); z (0); and p (+)

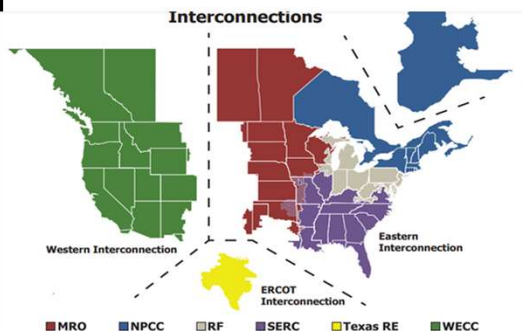


# North American Energy Reliability Corporation (NERC) Reliability Coordinators (RC) throughout the Interconnections



Mitigating Power Outage Potential to our Interconnected Power Grid:  
**NERC Hotline Call**

All RC's are on the NERC hotline call when we initiate the NERC hotline call beginning at G3



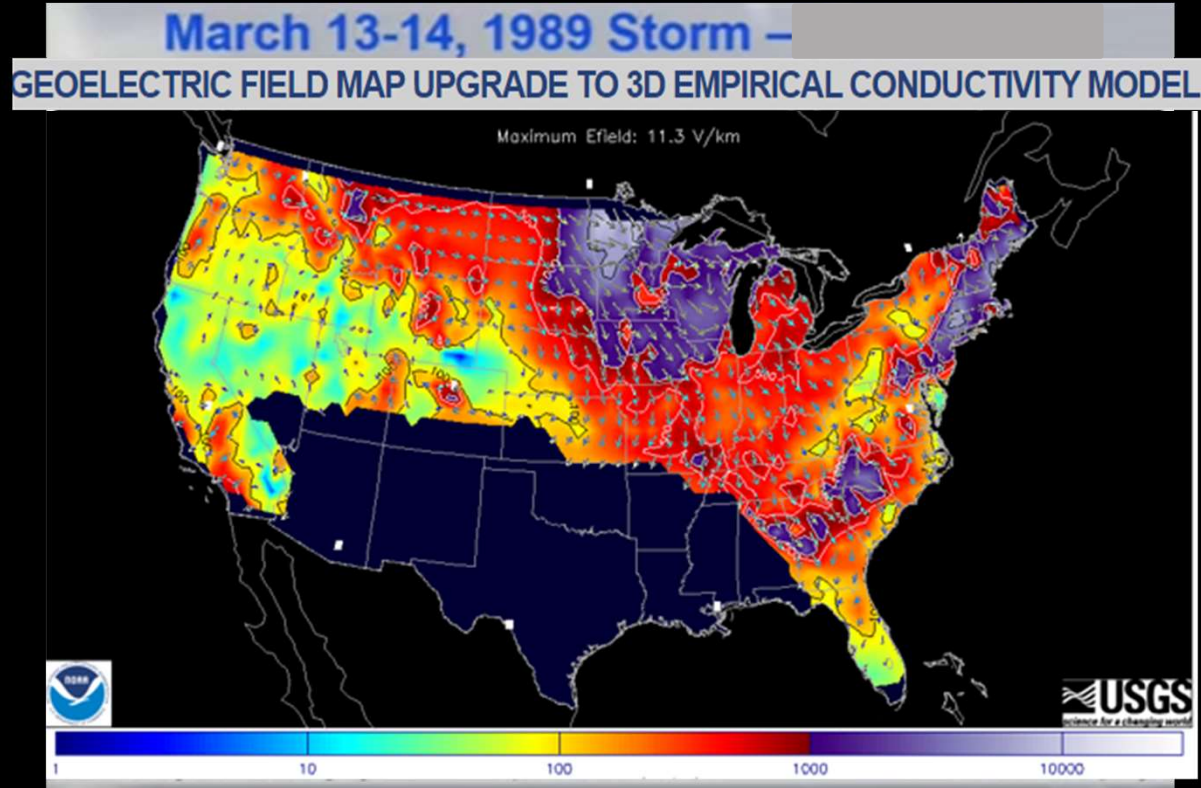
The three (really four) Interconnections are electrically tied together during normal system conditions and operate at a synchronized frequency at an average of 60 Hz



# Geoelectric Field Model

“nowcast” model projection with calculated voltage per kilometer approaching 1V/km are noteworthy; 12V/km may be impactful

Geoelectric fields are the electric potential on the earth’s surface and is directly related to rate of change in magnetic fields. They have amplitude and direction, and act as a voltage source that can cause GICs to flow along conductors – such as transmission lines



A measure of the induction hazard to artificial conductors, such as power lines.

Can be used to estimate induced geomagnetic current (GIC) integration along conducting pathways.



This model is our interpretation of the strength of GICs. Just like NWS radars observe storm echoes, this model gives estimations of the GIC potential on high voltage transmission lines.



# Normal Sequence of Events

## with regards to Watches, Warnings, and Alerts (WWA)

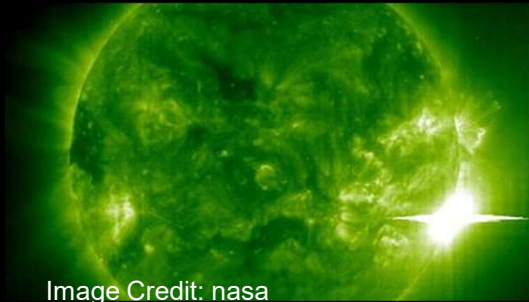
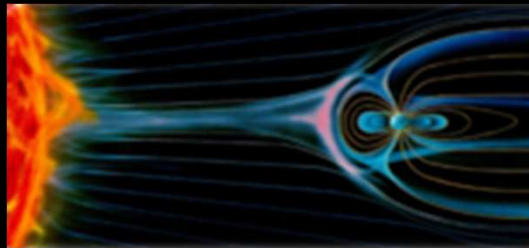


Image Credit: nasa

**R2**

**ALERT**  
Sent at R2 or greater

Probabilities predicted in 3-day forecast; a flare occurs (speed of light), effect already taking place in outer atmosphere



**S1**

**WARNING**  
Sent for S1 or greater  
**ALERT**  
Sent for each S1-S5 level

Probabilities predicted in 3-day forecast;  
Can be nearly speed of light, but warnings possible



**G3**

**WATCHES**  
Sent for G1-G4 or greater  
**WARNING**  
Sent for Kp4-7+ (G1-G3+)  
**ALERT**  
Sent for each level through Kp 9z (G1-G5)

Geomagnetic Storms can be predicted out to 3 days; so watches and warnings possible. Science limits threshold capabilities however

# Space Weather Messaging & Communication

## Communicating Space Weather Information

70k subscribers

Satellite Companies, Airlines, Communications  
State and Local Emergency Managers



Operations and Watch Centers  
*(S,G, 4 and 5)*



557th Weather Wing



NASA Mission Control  
*(multiple criteria)*



Space Weather Prediction Center



Situation Room  
*(R,S,G, 4 and 5)*



FEMA  
*(S,G, 4 and 5)*

NERC

NORTH AMERICAN ELECTRIC  
RELIABILITY CORPORATION  
*(G3-5)*



# Significant Space Weather Event Actions

## Space Weather Event Alert & Notification – Emergency Response



- Directly or indirectly cause or exacerbate a major disaster or emergency.
- Interfere with or seriously degrade FEMA's response & recovery capability.

**S4-S5 Radiation Storms**

**G4-G5 Geomagnetic Storms**

### Notification / Action

FEMA Operations Center (FOC)

Notify Leadership

FOC Alternate West (FAOC)

ENS to MOCs & Watches; Send Plain Language Email

National Watch Center

Notify NOC; Broad Distro Plain Language Email

FAOC- East

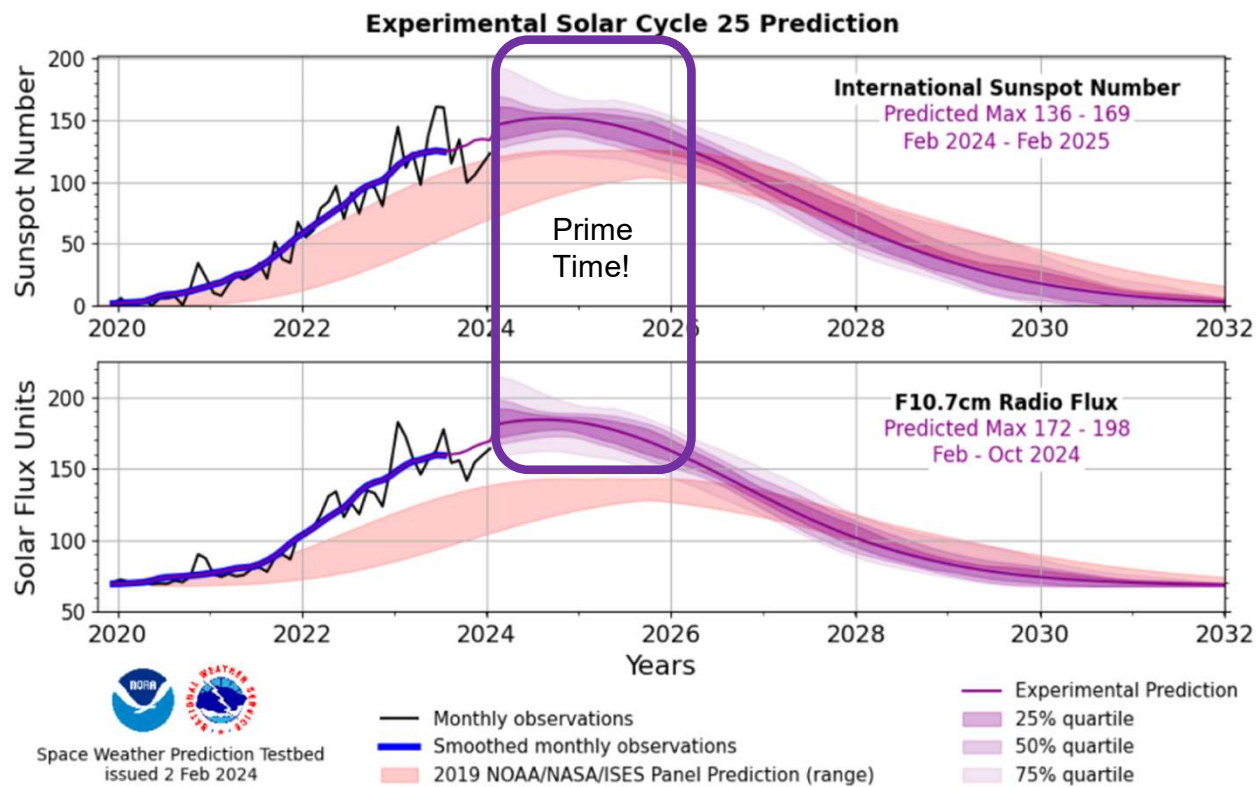
NAWAS / WAWAS (S5, G5 only)

Emergency notification system (ENS)  
 FEMA MERS Operations Center (MOC)  
 National Operations Center (NOC)  
 National Warning System (NAWAS)  
 Washington Metropolitan Area Warning System (WAWAS)



# Current Solar Cycle 25 is ramping up; currently above the original forecast margin of error

## Solar Cycle Progression Updated Prediction (Experimental)





# Notable Space Weather Events



## Carrington Event, 1-2 September 1859:

Most significant event on record. Telegraph system world-wide impacted. Aurora visible in Central America.

## Hydro-Quebec Storm, 14 March 1989:

Power blackout in Montreal and entire province of Quebec. Severely damaged New Jersey transformers. Numerous U.S. grid anomalies.

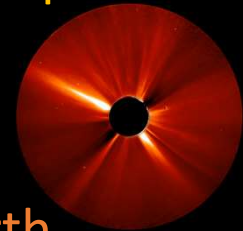


## Operation Anaconda, Afghanistan, 4 March 2002:

Three U.S. soldiers killed - space weather disrupted satellite communications.

## Halloween Storms, October 2003:

Power grid outage in Malmo, Sweden; damage to South Africa grid; Japan loses satellite.



## Near Miss, 23 July 2012:

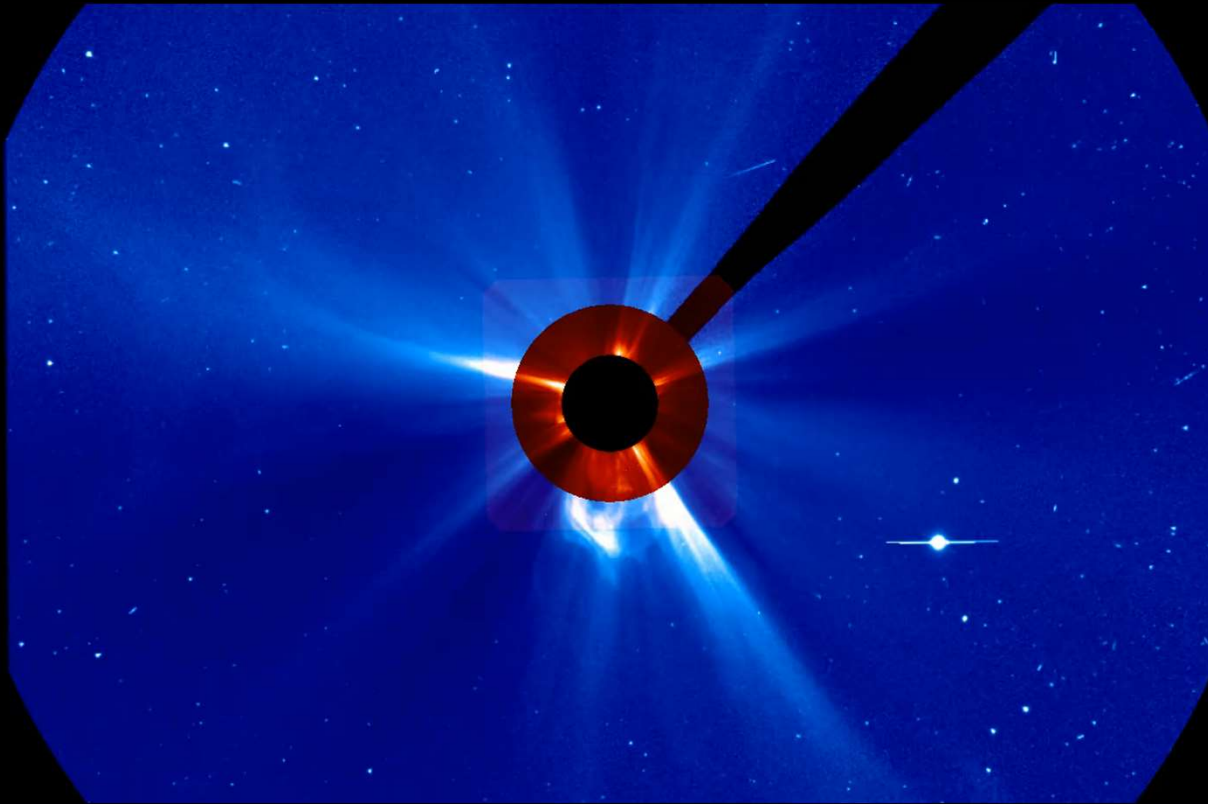
“Century class” event, but the eruption site was 90 deg ahead of Earth.

## SpaceX Starlink Loss, 3 February 2022:

Loss of 38 of 49 satellites due to a minor geomagnetic storm.



# ... and even more recently



**Potentially, a Severe event if aimed at Earth**

Carrington CME event reached Earth in about 18 hours

This could have reached Earth in a little over 24 hours

- What would have happened here at Earth is unknown, **but that is why planning is important**

**Massive CME ripped from the Sun late on 12 March, 2023**

Analysis from NASA Moon to Mars Space Weather Office measured the CME at 2,127 km/s (a rare event)

**CME was fortunately from the far-side of the Sun**

Headed completely away from Earth; but still we were impacted by an S1 Event (Minor Solar Radiation Storm) – quite extraordinary for these energetic particles (protons) to reach Earth from this event



# Emergency Management

Space weather is one of the 26 distinct hazard types identified by Howard County Emergency Management as a possible threat into Hazard Identification & Risk Assessment (HIRA)

OFFICE OF EMERGENCY MANAGEMENT | Howard County, Maryland

## SPACE WEATHER

Space Weather describes the conditions in space that affect Earth and its technological systems. Space Weather is a consequence of the behavior of the Sun, the nature of Earth's magnetic field and atmosphere, and our location in the solar system. The active elements of space weather are particles, electromagnetic energy, and magnetic field, rather than the more commonly known weather contributors of water, temperature, and air.

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### HAS IT HAPPENED LOCALLY?

There have been no notable occurrences of Space Weather significantly impacting Howard County.

### WHAT IS THE ONGOING RISK?

There is an expected **1-30% chance** of a Space Weather hazard in Howard County. In the most likely Space Weather scenario, the **Total Impact is considered Limited**. In the worst-case scenario, the **Total Impact is considered Limited-Significant**.

### DID YOU KNOW?

- A solar storm in 1859, known as the "Carrington Event," was one of the strongest coronal mass ejections in recorded history. Telegraph systems failed across Europe and North America.
- In 1972, a solar storm knocked out long-distance phone communications across the United States.

### FOR MORE INFORMATION:

- Howard County Hazard Identification and Risk Assessment [readyhoco.com/hazards](http://readyhoco.com/hazards)
- National Oceanic and Atmospheric Administration [swpc.noaa.gov](http://swpc.noaa.gov)
- Ready.gov

#### Space Weather Warning Time & Duration

	Likely	Worst-Case
<b>WARNING TIME</b>	Short. Less than six hours.	Short. Less than six hours.
<b>DURATION</b>	Short. Less than six hours.	Short. Less than six hours.

#### RISK MATRIX

#### LOCAL RISK OVERVIEW

LOCAL RISK OVERVIEW	
Future Likelihood	Infrequent-Likely 1-30% chance of annual occurrence
Impact	<b>MOST-LIKELY</b> <b>WORST-CASE</b>
	Limited                  Critical-Catastrophic
Risk Score	1.78                      2.63
Risk Ranking (High to Low)	Ranked #10 of 10 natural hazards.

#### SPACE WEATHER IMPACT

Where no Worst-Case bar is visible, Worst-Case impact is equivalent to Likely impact

More and more requests for information on space weather hazard planning

We work closely with EM officials as we can at city, county, state, national, and even international levels. The requests for support continue to grow

# How to STAY Informed

**SPACE WEATHER PREDICTION CENTER**  
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Wednesday, January 19, 2022 19:35:19 UTC

HOME ABOUT SPACE WEATHER PRODUCTS AND DATA DASHBOARDS MEDIA AND RESOURCES SUBSCRIBE ANNUAL MEETING

FEEDBACK

Search

**SPACE WEATHER CONDITIONS** on NOAA Scales

24-Hour Observed Maximums: **R** (none), **S** (none), **G2** (moderate)

Latest Observed: **R** (none), **S** (none), **G** (none)

Predicted 2022-01-19 UTC: R1-R2 20% S1 or greater 1%, R3-R5 5% **G** (none)

Solar Wind Speed: **584** km/sec      Solar Wind Magnetic Fields: Bt **4** nT, Bz **-1** nT      Noon 10.7cm Radio Flux: **115** sfu

:Product: 3-Day Forecast  
:Issued: 2024 Feb 11 1230 UTC  
# Prepared by the U.S. Dept. of Commerce, NOAA, Space Weather Prediction Center  
#  
A. NOAA Geomagnetic Activity Observation and Forecast

The greatest observed 3 hr Kp over the past 24 hours was 4 (below NOAA Scale Levels).  
The greatest expected 3 hr Kp for Feb 11-Feb 13 2024 is 5.67 (NOAA Scale G2).

NOAA Kp index breakdown Feb 11-Feb 13 2024

	Feb 11	Feb 12	Feb 13
00-03UT	4.33	1.67	4.67 (G1)
03-06UT	3.33	1.33	4.67 (G1)
06-09UT	3.67	1.33	4.67 (G1)
09-12UT	3.00	3.67	5.67 (G2)
12-15UT	3.33	3.00	4.67 (G1)
15-18UT	3.67	3.00	4.33
18-21UT	3.67	4.00	4.00
21-00UT	4.67 (G1)	5.00 (G1)	3.67

Rationale: Periods of G1 (Minor) geomagnetic storms are likely on 11-13 with G2 (Moderate) likely on 13 Feb due to the anticipated arrival of multiple CMEs.

**NOAA Space Weather** @NWSSWPC · Nov 2

G1 Watches posted for 3-4 Nov. Several CMEs occurred 1-2 Nov, to include a full halo CME related to an M1 flare (R1 - Minor Radio Blackout) from RGN 2891 at 02/0301 UTC. Analysis & model results suggest Earth-directed components possible. [swpc.noaa.gov](https://swpc.noaa.gov) for more info

**G1 MINOR Geomagnetic Storm WATCH:**  
03-04 Nov, 2021 UTC-days

Analysis suggests likely Earth-directed component from several CMEs. Visit <https://swpc.noaa.gov> for continuing updates and forecasts.

**What is a Coronal Mass Ejection (CME)?**  
published: Thursday, December 09, 2021 17:13 UTC  
Coronal Mass Ejections (CMEs) are large expulsions of plasma and magnetic field from the Sun's corona.

**Space Weather Education**  
published: Thursday, December 09, 2021 17:13 UTC  
Just like we experience weather in space!

**GOES-17 goes live!**  
published: Friday, September 24, 2021 17:13 UTC  
GOES-17 operational data operations on August 24.

**The WAM-IPE space weather operational!**

**3 May R3 Strong**

**X1 (R3) STRONG Solar Flare**  
3 May at 1325 UTC

**3 May R3 Strong**

**PRIMARY AREA of IMPACTS**  
Large portions of sunlit side of Earth

**POSSIBLE EFFECTS:**  
HF Radio: Areas of blackouts; loss of contact for up to an hour over sunlit side of Earth.  
Navigation: Low frequency communication degraded for about an hour.

Highest Frequency Affected by Ionospheric Absorption

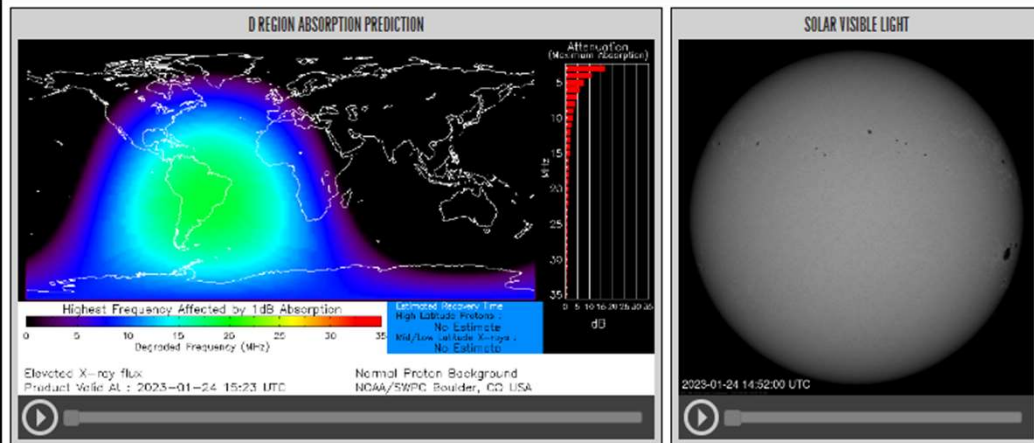
Global (100 ABS) Attenuation (Maximum Attenuation) dB

Moderate X-ray flux  
Product Valid At: 2022-05-03 13:25 UTC  
Normal Proton Background NOAA/SWPC Boulder, CO USA

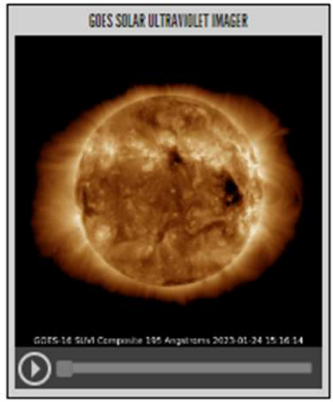
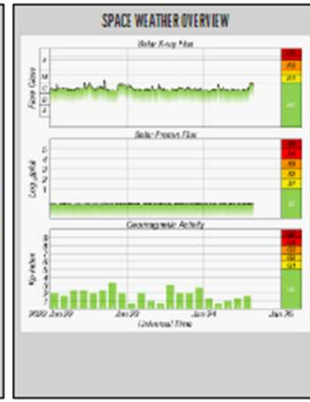
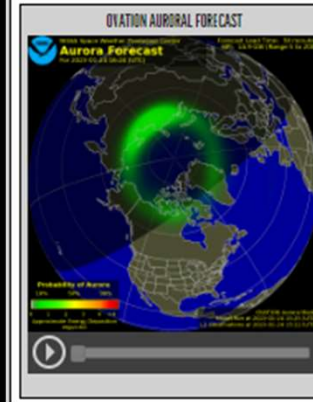
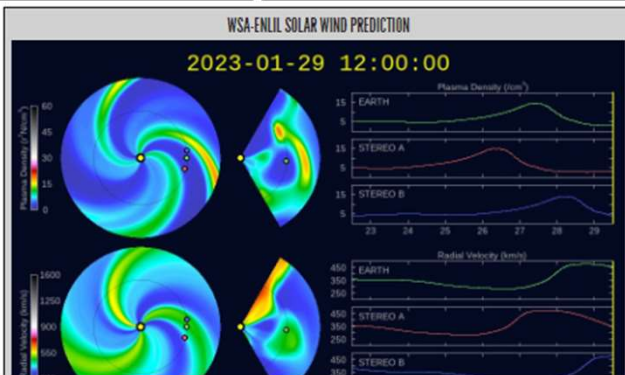
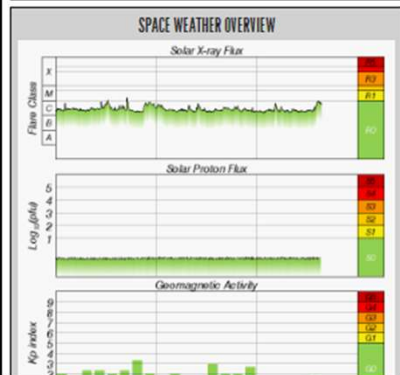
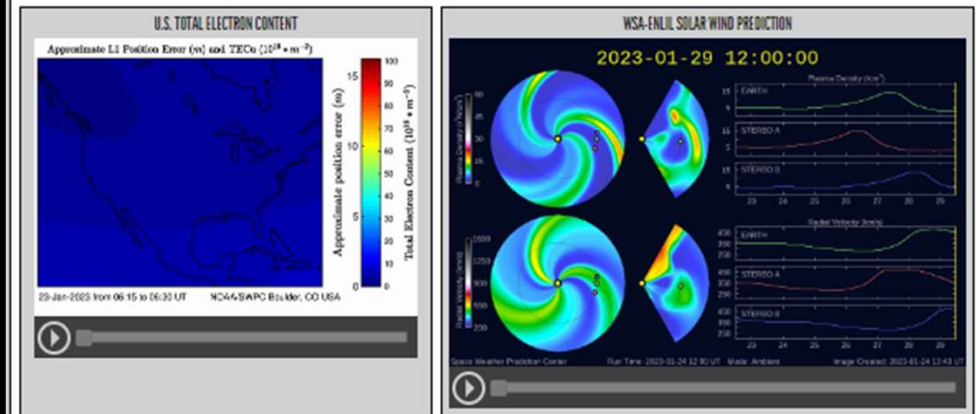
Webpage: [swpc.noaa.gov](https://swpc.noaa.gov)

# SWPC Dashboards for the EM Community

## EMERGENCY MANAGEMENT

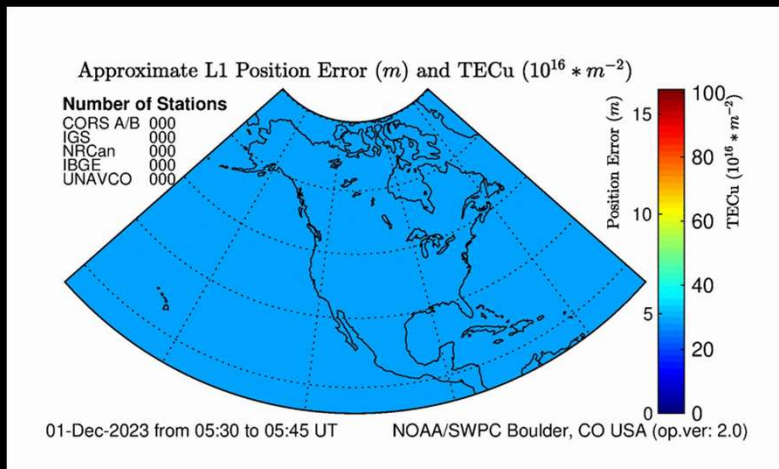
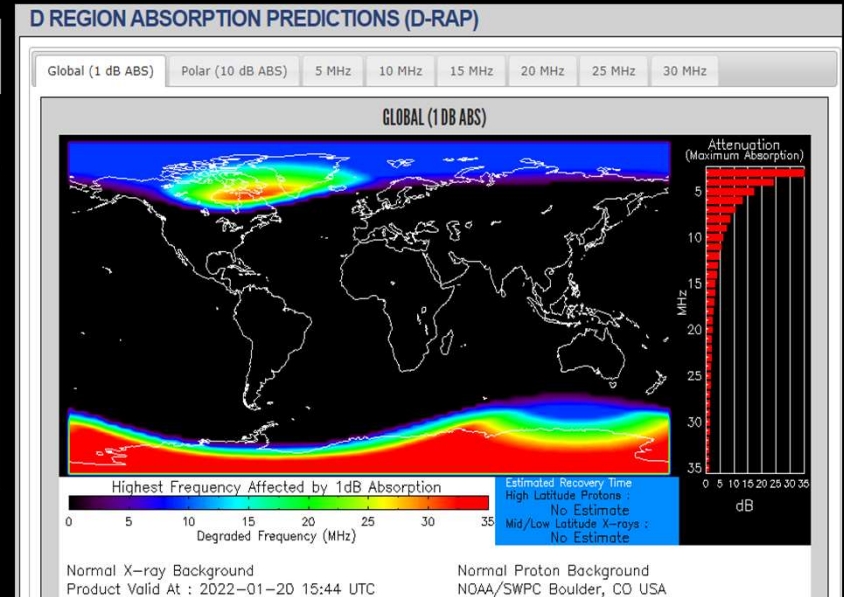
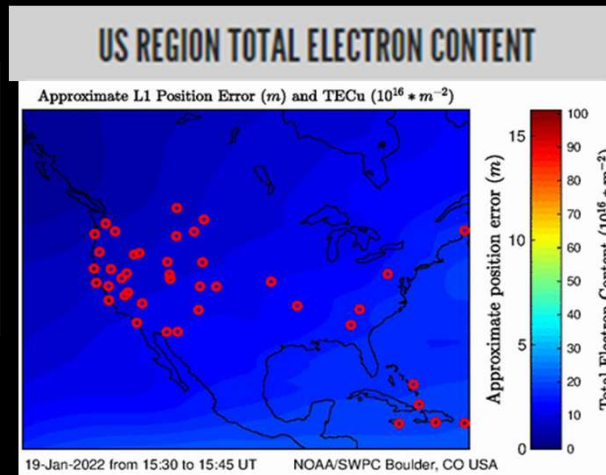
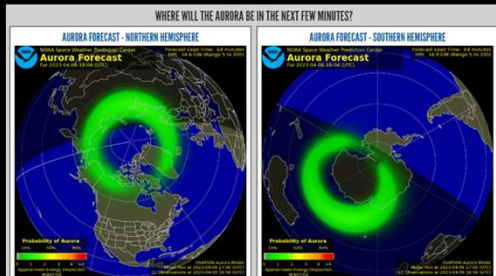


## GLOBAL POSITIONING SYSTEM (GPS) COMMUNITY DASHBOARD





# Some Models of Note for EM

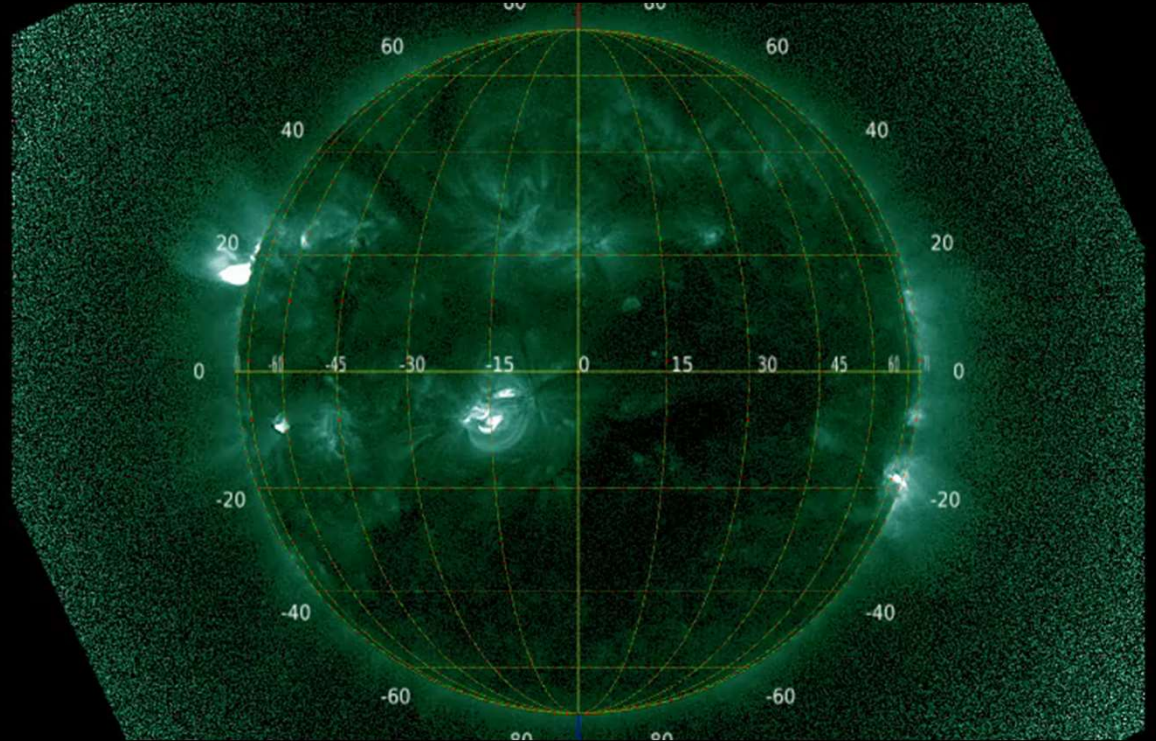
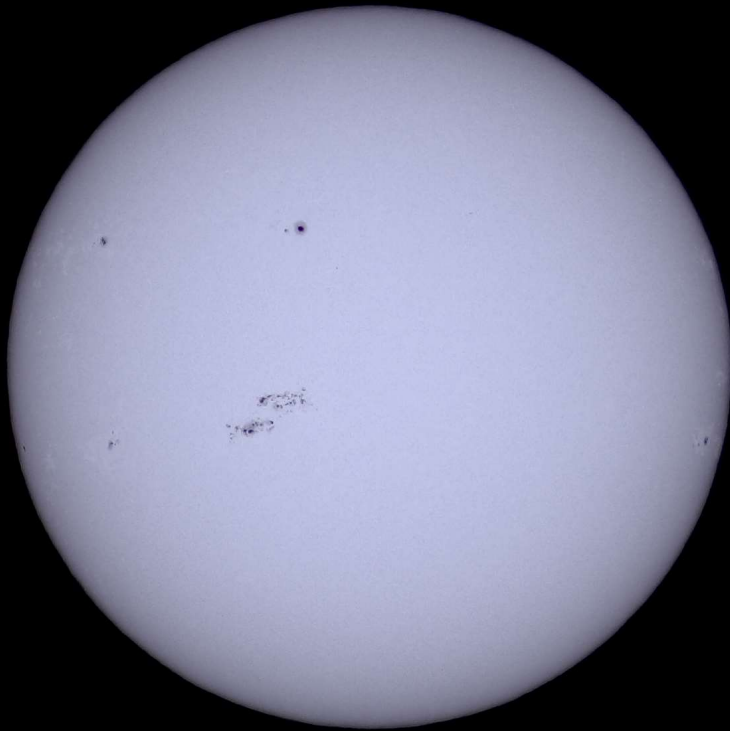


GNSS accuracy mainly single frequency methods - **TEC**  
i.e. cell phone navigation, emergency locaters

HF Comm blackouts/degradations - **D-RAP**  
i.e. land/marine mobile systems; HAM radio

GIC induced current on power grid – **Goelectric Model**

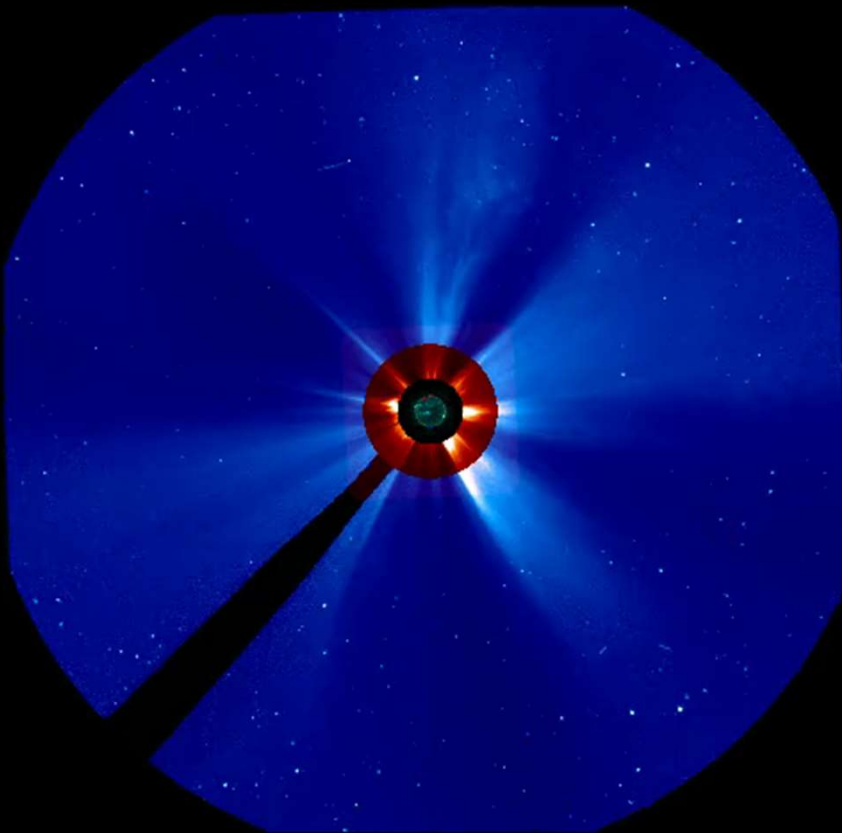
# 22 March 2024 – Sunspots/Flares



**Massive and magnetically complex active region sunspot group to the south and a much smaller and moderately complex active region sunspot group to the north. The northern spot group erupted with an X1 (R3) long duration flare (few hours). The southern group also flared shortly afterwards. SWPC forecasters made calls to NASA and Oakland ATC when flare activity reached M5 (R2).**



# 22-23 March 2024 – CME/Radiation Storm



## MODERATE Solar Radiation Storm Event S2

WHAT: A Solar Energetic Particle Event is in Progress

### EVENT:

The greater than 10 MeV proton flux became enhanced following an X1.1 flare at 23/0133 UTC. Solar radiation storms at S1-S2 (Minor-Moderate) levels have been observed.

### TIMING:

S1 (Minor) levels were observed beginning at 23/0815 UTC, and S2 (Moderate) levels began at 23/1405 UTC.

### EFFECTS:

Degradation to HF communications in the polar regions; possible risk to space launch and satellites; high flying interests along polar routes should monitor the situation for updates. The general public need not be concerned.



Several hours later, energetic particles (protons) arrive at GOES-16/18. SWPC forecasters call NASA/SRAG among others. About 6 hours later, imagery from the NASA coronagraph at L1 (1 million miles from Earth) captures the associated CME departing the Sun. It is a full halo and SWPC forecasters begin analyzing and modelling the CME for anticipated Earth arrival timing and intensity. Speed over 1000 km/s (fast)



# 24 Mar - Geomagnetic Storms

**Geomagnetic Storm Levels Continue** G1 G2 G3 G4 Updated 2024 Mar 24 4:15pm EDT

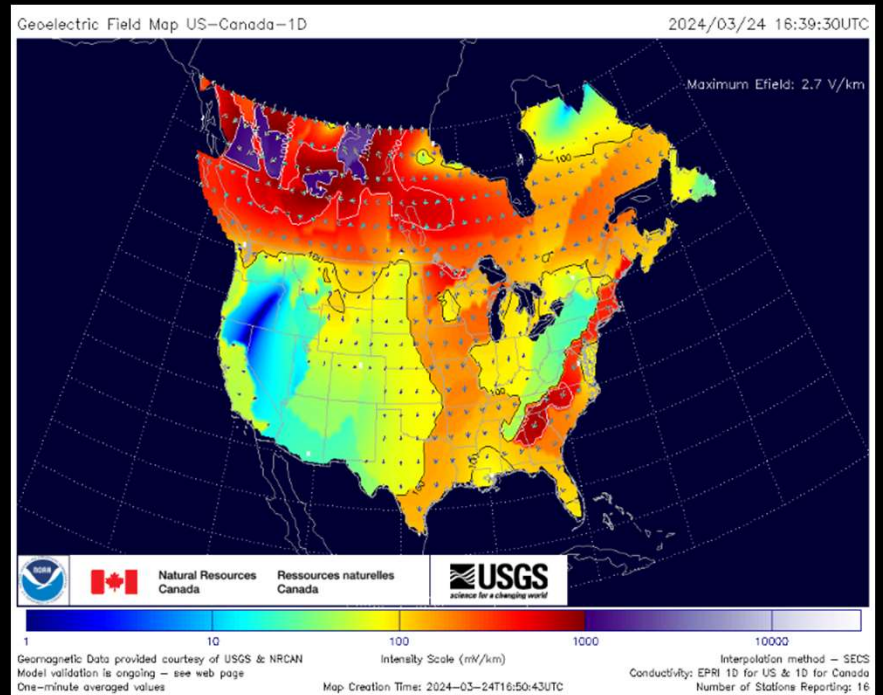
**WHAT:** CME progression continues and the effects are anticipated to linger into 25 March



**EVENT:**  
A coronal mass ejection (CME) that departed the Sun Friday evening, 22 March, reached Earth this morning and continues its progression and geomagnetic storm levels to at least G3 are expected through Sunday evening, 24 March.

**TIMING:**  
Changes in the strength of the geomagnetic storm levels will occur due to variations in solar wind as the CME continues to pass over Earth.

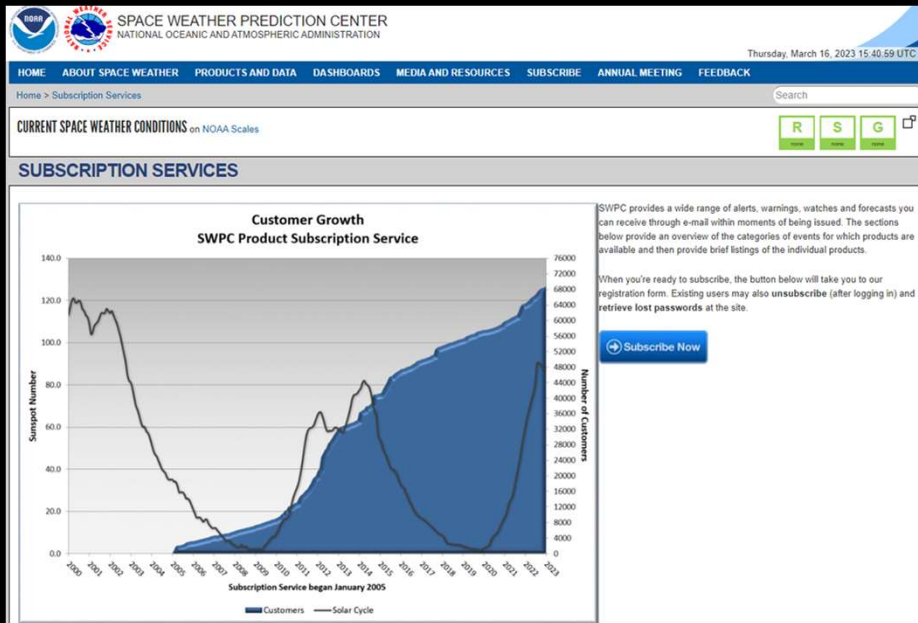
**EFFECTS:**  
G1 through G4 levels have been reached so far with this CME related activity and should G4 levels be reached tonight, the aurora may become visible over much of the northern half of the country, and maybe as far south as Alabama to northern California.



**CME shock arrives at L1 as observed by DSCOVR/ACE spacecraft. SWPC forecasters issue Sudden Impulse warning for benefit of the power grid. Decent SI observed less than 30 minutes later. Geomagnetic responses rapidly escalate and SWPC forecasters begin calling specific transmission operation centers, Oakland ATC, NASA/SRAG, NWS SOC. At G3 (NERC Hotline Call), at G4 – FEMA WOC and Denver MOC contacted.**



# How to GET Informed



**iNWS - Interactive NWS**  
National Weather Service Mobile Decision Support Services (MDSS)

**iNWS MOBILE ALERTING**  
Receive customized text message and e-mail alerts for National Weather Service products that you care about.

**Welcome**  
InteractiveNWS (iNWS) is the home of new mobile and desktop innovations of the National Weather Service. This application suite allows NWS partners to receive National Weather Service products in new and innovative ways, such as text messaging and mobile-enabled webpages. iNWS strives to fulfill our mission of protecting life and property by using technology to reach out to our customers.

**Recent News**

**Note:** If you are receiving alerts, but never signed up for them, they may be coming from a new FEMA public system called the Wireless Emergency Alerts (WEA). More information can be found at [Wireless Emergency Alerts Consumer Guide](#)

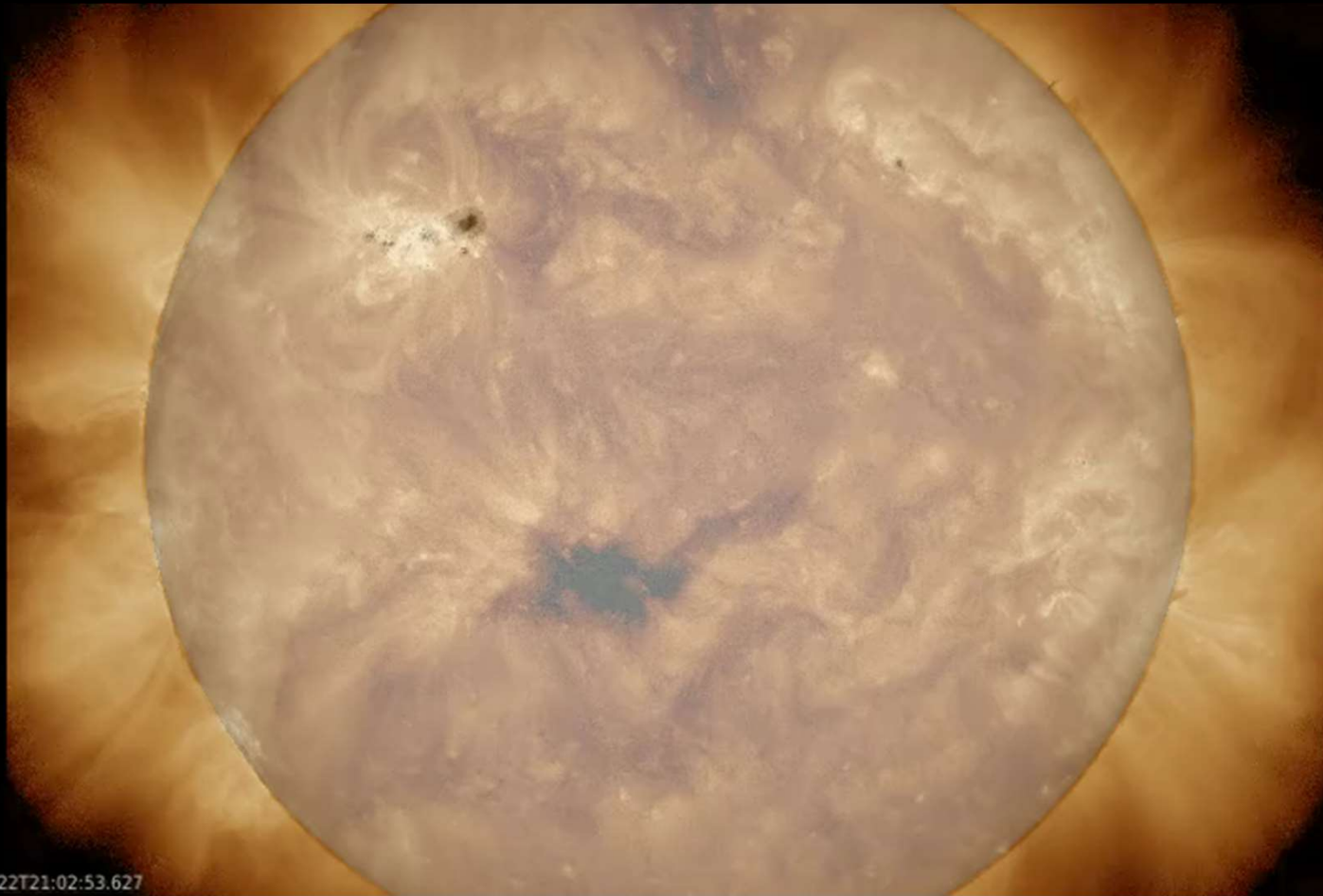
iNWS is an experimental service intended for NWS core partners: emergency managers, community leaders, other government agencies and the electronic media.

DOC | NOAA | National Weather Service - iNWS Version 6.7.7  
Privacy Policy | Terms of Use | FOIA | Information Quality | Disclaimer | Glossary | Texting While Driving

- SWPC PSS for direct emails of many various products and WWA
- \*NWS INWS for direct text messages and/or emails of primary WA
- \*experimental service intended only for NWS core partners, EMs, and other government agencies

# Feb 22<sup>nd</sup> – X6 flare (R3): Largest of Solar Cycle 25 thus far

Large and complex sunspot group Region 3590 over northeast area of the Sun (top left) erupted with an X6 flare on 22 Feb.



2024-02-22T21:02:53.627

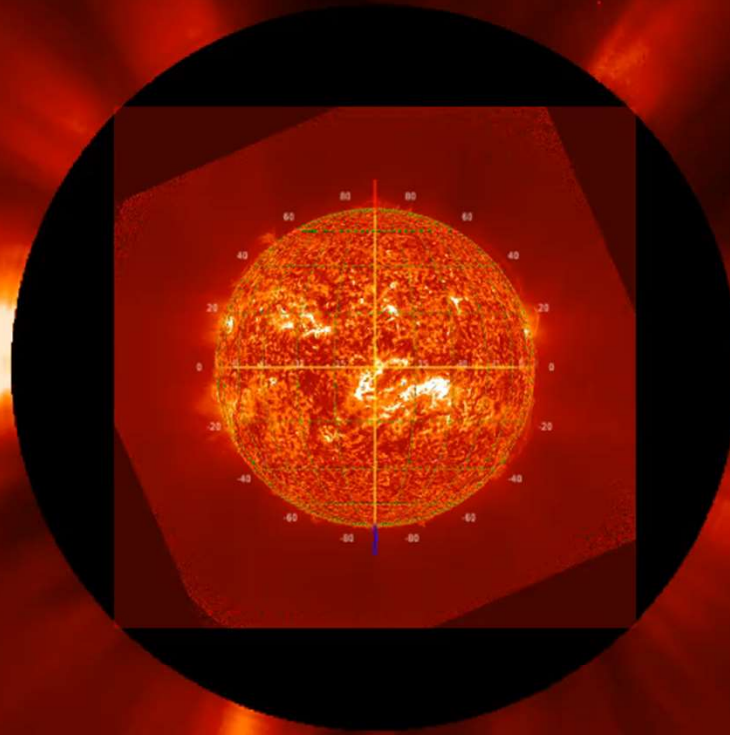
This animation blends imagery we use from the NASA SDO satellite to look at sunspots and also the lower corona. So you can see the flare erupt in relation to a very tight and magnetically complex area of Region 3590.

All animations courtesy of jehlioviewer

**Quite surprisingly, this flare and the other R3 events over two days did not have any associated CME**



# Solar Maximum is Coming Plenty more CMEs to Come



**We are overdue for a Carrington level geomagnetic storm. Today's impact upon the technologies we rely in such a storm could be catastrophic. Space Weather Situational Awareness is essential in today's world. Emergency Preparedness and Readiness is necessary for such and extremely impactful event. You are all KEY in our shared protection of lives & property mission!**

# Thank You. And Thank You again for all you do!

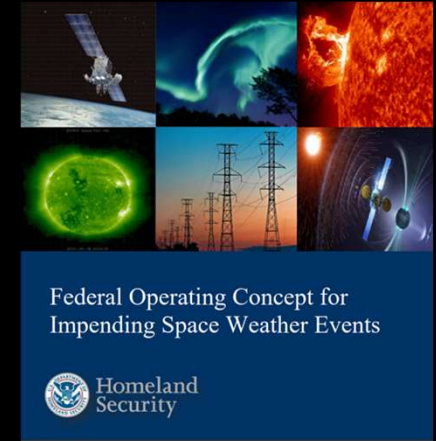
POC for your space weather questions or needs

Shawn Dahl – SWPC Service Coordinator  
[shawn.dahl@noaa.gov](mailto:shawn.dahl@noaa.gov)

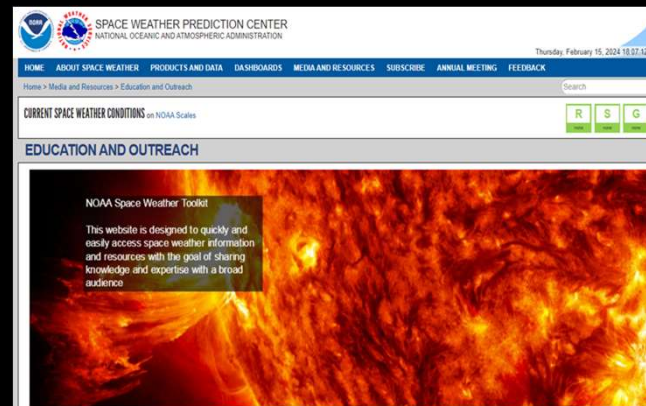
Additional Training and Resources:



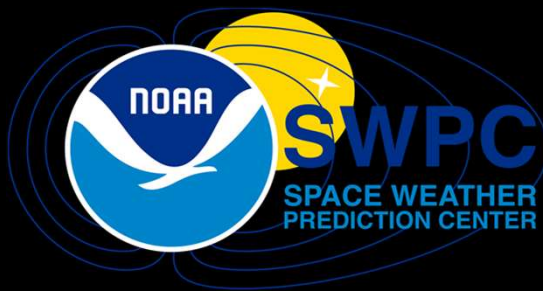
[https://emilms.fema.gov/is\\_0066/](https://emilms.fema.gov/is_0066/)



[https://www.fema.gov/sites/default/files/2020-07/fema\\_incident-annex\\_space-weather.pdf](https://www.fema.gov/sites/default/files/2020-07/fema_incident-annex_space-weather.pdf)



<https://www.swpc.noaa.gov/content/education-and-outreach>



*“Safeguarding Society with Actionable Space Weather Information”*

