

SOLAR STORMS AND WHAT THEY MEAN FOR UTILITIES

Bill Murtagh

Program Coordinator
NOAA Space Weather Prediction Center (SWPC)
National Weather Service

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Overview

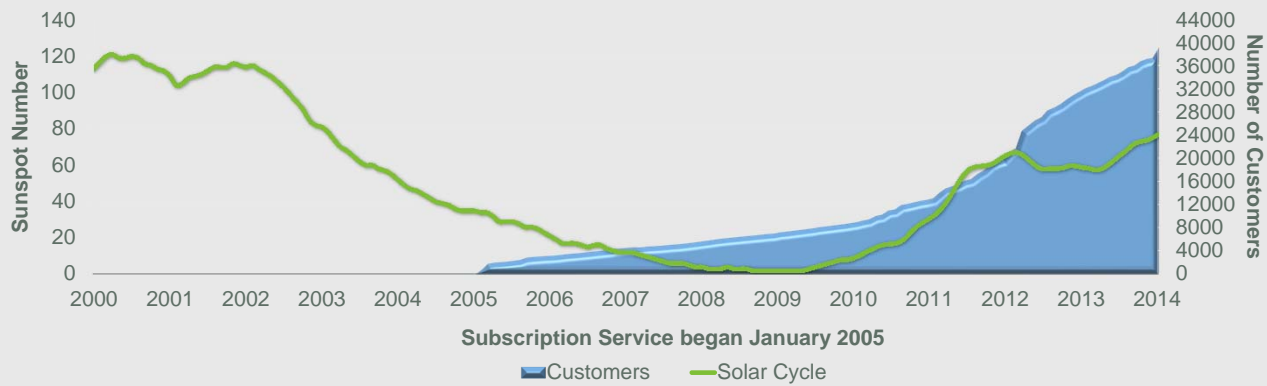
- Growing concerns
- Solar cycles
- Extreme events
- Space weather types and impacts
- Government response

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Customer Growth

SWPC Product Subscription Service



Banking

State Depts. of Transportation
Precision agriculture

FEMA

Communication companies
Major airlines

Auto Industry

Oil drilling companies
Satellite companies

FAA

Electric utilities
Surveying groups

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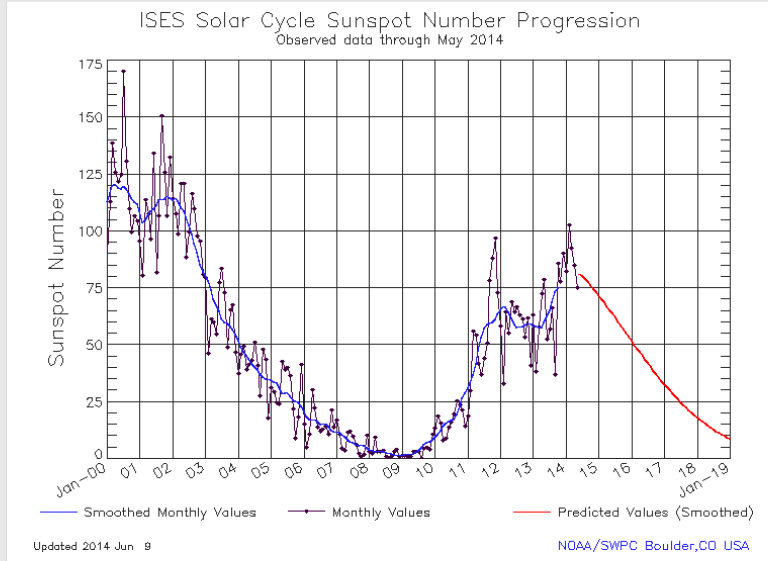
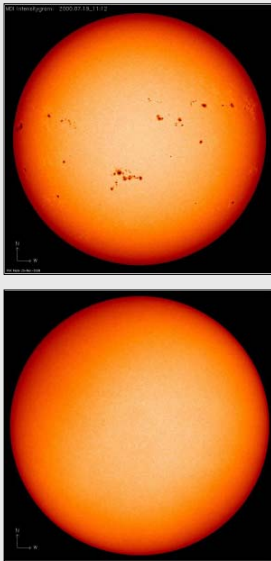


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Solar Cycle 24

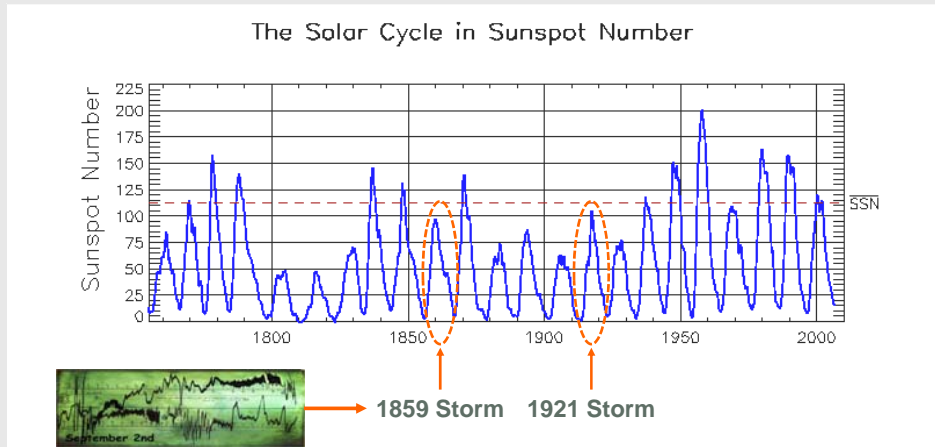


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Solar Cycle

- Large geomagnetic storms can occur with smaller cycles
- The largest geomagnetic storms on record occurred during smaller than average cycles



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Carrington Event, September, 1859

"All our exchanges, from the northern coast of the Island of Cuba gave glowing descriptions of the Aurora Borealis - as bright in the tropics as in the northern zones"

[New Orleans Daily Picayune, September 7, 1859]

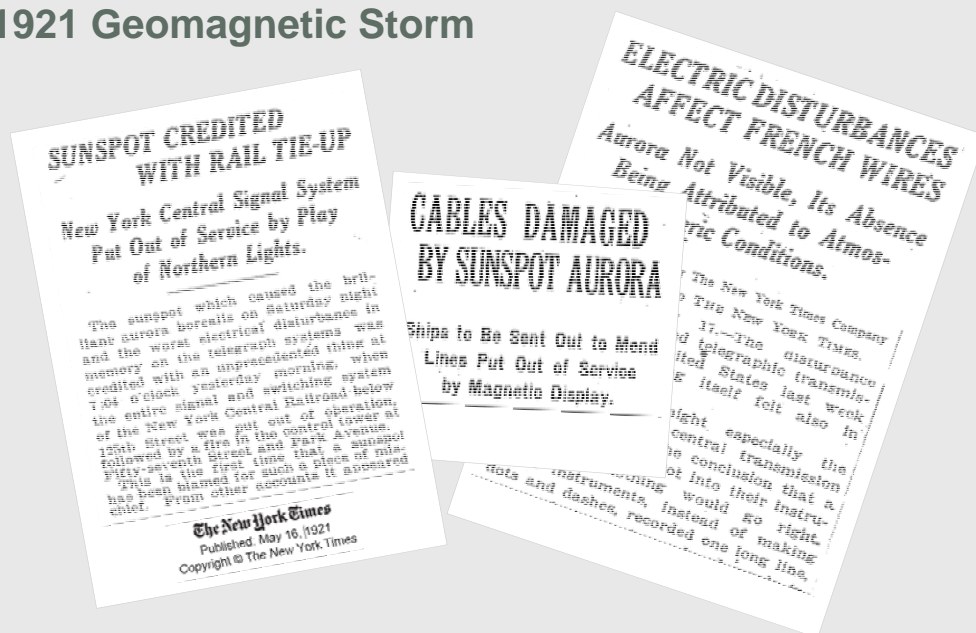


- Discharges shocked telegraph operators and set the telegraph paper on fire

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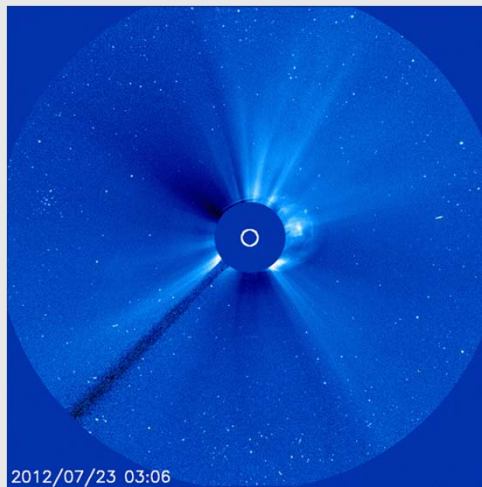
May, 1921 Geomagnetic Storm



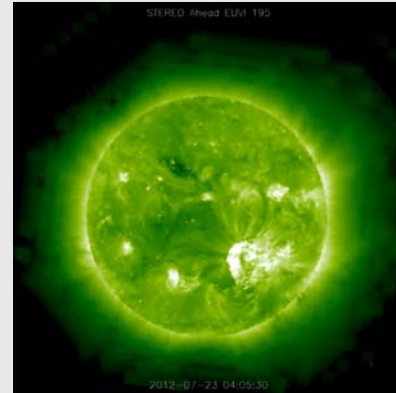
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23 July, 2012 – Dodging the Bullet!



Powerful solar flare on 23 July, 2012...
...not Earth-directed



- A coronal mass ejection speed: ~2900 km/s or 6.5 million mph occur only once every ~5 to 10 years.

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23 July, 2012

- “Using a well-proven geomagnetic storm forecast model, we find the 23-24 July event would have produced a geomagnetic storm that was comparable to the largest events of the 20th Century.”
- “Using plausible assumptions about seasonal and time-of-day orientation of the Earth’s magnetic dipole – This would be considerably larger than estimates for the famous Carrington storm of 1859.”

*A Major Solar Eruptive Event in July 2012:
Defining Extreme Space Weather Scenarios; D.N. Baker et al.*

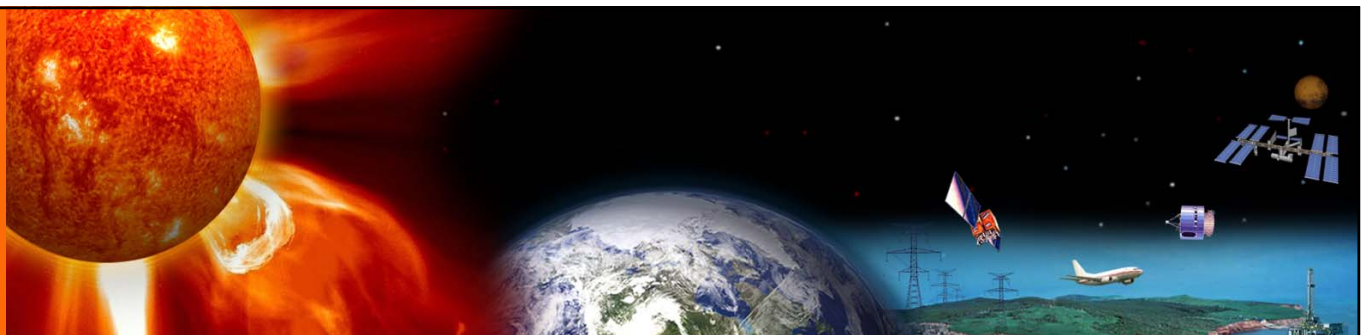
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On the Probability of a Carrington-like Event

- **Predictive Science, San Diego – February, 2012:** *"On the probability of occurrence of extreme space weather events" indicates "the probability of another Carrington event occurring within the next decade is 12%."*
- **US Geological Survey – May, 2012:** *"The most likely Poisson occurrence probability for another Carrington event in the next 10 years is 0.063, or about half the 0.120 probability that Riley [2012] estimates by extrapolating from smaller events."*

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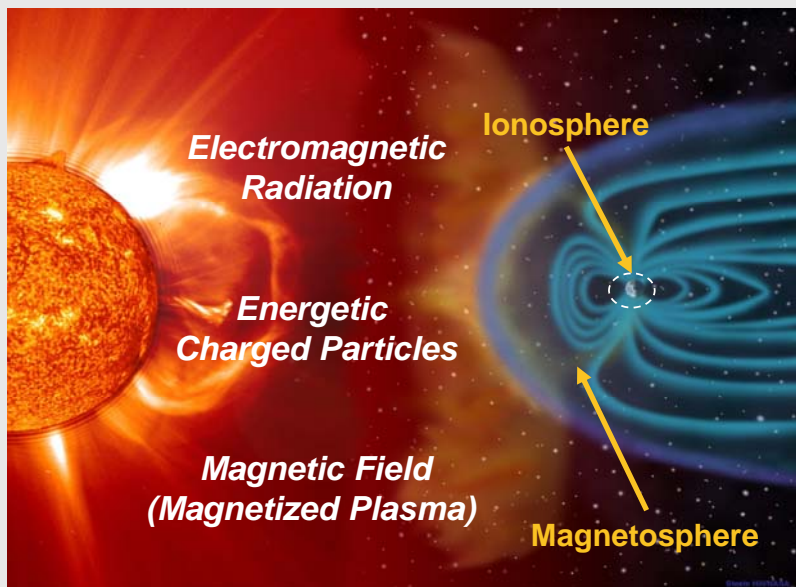
Space Weather Types and Associated Impacts

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What Is Space Weather?

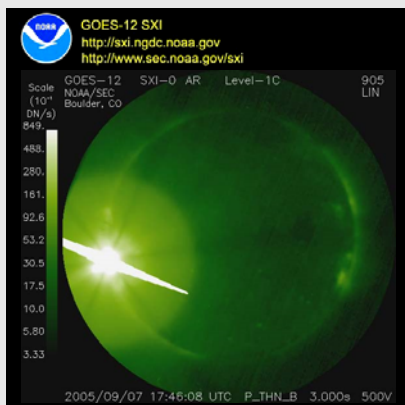
Space weather refers to the variable conditions on the Sun and in space that can influence performance and reliability of space and ground-based technological systems, and endanger life or health



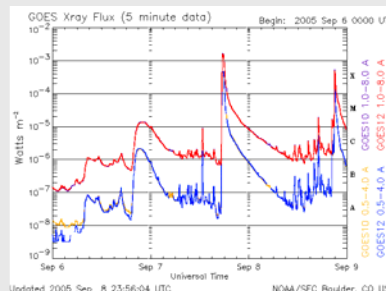
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Solar Flares Radio Blackouts (R Scale)



A violent explosion on Sun – energy equivalent of a hundred million hydrogen bombs



Impacts:



GPS Network



Radar



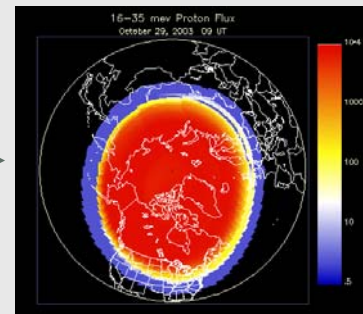
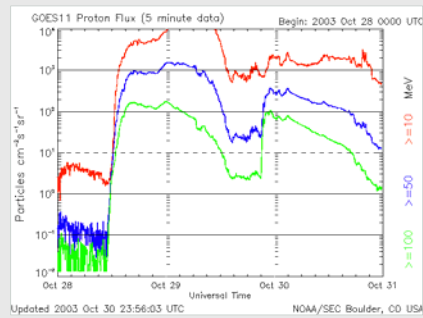
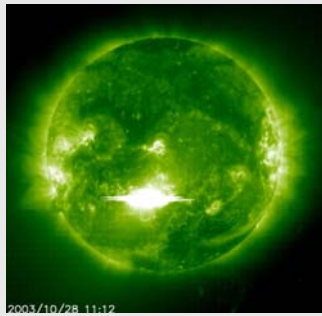
Communications
Ground and Space-based

Image from NASA SOHO Satellite

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Solar Radiation Storms (S Scale)



Impacts...

- Satellite operations (range from loss of data to loss of satellite)
- Aviation (communications and exposure concerns)
- High-latitude High Frequency communication outage


Duration: hours to days

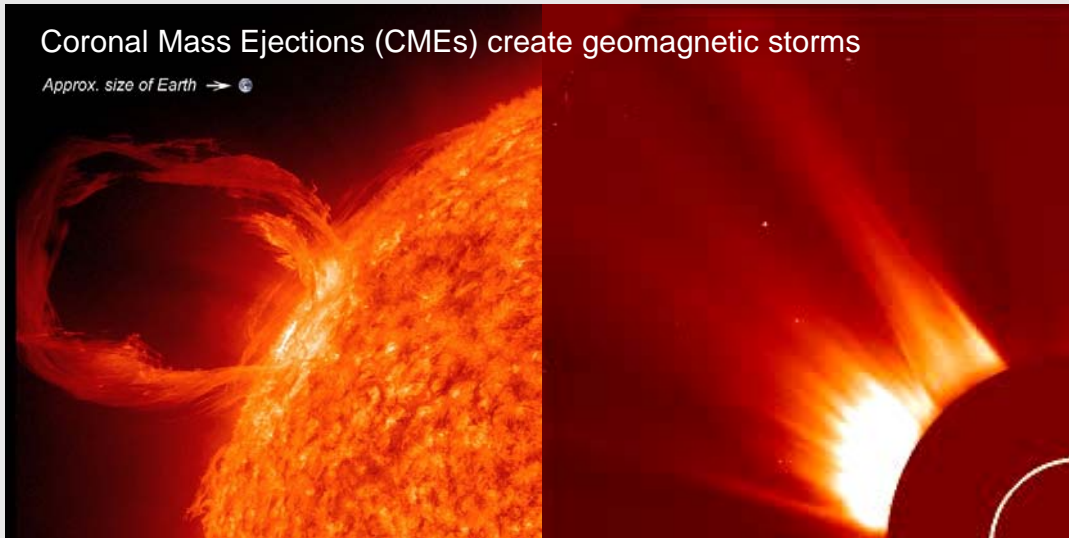
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Geomagnetic Storms (G Scale)

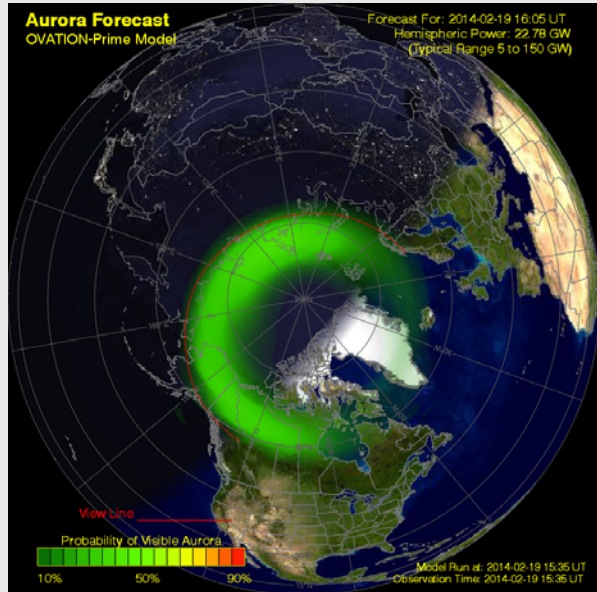
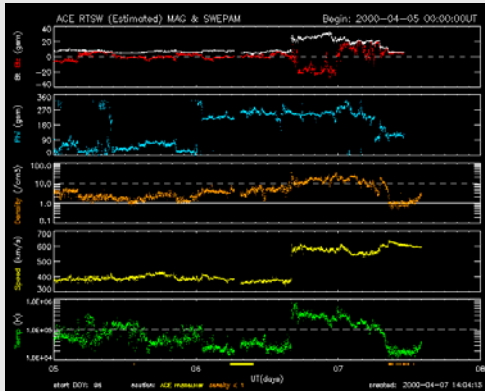
Coronal Mass Ejections (CMEs) create geomagnetic storms

Approx. size of Earth → 

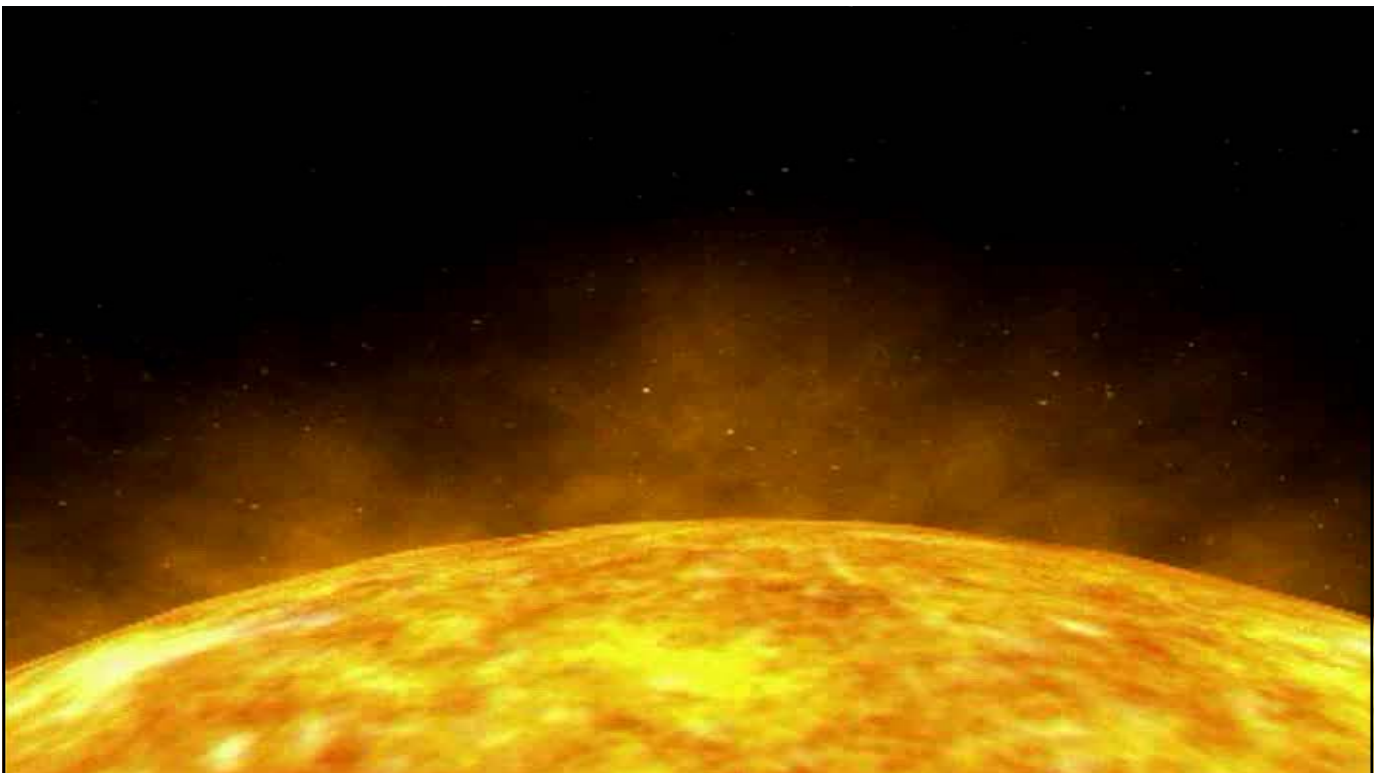


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Geomagnetic Storm Impacts

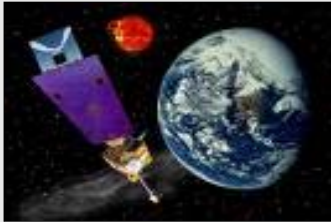


GPS

Impacts from geomagnetic storms are wide-ranging with potentially significant consequences



Manned Spaceflight



Satellite Operations



Power Grid Operations



Aircraft Operations

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Impacts on Electric Power Grid

- CME impacts Earth's magnetic field
- Fluctuations generate electric fields on Earth. These geomagnetically induced currents (GIC) can flow into power lines and transformers.
- Leads to transformer saturation and over-heating, voltage drops, transformer damage, grid collapse

Vulnerability of US Grid

- Northern latitude (location of aurora during geomagnetic storms)
- Areas of relatively high resistive igneous rock
- Very high voltage interconnected transmission network
- Proximity to oceans (conductivity of ocean salt water)



(Credit: K. Turnbull / J. Wild / ESA)

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Significant Grid Problems Have Occurred...

HYDRO-QUEBEC PRESS RELEASE
 Direction Relations Publicites
 HYDRO-QUEBEC
 MONTREAL, CANADA

MARCH 13 BLACKOUT CAUSED BY AN EXCEPTIONALLY STRONG MAGNETIC STORM

Montreal, March 15, 1989 - Hydro-Quebec confirms that the March 13 blackout was caused by the strongest magnetic storm ever recorded since the 735-kv power system was commissioned. At 2:41 AM the storm, which resulted from a solar flare, tripped four lines from James Bay and caused a generation loss of 9,450 MW. With a load of some 21,350 MW at that moment, the system was unable to withstand this sudden loss and collapsed within seconds, thereby causing the further loss of generation from Churchill Falls and Manic-Outarde.

Information Notice No. 90-42:
FAILURE OF ELECTRICAL POWER EQUIPMENT DUE TO SOLAR MAGNETIC DISTURBANCES

Specific events occurred at the Three Mile Island Unit 1, Hope Creek Unit 1, and Salem Unit 1 nuclear power plants. ...inspection of the generator step-up transformer... severe overheating, melted low-voltage service connections in phases A and C, and insulation discoloration in phase B. On September 19, at Salem Unit 2 nuclear power plant, a second solar storm damaged the generator step-up transformer. Sep 1990

U.S. DEPARTMENT OF HOMELAND SECURITY
 Information Analysis and Infrastructure Protection
 Daily Open Source Infrastructure Report
 for 03 November 2003

Current Nationwide Threat Level is **ELEVATED**
 For info click here www.whitehouse.gov/secure/

Energy Sector

Current Electricity Sector Threat Alert Levels: Physical: Elevated, Cyber: Elevated
 Scale: LOW, GUARDED, ELEVATED, HIGH, SEVERE [Source: ISAC for the Electricity Sector (ES-ISAC) - <http://esisac.com>]

October 31 - Sun storm causes problems for Swedish power system. The solar storm has caused technical glitches in Sweden's power system in the past few days and may be to blame for a blackout that affected 50,000 people on Thursday, October 30.



Transformer winding failure



Transformer exit-lead overheating

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Halloween Storms October, 2003

*US Nuclear Regulatory Commission
 Power Reactor Status Report, October 30, 2003*

Unit	Power	Reason or Comment
Salem 1 (New Jersey)	80	Reduced power due to solar magnetic disturbances
Braidwood 2 (Illinois)	90	Coastdown to refueling outage reviewing system planning operating guide for solar flare response
Duane Arnold (Iowa)	94	Electrical capability no D/G or switchyard work due to solar flare response
Point Beach 1 (Wisconsin)	83	Increasing power following A decrease in power due to grid geo-magnetic disturbances
Arkansas Nuclear 1 (Arkansas)	100	Holding off on switchyard maintenance for solar flare response
Palo Verde 1 (Arizona)	98	T-hot limited taking extra readings on plant computer due to solar flare response
River Bend 1 (Louisiana)	100	No D/G or relay testing due to solar flare response

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Assessing the Risk

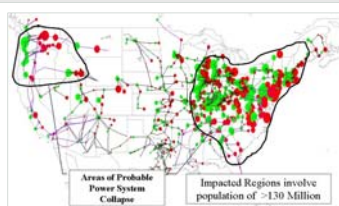


Image courtesy of NASA, Original by Metatech Corp

100 Year Geomagnetic Storm Impact
Electrojet at **50° north latitude.**

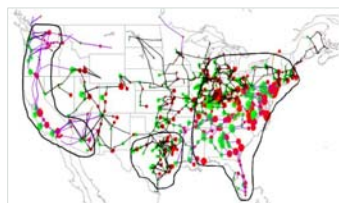
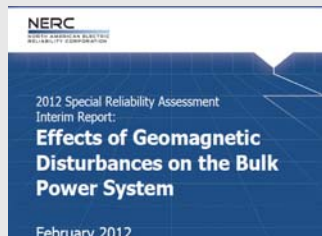


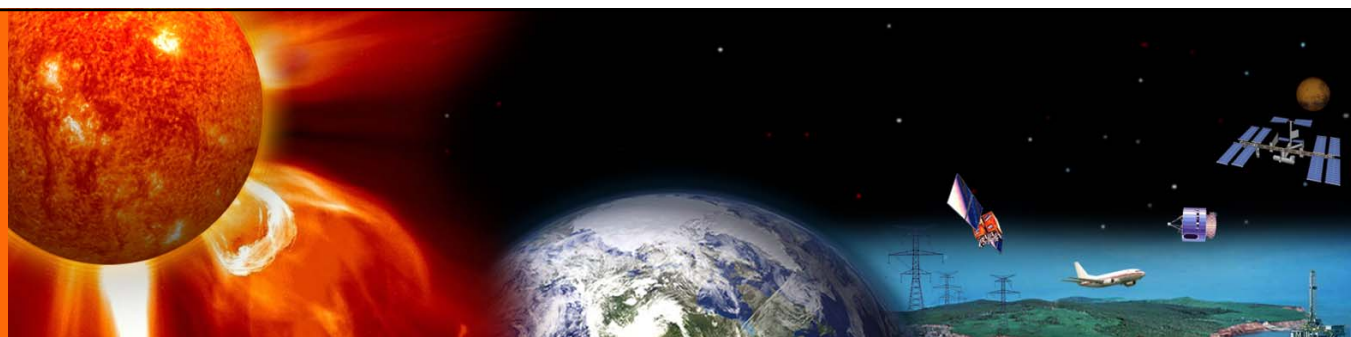
Image courtesy of Metatech Corp

100 Year Geomagnetic Storm Impact
Electrojet at **45° north latitude.**



“The **most likely** worst-case system **impacts** from a severe GMD event... is **voltage instability**....”

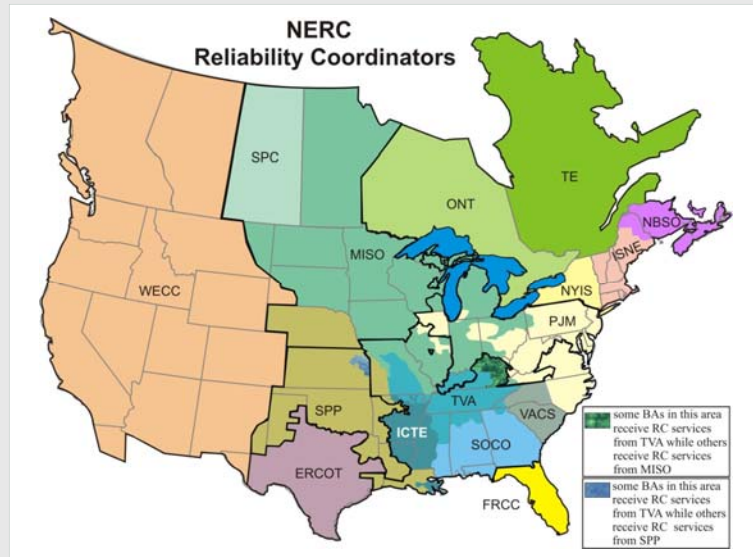
“NERC recognizes that other studies have indicated a severe GMD event would result in the failure of a large number of EHV transformers...this report does not support that conclusion....”



Government Response

Space Weather Warning Dissemination Process

- Disseminate to Reliability Coordinators through NERC Hotline
- NOTE: Many individual power grid customers sign up for SWPC products



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Responding to the Threat

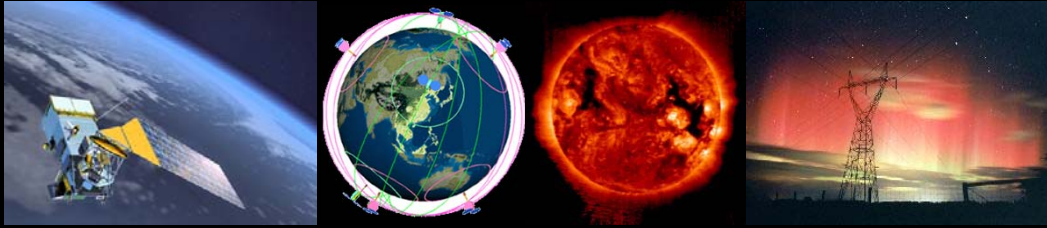
- Federal Energy Regulatory Commission
 - Standards for geomagnetic storms
- White House Space Weather Interagency Working Group
- Federal Emergency Management Agency
 - Federal interagency operations plan
- North American Electric Reliability Corp.
 - Joint industry-government task force



Space weather now included in the DHS Strategic National Risk Assessment

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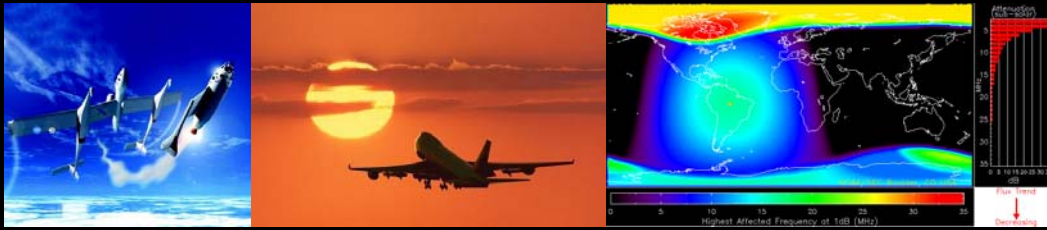




- Technology evolution
- Interconnection / interdependency
- Reliance on space-based systems



Increased vulnerability of critical infrastructure to space weather



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