Operational Space Weather Forecasting

Environmental Intelligence for a Diverse Customer Base

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Space Weather Prediction Center

National Centers for Environmental Prediction

National Weather Service

NOAA

Department of Commerce

NOAA's Space Weather Prediction Center

The Nation's official source of space weather watches warnings, and alerts

24/7/365 Operations

- National Critical System
- Redundant systems
- Full off-site back-up
- NWS resiliency

Quantifying Space Weather

SWPC Space Weather Scales

www.spaceweather.gov/NOAAscales

Radio Blackouts

			GOES X-ray peak brightness by class and by flux*	Number of events when flux level was met; (number of storm days)
R 5	Extre	HF Radio: Complete HF (high frequency**) radio blackout on the entire sunlit side of the Earth lasting for a number of hours. This results in no HF radio contact with mariners and en route aviators in this sector.	X20 ($2x10^{-3}$)	Fewer than 1 per cycle
R 4	Severe			
R 3	Strong			
R 2	Mode			
R 1	Minor			

Solar Radiation Storms

			Flux level of ≥ 10 MeV particles (ions)*	Number of events when flux level was met**
S 5	Extreme	Biological: unavoidable high radiation hazard to astronauts on EVA (extra-vehicular activity); passengers and crew in high-flying aircraft at high latitudes may be exposed to radiation risk. ***	10^5	Fewer than 1 per cycle
S 4	Severe			
S 3	Strong			
S 2	Moderate			
S1	Minor			

Geomagnetic Storms

Category		Effect	Physical measure	Average Frequency (1 cycle = 11 years)
Scale	Descriptor	Duration of event will influence severity of effects		
			Kp values* determined every 3 hours	Number of storm events when Kp level was met; (number of storm days)
G 5	Extreme	Power systems: widespread voltage control problems and protective system problems can occur, some grid systems may experience complete collapse or blackouts. Transformers may experience damage. Spacecraft operations: may experience extensive surface charging, problems with orientation, uplink/downlink and tracking satellites. Other systems: pipeline currents can reach hundreds of amps, HF (high frequency) radio propagation may be impossible in many areas for one to two days, satellite navigation may be degraded for days, low-frequency radio navigation can be out for hours, and aurora has been seen as low as Florida and southern Texas (typically 40° geomagnetic lat.).**	Kp=9	4 per cycle (4 days per cycle)
G 4	Severe	Power systems: possible widespread voltage control problems and some protective systems will mistakenly trip out key assets from the grid. Spacecraft operations: may experience surface charging and tracking problems, corrections may be needed for orientation problems. Other systems: induced pipeline currents affect preventive measures, HF radio propagation sporadic, satellite navigation degraded for hours, low-frequency radio navigation disrupted, and aurora has been seen as low as Alabama and northern California (typically 45° geomagnetic lat.).**	Kp=8	100 per cycle (60 days per cycle)
G 3	Strong	Power systems: voltage corrections may be required, false alarms triggered on some protection devices. Spacecraft operations: surface charging may occur on satellite components, drag may increase on low-Earth-orbit satellites, and corrections may be needed for orientation problems. Other systems: intermittent satellite navigation and low-frequency radio navigation problems may occur, HF radio may be intermittent, and aurora has been seen as low as Illinois and Oregon (typically 50° geomagnetic lat.).**	Kp=7	200 per cycle (130 days per cycle)
G 2	Moderate	Power systems: high-latitude power systems may experience voltage alarms, long-duration storms may cause transformer damage. Spacecraft operations: corrective actions to orientation may be required by ground control; possible changes in drag affect orbit predictions. Other systems: HF radio propagation can fade at higher latitudes, and aurora has been seen as low as New York and Idaho (typically 55° geomagnetic lat.).**	Kp=6	600 per cycle (360 days per cycle)
G 1	Minor	Power systems: weak power grid fluctuations can occur. Spacecraft operations: minor impact on satellite operations possible. Other systems: migratory animals are affected at this and higher levels; aurora is commonly visible at high latitudes (northern Michigan and Maine).**	Kp=5	1700 per cycle (900 days per cycle)

Impacts to technology

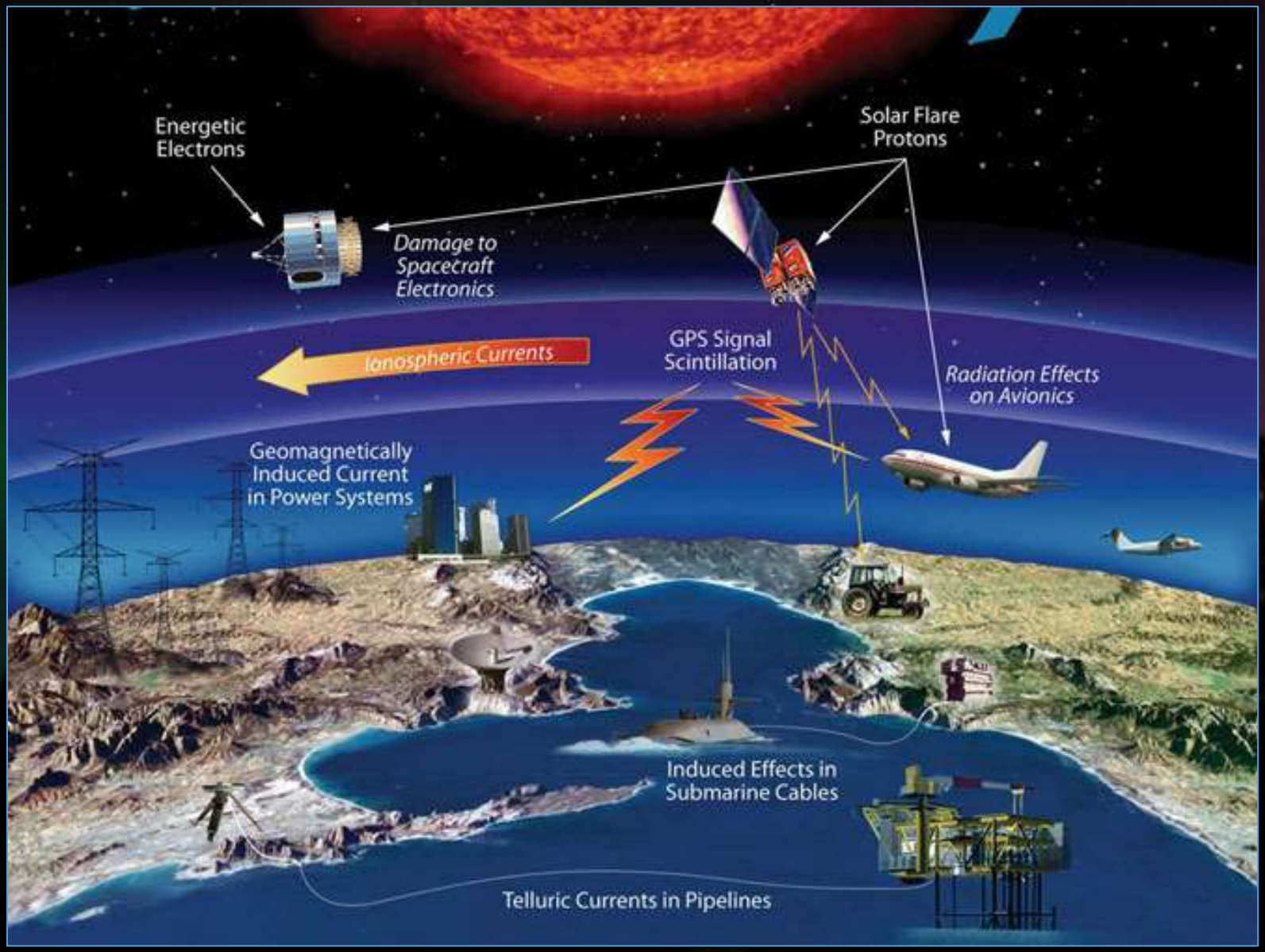


Image courtesy of NASA

Example: satellites in orbit

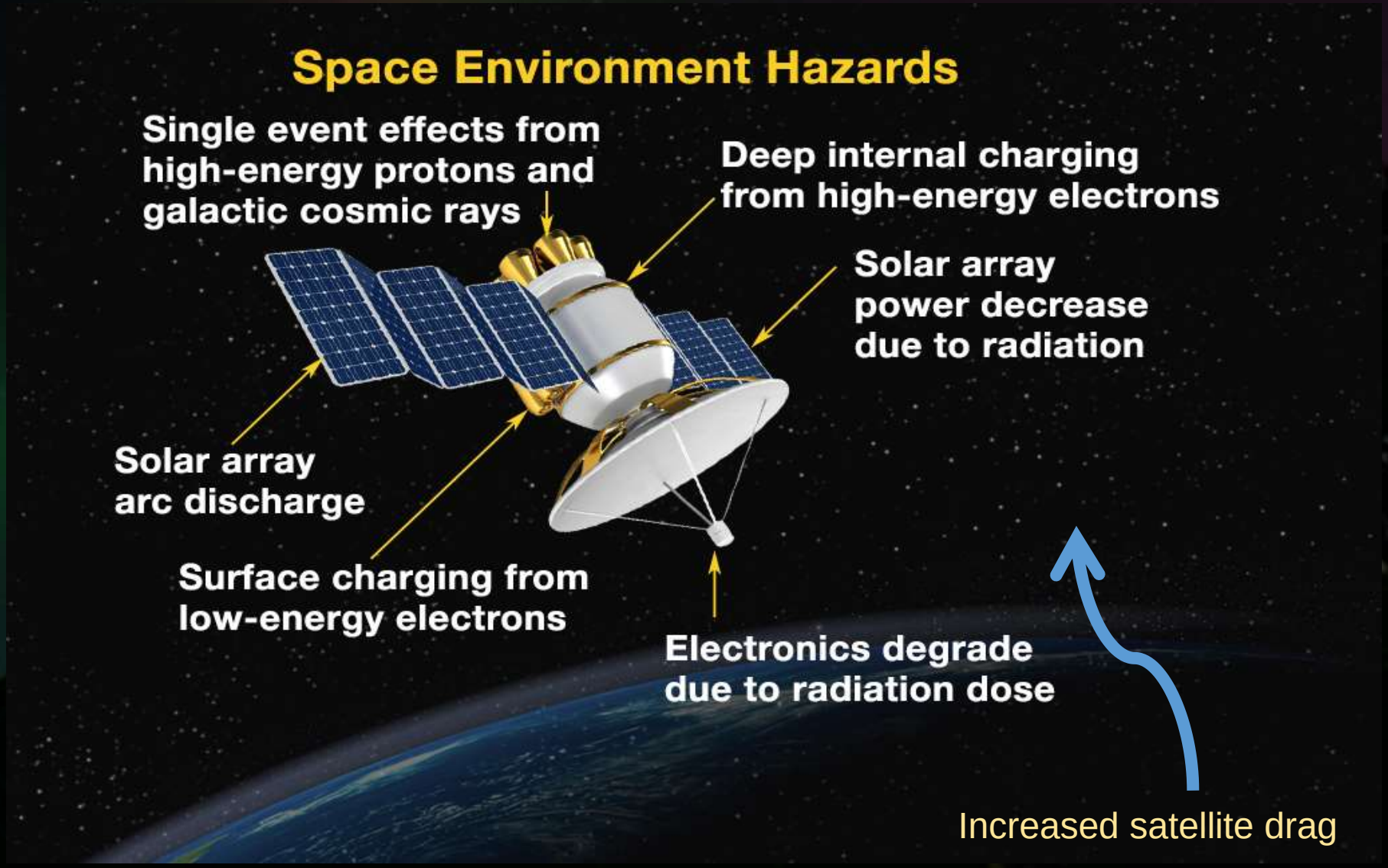
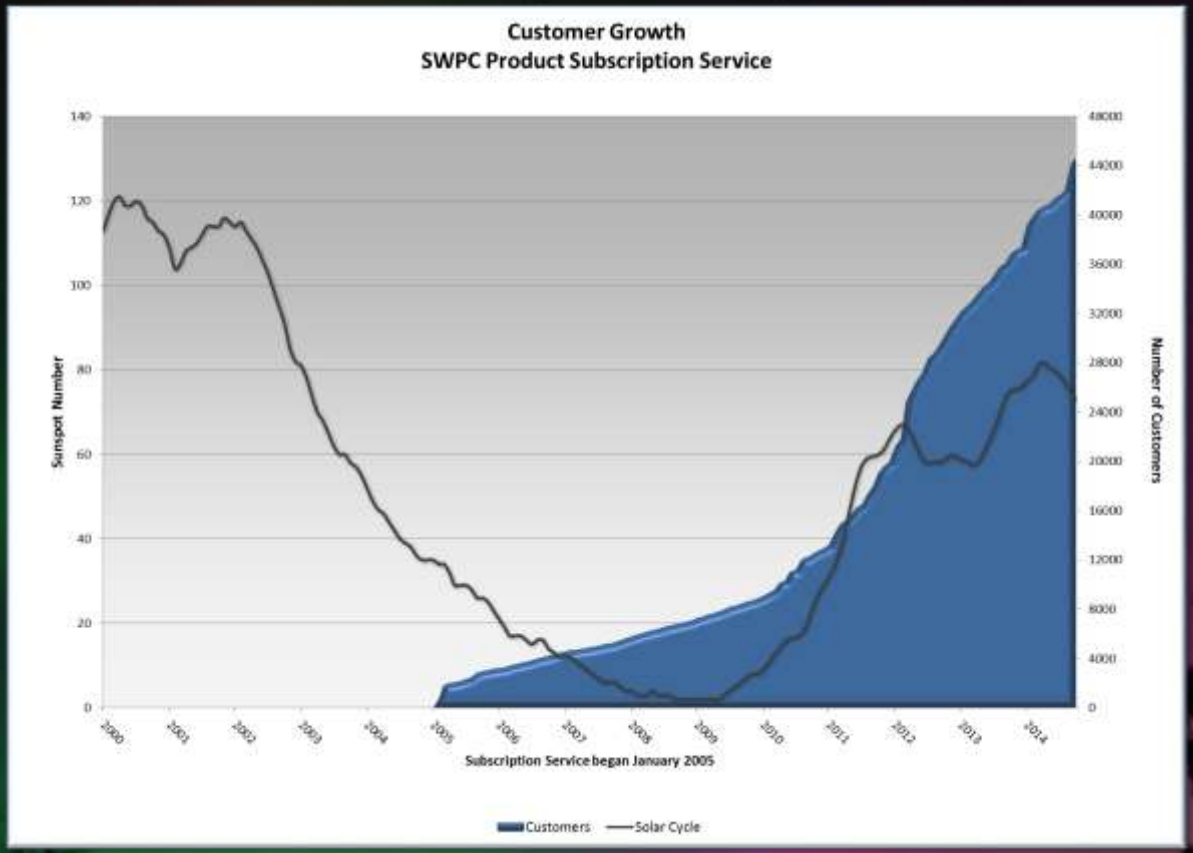


Image courtesy of JHU/APL

SWPC Customers



pss.swpc.noaa.gov

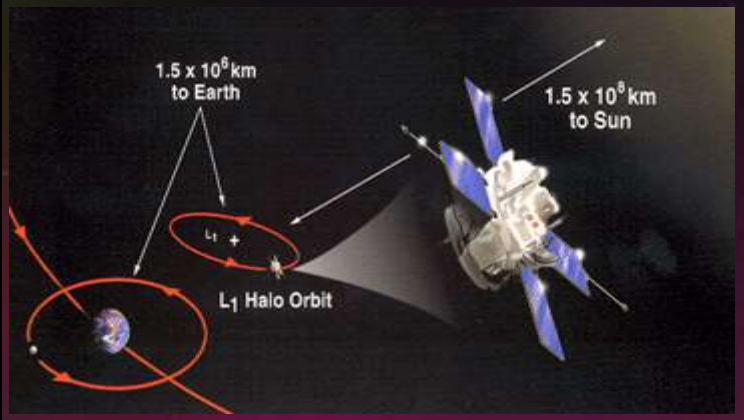
Satellite companies	Banking	FEMA	Academia	FAA
Shipping companies	Automobile industry	Communication companies	Oil drilling companies	Electric utilities
State Departments of Transportation	Precision agriculture	Major Airlines	Space Launch Services	Surveying groups

NOAA partners with other agencies to protect critical national infrastructure

- NASA, NSF: observations and operational model development.
- DHS/FEMA: preparation for and response to major events.
- DoD/AFWA: forecast collaboration and back-up.
- DoI/USGS: ground-based magnetic measurements.
- DoT/FAA: commercial aviation protection.
- DoE: power grid protection.
- Commercial service providers: custom products.

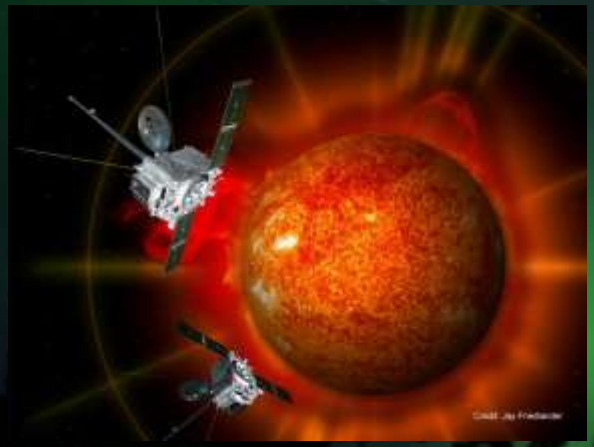
Forecasting begins with Observations (Data)…

NOAA GOES & POES



NASA ACE

ESA/NASA SOHO

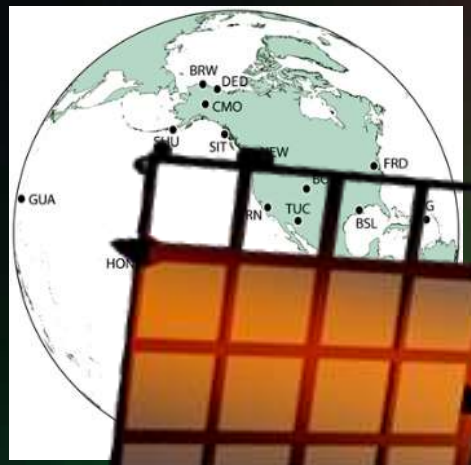


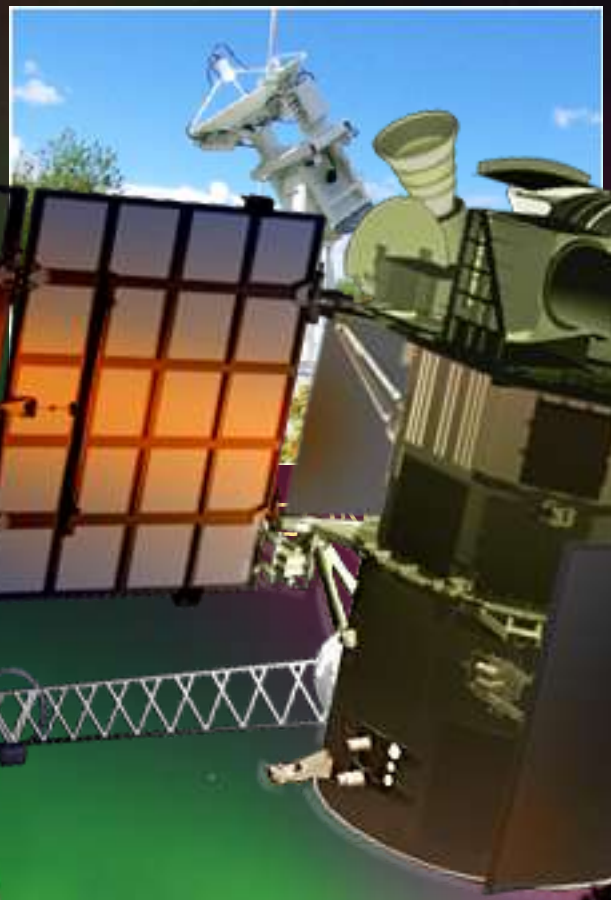
NASA STEREO

NASA Solar Dynamics Observatory

NSF GONG Network

Forecasting begins with Observations (Data)…





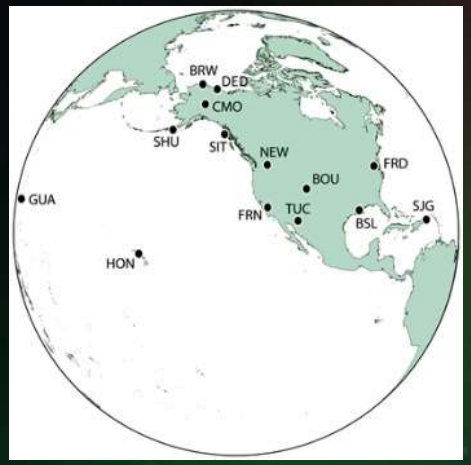
USGS

CORS Network

NOAA DSCOVR

Launching to L1 in late January 2015!

Forecasting begins with Observations (Data)…

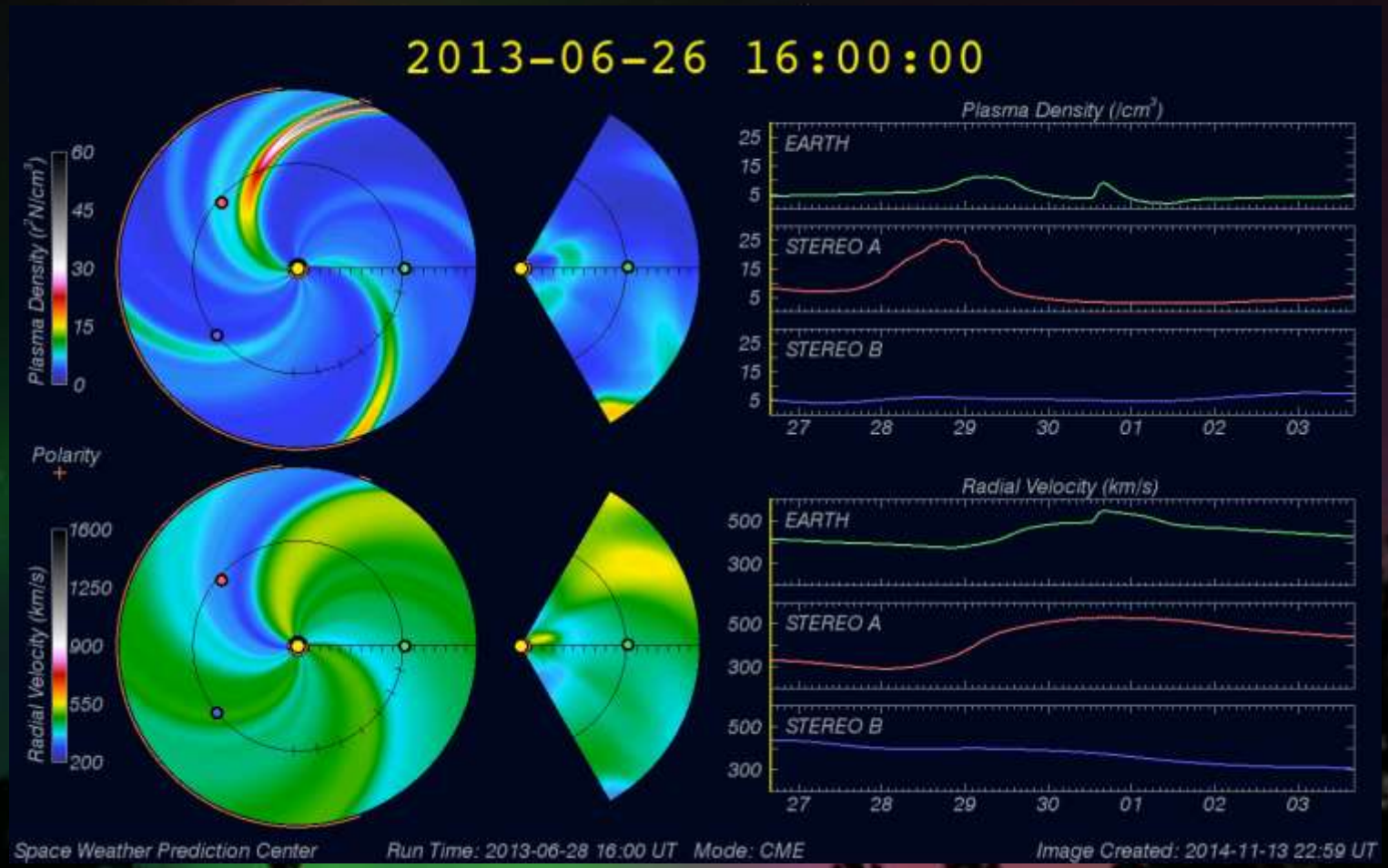


USGS Magnetometer

NOAA GOES-R

Launching to Geosynch in early 2016!

…continues with Models…

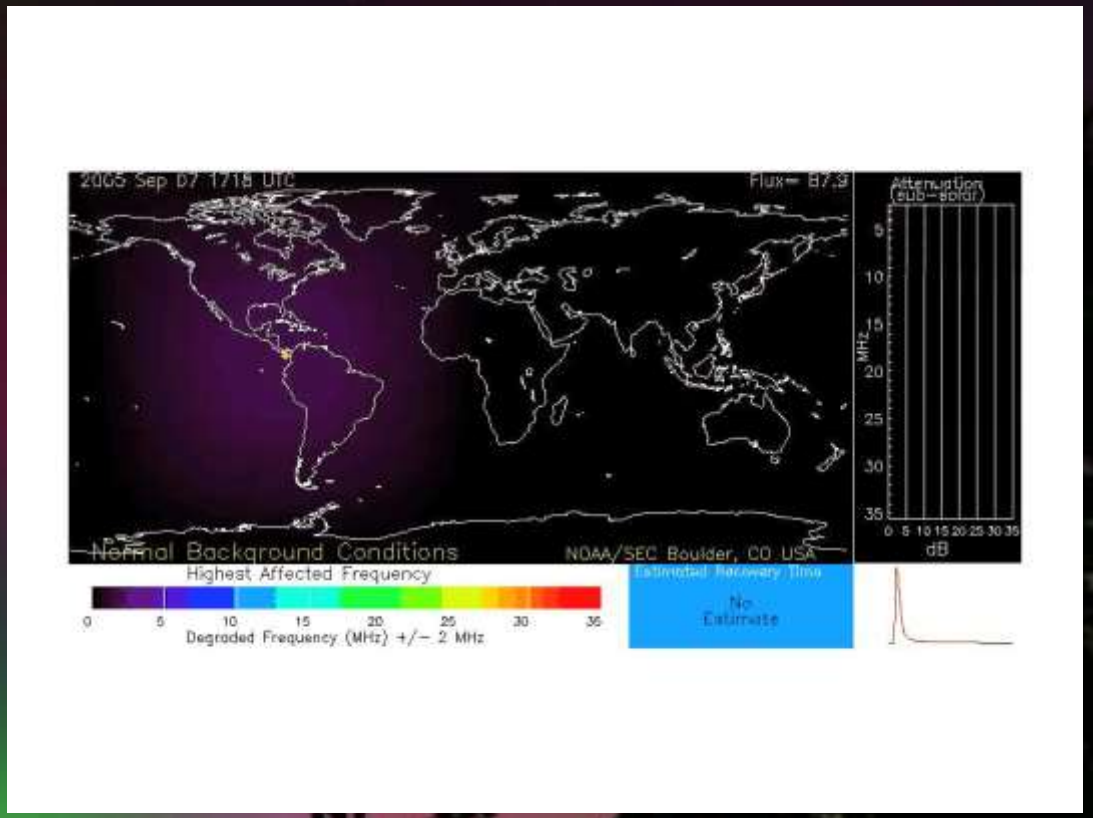


High Speed Solar Wind Stream and CME Arrival time forecasting

- WSA-Enlil model predicts arrival of High Speed Wind and CME at Earth
- L1 spacecraft data verifies forecast and provides precise alert timing

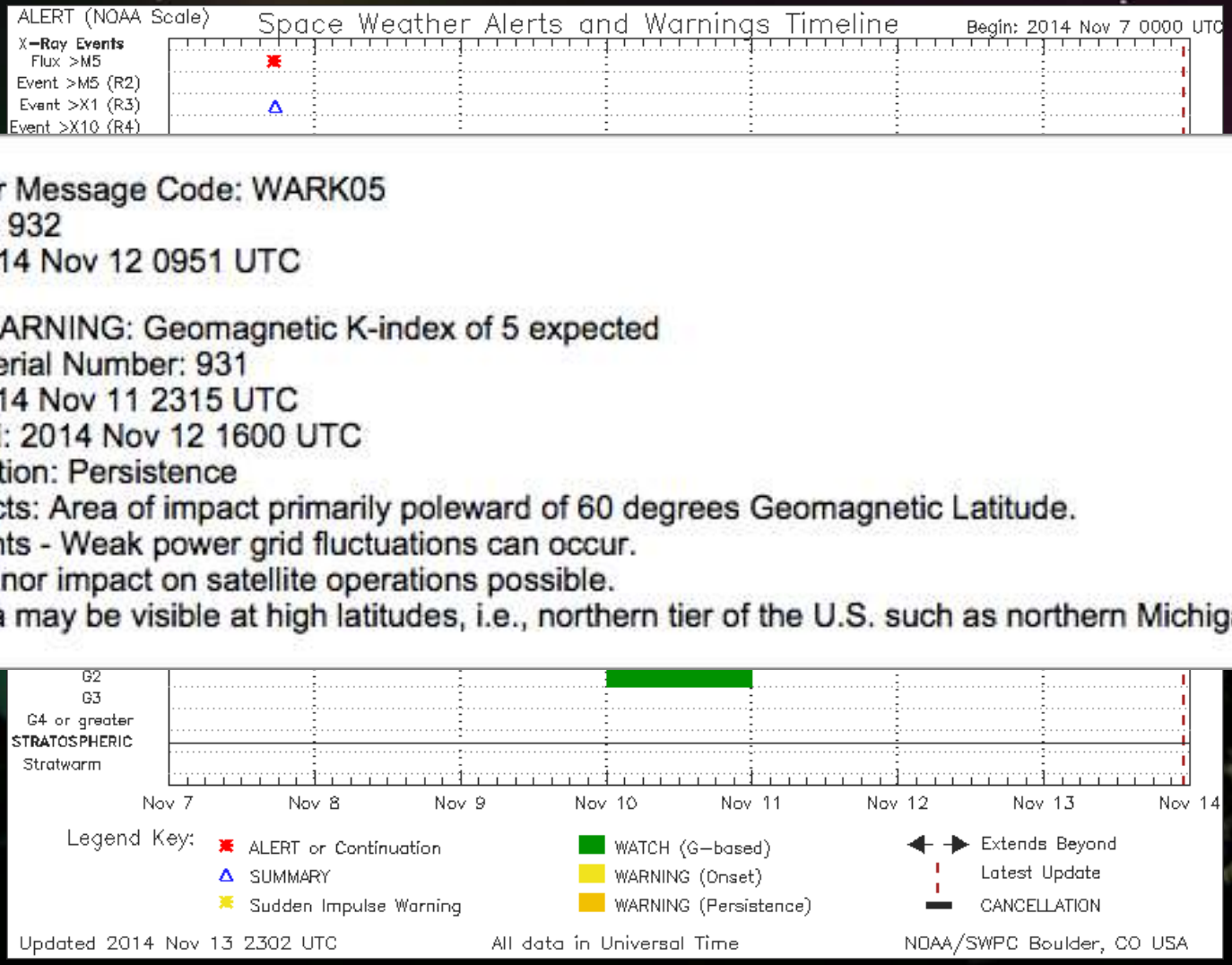
…produces real-time Products…

Ovation Auroral Nowcast



D-Region Ionospheric Absorption
(High Frequency Radio communication blackouts)

…and ends with Watches, Warnings, Alerts, Situational Awareness, and Outreach

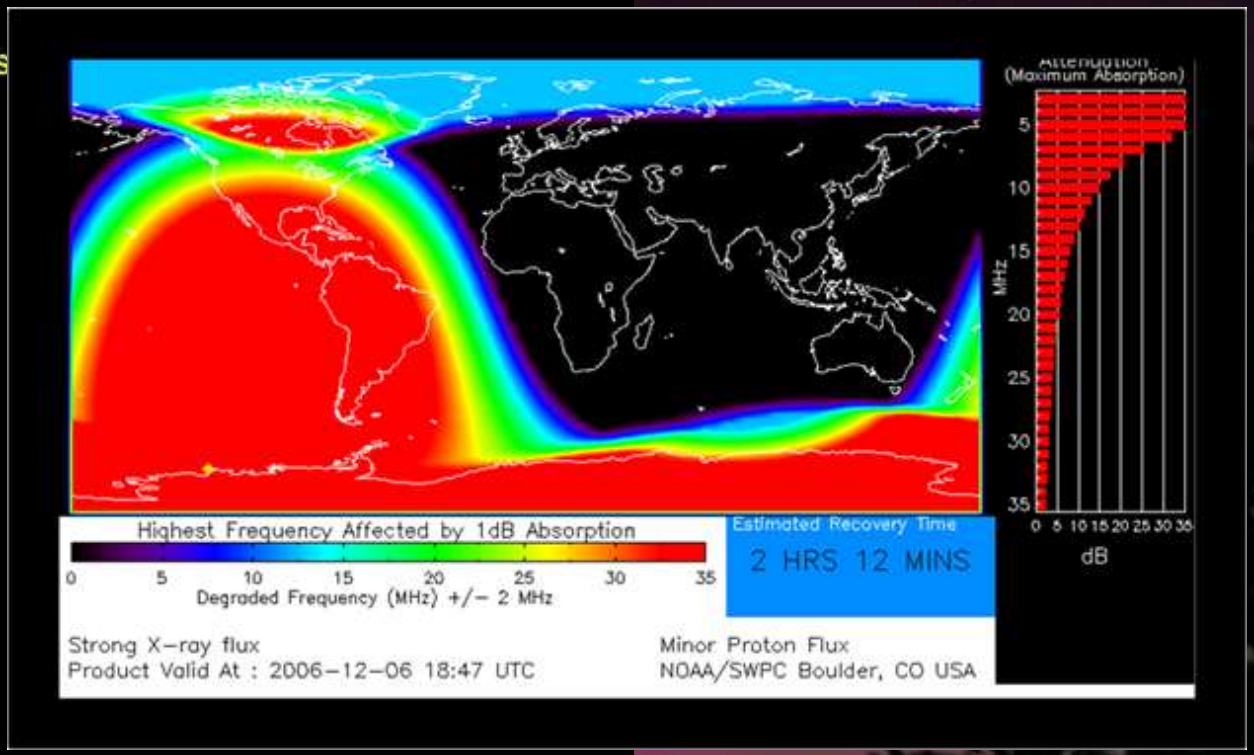


Space Weather Message Code: WARK05
Serial Number: 932
Issue Time: 2014 Nov 12 0951 UTC

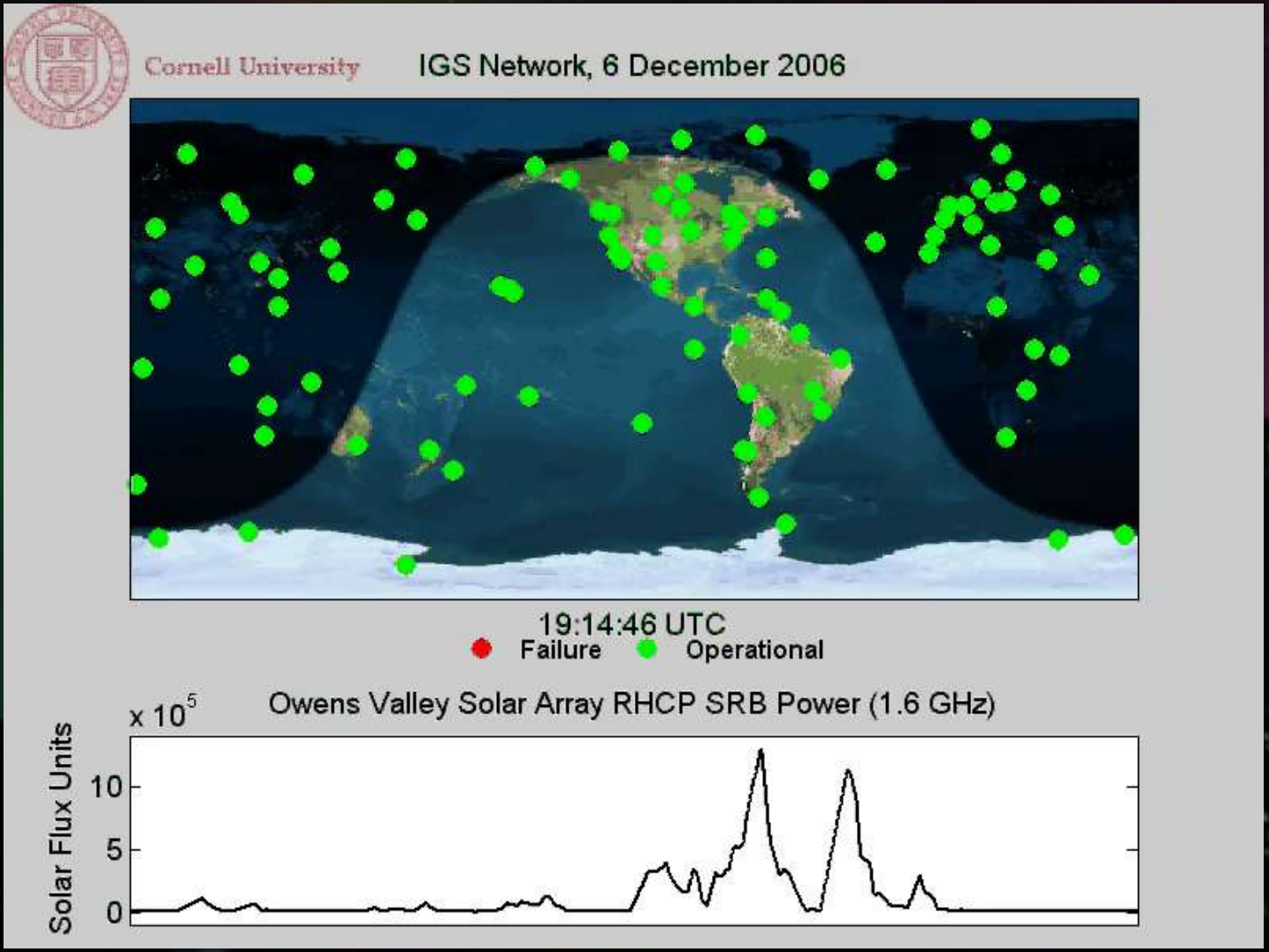
EXTENDED WARNING: Geomagnetic K-index of 5 expected
Extension to Serial Number: 931
Valid From: 2014 Nov 11 2315 UTC
Now Valid Until: 2014 Nov 12 1600 UTC
Warning Condition: Persistence
Potential Impacts: Area of impact primarily poleward of 60 degrees Geomagnetic Latitude.
Induced Currents - Weak power grid fluctuations can occur.
Spacecraft - Minor impact on satellite operations possible.
Aurora - Aurora may be visible at high latitudes, i.e., northern tier of the U.S. such as northern Michigan and Maine.

Example events: 06-December-2006

GOES-12 SXI
http://sxi.ngdc.noaa.gov
http://www.sec.noaa.gov/s

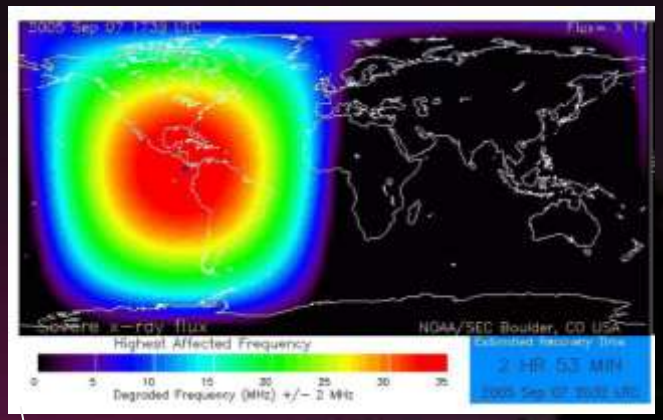


Example events: 06-December-2006



Environmental Intelligence → Decision Support

Aviation Communication Center:
07Sep05 1800Z: "Solar activity severely impacted all HF comms. Higher frequencies utilized with little effect. 24 aircraft position reports and NYC ATC messages were relayed via sat-voice between 1040Z and 1939Z. Severe operational impact."



NavCanada ATC
"The flare resulted in significant impacts to the network of air traffic control radars in Canada, causing false targets and interference in the N/S direction on scales of approximately 150 miles in length."

Oakland ARTCC

Thank You!

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www.spaceweather.gov