GOES-R Brown Bag Series

GOES-R Space Weather (SWx) Mission

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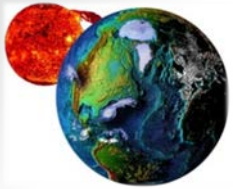


GOES-R Space Weather Mission

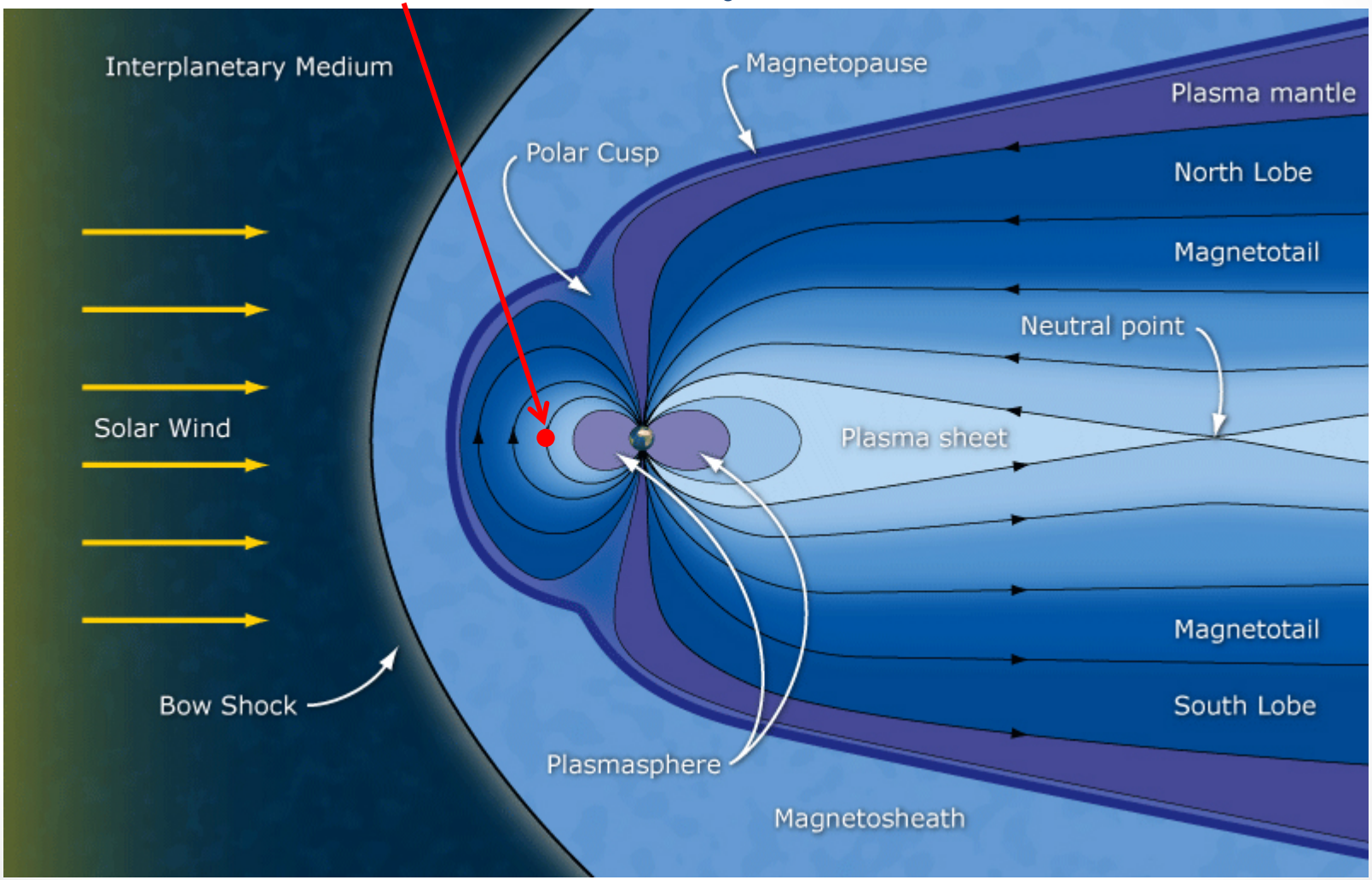
Abstract

Space weather refers to the variable conditions on the sun, throughout space, and in the earth's magnetic field and upper atmosphere that can influence the performance of space-borne and ground-based technological systems and endanger human life or health. Since 1974 the GOES system of spacecraft has been NOAA's sentinel in geostationary orbit, continuously monitoring the near-earth and solar environments for hazardous space weather. These data are used within the National Weather Service's Space Weather Prediction Center (SWPC) to assess the near-earth status of space weather and to issue, when necessary, space weather alerts, watches and warnings. The GOES-R space environmental sensors are an evolutionary improvement in capability for monitoring and forecasting space weather. However it is perhaps more appropriate to view the contributions of GOES-R within the context of NOAA's overall space weather program. In this talk I will discuss the GOES-R space weather mission using the "real world" scenario of the severe geomagnetic storm that occurred last week on Saint Patrick's Day and illustrating how various assets, including GOES, are used to better understand the drivers and consequences of space weather.

GOES-R Space Weather Mission

GOES-R is Located within the Magnetosphere

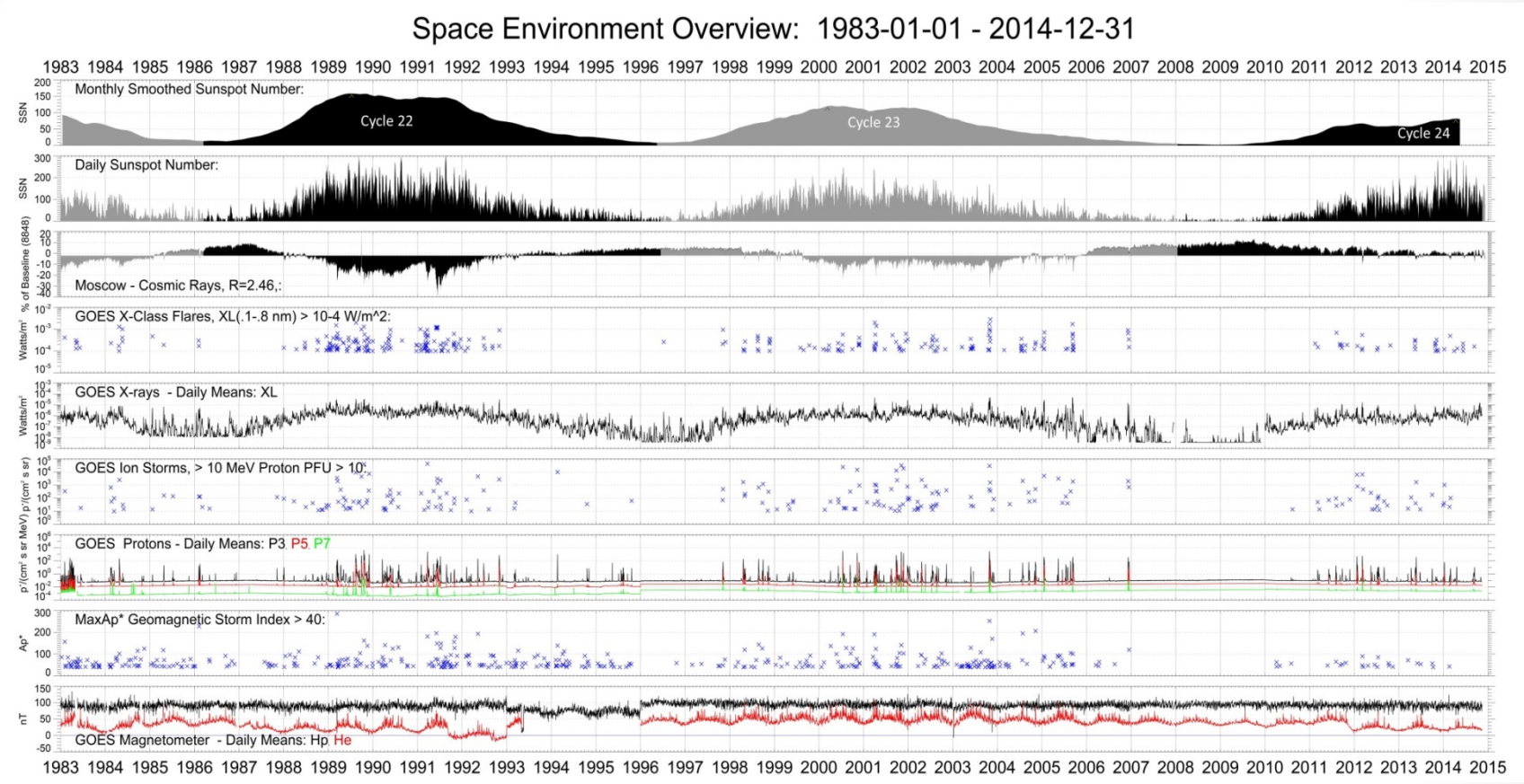
GOES-R Spacecraft Location (~6.6 R_e)



Distance to L1 (DSCOVR): 240 R_e / Distance to sun: 23,481 R_e

GOES-R Space Weather Mission

GOES - Maintaining a Long-term Record of SWx



	Start Date	Max Date	End Date	C-Class Flares	M-Class Flares	X-Class Flares	Ion Storms	Mag Storms Ap* > 40
Solar Cycle 22	1986-03	1989-07	1996-06	12,447	2,021	151	73	191
Solar Cycle 23	1996-06	2000-03	2008-01	13,102	1,437	126	92	158
Solar Cycle 24 *	2008-01	2014-04	TBD	5,288	488	35	32	25

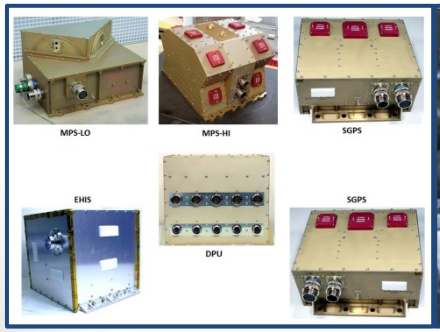
- We are far from the end of Solar Cycle 24 so these numbers should be considered a progress report rather than a final grade. Event totals are through November 2014.

GOES-R Space Weather Mission

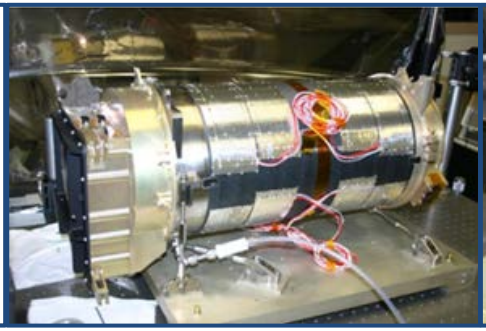
Sensor Overview – SEISS/SUVI/EXIS/MAG

GOES-R includes of a complement of in-situ particle/field and solar-viewing sensors providing a synoptic assessment of space weather.

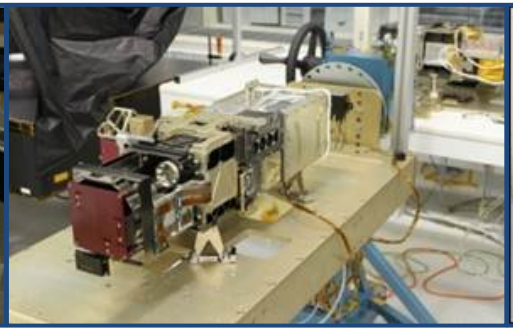
SENSOR	IMPROVEMENT	APPLICATION
Space Environmental In-Situ Suite (SEISS)	Improved energy range / contamination rejection	Spacecraft charge models for electrostatic discharge
Solar Ultra-Violet Imager (SUVI)	Multi-wavelength solar imagery	Surface features and thermal height profiles
EUV and X-ray Irradiance Sensors (EXIS)	Improved accuracy and precision	Solar backgrounds/events impacting climate models
Magnetometer (MAG)	Gradiometer rejection of satellite generated fields	Geomagnetic field data with improved fidelity



SEISS



SUVI



EXIS

MAG

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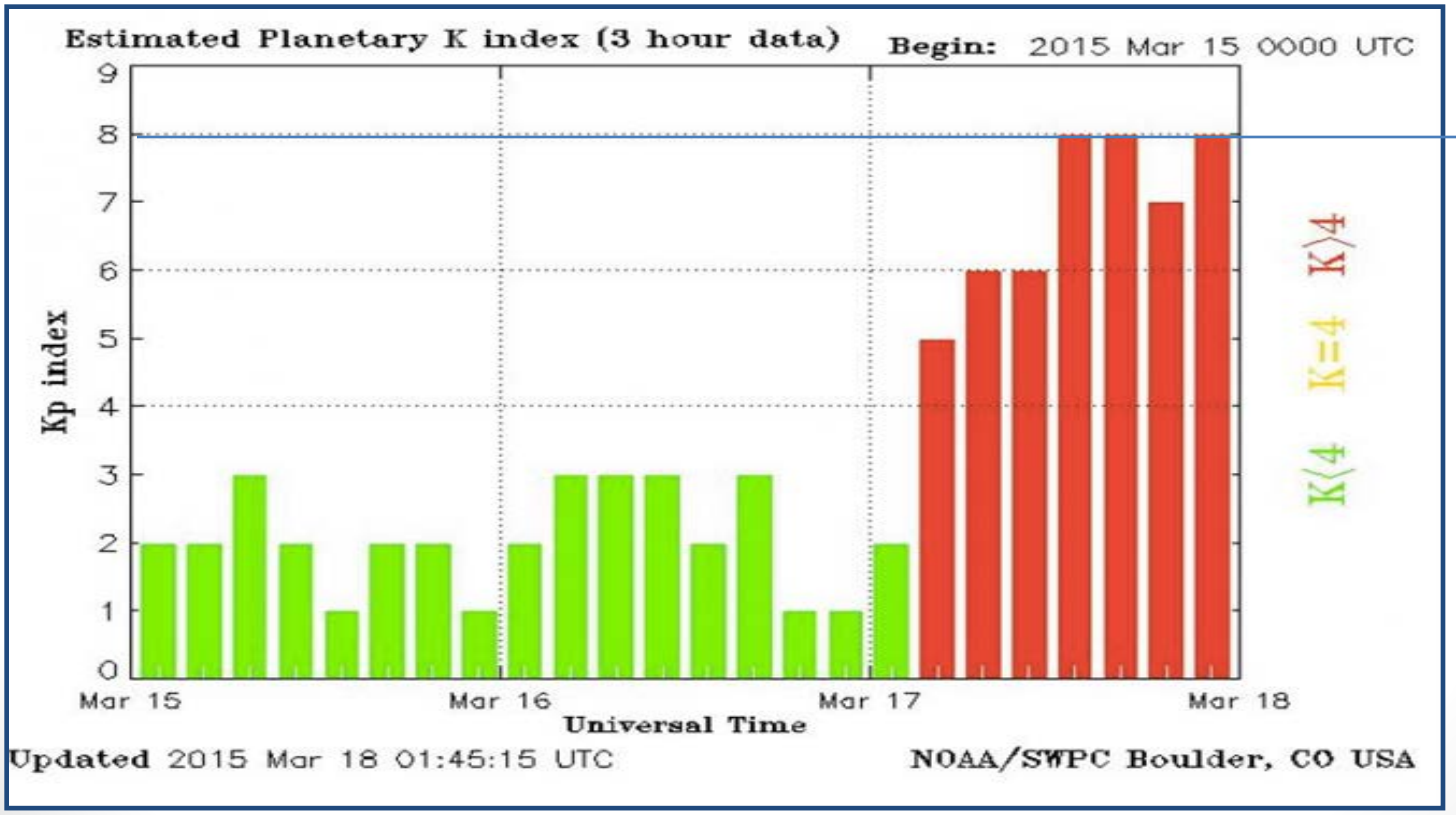
Saint Patrick's Day Storm – 17 Mar 2015

Background: On 17 Mar the earth experienced a severe geomagnetic storm associated with a modest C9.1 solar flare originating from active region (AR) 2297 on 15 Mar @02:13 UT (max). The remarkable auroras resulting from this geomagnetic storm could be viewed at higher latitudes in the western hemisphere.



G4 Storm Index

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NOAA SWx Scales – Geomagnetic Storms

A G4 geomagnetic storm is rated as "severe" on the NOAA storm scales – Deleterious impacts to the power grids, satellite operations, and radio communications are expected. (Radio Blackouts / Solar Radiation Storm)

Scale	Description	Effect	Physical measure	Average Frequency (1 cycle = 11 years)
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, including a 9-	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)

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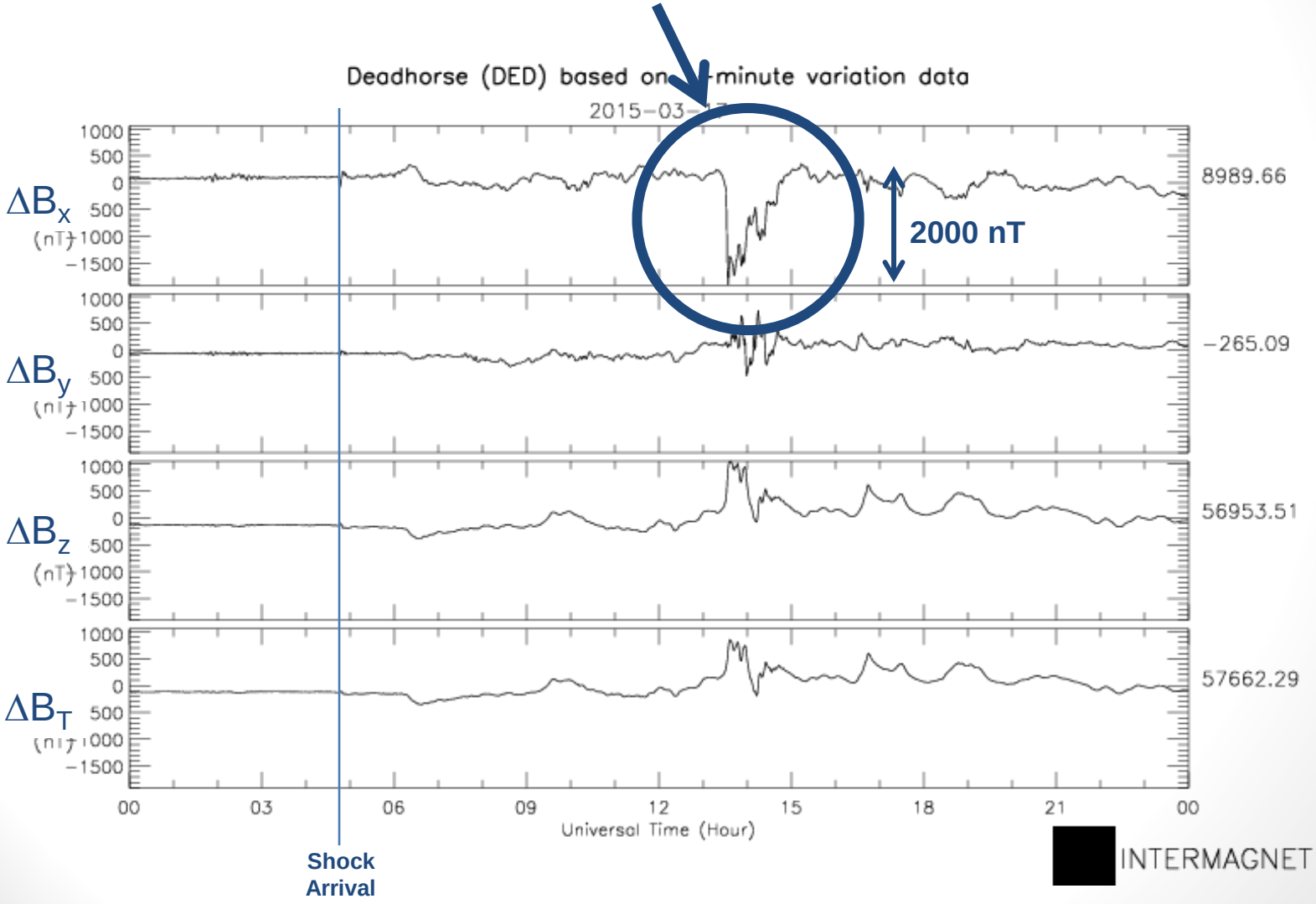
Kp Index is a SWx Situational Awareness Metric

Impressive deflection of the earth's main field by ~4%



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Auroras are a More Impressive Metric – 17 Mar

Dalton Highway Alaska


Imternational Space Station

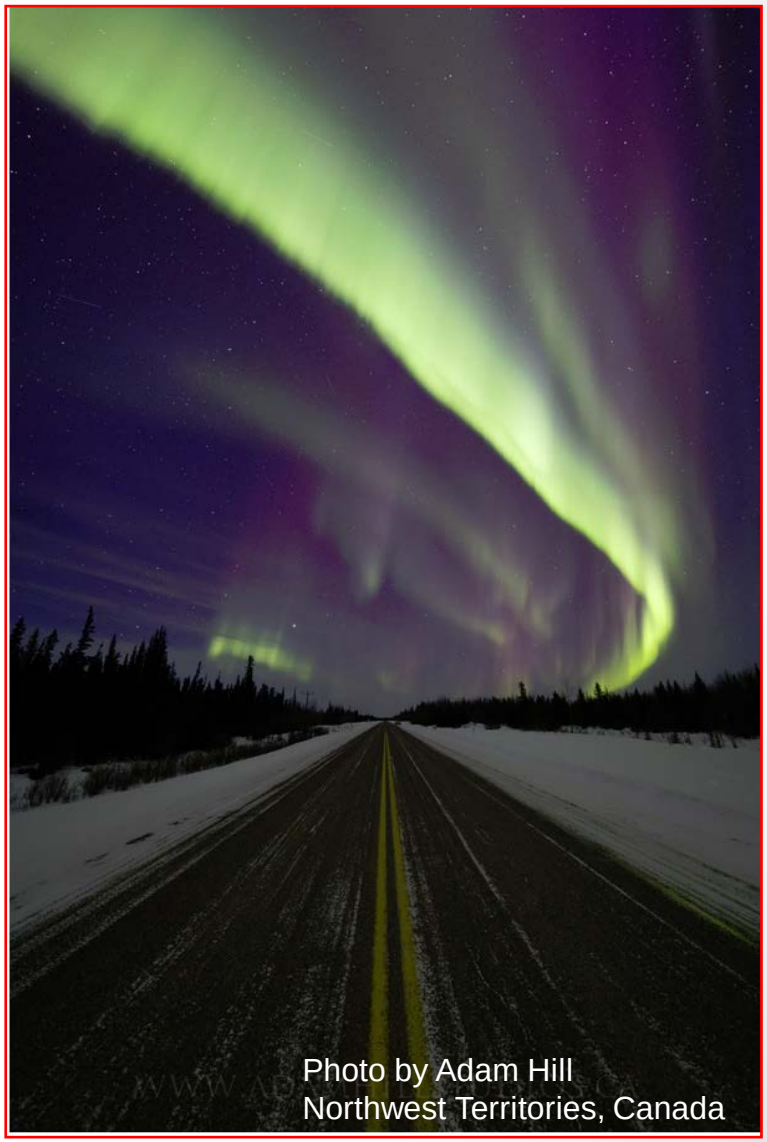
Photo by Adam Hill
Northwest Territories, Canada

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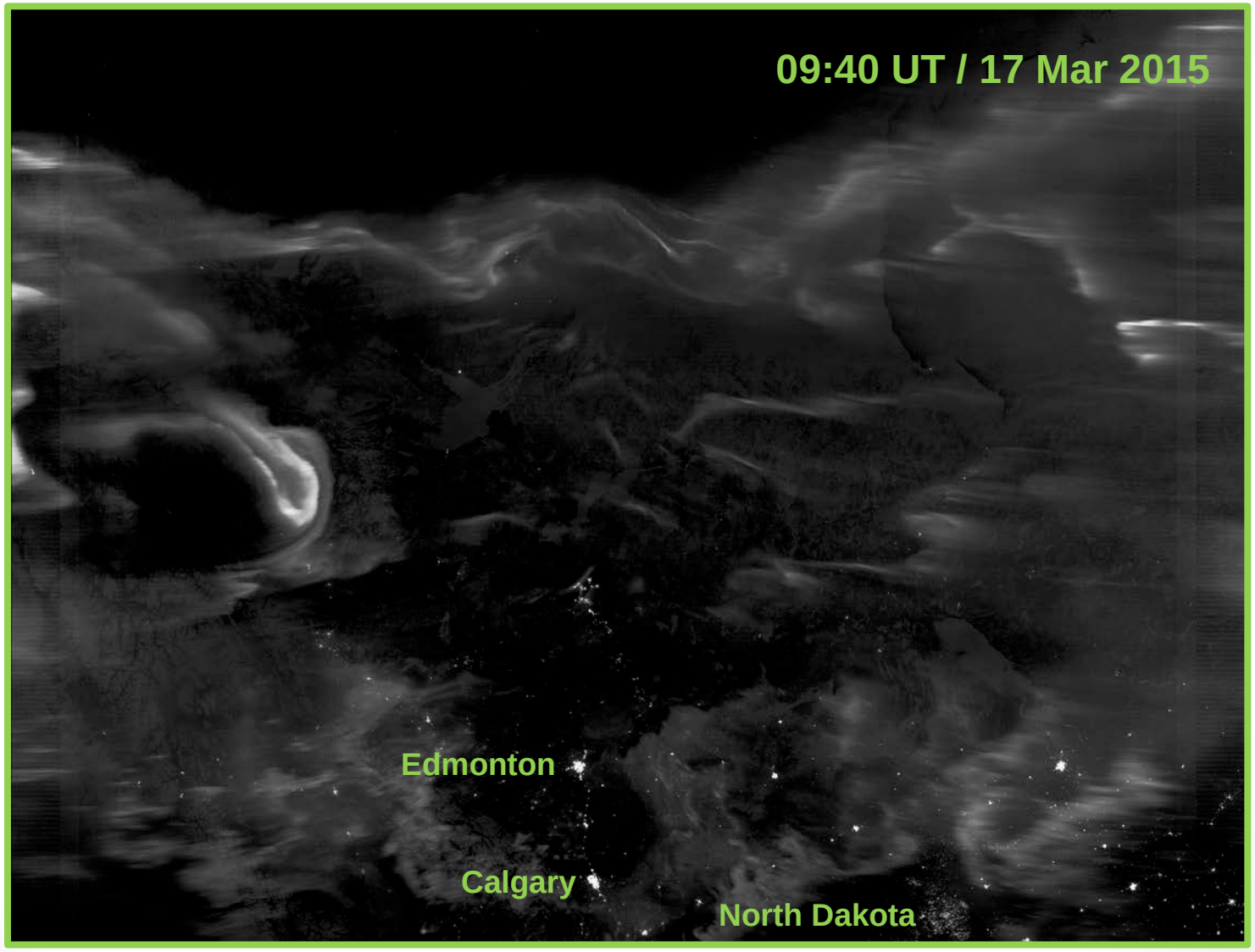
Aurora Over Alberta – NPP/VIIRS – 17 Mar



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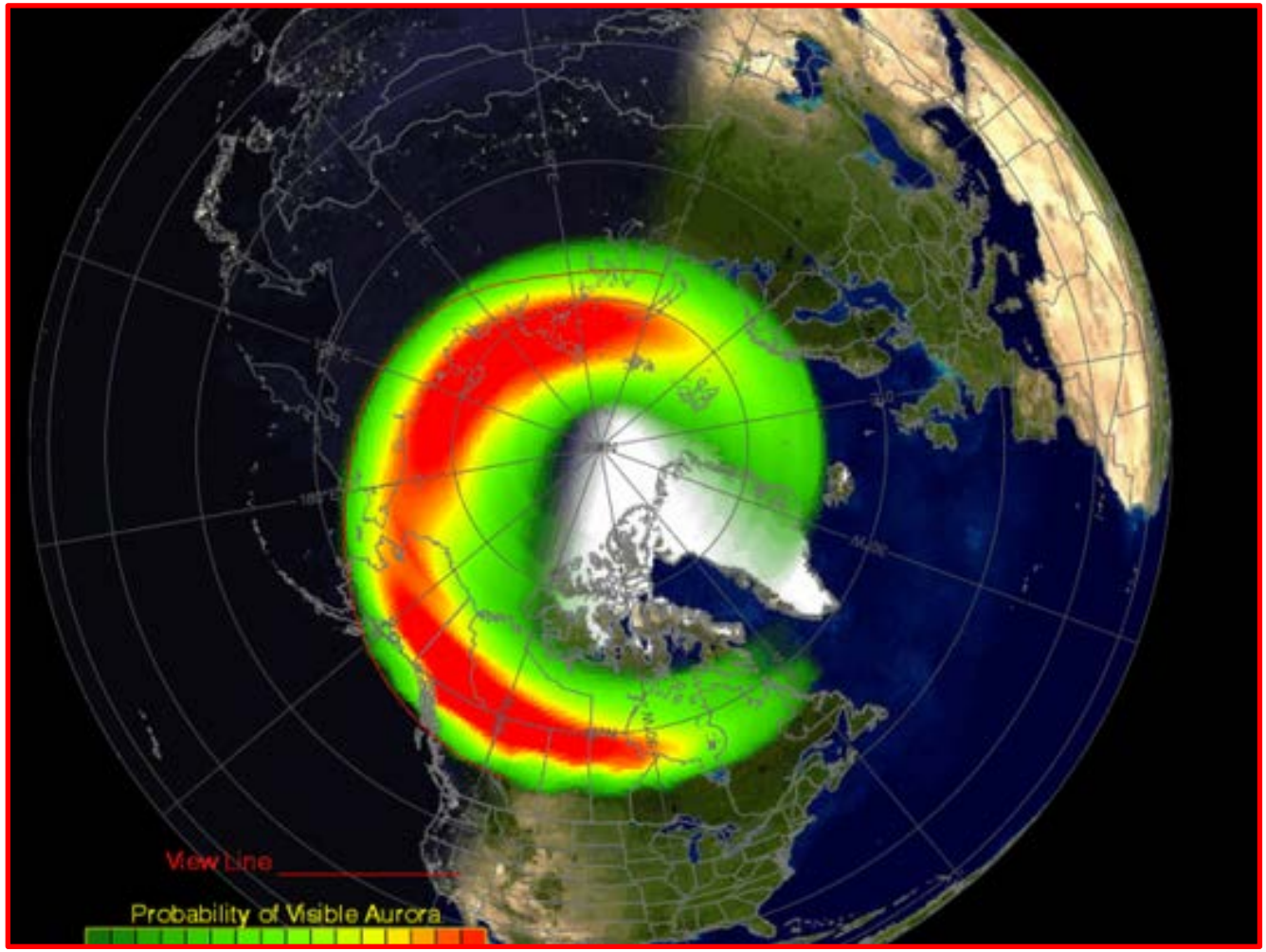
NOAA Predictions of Global Aurora



http://www.swpc.noaa.gov/products/30-minute-aurora-forecast

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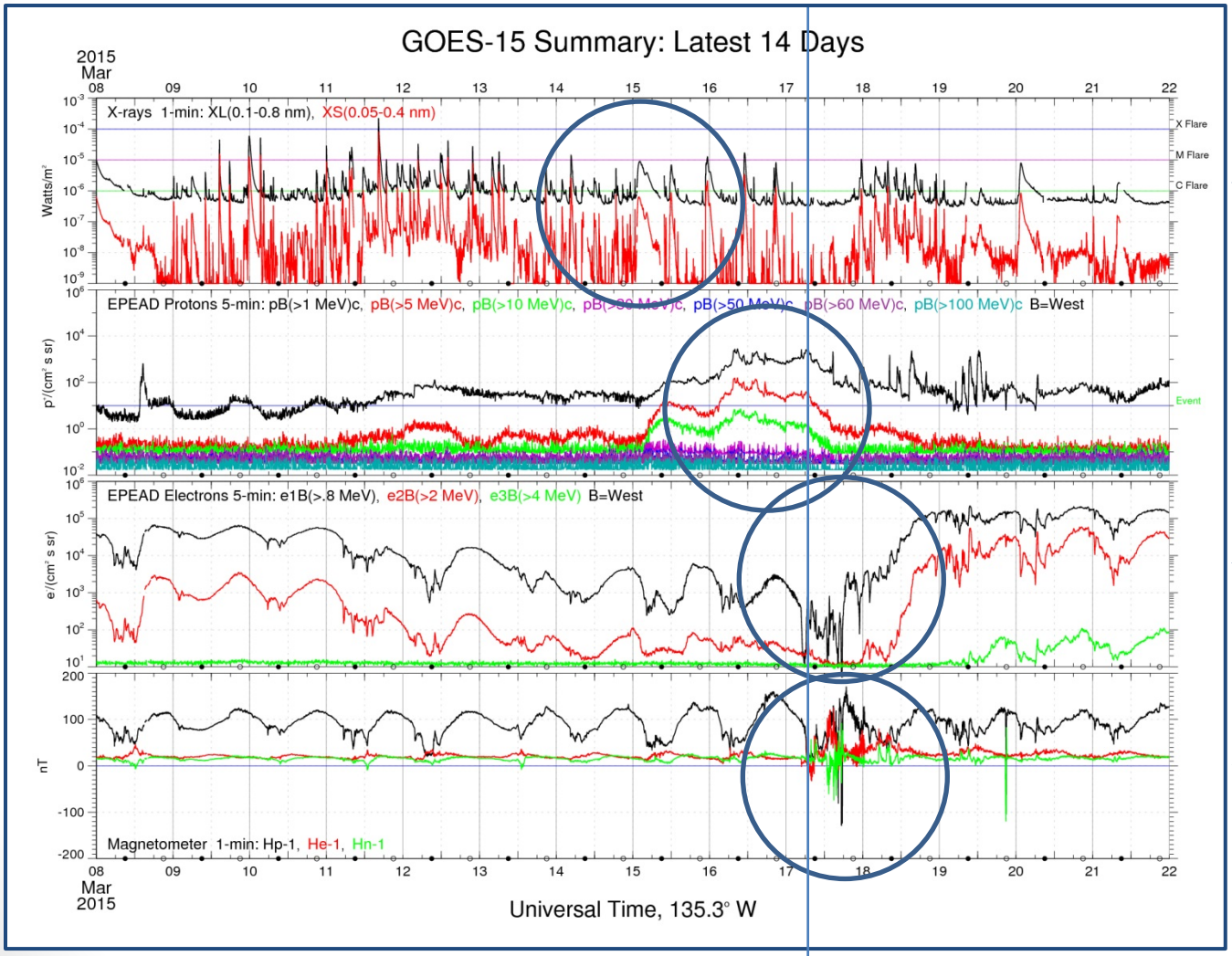
GOES-15 Overview of Space Weather Conditions



X-ray Flare
C9.1
-Weak-

Energetic
Protons
-Modest-

Energetic
Electrons
-Substorm-

B-Field
at GEO

14-Day View

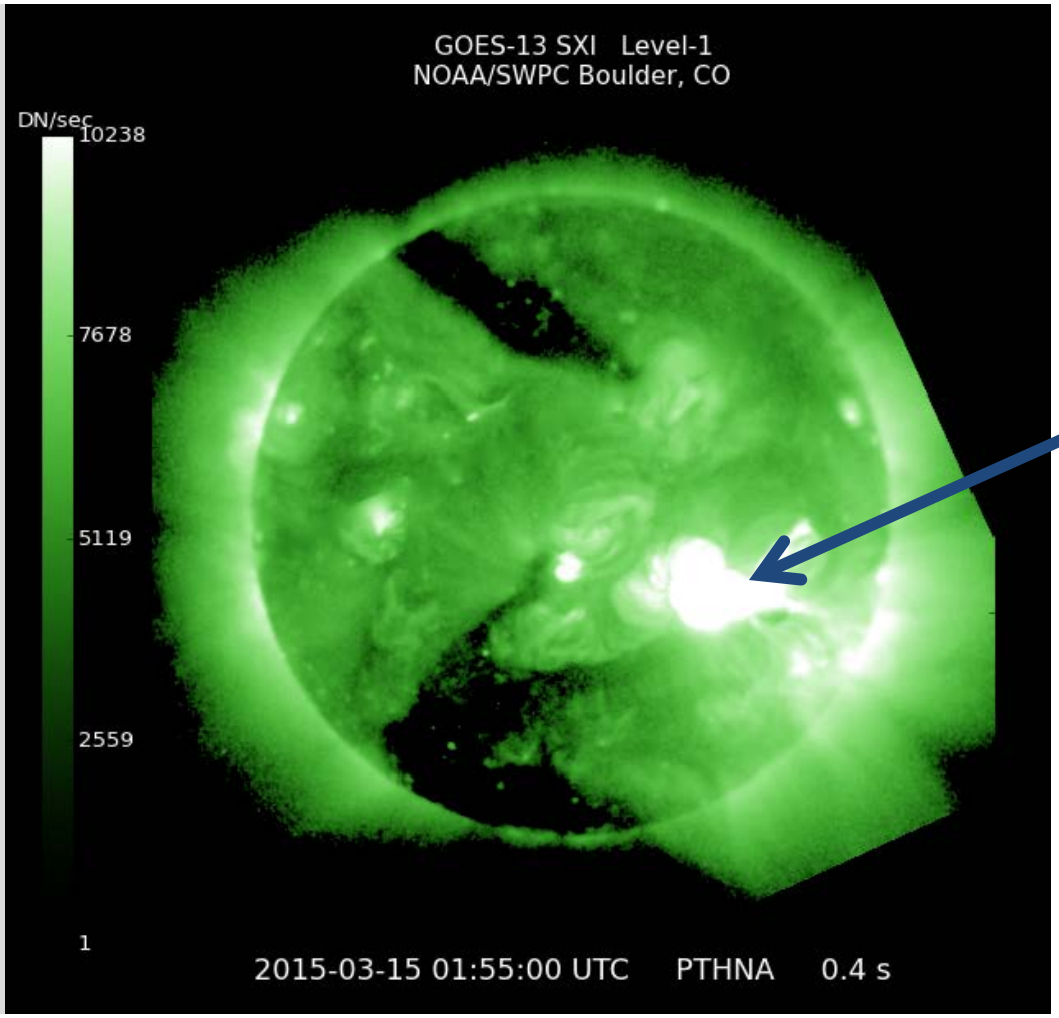
17 Mar

GOES-R Brown Bag Series – 25 March 2015

GOES-R Space Weather Mission

Let's Back Up and Look at the Sun – 15 March

Filter – Thin Poly (poly/Al/Ti): 0.6 – 6 nm
Exposure: 0.4 s



C9 flare from AR 2297 at 01:55 UT

GOES-13 Solar X-Ray Imager – Current Capability

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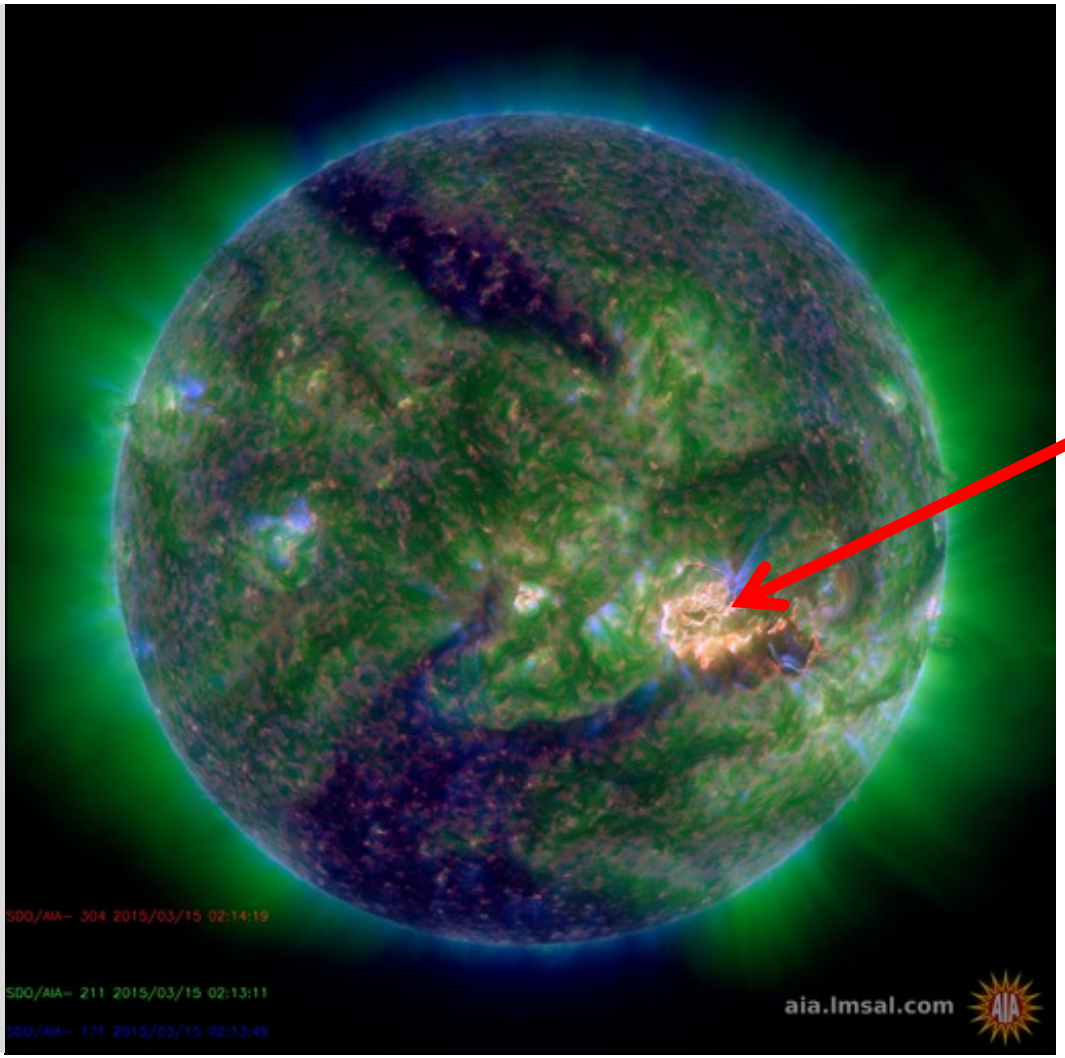
NASA Solar Imagery – SUVI Proxy Data

Solar Dynamics Observatory
AIA Composite: 30.4 nm / 21.1 nm / 17.1 nm



C9 flare from AR 2297 at 02:14 UT

Future Capability – GOES-R Solar UltraViolet Imager

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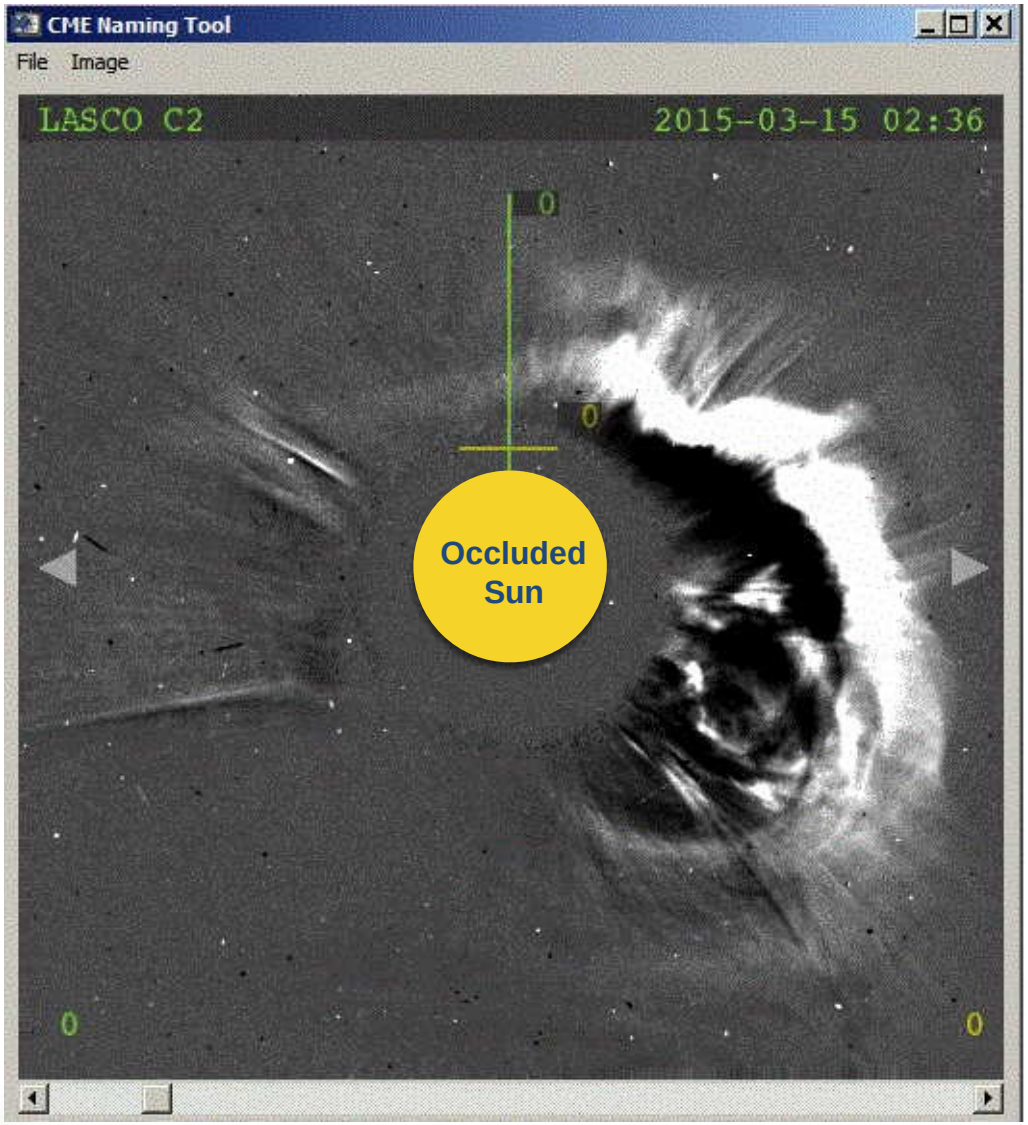
Coronal Mass Ejection – NASA SOHO Image



Coronal Mass Ejection (CME) detected at 02:36 on 15 Mar 2015

NOTE

NOAA plans to included a coronagraph as a part of the DSCOVR follow-on mission

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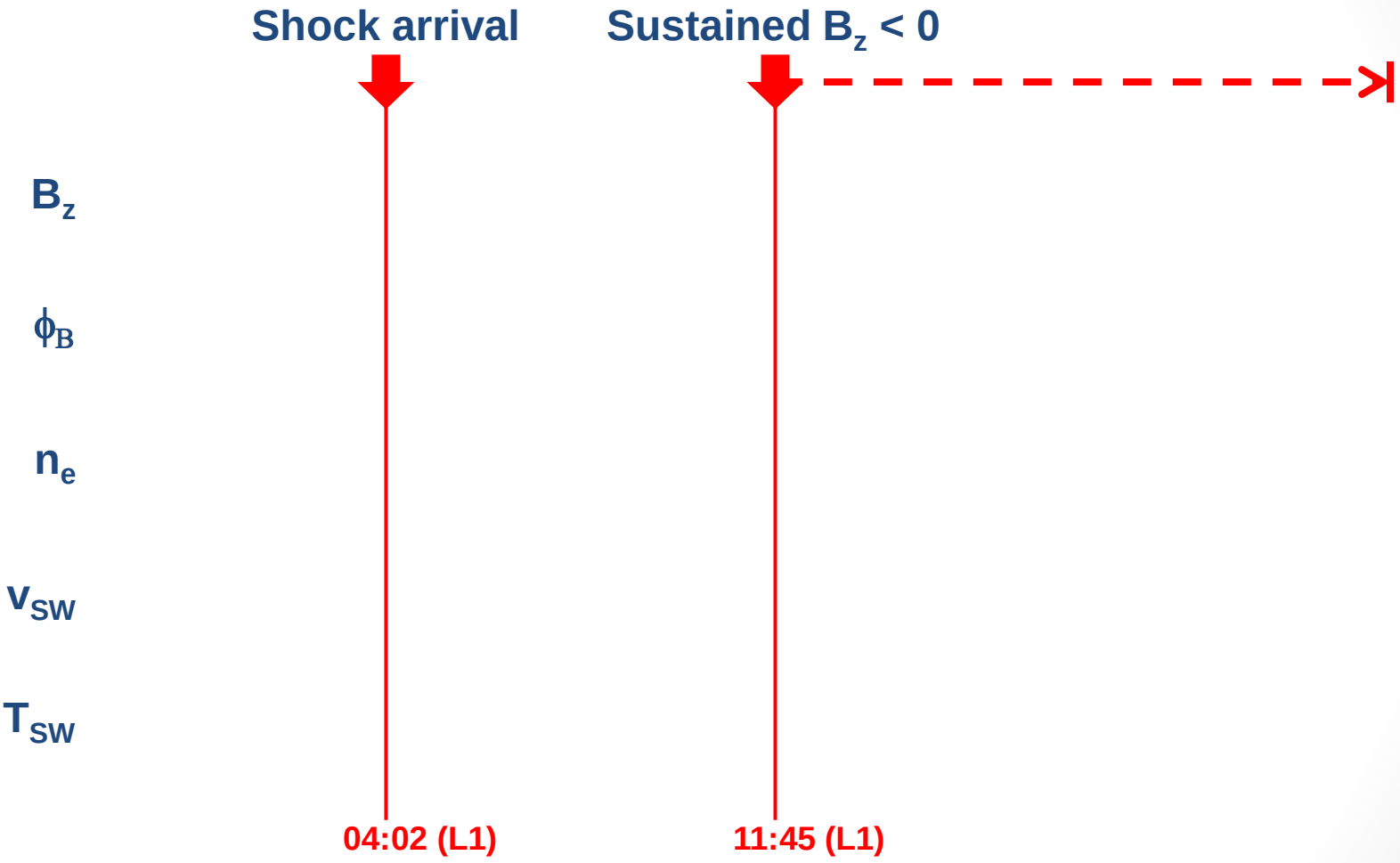
Solar-Wind Measurements – aka DSCOVR (ACE)



Note: Add ~30 minutes to account for transit time (L1 to earth)

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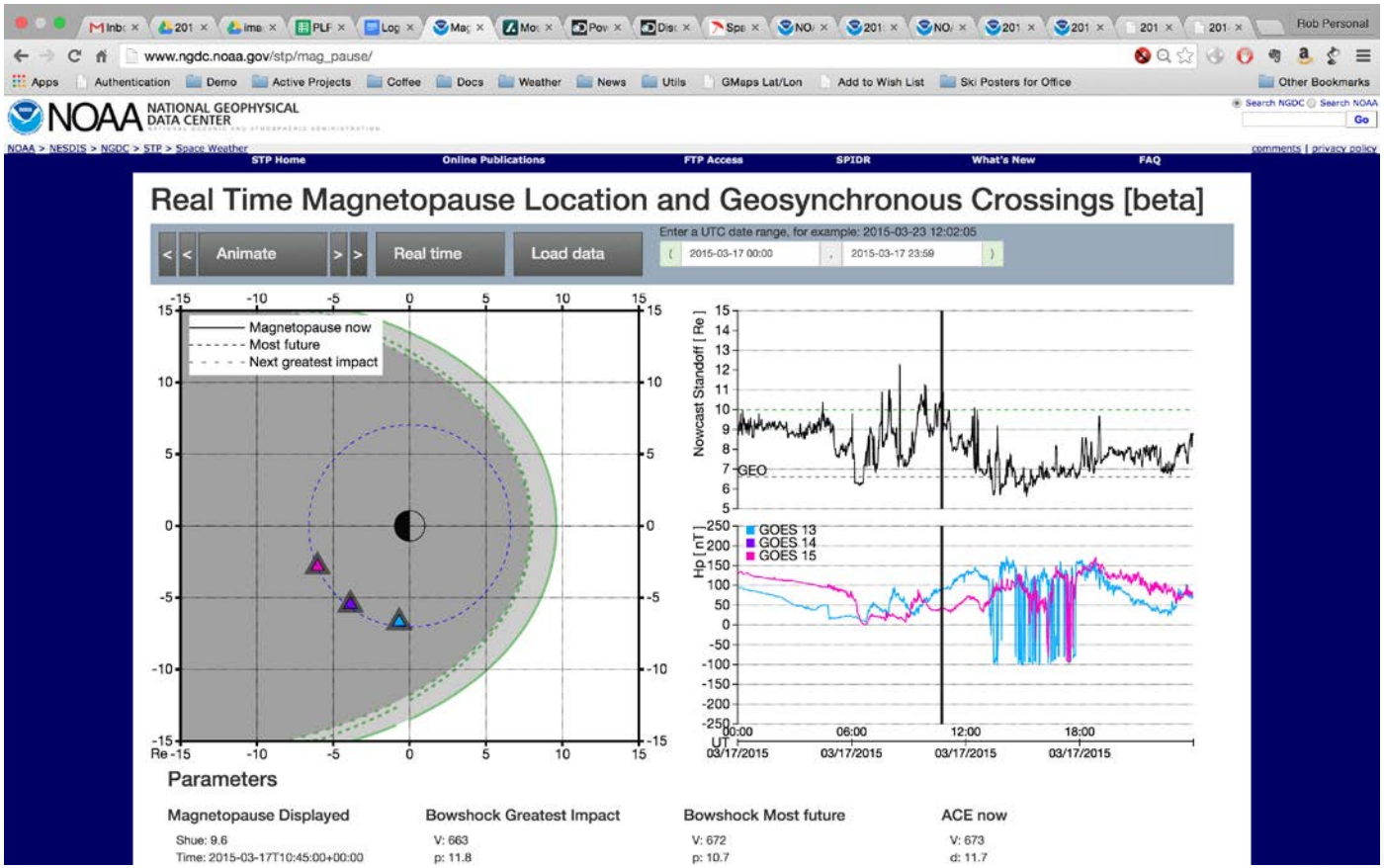
Monitoring the Magnetopause Location

Just after 12:00 UT on Mar 17th the GOES-13 spacecraft left the protective bubble of the magnetosphere and was exposed to interplanetary space. MAG fluctuations indicate crossing of the earth's magnetopause.



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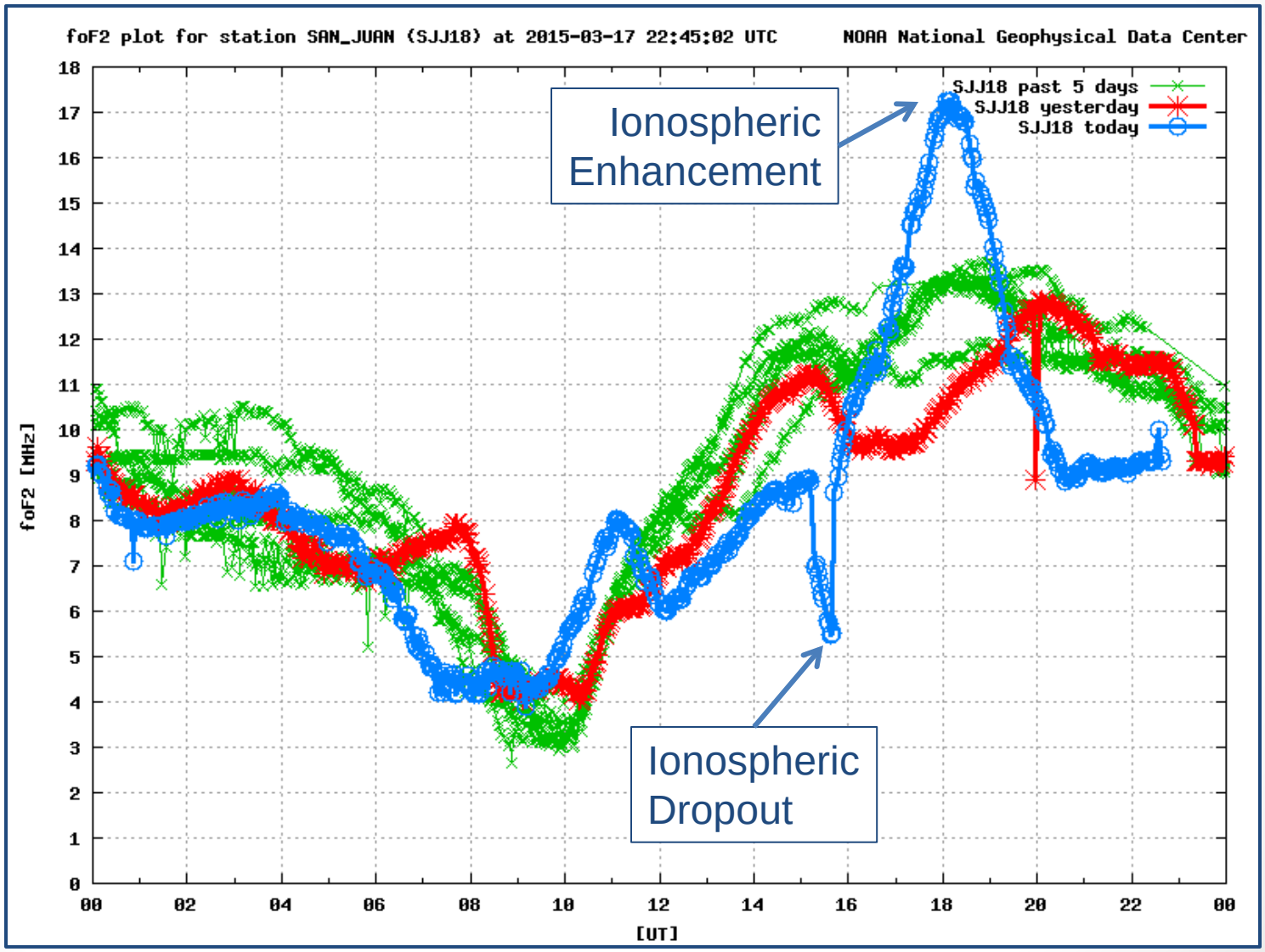
Ionospheric Sounding – San Juan



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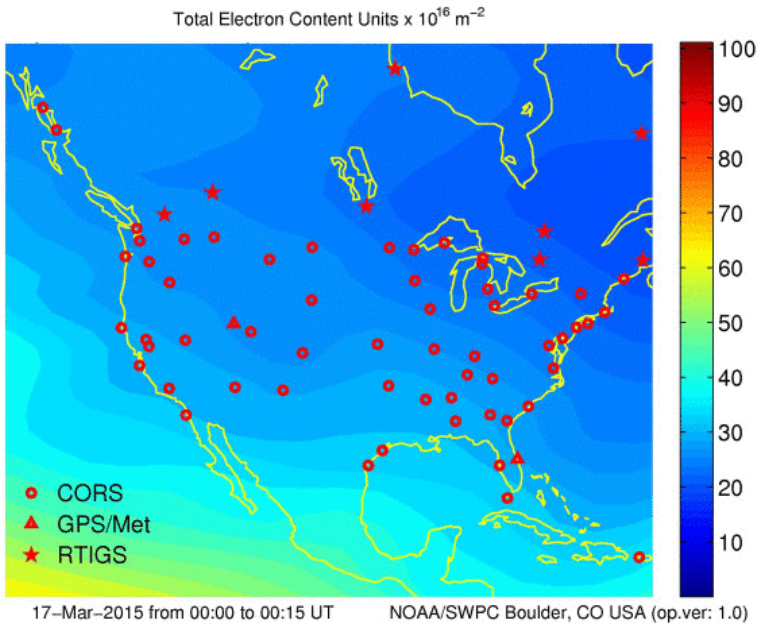
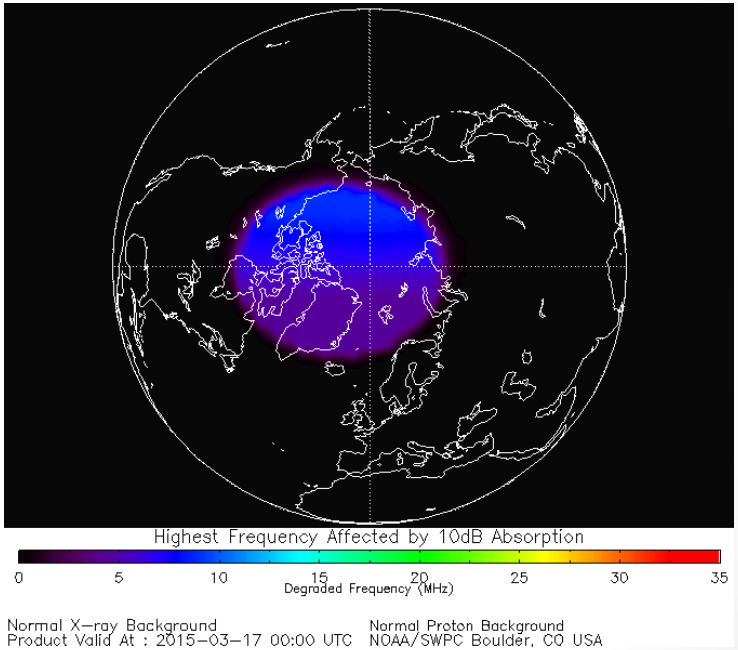
US Total Electron Content (US-TEC)

Data Driven Models of the Ionosphere:

1. Ionospheric density gradients are interesting but not striking
2. Modest increase in radiowave absorption for HF users





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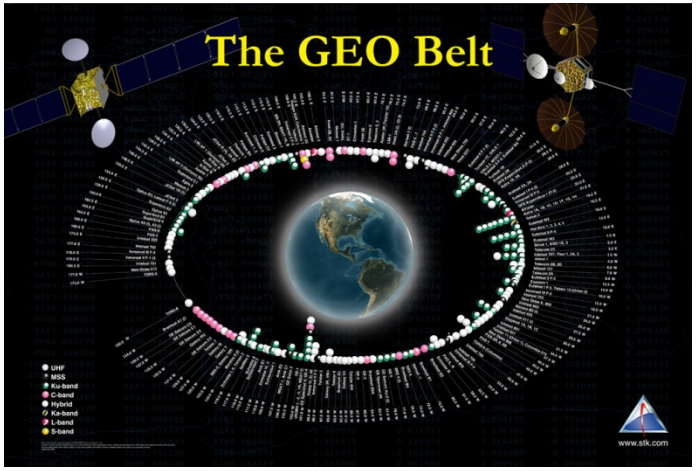
Concluding Thoughts



Today's Technology Infrastructure is Vulnerable to Space Weather (SWx)

- Satellite Systems (Galaxy-15)
- Power Grids (March 1989)
- Manned Spaceflight (EVA)
- Radio Communications (Polar Flights)

GOES-R is a Key Component of NOAA's SWx Program

- Continuing a 40-year Tradition
- In-situ / Remote Sensing
- Improved Sensors/Capabilities
- Launch – 2QFY16

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