GOES-R Space Weather L2+ Algorithms

GOES Science Week

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GOES-R Space Weather

GOES-R Space Weather Team

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Space Weather Forecast Office, Boulder, CO

GOES-R Space Weather

Space Weather L2+ Product Overview

Product Set 1
Complete

- XRS.04: One-minute averages for both long and short channels
- EUVS.03: One-minute averages of broad spectral bands
- SEISS.16: One-minute averages - all MPS channels
- SEISS.17: Five-minute averages - all MPS and SGPS channels
- SEISS.18: Convert differential proton flux values to integral flux values
- MAG.07: MAG data in alternate geophysical coordinate systems
- MAG.08: One-minute averages
- MAG.09: Comparison to quiet fields
- SUVI.07: Composite (wide dynamic range) images
- SUVI.09 and .10: Fixed and running difference images

Product Set 2
Complete

- XRS.05: Calculate the ratio of the short over long channels
- XRS.09: Daily Background
- XRS.07: Event Detection with one-minute data
- EUVS.03D: Daily averages of broad spectral bands
- EUVS.04: Event Detection
- SEISS.19: Density & temperature moments & level of spacecraft charging
- MAG.10: Magnetopause crossing detection
- SUVI.12: Coronal Hole Images
- SUVI.19: Thematic Map

Legacy Product
New Product

Product Set 3
In Process

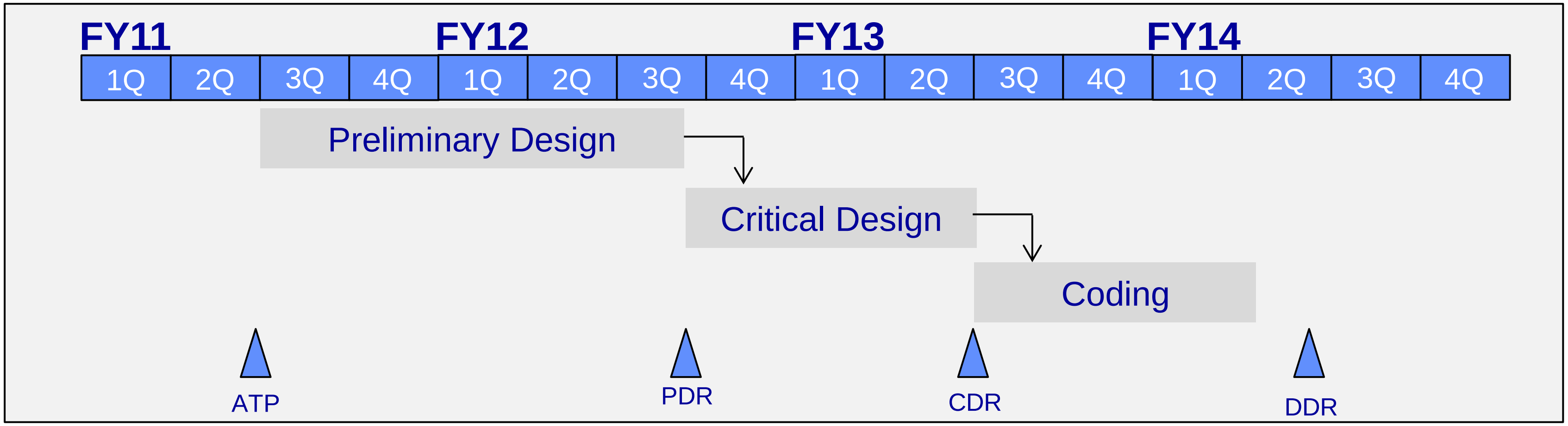
- XRS.10: Flare Location
- EUVS.05: Multi-wavelength Proxy
- SEISS.20: Event detection based on flux values
- MAG.12: Sudden Impulse (SI) detection
- SUVI.13: Bright Region Data
- SUVI.14: Flare Location (XFL) Reports
- SUVI.15: Coronal Hole Boundaries

Algorithms leverage new sensor capabilities and extended environmental ranges.

- 26 Level 2+ Space Weather Products in three product sets
- 18 are operational legacy, 8 are new or have experimental heritage

GOES-R Space Weather
Product Set 3 – Schedule

Product	Description	PDR	CDR	DDR
XRS.10	Flare Location	08/2012	3QFY13	2QFY14
EUVS.05	Multi-wavelength Proxy	08/2012	3QFY13	2QFY14
SEISS.20	Event Detection	08/2012	3QFY13	2QFY14
MAG.12	Sudden Impulse Detection	08/2012	3QFY13	2QFY14
SUVI.13	Bright Region Data	08/2012	3QFY13	2QFY14
SUVI.14	Flare Location Reports	08/2012	3QFY13	2QFY14
SUVI.15	Coronal Hole Boundaries	08/2012	3QFY13	2QFY14



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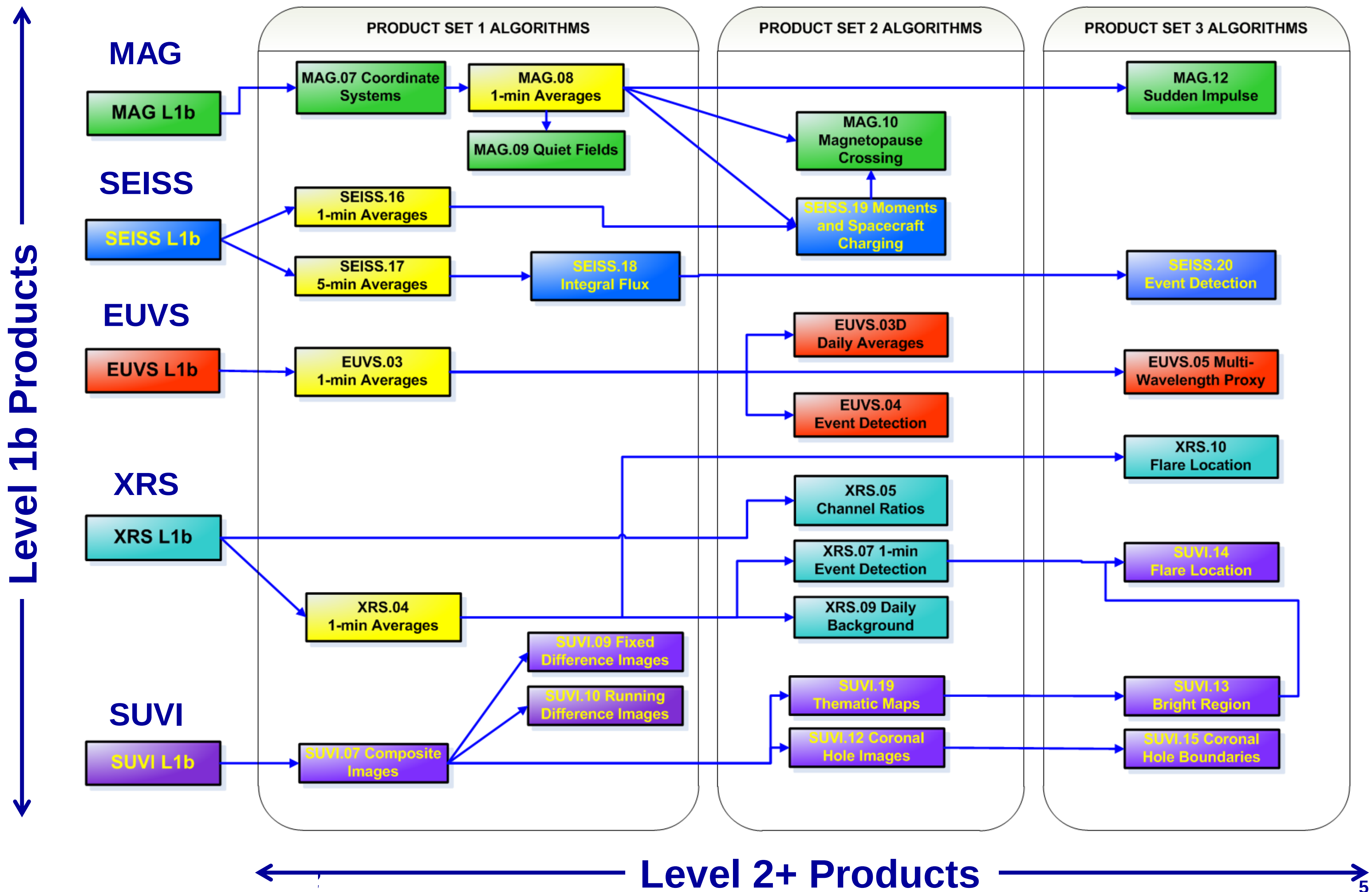
Product L1b/L2+ Interdependencies



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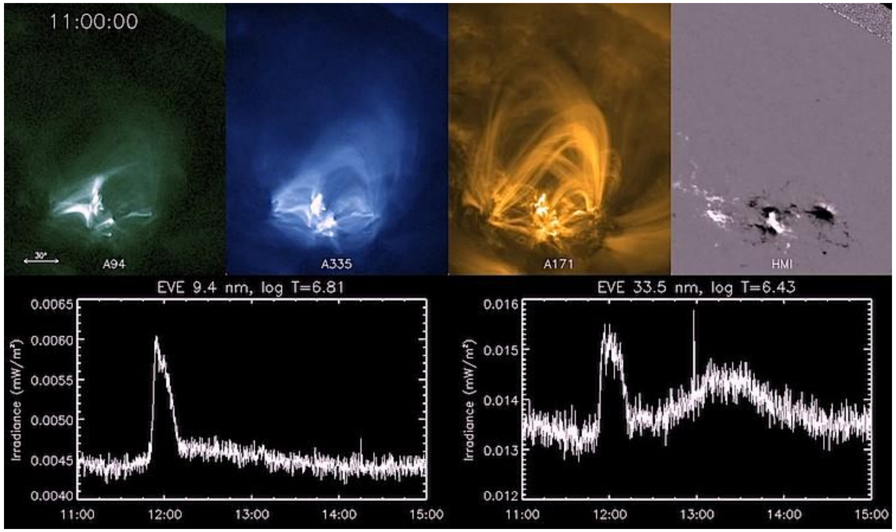
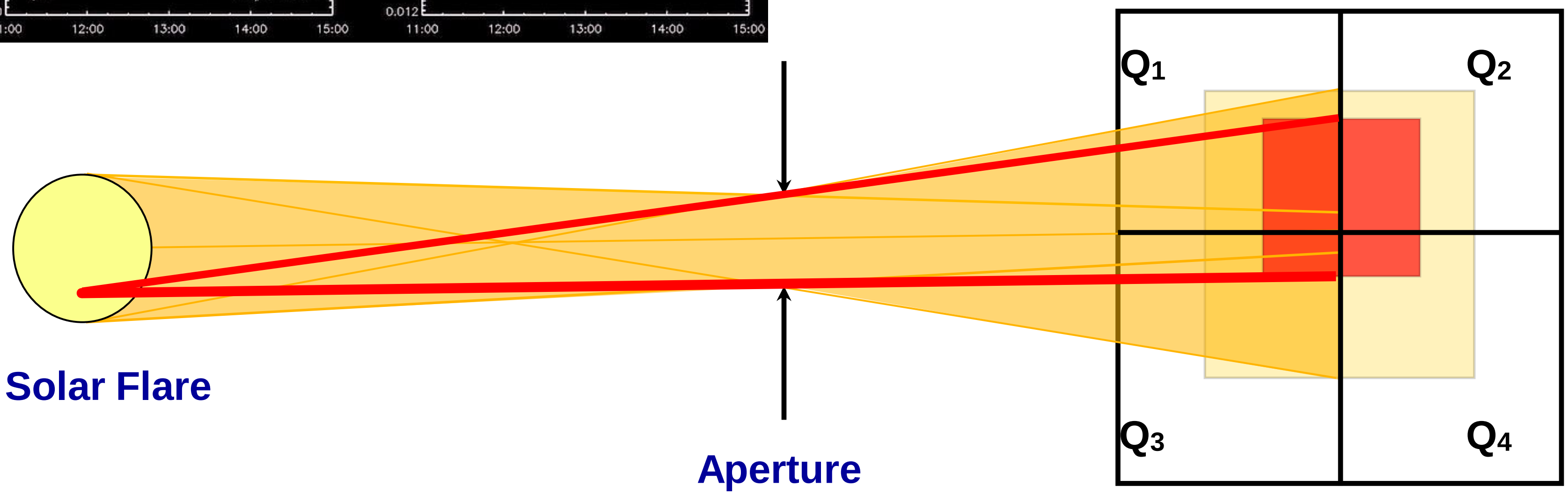
XRS.10 Flare Location

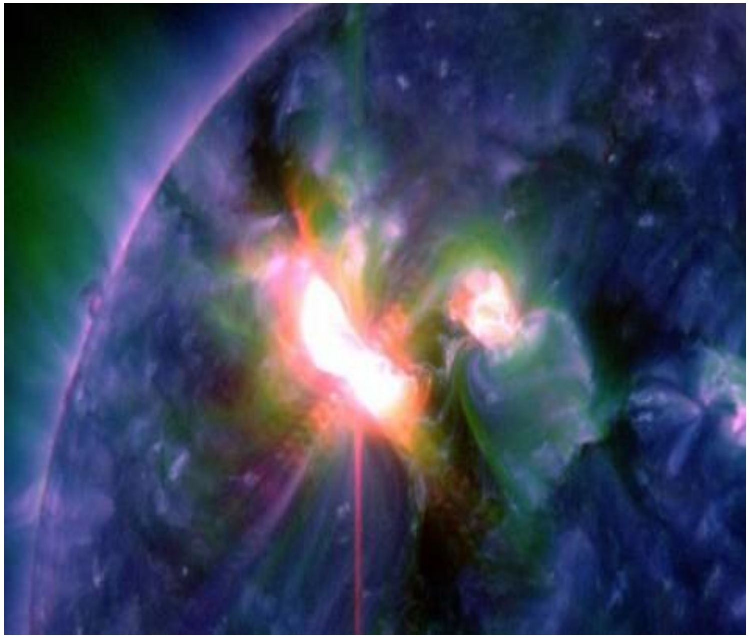


New quad-diode XRS design will provide an ability to locate solar flares on the disk. Algorithm will automate the locations of solar flares to aid in predicting impacts to earth-based and satellite systems. Proxy data from the GOES SXI and/or SDO EVE will be used to develop this new approach.

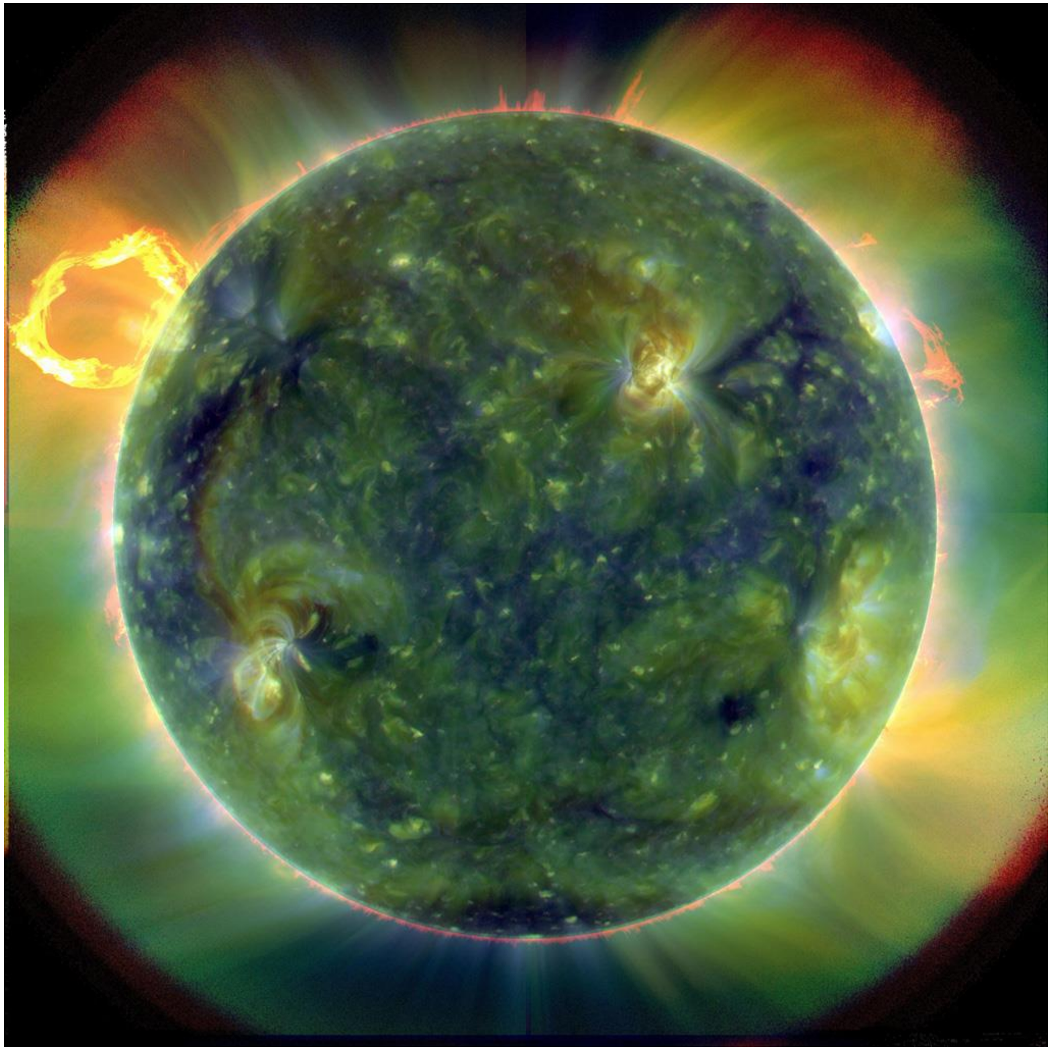


GOES-R Space Weather
EUVS.05 Multi-Wavelength Proxy

EUVS measurements within three spectral regions in the extreme ultra-violet (EUV) to monitor solar emissions from the chromosphere, transition region, and the corona. Algorithm will regenerate the full EUV spectrum via a bootstrap technique. Proxy data provided from the SDO EVE and the SORCE SOLSTICE sensors.



Solar Flare – 07 Mar 12



EUV Composite Solar Image

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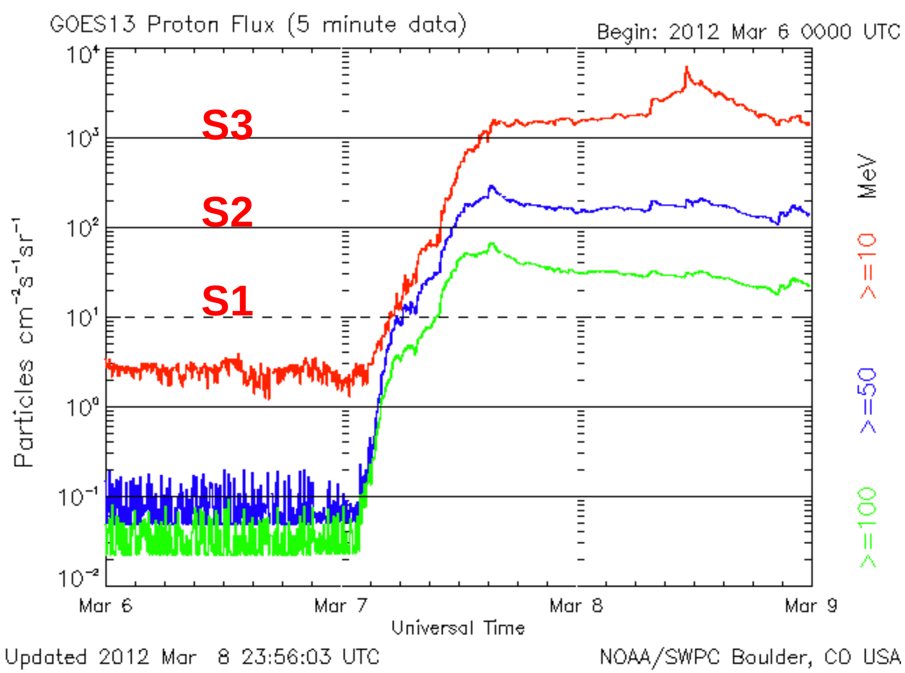
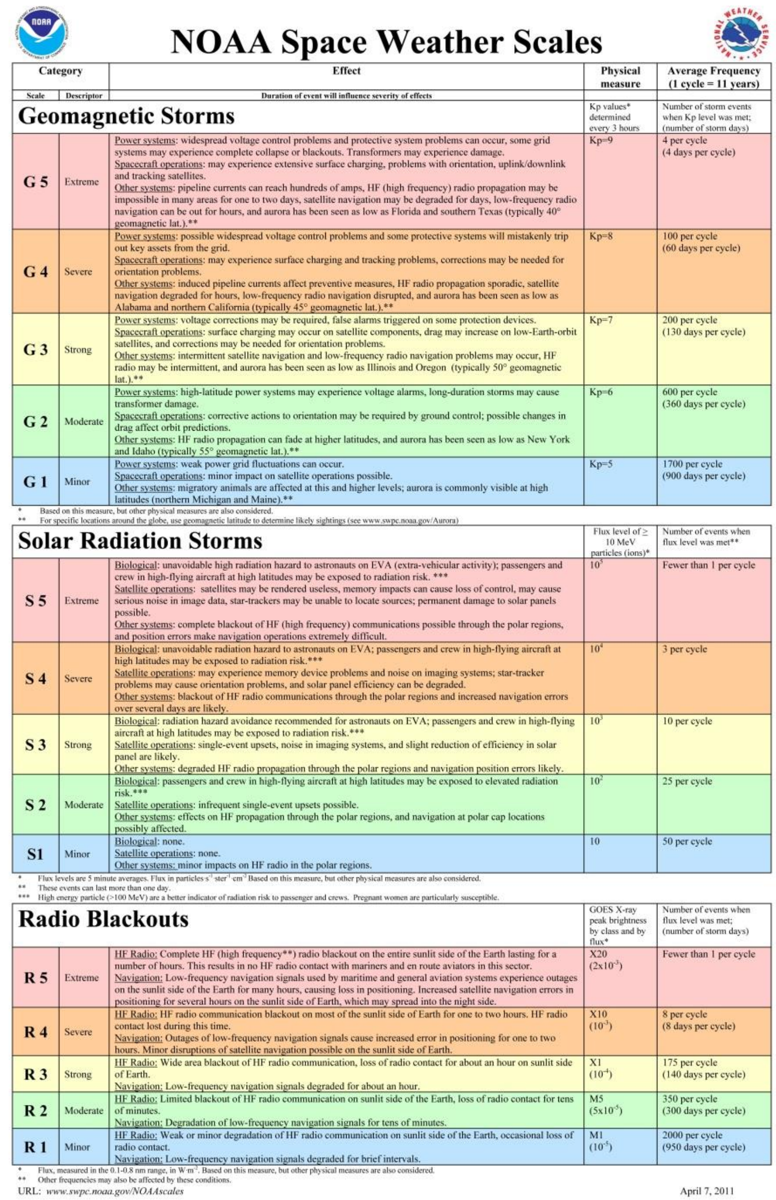
SEISS.20 Event Detection

Algorithm will report all event detection parameters, peak fluxes and event fluences based on SEISS SGPS measurements. Adding a rate of rise quantity to the event onset detection will enhance the algorithm's prediction capabilities.





NOAA Space Weather Scales

Category: Scale	Category: Descriptor	Effect (Duration of event will influence severity of effects)	Physical measure	Average Frequency (1 cycle = 11 years)
Geomagnetic Storms			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)

* Based on this measure, but other physical measures are also considered.
** For specific locations around the globe, use geomagnetic latitude to determine likely sightings (see www.swpc.noaa.gov/Aurora)

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. *** Satellite operations: satellites may be rendered useless, memory impacts can cause loss of control, may cause serious noise in image data, star-trackers may be unable to locate sources; permanent damage to solar panels possible. Other systems: complete blackout of HF (high frequency) communications possible through the polar regions, and position errors make navigation operations extremely difficult.	10^5	Fewer than 1 per cycle
S 4	Severe	Biological: unavoidable radiation hazard to astronauts on EVA; passengers and crew in high-flying aircraft at high latitudes may be exposed to radiation risk.*** Satellite operations: may experience memory device problems and noise on imaging systems; star-tracker problems may cause orientation problems, and solar panel efficiency can be degraded. Other systems: blackout of HF radio communications through the polar regions and increased navigation errors over several days are likely.	10^4	3 per cycle
S 3	Strong	Biological: radiation hazard avoidance recommended for astronauts on EVA; passengers and crew in high-flying aircraft at high latitudes may be exposed to radiation risk.*** Satellite operations: single-event upsets, noise in imaging systems, and slight reduction of efficiency in solar panel are likely. Other systems: degraded HF radio propagation through the polar regions and navigation position errors likely.	10^3	10 per cycle
S 2	Moderate	Biological: passengers and crew in high-flying aircraft at high latitudes may be exposed to elevated radiation risk.*** Satellite operations: infrequent single-event upsets possible. Other systems: effects on HF propagation through the polar regions, and navigation at polar cap locations possibly affected.	10^2	25 per cycle
S1	Minor	Biological: none. Satellite operations: none. Other systems: minor impacts on HF radio in the polar regions.	10	50 per cycle

* Flux levels are 5 minute averages. Flux in particles·s^{-1}·ster^{-1}·cm^{-2} Based on this measure, but other physical measures are also considered.
** These events can last more than one day.
*** High energy particle (>100 MeV) are a better indicator of radiation risk to passenger and crews. Pregnant women are particularly susceptible.

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	Extreme	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. Navigation: Low-frequency navigation signals used by maritime and general aviation systems experience outages on the sunlit side of the Earth for many hours, causing loss in positioning. Increased satellite navigation errors in positioning for several hours on the sunlit side of Earth, which may spread into the night side.	X20 ($2x10^{-3}$)	Fewer than 1 per cycle
R 4	Severe	HF Radio: HF radio communication blackout on most of the sunlit side of Earth for one to two hours. HF radio contact lost during this time. Navigation: Outages of low-frequency navigation signals cause increased error in positioning for one to two hours. Minor disruptions of satellite navigation possible on the sunlit side of Earth.	X10 (10^{-3})	8 per cycle (8 days per cycle)
R 3	Strong	HF Radio: Wide area blackout of HF radio communication, loss of radio contact for about an hour on sunlit side of Earth. Navigation: Low-frequency navigation signals degraded for about an hour.	X1 (10^{-4})	175 per cycle (140 days per cycle)
R 2	Moderate	HF Radio: Limited blackout of HF radio communication on sunlit side of the Earth, loss of radio contact for tens of minutes. Navigation: Degradation of low-frequency navigation signals for tens of minutes.	M5 ($5x10^{-5}$)	350 per cycle (300 days per cycle)
R 1	Minor	HF Radio: Weak or minor degradation of HF radio communication on sunlit side of the Earth, occasional loss of radio contact. Navigation: Low-frequency navigation signals degraded for brief intervals.	M1 (10^{-5})	2000 per cycle (950 days per cycle)

* Flux, measured in the 0.1-0.8 nm range, in W·m^{-2}. Based on this measure, but other physical measures are also considered.
** Other frequencies may also be affected by these conditions.

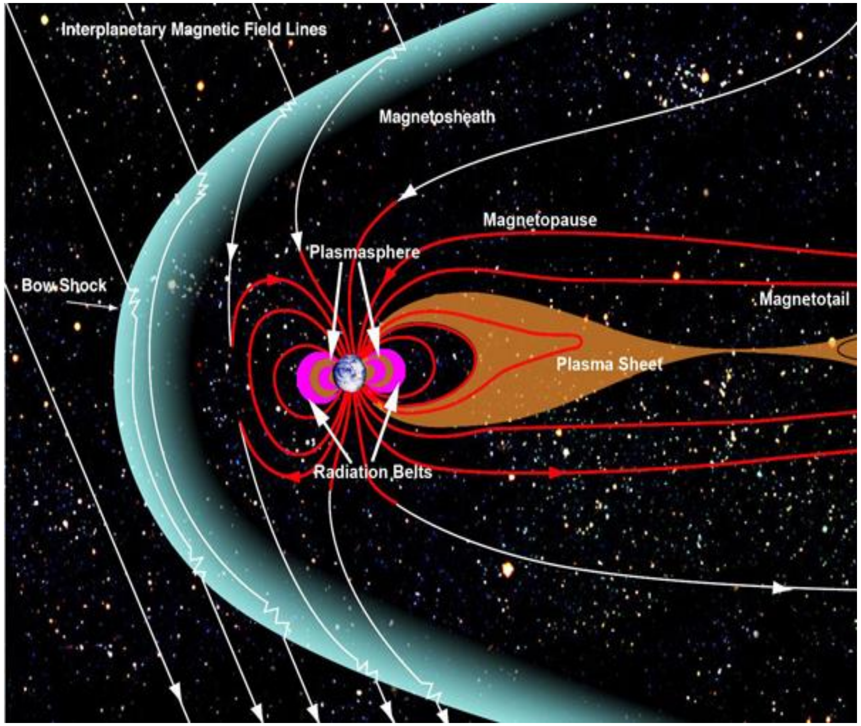
URL: *www.swpc.noaa.gov/NOAAscales*

April 7, 2011

GOES-R Space Weather

MAG.12 Sudden Impulse Detection

Algorithm to detect impulsive magnetospheric events. GOES-R data to be used in conjunction with ground magnetometer observations to detect events. Outputs used for SWPC geomagnetic storm warning.



Geomagnetic Storms			Kp values* determined every 3 hours	Number of storm events when Kp level was met; (number of storm days)
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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)
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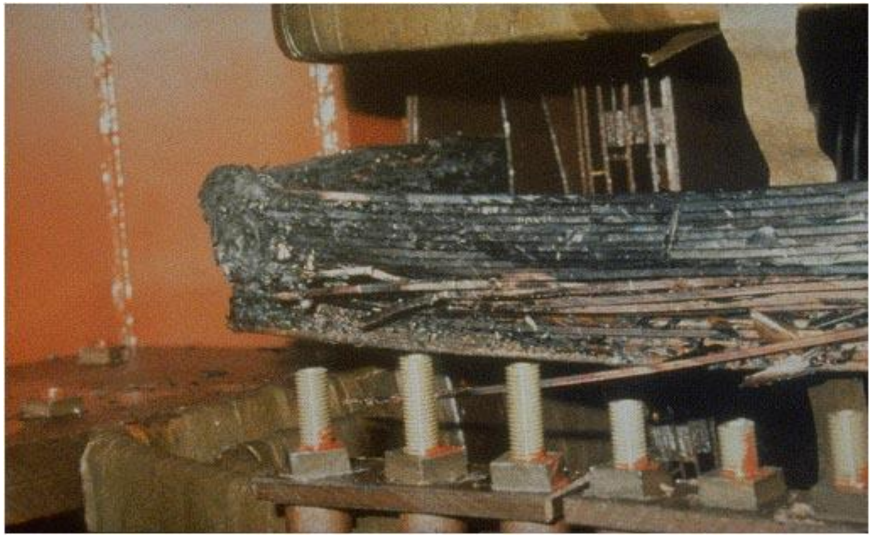
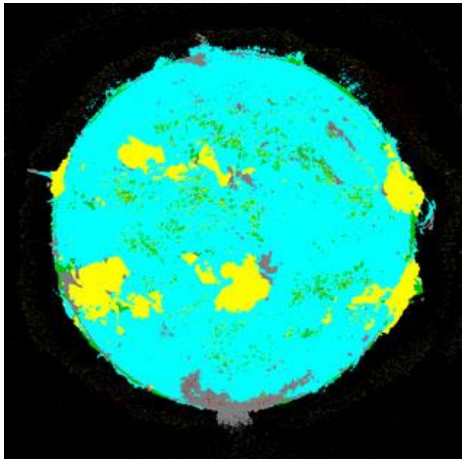


Destroyed Power Transformer – March 1989

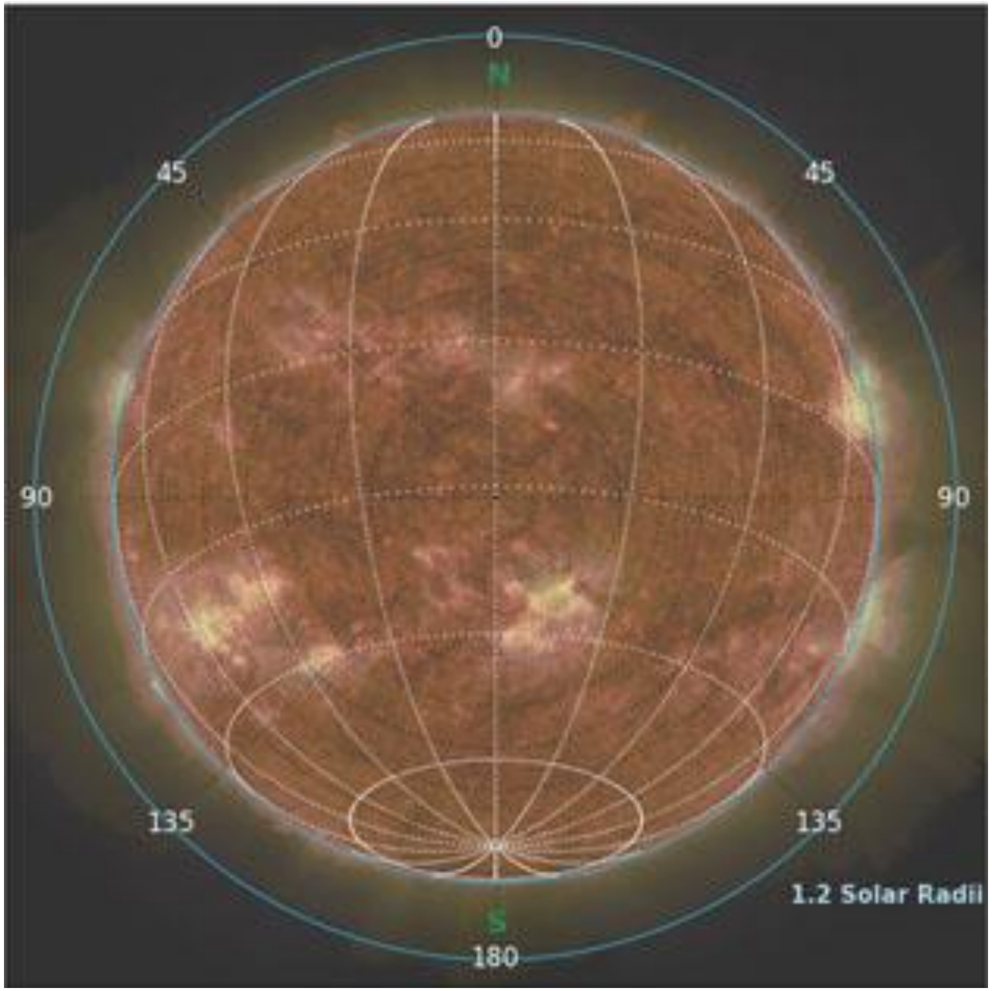
GOES-R Space Weather
SUVI.13 – 15 Solar Features

SUVI.13 – Bright Regions (Faculae)
SUVI.14 – Solar Flare Locations
SUVI.15 – Coronal Hole Boundaries

Thematic maps will be used to automate the identification and location of bright regions, flares and coronal hole boundaries in solar images. For on-disk features, locations specified in helio-graphic coordinates (i.e. the lat/lon grid). For off-disk features, a radius from solar center and angle from solar north is used.



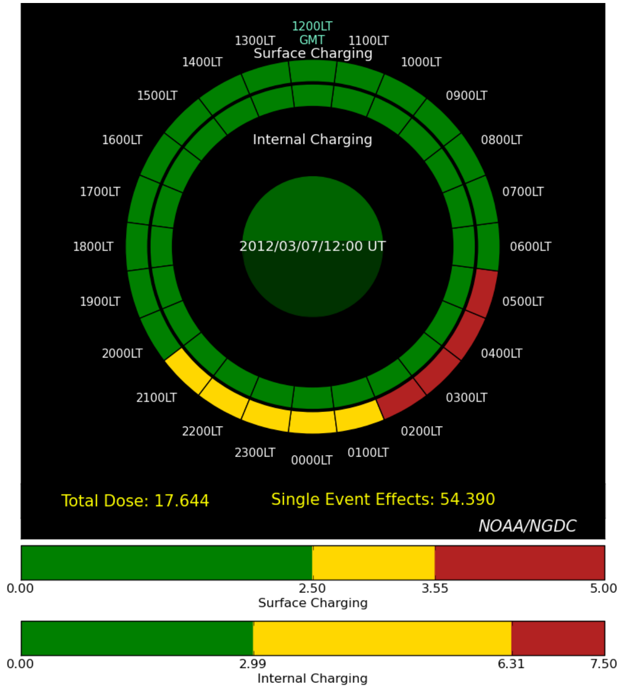
Thematic Map
2012-04-30 12:04 UT

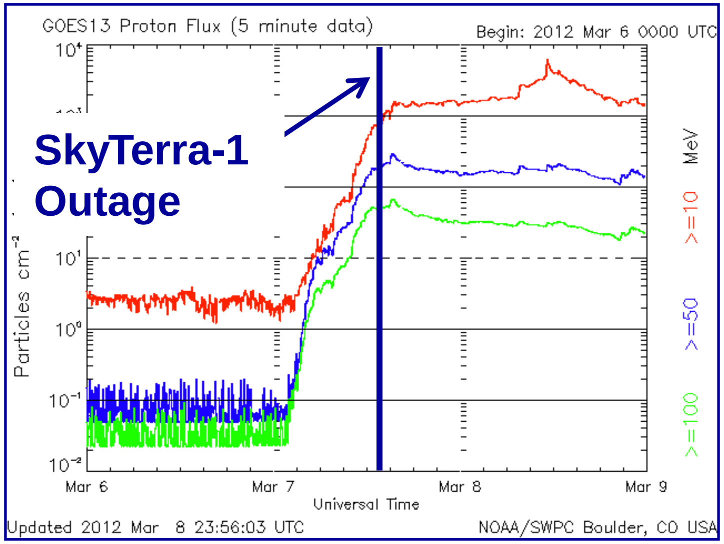


Solar Geometry

Leveraged Development
Environmental Assessments

On March 7th, 2012 the SkyTerra-1 satellite suffered an anomaly causing a COMM outage that adversely impacted homeland security readiness. Using tools developed under the GOES-RRR/AR program, NGDC conducted an environmental assessment that showed that the SkyTerra-1 was at increased risk of experiencing a Single Event Upset (SEU) .





GOES-R Space Weather
Overall Status

- GOES-R Risk Reduction activities are researching and developing operational algorithms for existing and new space weather products
  - User requirements for improved GOES-R space weather products have presented challenges requiring new approaches and algorithms for processing and interpreting the sensor data
  - Product Sets 1 and 2 are complete with completion of 20 of 27 science algorithms completed to date
  - Product Set 3 algorithm research and development is well underway with PDR expected in late summer
- Metadata and archival requirements definition efforts have been supported by the core team
- Team has also been heavily involved in calibration and validation activities needed for the space weather sensors