GOES Data and Products in the Space Weather Prediction Center and National Geophysical Data Center

Mary Shouldis

Satellite Data Product Development Team Lead
NGDC/University of Colorado/CIRES

Putting Science to Work to Protect the Nation's Technologies from Space Weather

NOAA Space Weather Prediction Center

(established in 1946)

The Space Weather Prediction Center:

- Three Primary Functions
  - Forecast Office operating 24/7

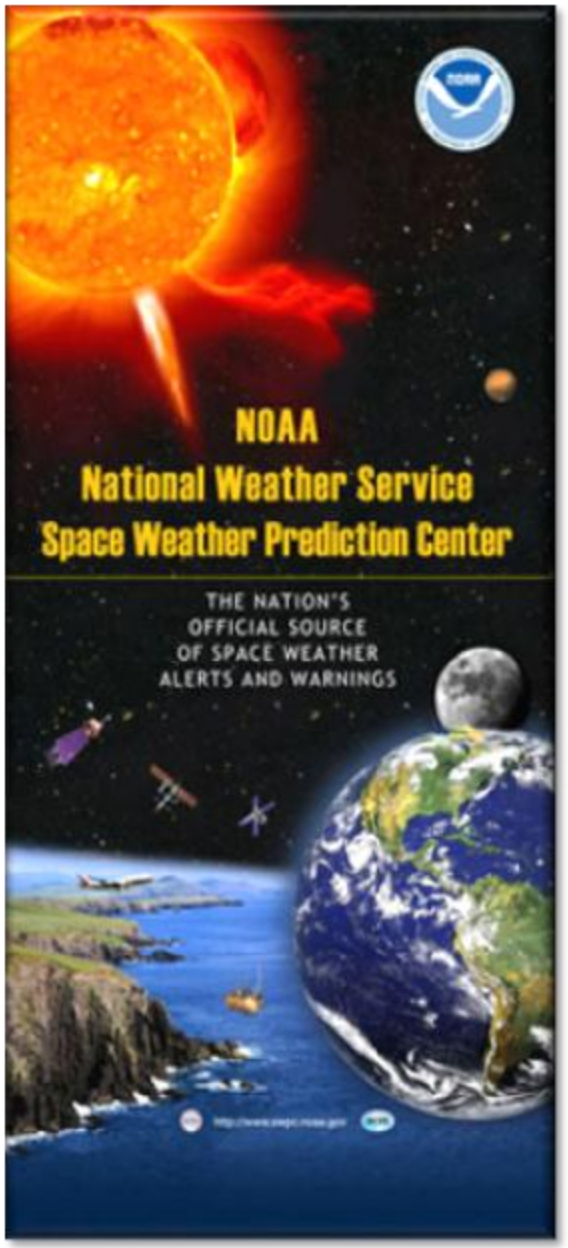
The Nation's official source of space weather alerts, watches and warnings

  - Research: Developing new models and products in solar, heliosphere, magnetosphere, thermosphere, ionosphere
  - Transition: Moving models and products from Research to Operations

A "National Critical System" in the National Weather Service

Providing Support to…

- Electric Power Industry
- Commercial Airlines
- GPS users such as oil exploration, aviation, agriculture, surveying…
- Aerospace and satellite industries
- Other government agencies
  - FAA and commercial airlines
  - FEMA and emergency preparedness
  - NASA and the Nation's space exploration programs
  - DOD, the Air Force Weather Agency, and Space Command



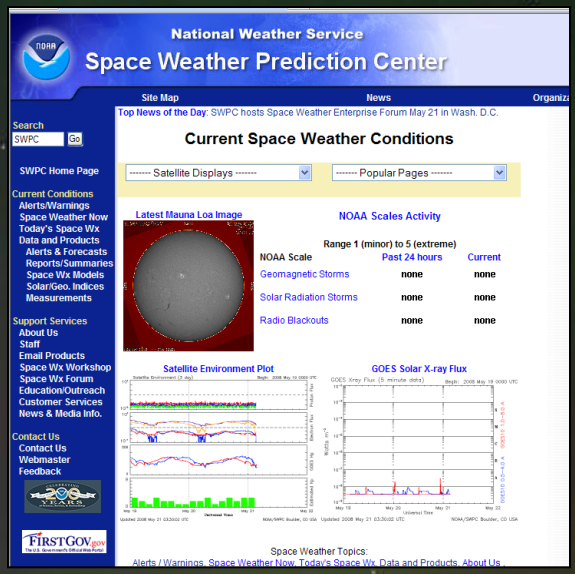
NOAA Space Weather Prediction Center

Boulder, Colorado

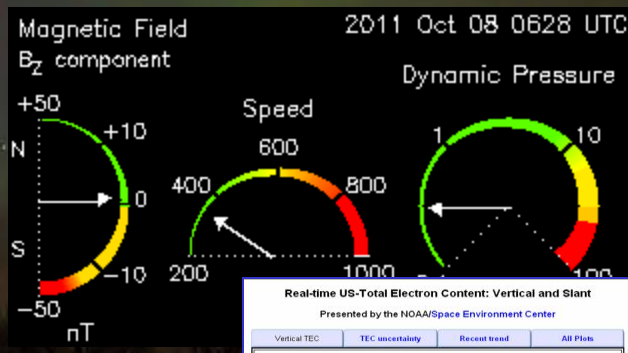
Space Weather Products and Services

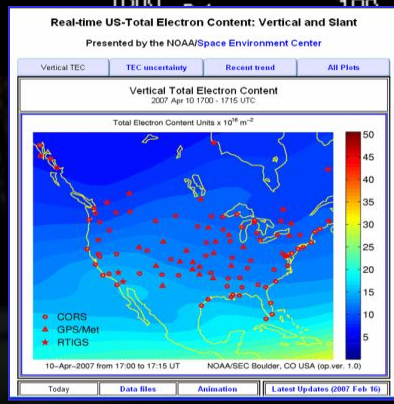
- Specifications: What are the current conditions?
- Forecast: What will conditions be tomorrow?
- Watches: The conditions are favorable for storm
- Warnings: Storm is imminent, expected in the near future with high probability
- Alerts: Observed conditions meeting or exceeding storm thresholds

Web Services



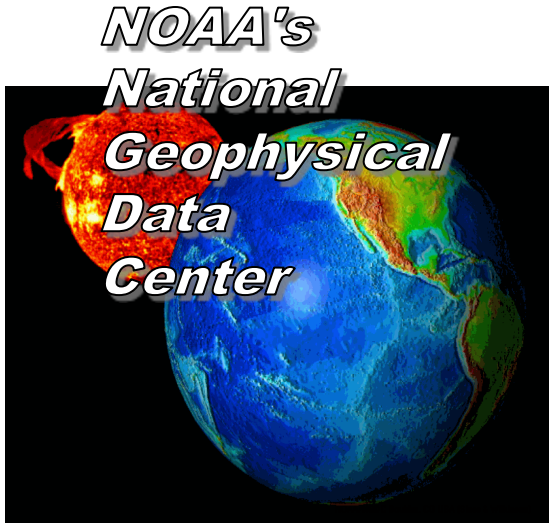
Model Outputs





www.spaceweather.gov

NOAA National Geophysical Data Center (NGDC)
Solar & Terrestrial Physics Division(STP)



NGDC Focus Areas
Satellite Data Services

- Scientific Data Stewardship
- Cal/Val Observation Systems
- Post Launch Testing
- Algorithm Research
- Post-Event Analysis
- Instrument Science/Research
- Instrument Performance
- POES Processing

- Provides the archive, access and assessment (AAA) functions for the NOAA Space Weather program
- Space weather data from NOAA's fleet of geostationary satellites provides a continuous monitor of the sun and near-earth space environment
- Available GOES data sets include solar x-ray measurements and imagery, observations of energetic charged particles and measurements of local magnetic field
- The long-term observational record, since 1976, leverages continued improvements in sensor capabilities
- NGDC is also the organizational host for the World Data Center (WDC) for Geophysics, Boulder
- The purpose of the WDCs is to collect, archive and distribute geophysical data and related products to world-wide users

Space Weather Services:

Critical to the World's Economy and Security

- **Aviation**
  - Polar route use – ~10,000 flights in 2010
  - Next Generation Air Transportation System – GPS based

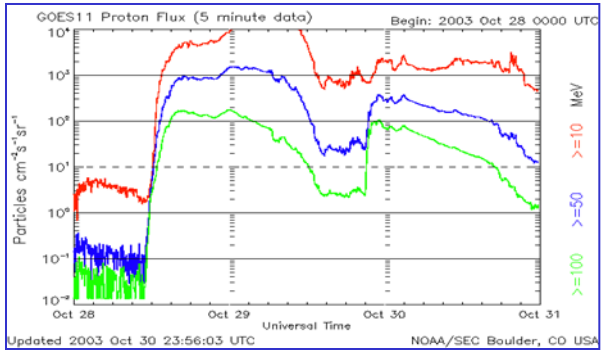
- **Communication**
  - HF radio communication heavily relied upon by airlines, DOD, Emergency Managers, Search and Rescue, etc…

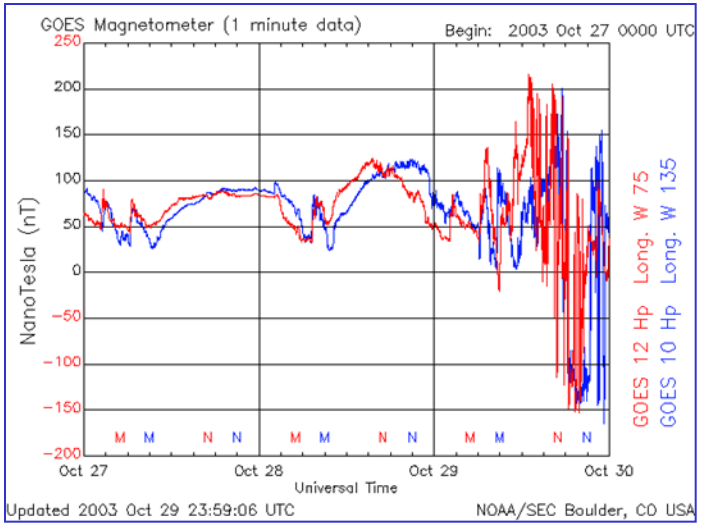
- **GPS**
  - Single biggest source of error is ionosphere
  - Strong growth in applications – surveying, drilling, precision agriculture, navigation, aviation

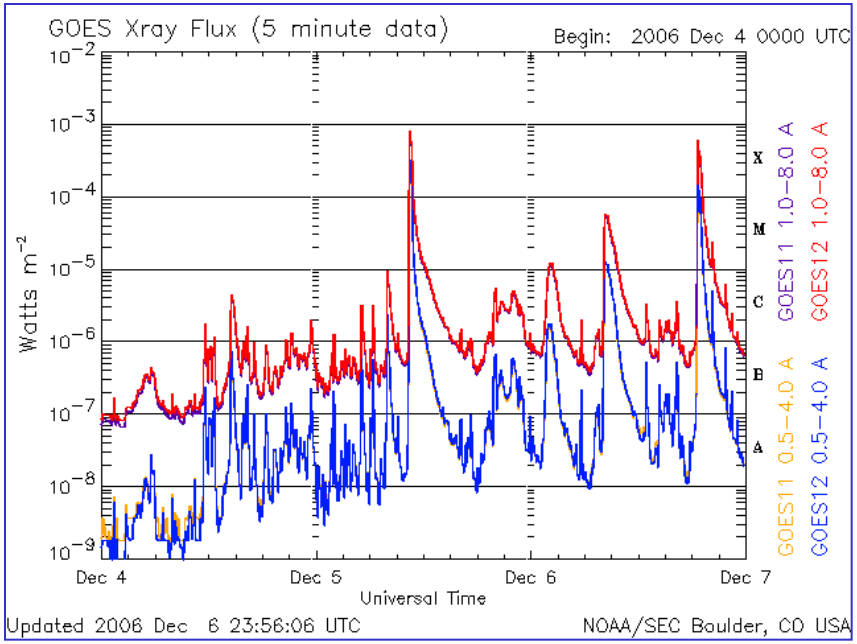
- **Electric Utilities**
  - Potential for significant disruption of service due to geomagnetic storms
  - FEMA addressing potential impacts related to space weather events through simulated exercise

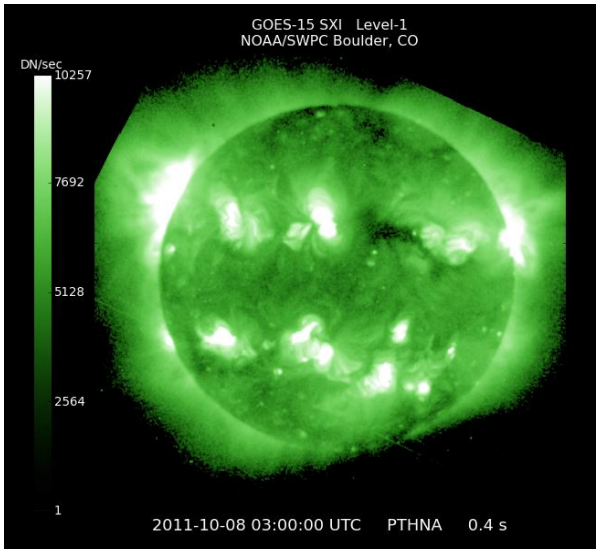
- **Space Systems**
  - World satellite industry revenues in 2008: >$144 billion
  - Space weather support is critical for manned space flight and NASA robotic missions

GOES Space Weather Data Streams









GOES Space Weather Sensors - Current and Future

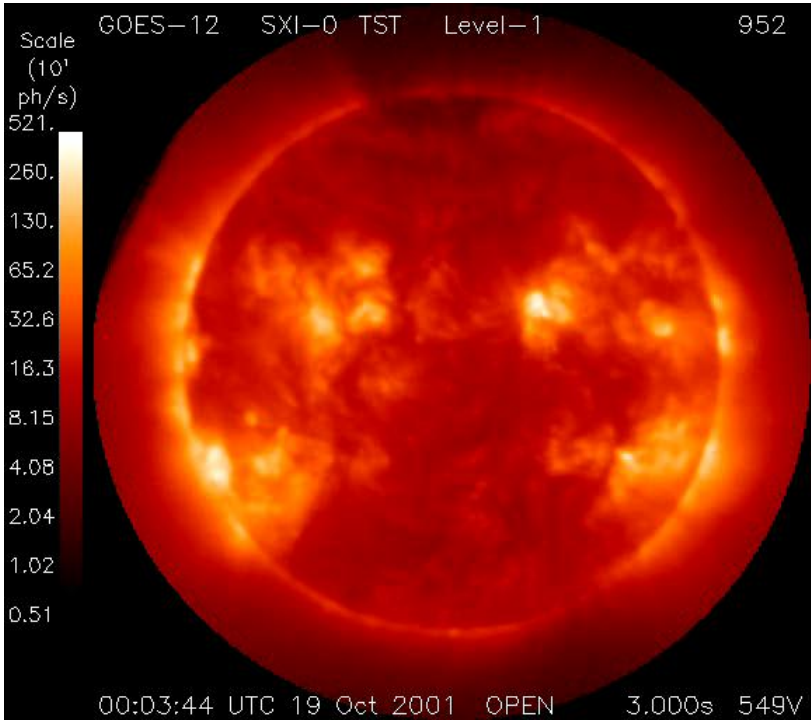
Current GOES	GOES-R
Energetic Particle Sensor (EPS)	Space Environment In-Situ Suite (SEISS)
Magnetometer (MAG)	Magnetometer (MAG)
EUV Sensor (EUVS)	Extreme Ultra-Violet Sensor (EUVS)
X-Ray Sensor (XRS)	X-Ray Sensor (XRS)
Solar X-ray Imager (SXI)	Solar Ultra-Violet Imager (SUVI)

GOES-R Space Weather Team

Name - Organization	Focus
Dr. William Denig - NGDC	Management
Dr. Steven Hill – SWPC	SXI/SUVI
Dr. Rodney Viereck – SWPC	XRS and EUVS
Dr. Howard Singer – SWPC	Magnetometer
Dr. Janet Green – NGDC	EPS/SEISS
Dr. Christopher Balch – SWPC	Forecaster
Daniel Wilkinson – NGDC	Archive
Mary Shouldis – CIRES	Management
Jonathan Darnel– CIRES	SUVI
Dr. Alysha Reinard - CIRES	XRS and EUVS
Dr. Juan Rodriguez– CIRES	EPS/SEISS
Jim Vickroy – CIRES	SUVI
Leslie Mayer – CIRES	SEISS/MAG

Tasks

Requirements
Algorithms
Telemetry
Cal/Val
Product Development
Archive



Current GOES Energetic Particle Sensors

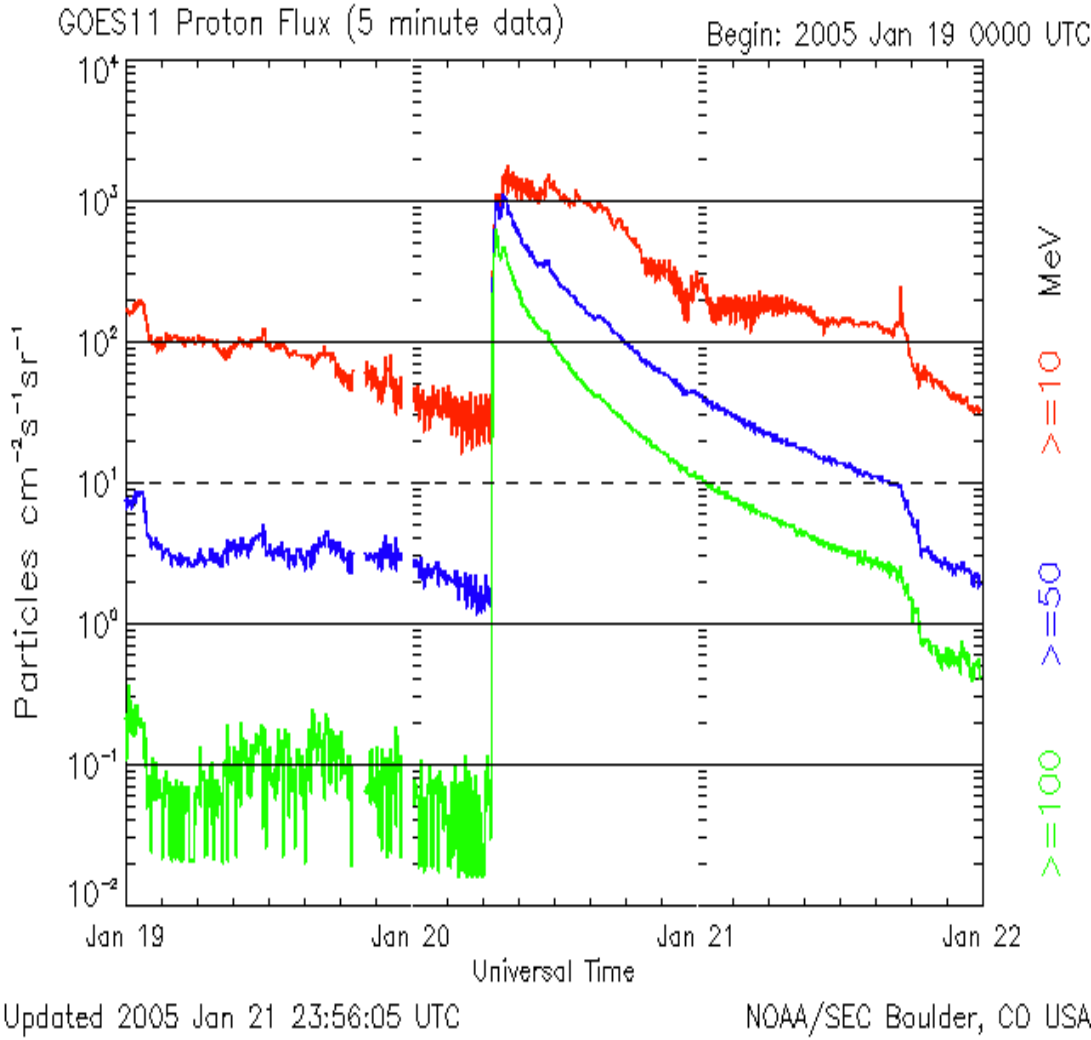
EPS:

Monitors the energetic electrons, protons, and heavy ions

e: 0.6 to 4.0 MeV, p: 0.7 to 700 MeV, a: 4 to 3400 MeV

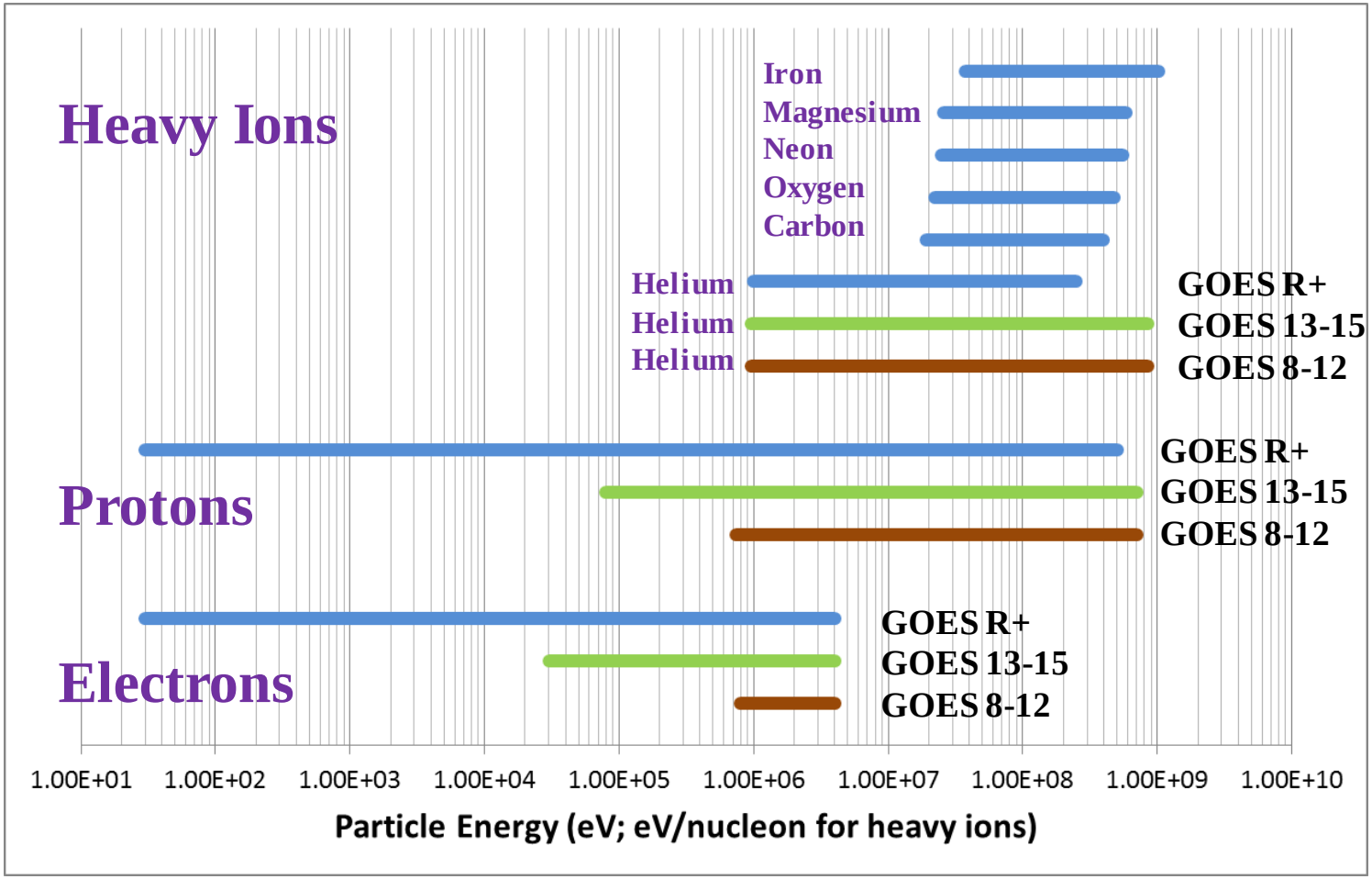
Customer Uses:

- HF Communications
- Space Station operations
- Spacecraft system design
- Spacecraft anomaly assessment
- Satellite launch readiness



GOES-R+ Energetic Particle Measurements from SEISS

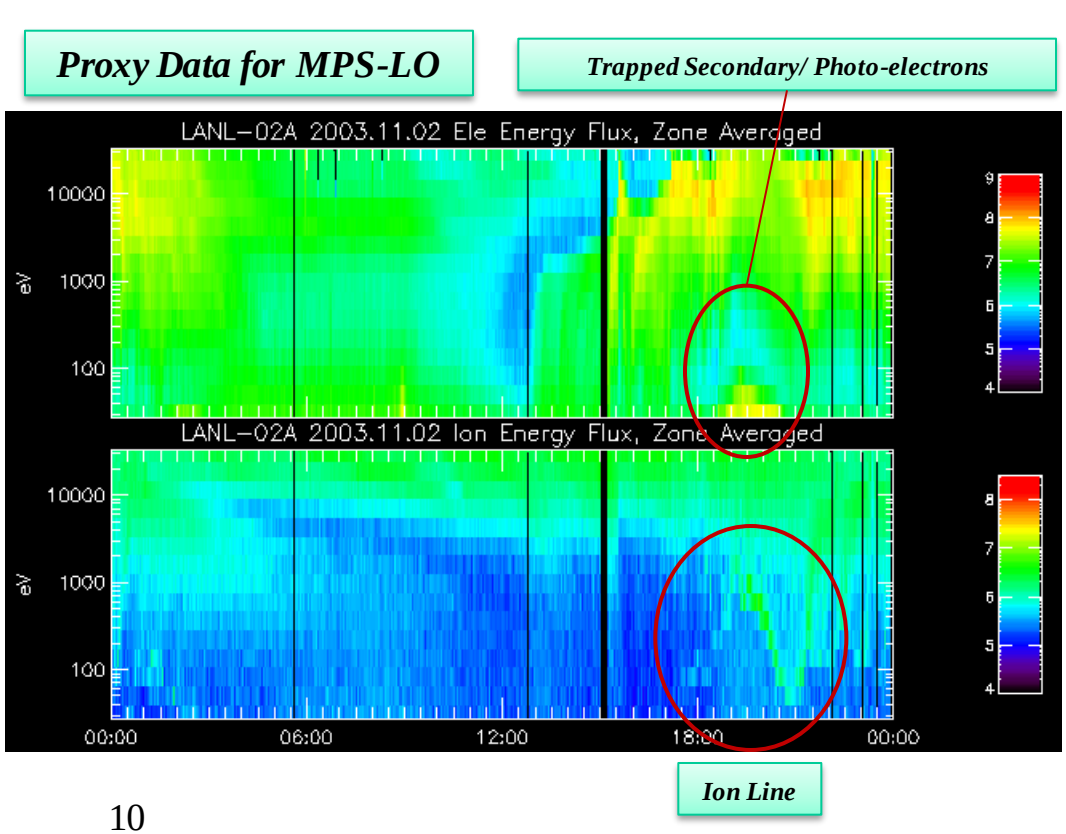
- Provide a Major Jump in Energy Range and Heavy Ion Composition Over Earlier Series

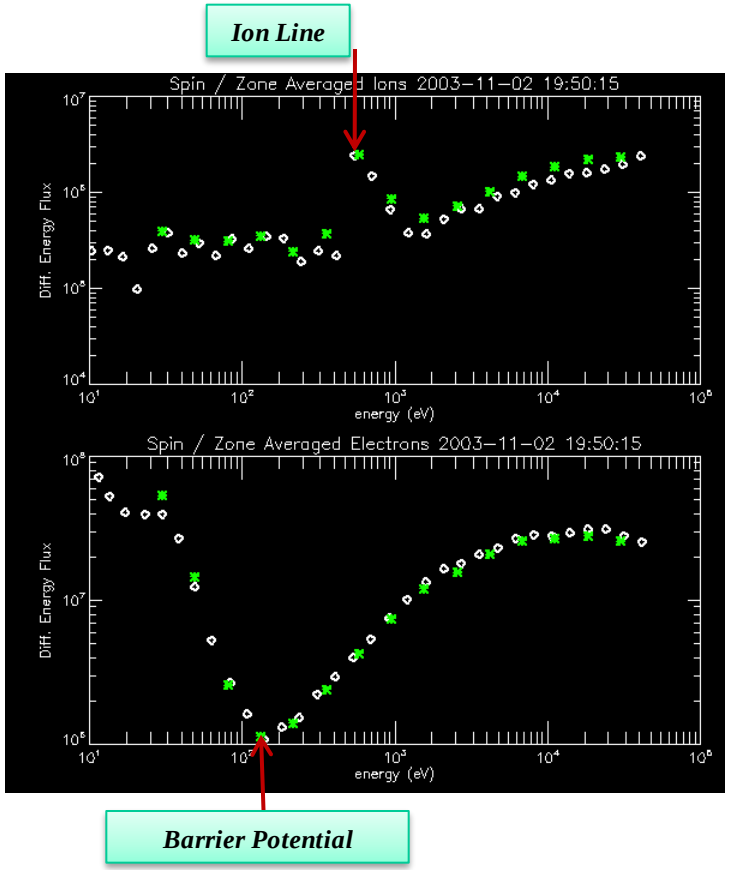


GOES-R+ Particle Requirements Based on User Community Input at Workshop on Energetic Particle Measurements for the GOES R+ Satellites, Held at NOAA SEC, October 28-29, 2002

SEISS will provide real-time situational awareness for operators of GOES and other GEO satellites

- Spacecraft potential is a L2 product planned to be derived from GOES-R SEISS MPS-LO flux measurements
  - Geosynchronous spacecraft charge negatively in order to balance currents due to incident and emitted electrons and ions
  - Upsets can be caused by discharges due to differential charging when satellite is in sunlight or emerges from eclipse
  - Uniform (frame) charging is diagnosed by a peak in the ion spectrum ('ion line') at the spacecraft potential [*DeForest*, 1972]
  - Differential (surface) charging traps secondaries and photoelectrons behind a barrier potential [*Whipple*, 1976]
- Deep dielectric charging due to >500 keV electrons (MPS-HI) can also lead to upsetting or damaging discharges





LANL MPA data provided by Dr. M. Thomsen, Los Alamos National Laboratory.

Magnetometer (MAG)

Magnetometer:

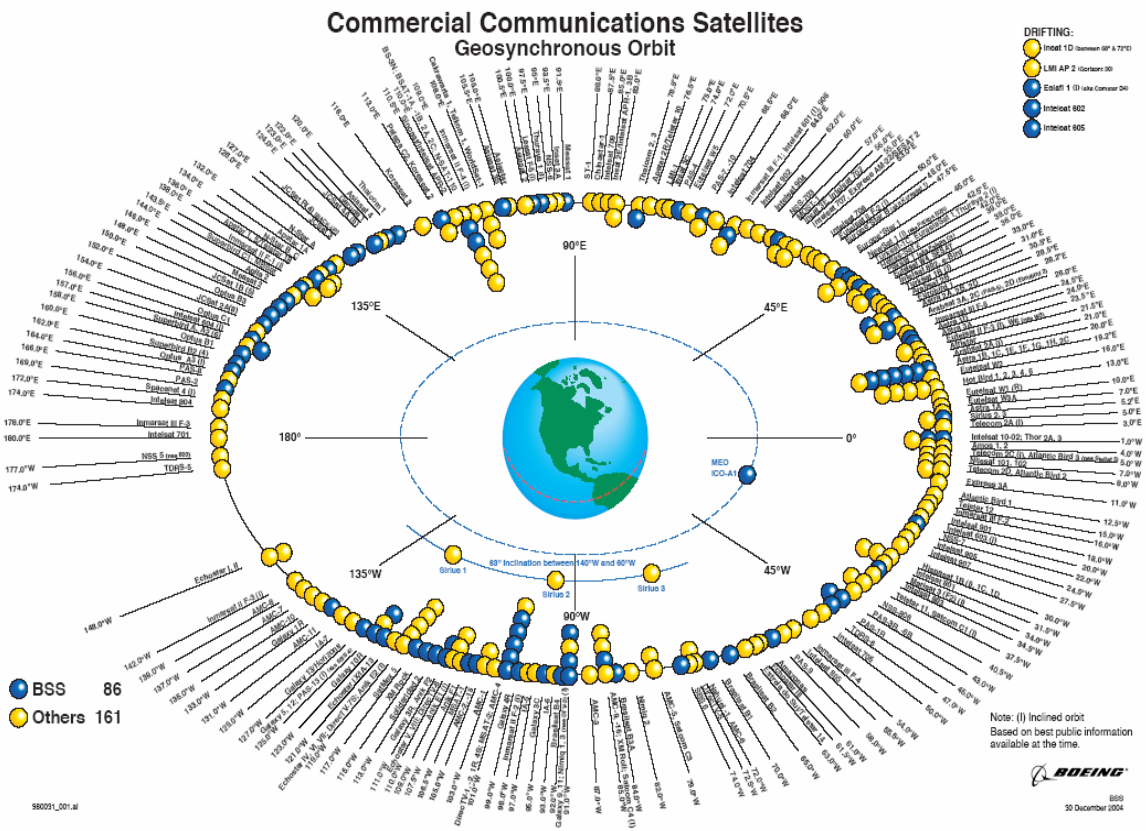
- Monitors the vector magnetic field at geosynchronous orbit
- 0.512 second samples, ~0.1 nT sensitivity, +/- 1000 nT

Customer Uses:

- Satellite Operations
  - Magnetopause Crossing
  - Attitude Control
- Energetic Particle Support
  - Provides key environment parameters

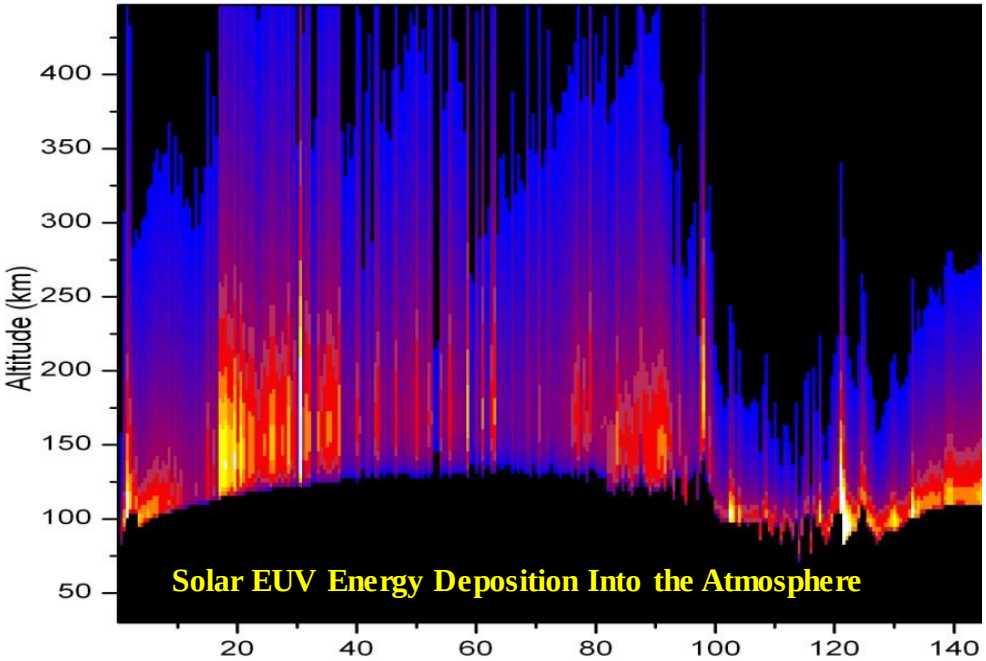
GOES-R Enhancements

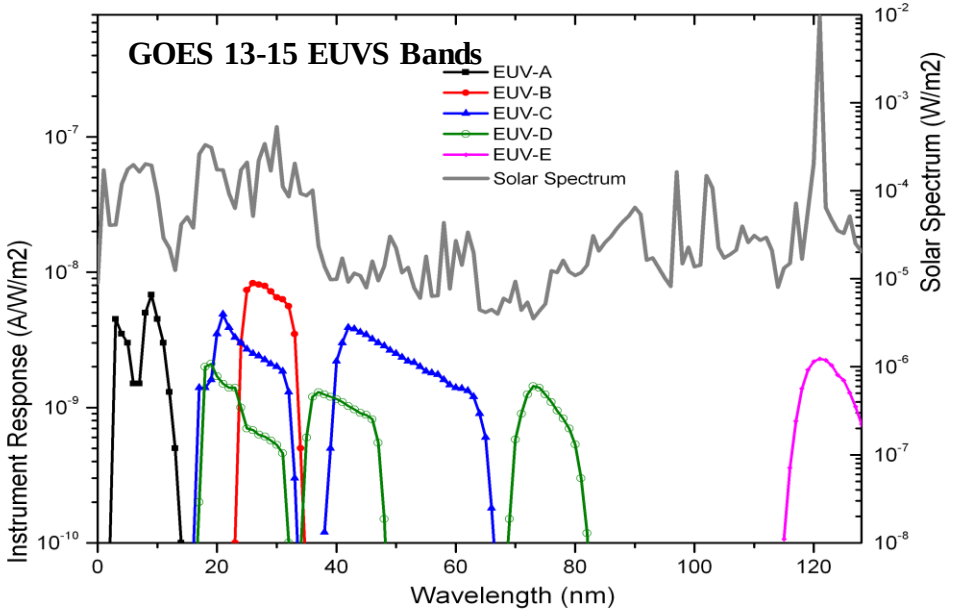
- Level 2+ algorithms to provide
  - Automated Magnetopause Crossing Detection
  - Quiet Field Comparisons
  - Automated Sudden Impulse Detection



Current GOES Solar Extreme Ultra-Violet Sensor (EUVS)

- Observations of the Solar EUV Spectrum from 5 to 125 nm
- Provides solar EUV input to thermosphere and ionosphere models which provide specification and forecasts
- Models provide specification and forecasts of the ionosphere (HF com, GPS, etc…) and the thermosphere (satellite drag)





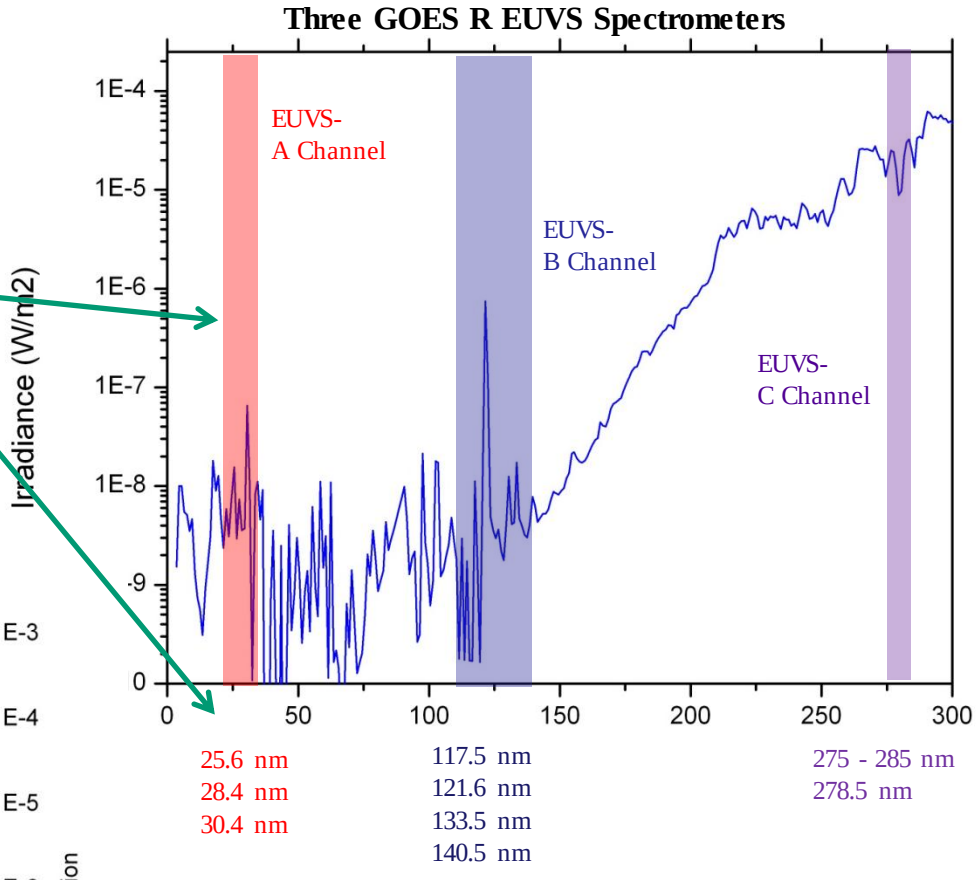
GOES-R EUVS Improvements

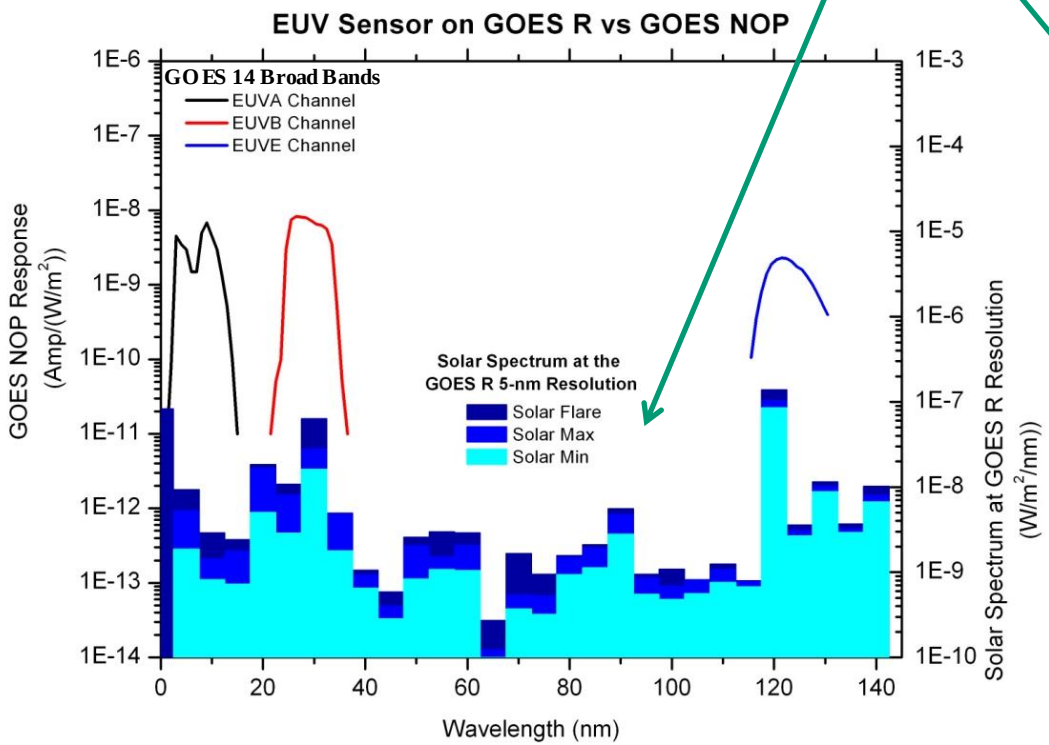
GOES NOP observed 3 (or 5) broad spectral bands

- No spectral information
- Difficult to interpret
- Impossible to build

GOES R EUVS will take a different approach

- Observe three spectral regions with three small spectrometers
- Measure the intensity of critical solar lines from various parts of the solar atmosphere
- Model the rest of the solar spectrum scaling each spectral line to the ones observed from the same region of the solar atmosphere.





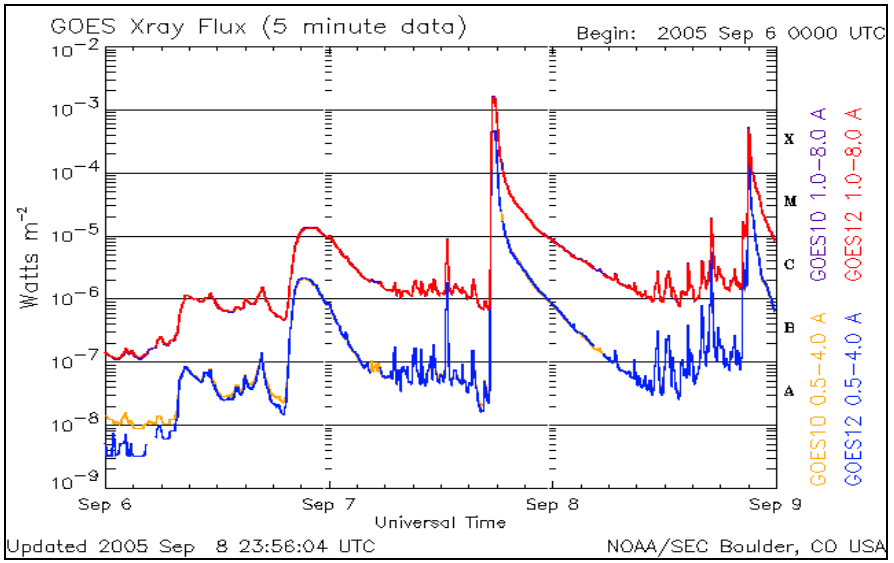
Risk Reduction Challenges

- Validating the spectral model provided by the instrument contractor
- Validating compliance with measurement requirements.
- Comparing GOES NOP data with NASA and ESA EUV mission data (SOHO, SDO, PROBA2, etc…)

Current GOES X-Ray Sensor

X-Ray Sensor:

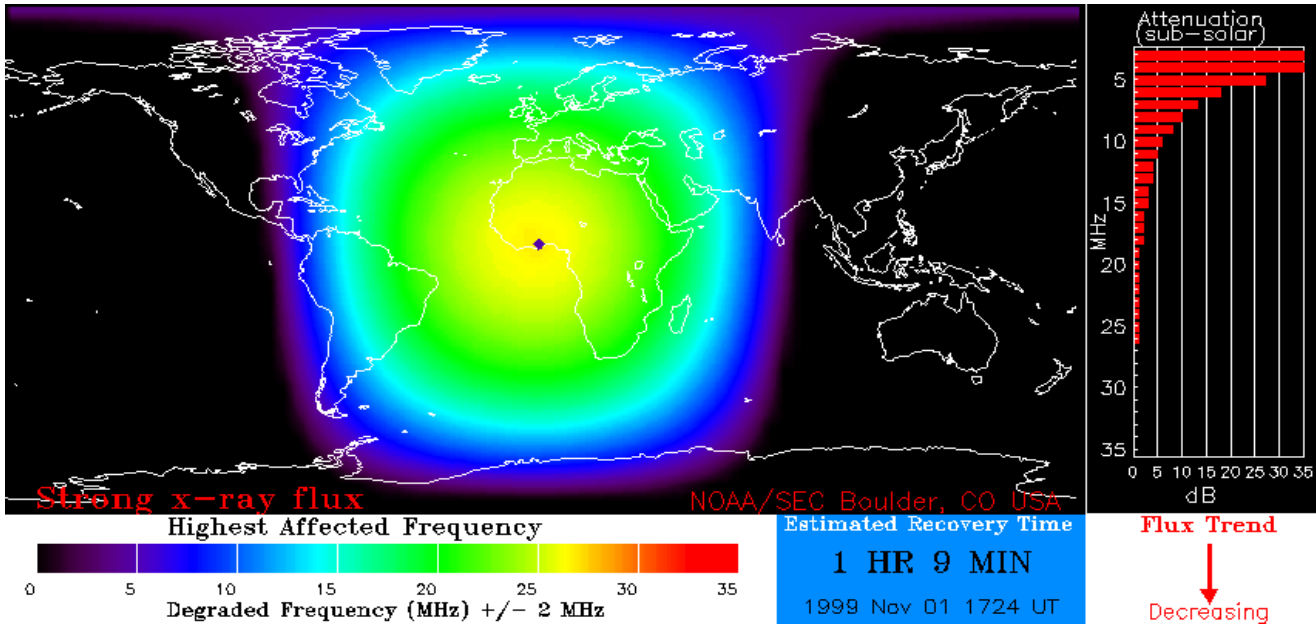
- Monitors whole-Sun x-ray irradiance
- Two Channels
  - 0.05 – 4 nm
  - 0.1 to 0.8 nm
- 3 Second Cadence
- 3 Second Latency



Customer Uses:

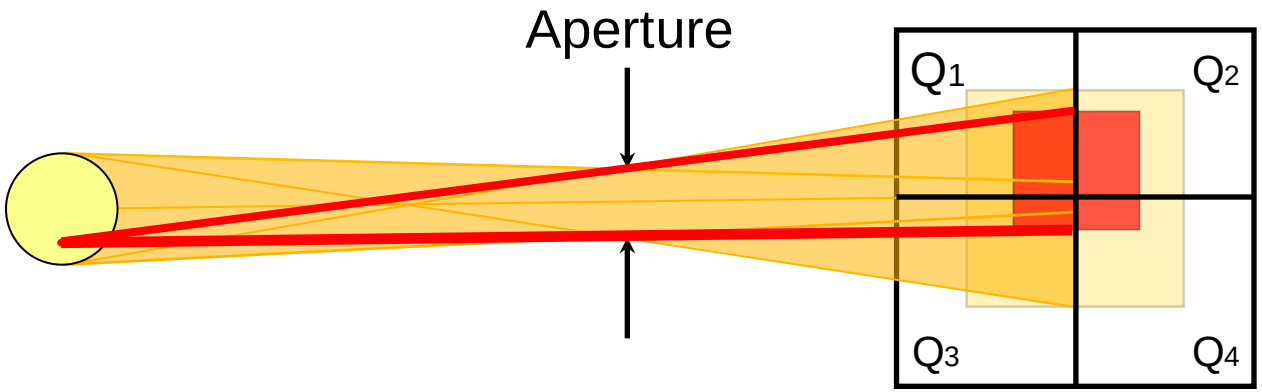
- Detect Solar Flare Onset
- Measure Flare Magnitude complexity
- Precursor for Other Major Events
- Key for Radio HF Radio Communication

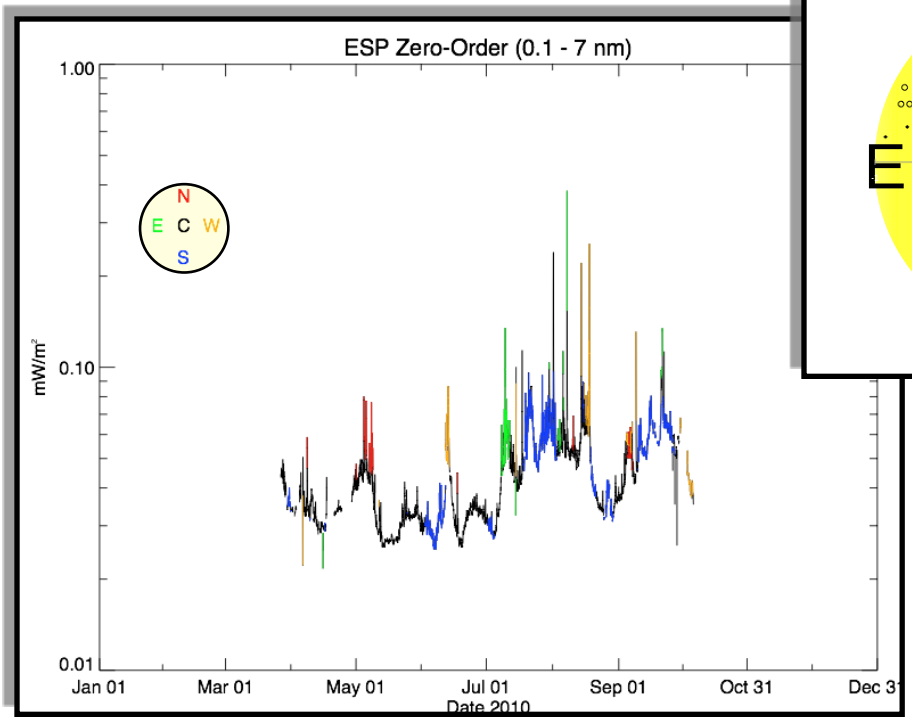
HF Radio Communication Absorption Product:
http://sec.noaa.gov/rt_plots/dregion.html

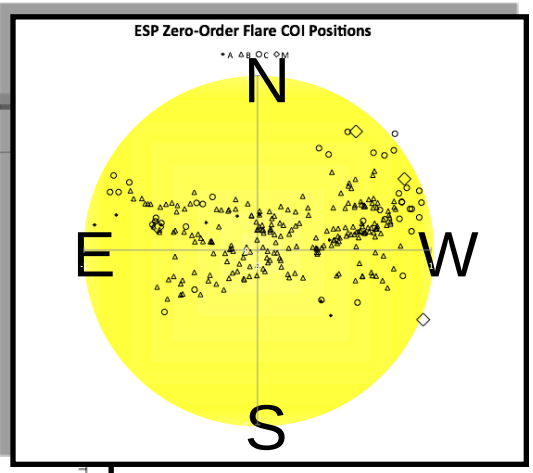


GOES-R XRS Enhancements

- Quad-diode design will provide the capability to automate flare location on the sun using sensor capabilities
- Automated flare event detection will be combined with SUVI flare detection to highly automate flare reports and enhance warning capabilities







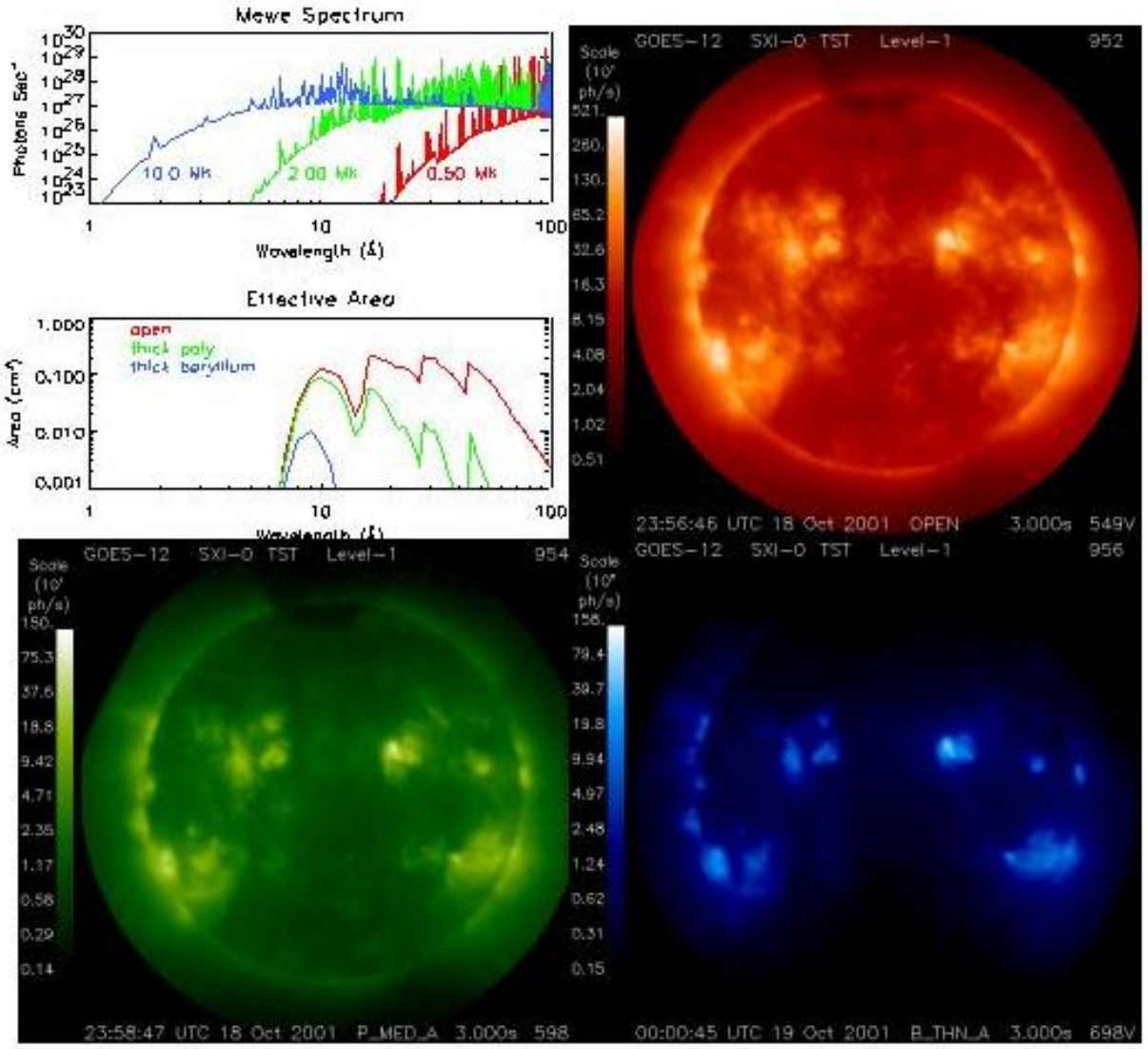
Current GOES Solar X-Ray Imager

Full disk soft x-ray images

- One - minute cadence,
- Full disk, 512 x 512 pixel array
- 5 arc sec pixels,
- 0.6 – 6 nm,

SXI Utility

- Identify Flare location and other solar features
- Forecast flare probability:
  - Assess active region complexity
- Forecasts geomagnetic storms:
  - Locate coronal holes
  - Coronal Mass Ejections
- Forecast radiation storms:
  - Locate flares
- Forecast solar activity:
  - Monitor active regions beyond east limb



GOES-R Enhanced Solar Imager – Solar Ultra-Violet Imager (SUVI)

SUVI will provide

- Flare location information (Forecasting event arrival time and geo-effectiveness)
- Active region complexity (Flare forecasting)
- Coronal hole specification (High speed solar wind forecasting)

High dynamic range (HDR) composite EUV images

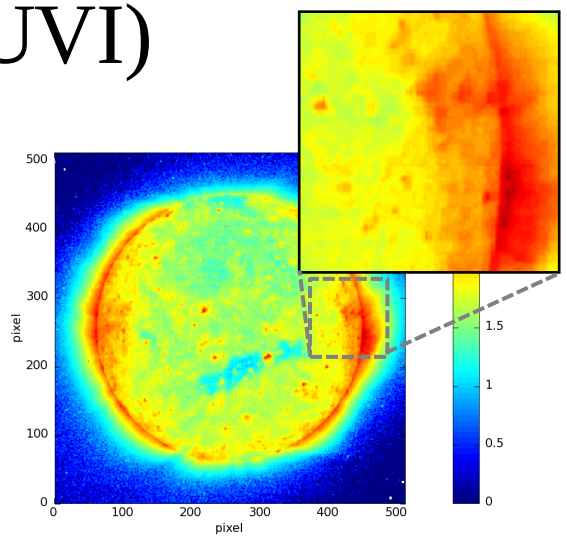
- Multiple exposures optimally combined to capture full dynamic range across all spectral channels

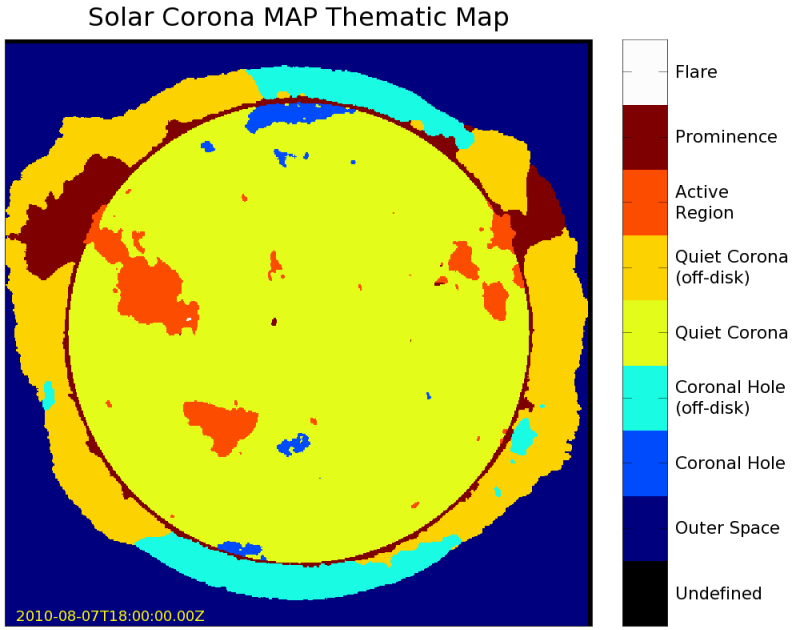
Dynamical feature tracking in the solar corona

- Corrections for latitudinally-differential solar rotation
- Fixed and running difference or ratio images to capture CME signatures in EUV

Multispectral solar EUV image products

- Principle component pseudo-bands
- Expert-trained Bayesian pixel classification
- Coronal thematic maps





Conclusions

- Our ever-growing dependence on space-based technology has resulted in an increasing need for space weather services
- The health of the Nation's technological infrastructure will depend heavily on our understanding of the space environment and our ability to predict hazardous space weather storms
- GOES satellite data are key to meeting our increasing needs and GOES-R enhanced capabilities will improve our capabilities, timeliness and accuracies.