GOES-R Space Weather Observations and Products

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AMS Meeting
New Orleans, Louisiana
January 2012

Outline

- GOES Role in Forecasting and Nowcasting
- NWS and WMO Product Integration
- Pilot Projects Building on Risk Reduction

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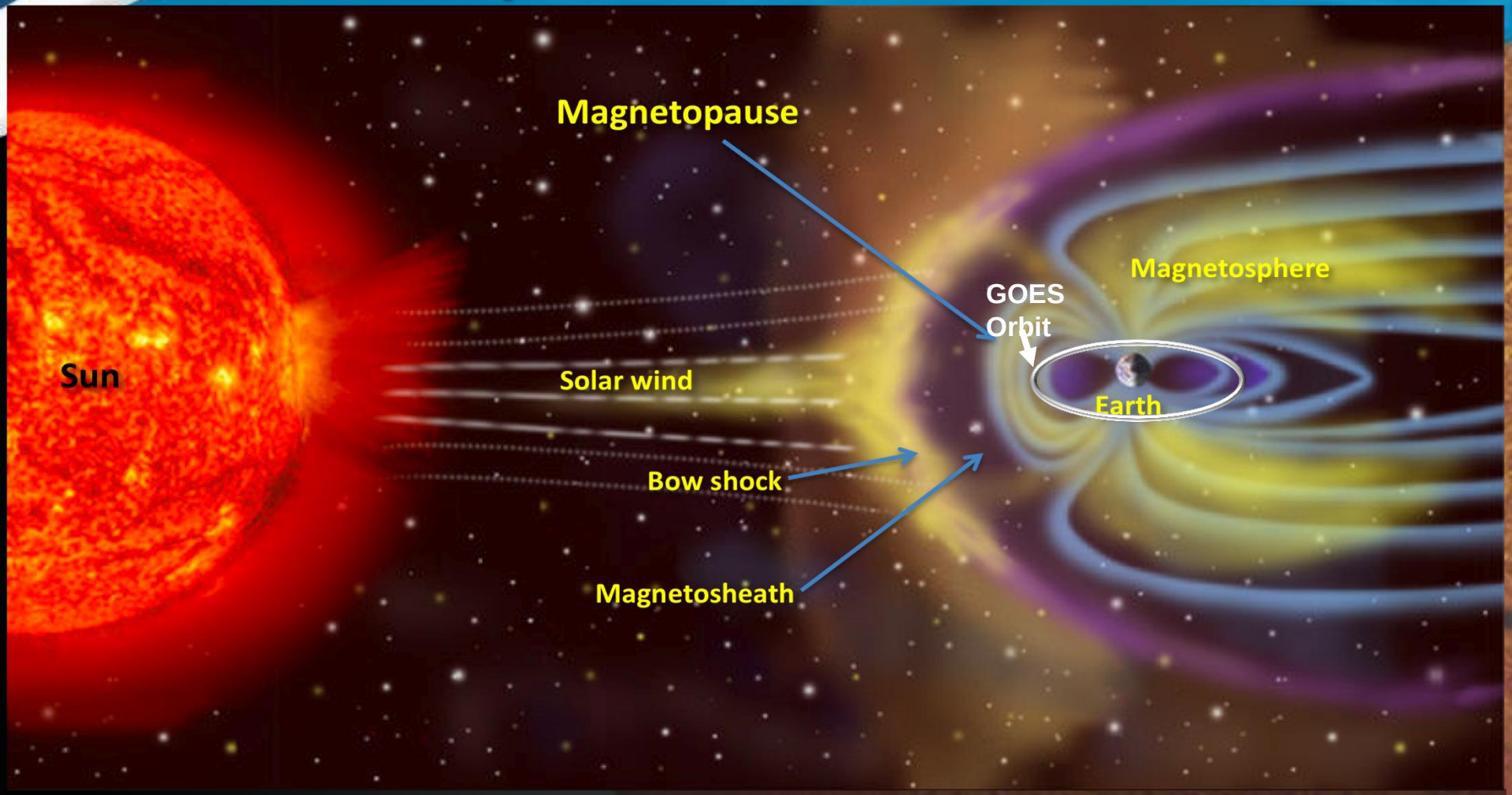
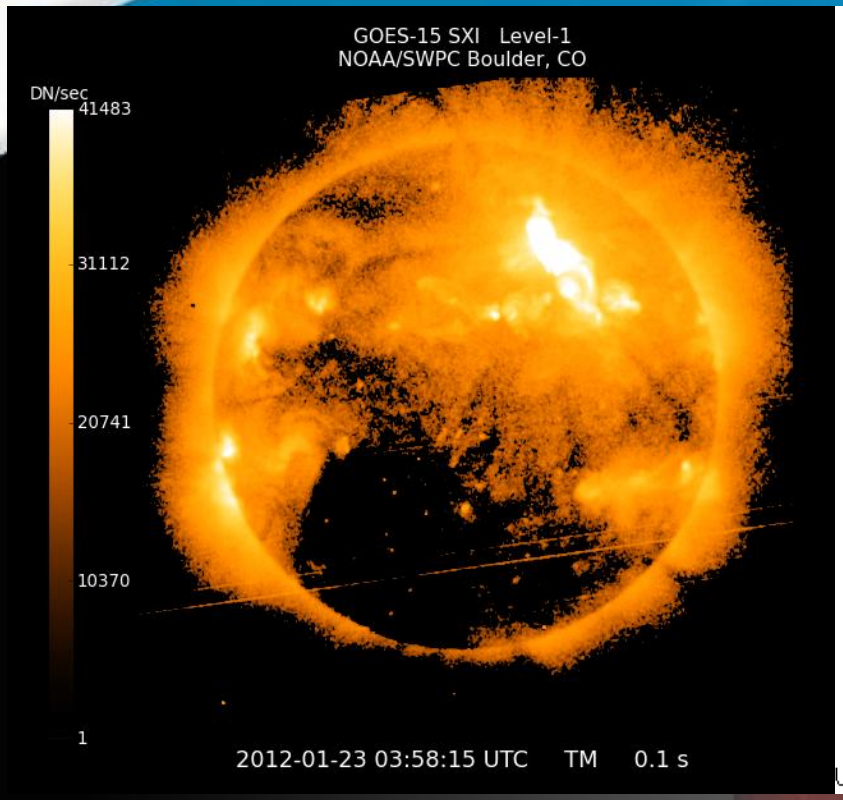
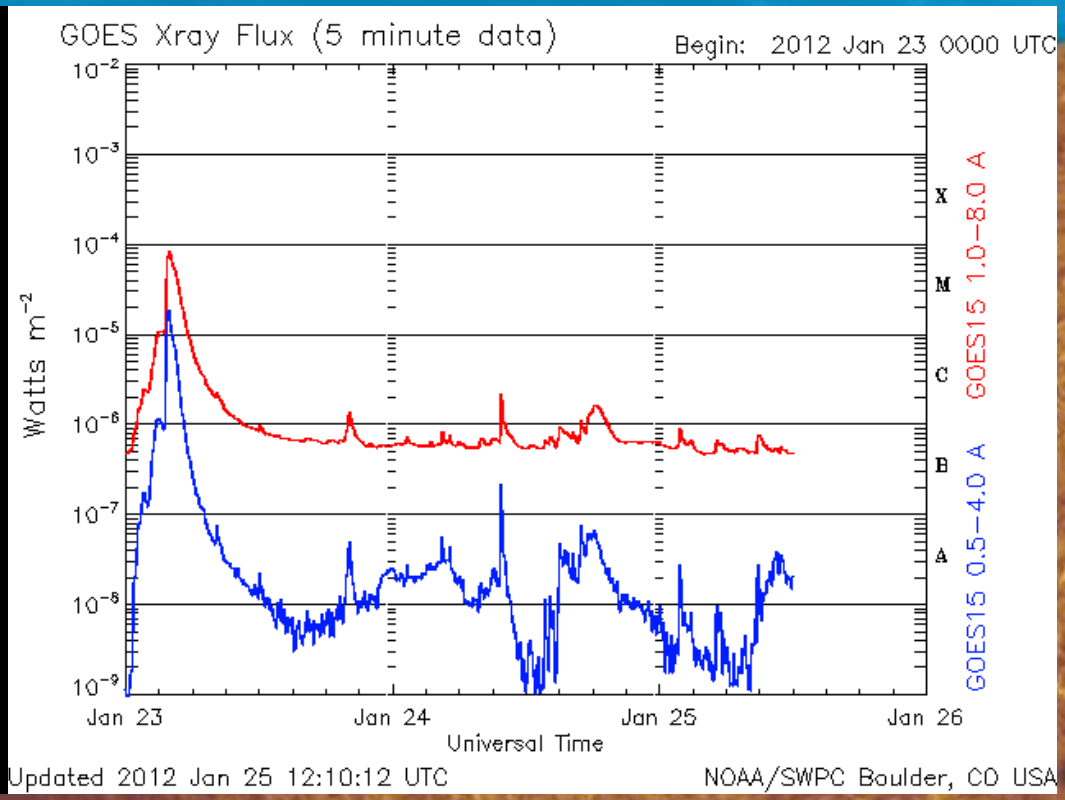
The Space Weather Domain



Despite minimal direct human experience, space weather is as real and palpable as terrestrial weather.
It is a dynamic, evolving fluid bridging the space between the sun and planets.

Initial Event Detection and Location

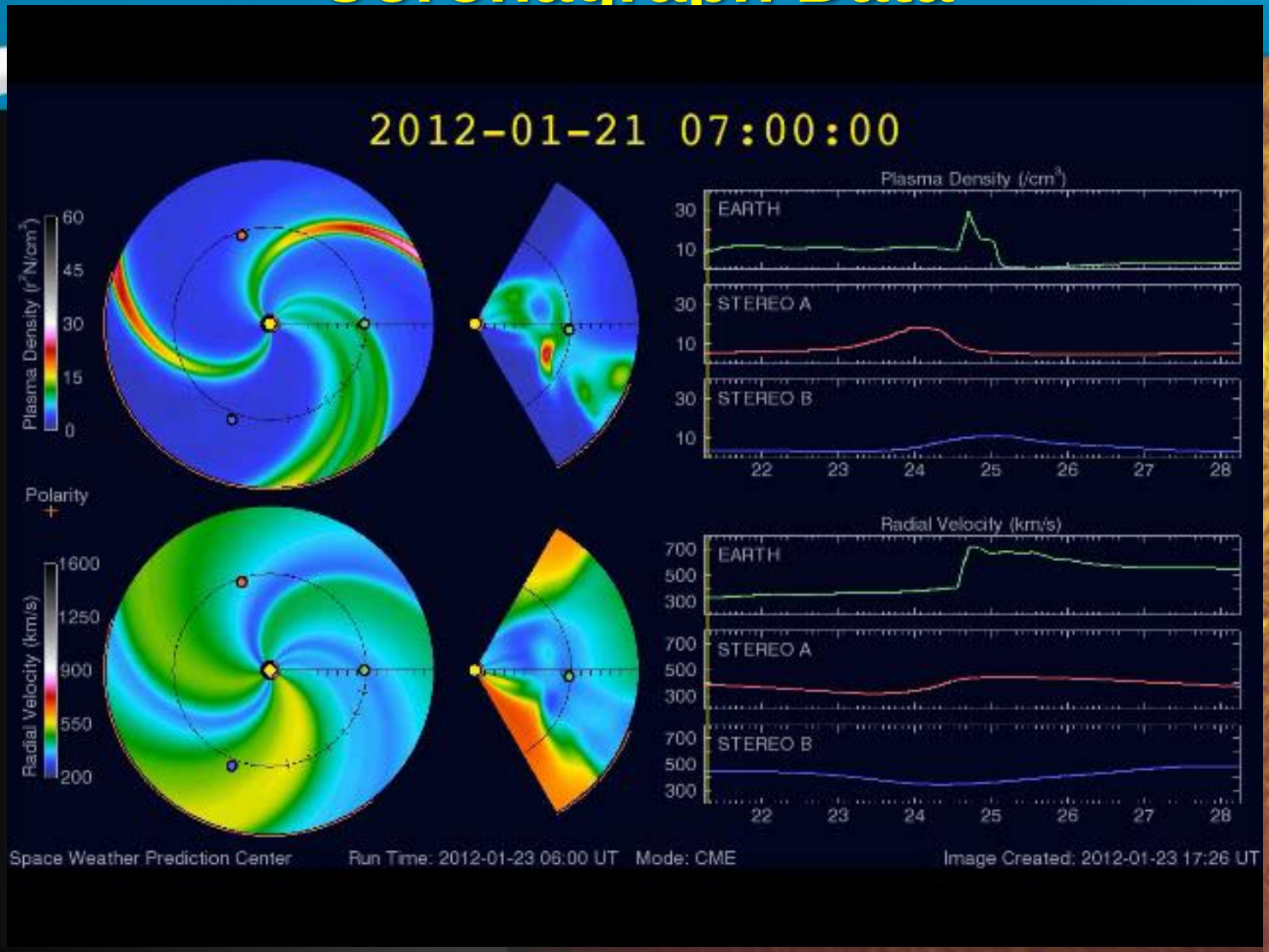




SXI provides flare location and context such as dimmings

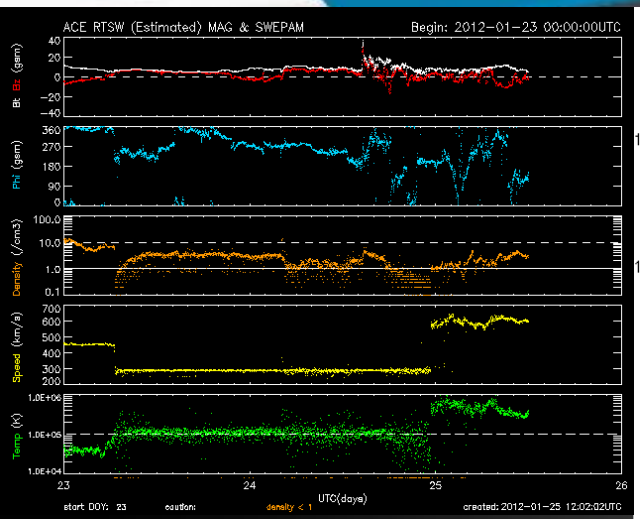
XRS provides the first detection of an event within seconds

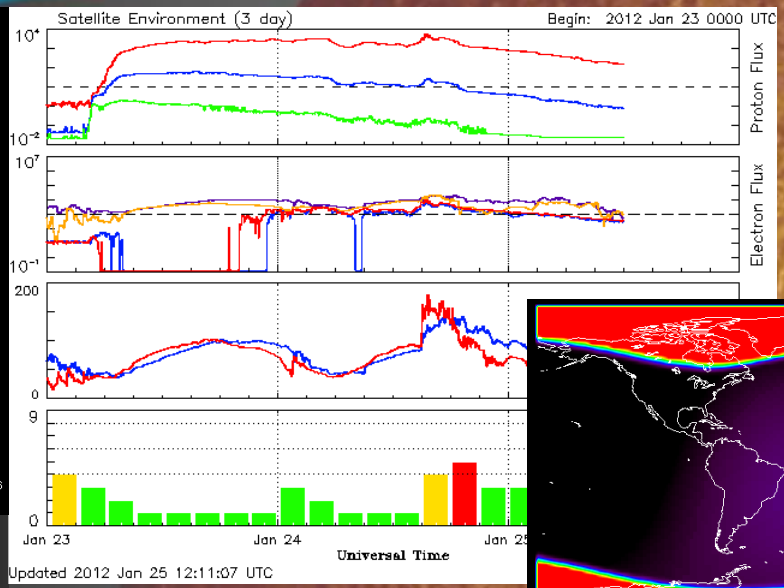
WSA-Enlil Model Driven by Coronagraph Data

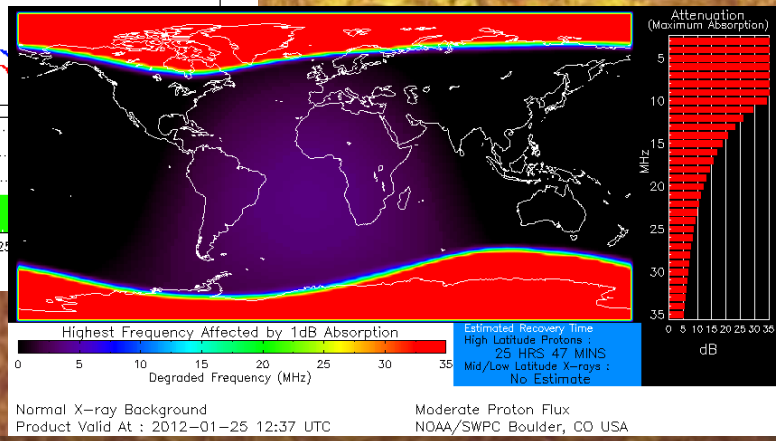


Data from NASA spacecraft provide inputs

Situational Awareness and User Impacts







ACE provides short term warning of CME arrival and feeds models

GOES provides real-time monitoring of geospace and along with ground magnetometers feeds models

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- NWS and WMO Product Integration
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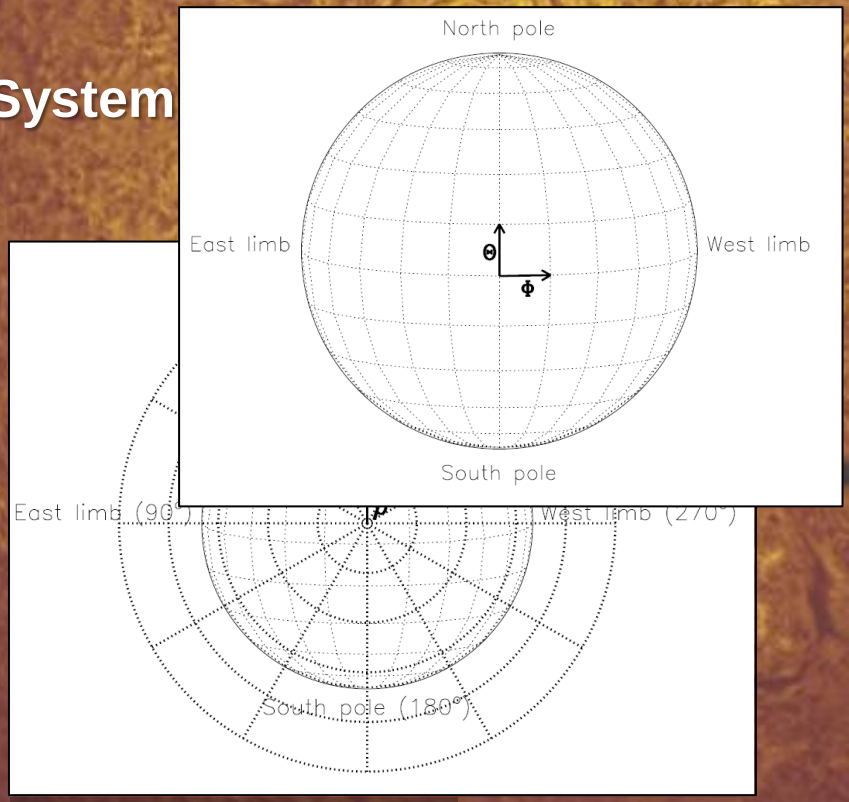
Space Weather and WMO Standards

- <u>Today's Products</u> are provided in a mix of formats including FITS, PNG, ASCII, CDF, NetCDF, and SQL
- <u>Tomorrow's Products</u> will be integrated to work with NWS and WMO infrastructure and standards (NetCDF, GRIB2, BUFR)
- <u>This year</u> SWPC began its product migration with a pathfinder product and sample products for validation

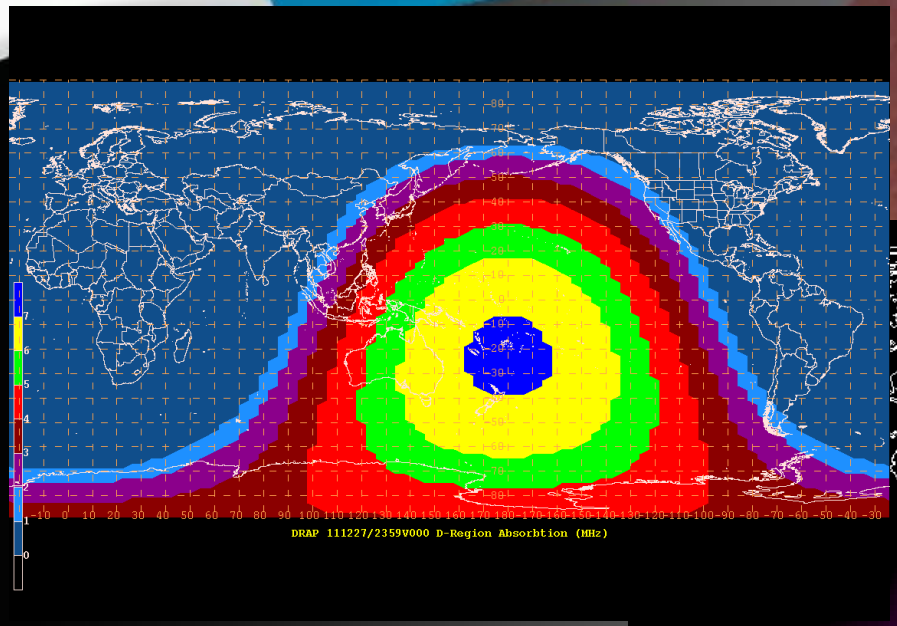
WMO GRIB2 Space Weather Proposal

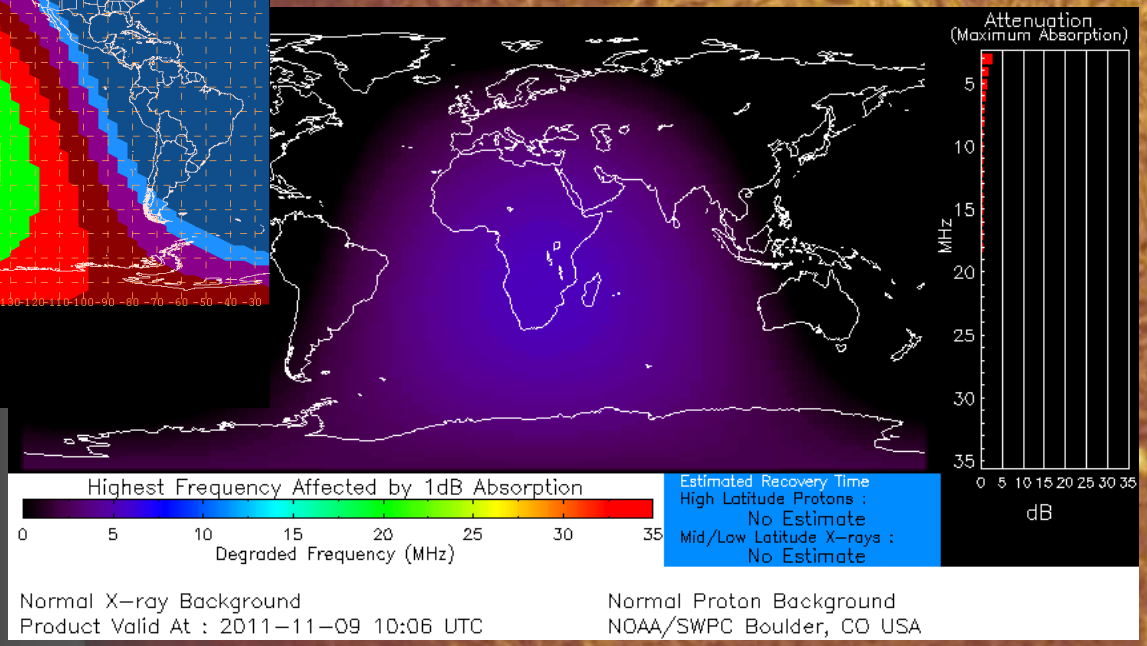
- Product Discipline 4: Space Weather Products
- Code Table 3.2 – Shape of Reference System
  - Sun (Radius: 695,990,000 m)
  - Geomagnetic
- Code Table 4.1 – Parameter Category
  - Temperature, Momentum, etc.
- Code Table 4.5 – Fixed Surface Types
  - Ionospheric D-Region level, etc.



Thompson, 2005

Product Samples in Validation

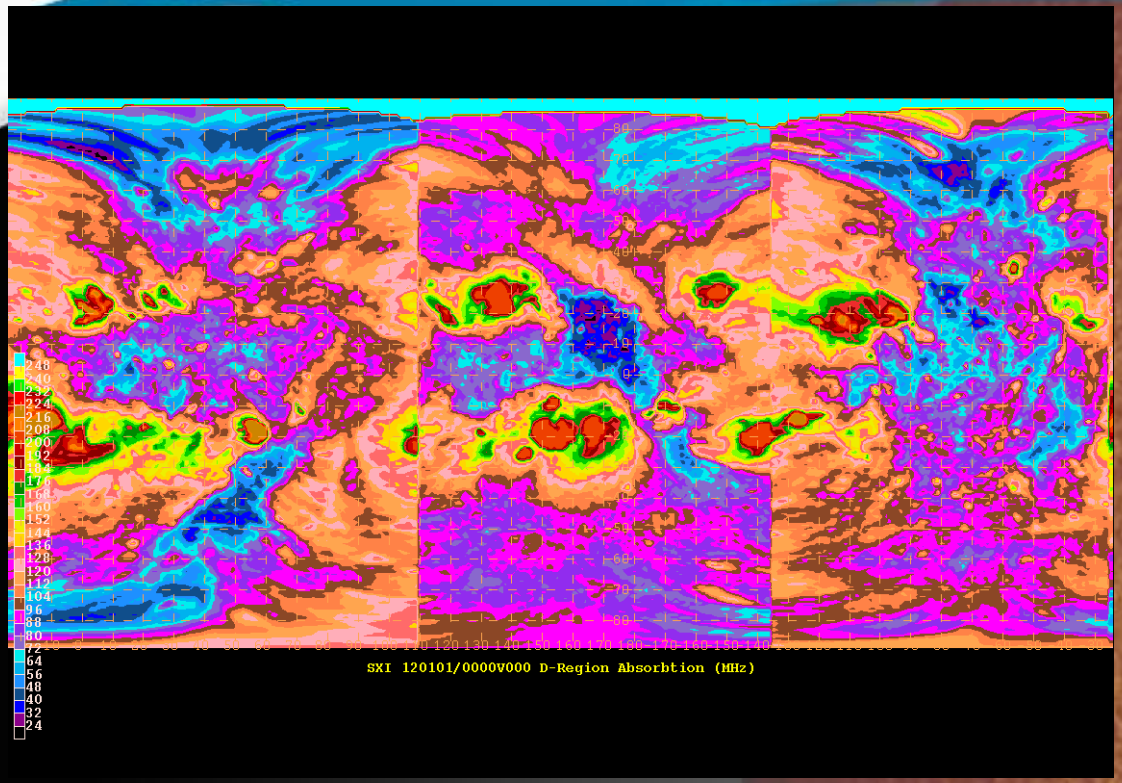


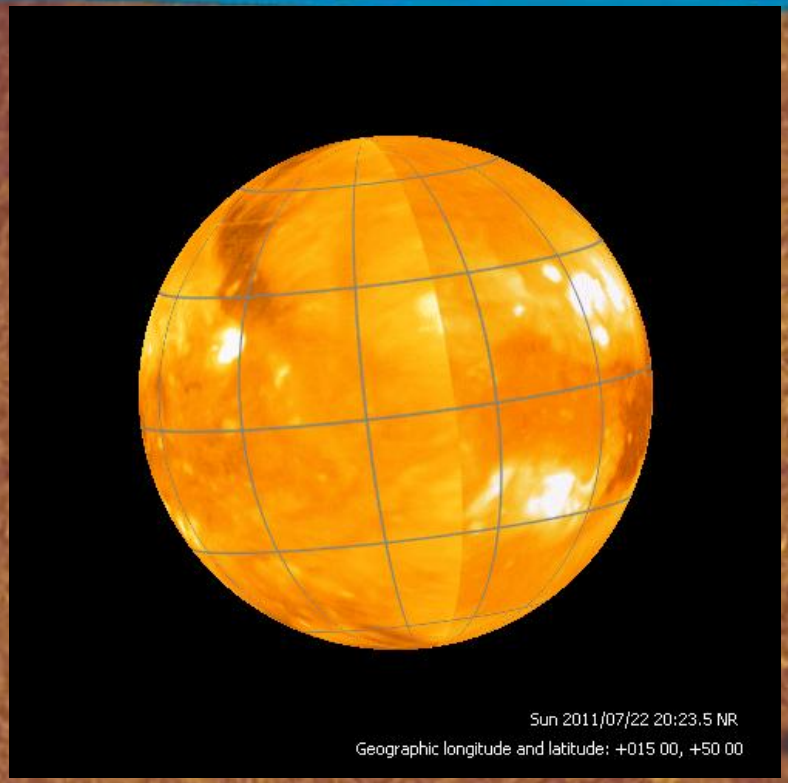


Global D-Region Absorption (D-RAP) rendered in NAWIPS;

Provided to AK Region as a test product

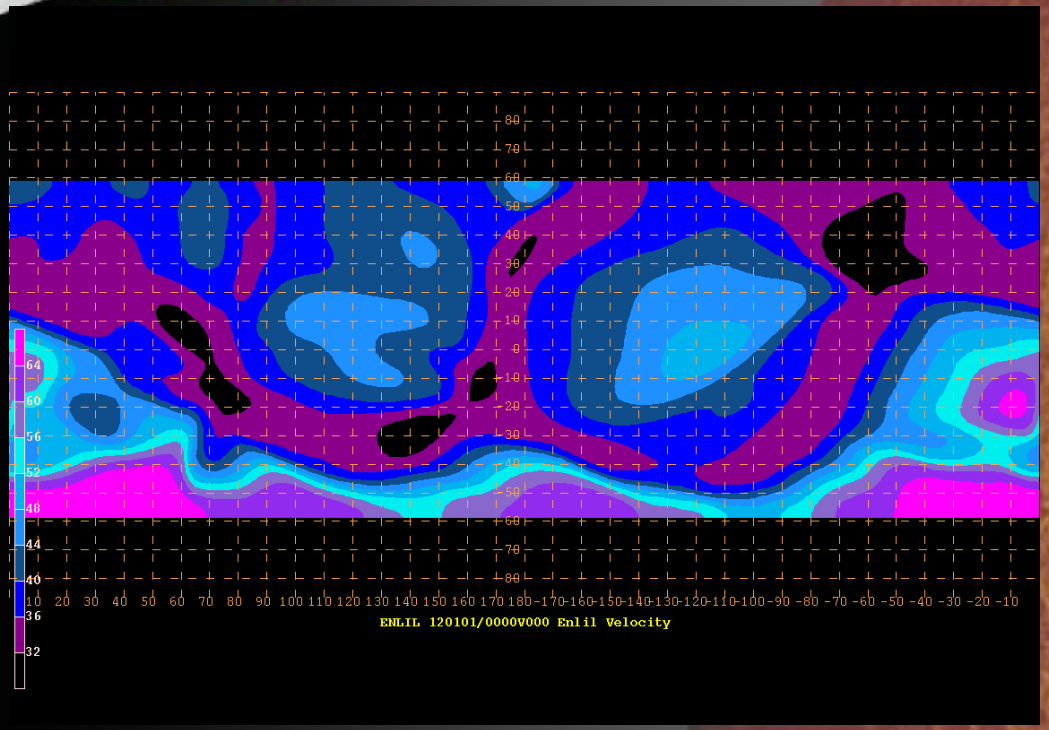
Product Samples in Validation

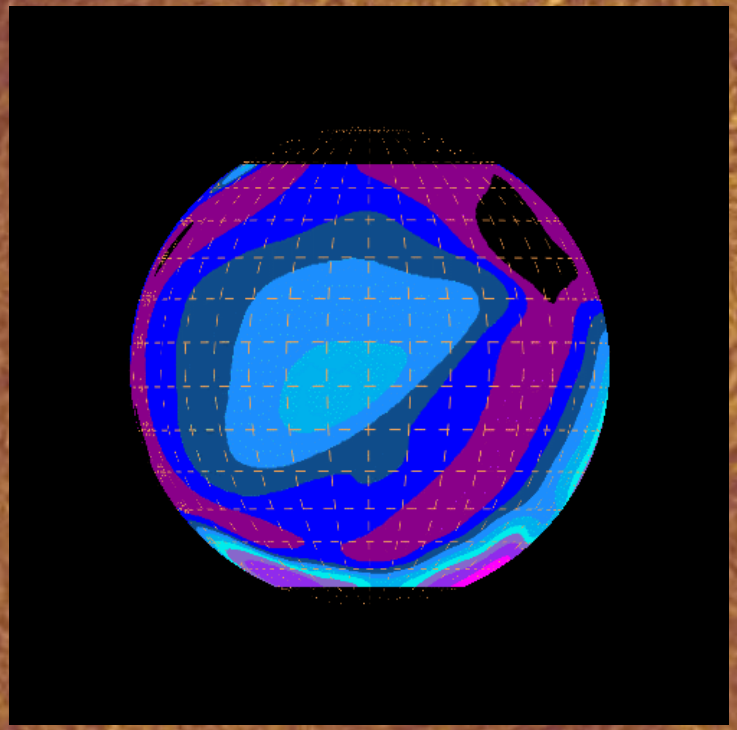




GOES-15 SXI radiance rendered in NAWIPS

Product Samples in Validation





WSA-Enlil radial velocity field at 1 AU rendered in NAWIPS

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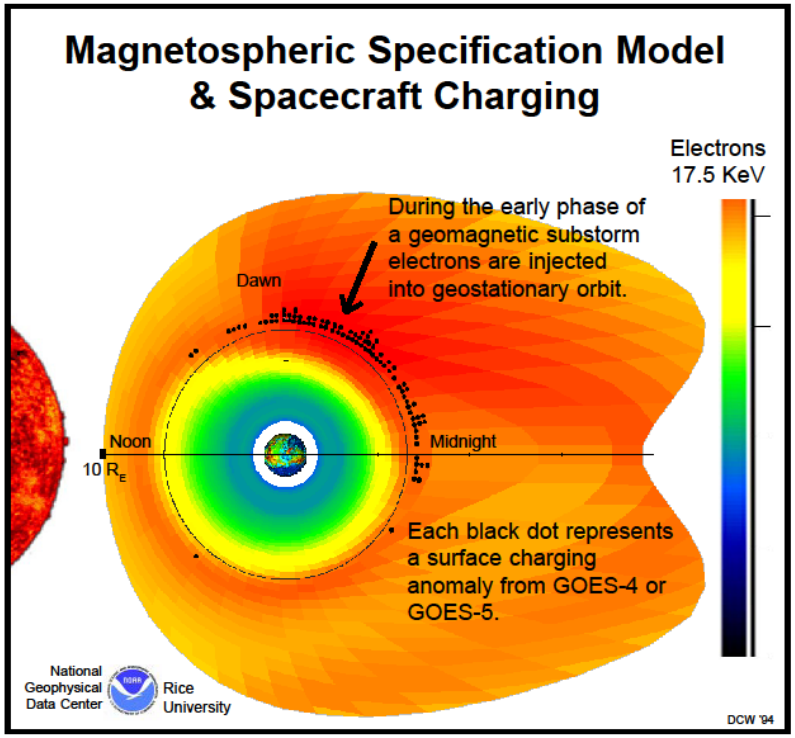
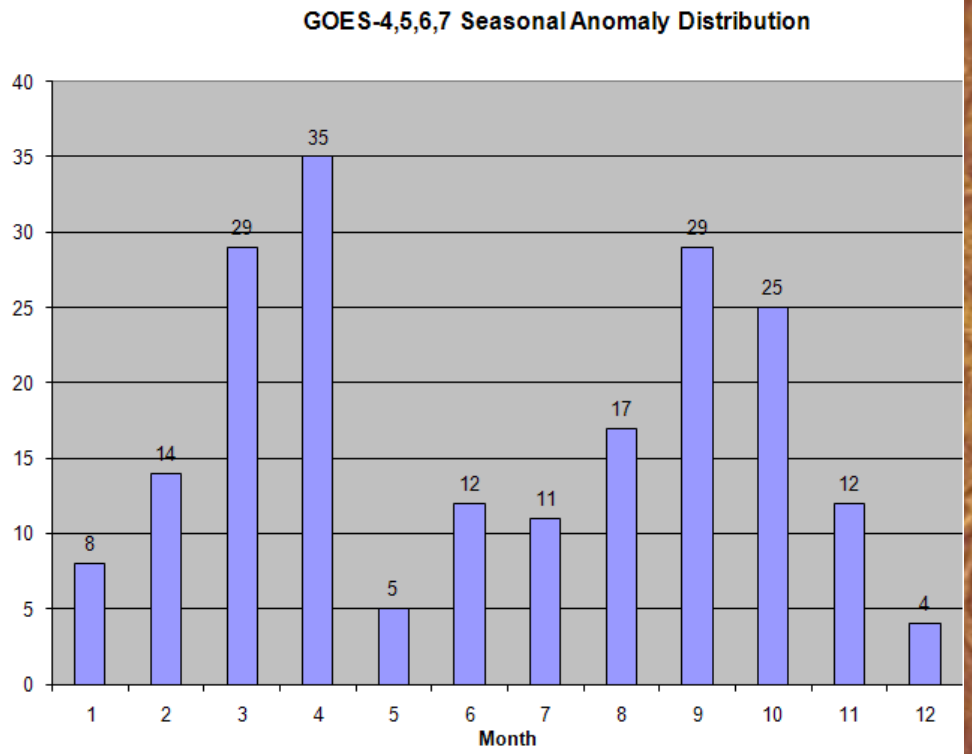
Plasma Density, Temperature and Spacecraft Charging





Climatology shows increased likelihood of satellite charging both from midnight to dawn and around equinox, but is insufficient to describe actual conditions at any given time.

Electron and Proton Densities and Temperatures (Moments)

- GOES 13-15 (MAGED and MAGPD) extend GOES electron and proton flux measurements down to auroral energies
- Electron and proton fluxes are reduced to densities and temperatures (moments)
  - –GOES Magnetometer field components are required by Moments calculation)
- Purposes of Moments product:
  - –For each species, reduces 45 flux measurements to one density and two temperatures – easier to assess for situational awareness
  - –Densities and temperatures can be used in spacecraft charging calculations, e.g., the NASCAP-2k model.
  - –Boundary conditions for geospace models

Image Credit: R. Berdan, The Canadian Nature Photographer, Sep. 2010

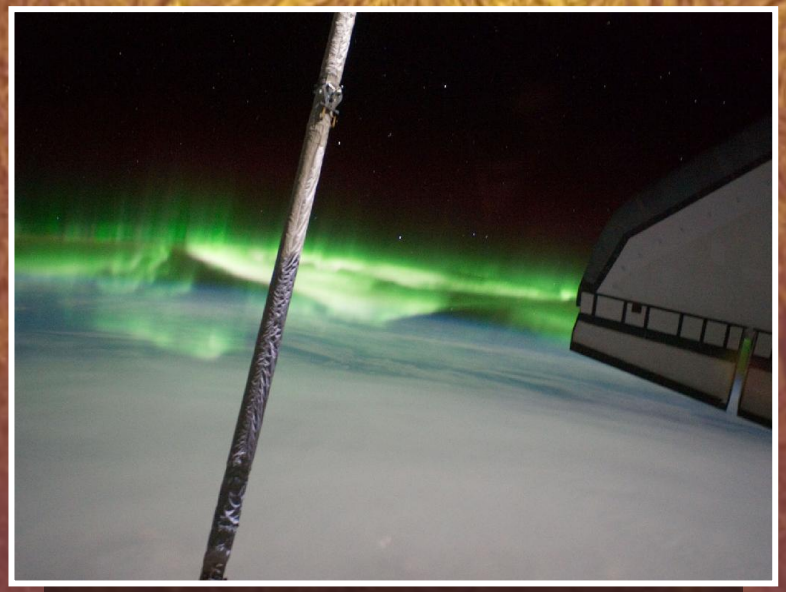


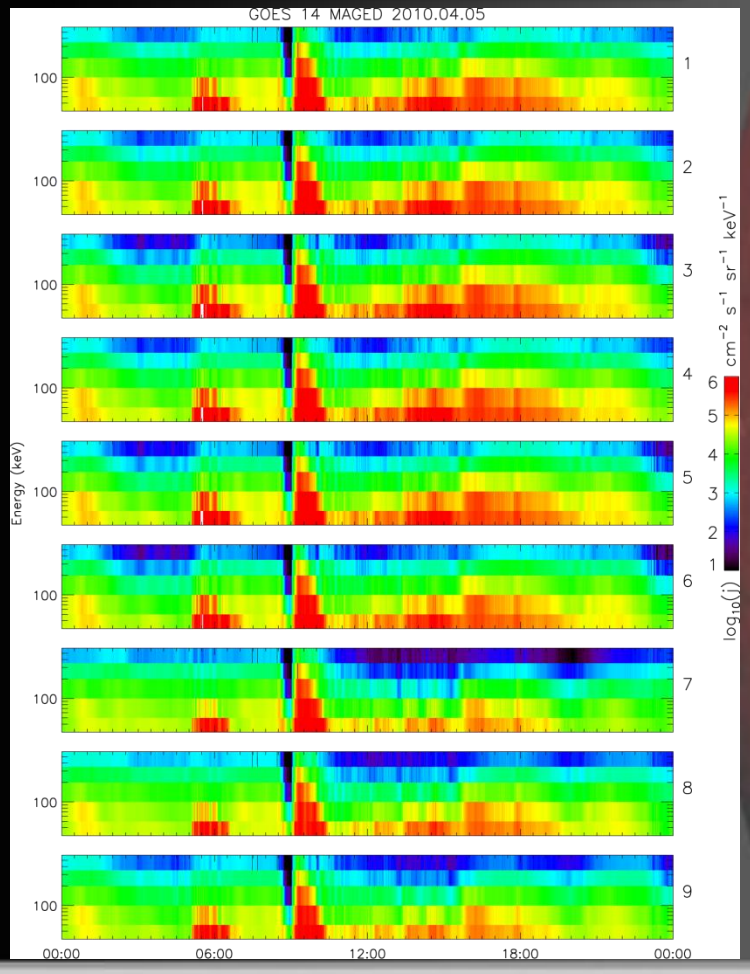
Image Credit: NASA/STS-135 crew, 14 July 2011

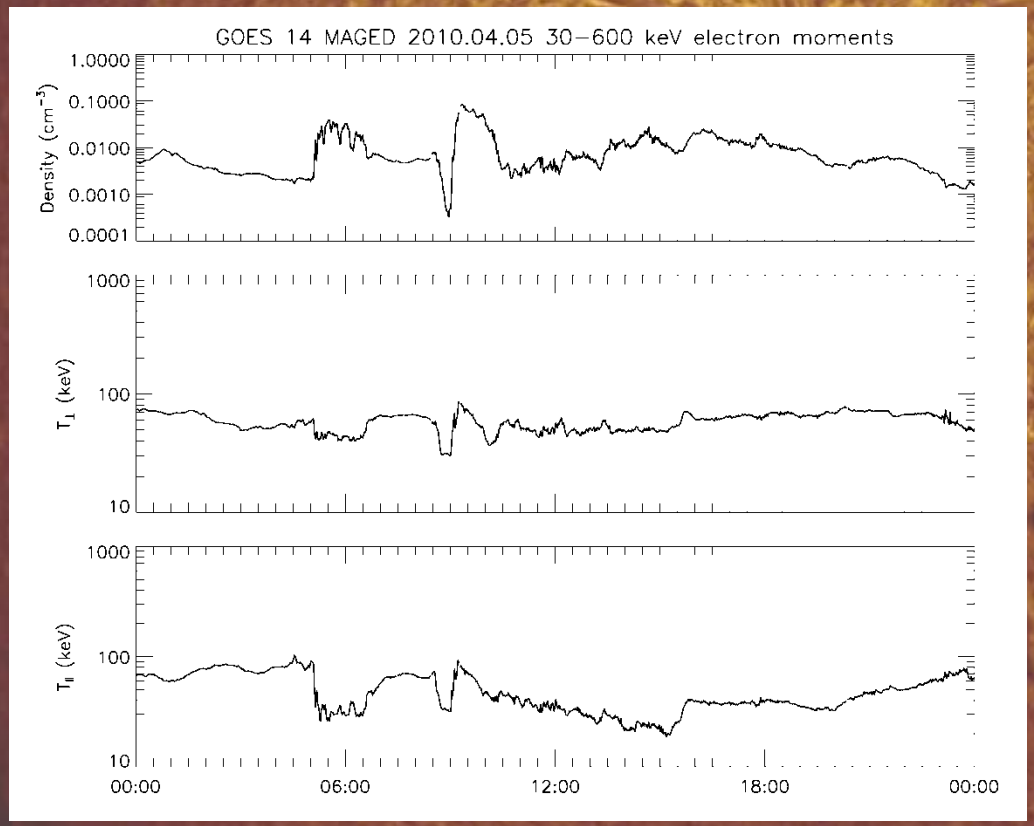
http://www.ngdc.noaa.gov/stp/satellite/goes/dataaccess.html

Moments Algorithm Reduces 45 Flux Measurements to Density and Temperatures for Operational Use

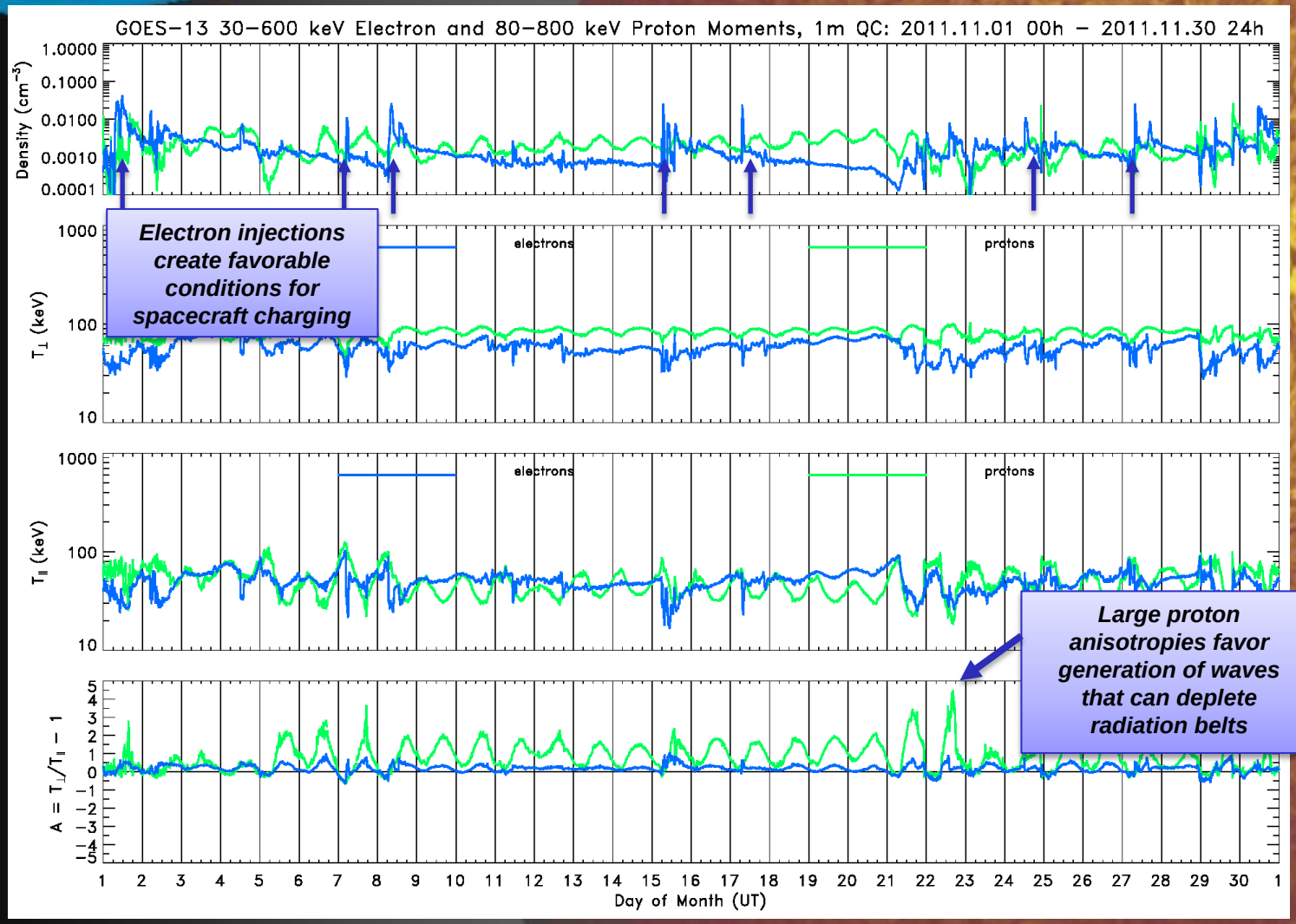
MAGED: 9 look directions x 5 energy channels (30-600 keV)

Electron Density and Temperatures (Parallel and Perpendicular to Magnetic Field)





A Month of the Charged Particle Environment at a Glance:



Density and Temperatures Applied

- Algorithm developed and coded under GOES-R Risk Reduction by CIRES at NOAA at NGDC
- Currently calculated by NGDC from GOES 13-15 on an experimental, non-real-time basis
  - Used to evaluate charging conditions during Galaxy 15 anomaly
  - Used by satellite operators to evaluate conditions under which upsets have occurred

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Rogue satellite may impact cable TV in U.S.

By Doug Gross, CNN
May 12, 2010 12:18 p.m. EDT

A Russian rocket launches an Intelsat satellite in February.

STORY HIGHLIGHTS

- Cable satellite is out of control, could disrupt some cable TV service later in May
- Owners of satellite say the impact will be minor, if not eliminated entirely

(CNN) -- A rogue satellite is floating through space, threatening to push into another satellite's orbit and interrupt cable TV programming in the United States.

But the company that owns the satellite says they've known about the problem for more than a month and that the impact on cable TV will be minimal.

Galaxy 15, a satellite that catches cable signals and beams them back to Earth, broke loose from its orbit and began a slow, out-of-control drift at about a tenth of a degree per day, according to its owners, communications company Intelsat.

At that rate, the satellite will be close enough for its signals to interfere with the other satellite's signals beginning May 23.

"Intelsat lost control of the satellite, which was launched in 2005, during a solar storm on April 5." – May 12, 2010 12:18 p.m. EDT

Solar Image Interpretation

The Sun presents highly complex surface and atmospheric features that are currently interpreted by forecasters by subjective visual inspection.

GOES-R SUVI will provide six spectral channels in the EUV at rapid cadence.

The current approach can be time consuming and exhibit substantial forecaster-to-forecaster variability.

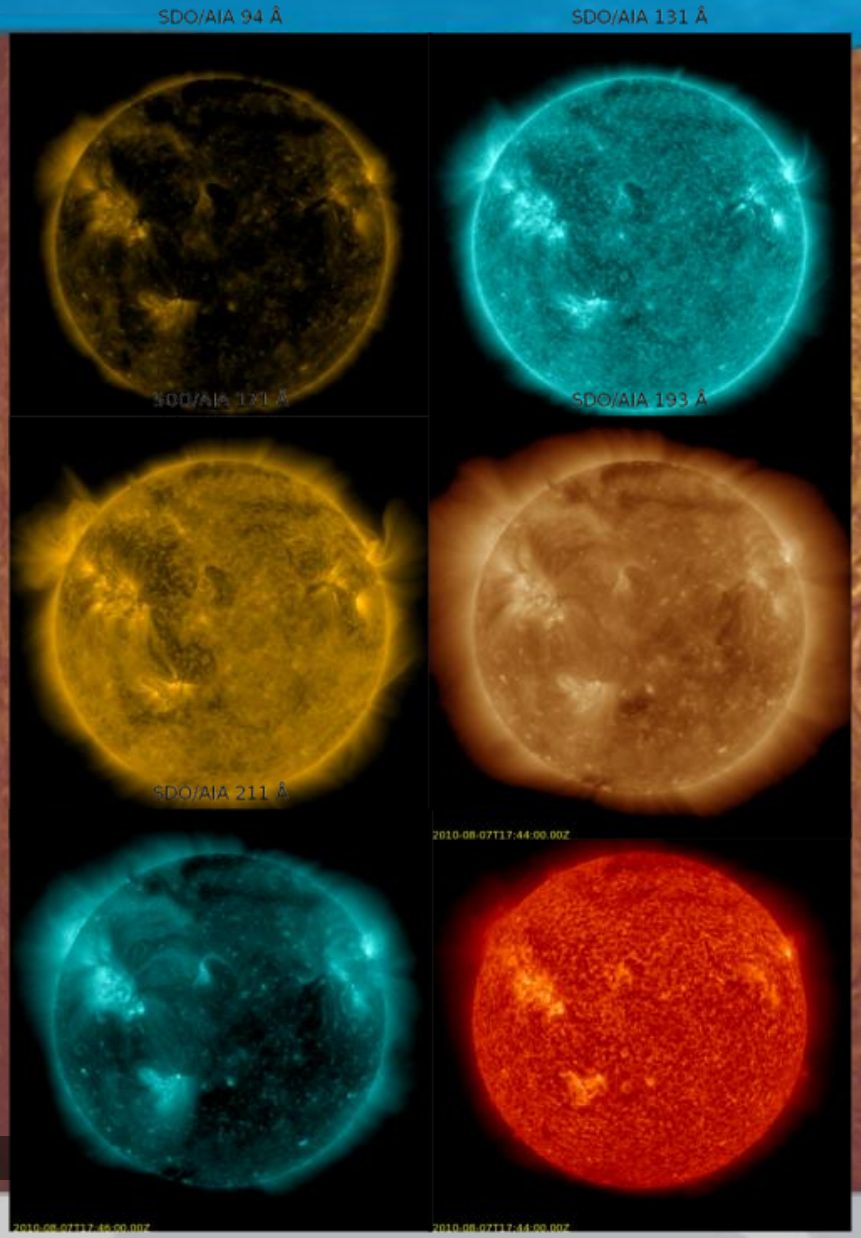
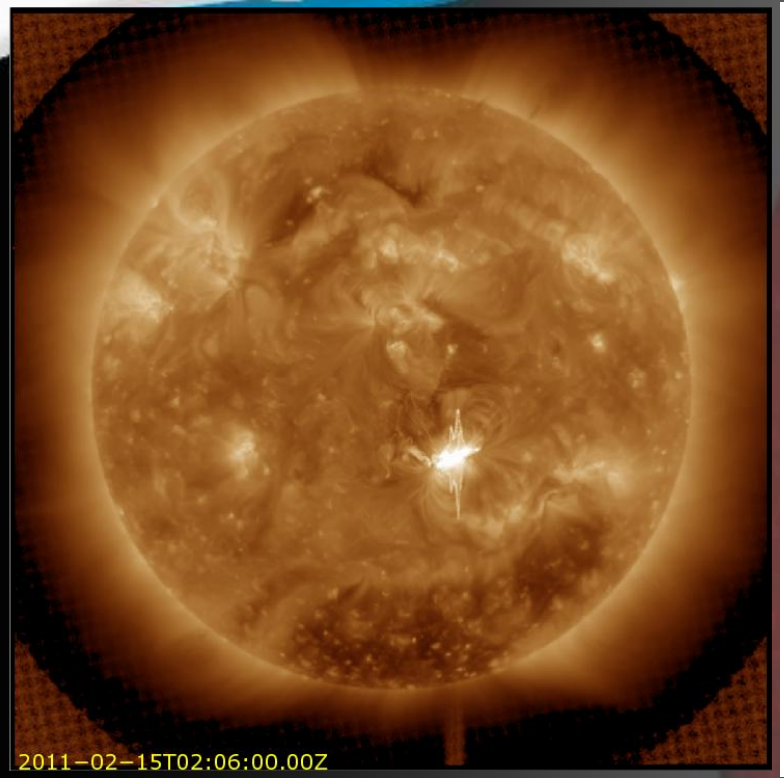


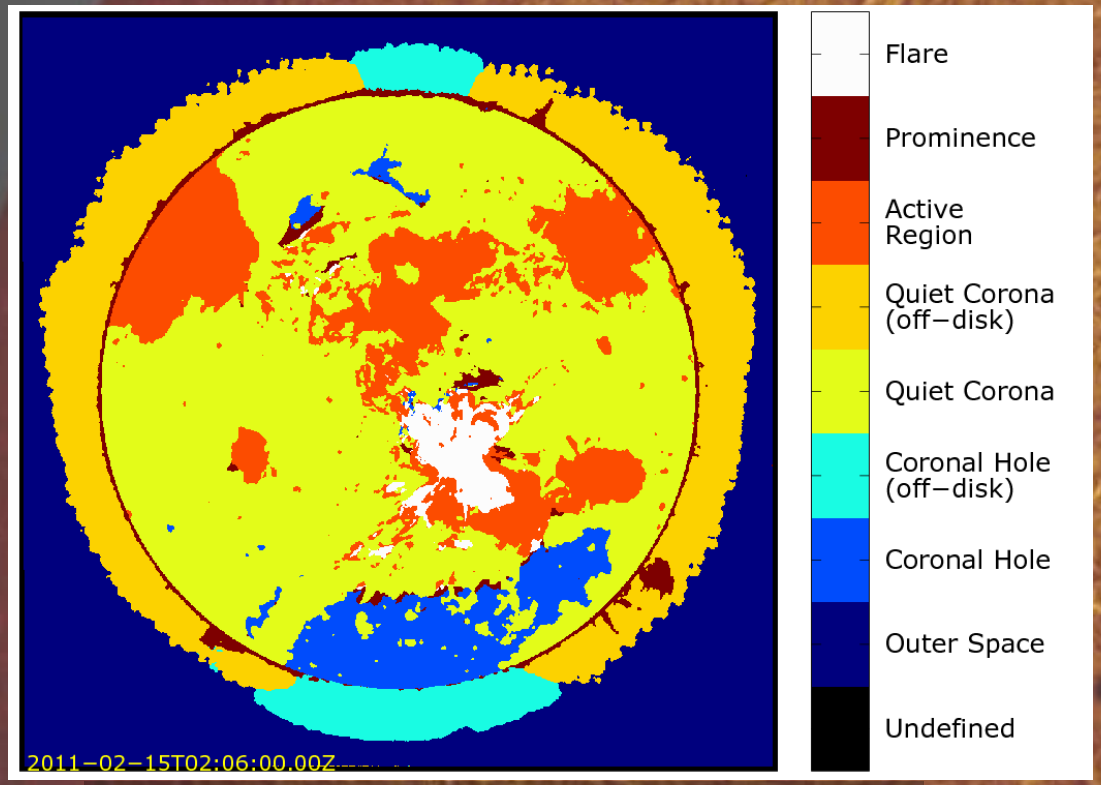
Image Credit: NASA SDO AIA

Automation Approaches

- Physics-Based
  - Differential Emission Measure (DEM) Retrieval
  - Continuum of values do not necessarily simplify forecaster interpretation
  - Models are not mature enough to ingest such data
- **Statistical**
  - Multispectral Bayesian classification
  - Segments images in to a limited number of meaningful classifications
  - Extensive heritage in terrestrial remote sensing
  - Forecaster training of algorithm ensures results are aligned with traditional visual interpretation

SUVI Thematic Map Algorithm Sample





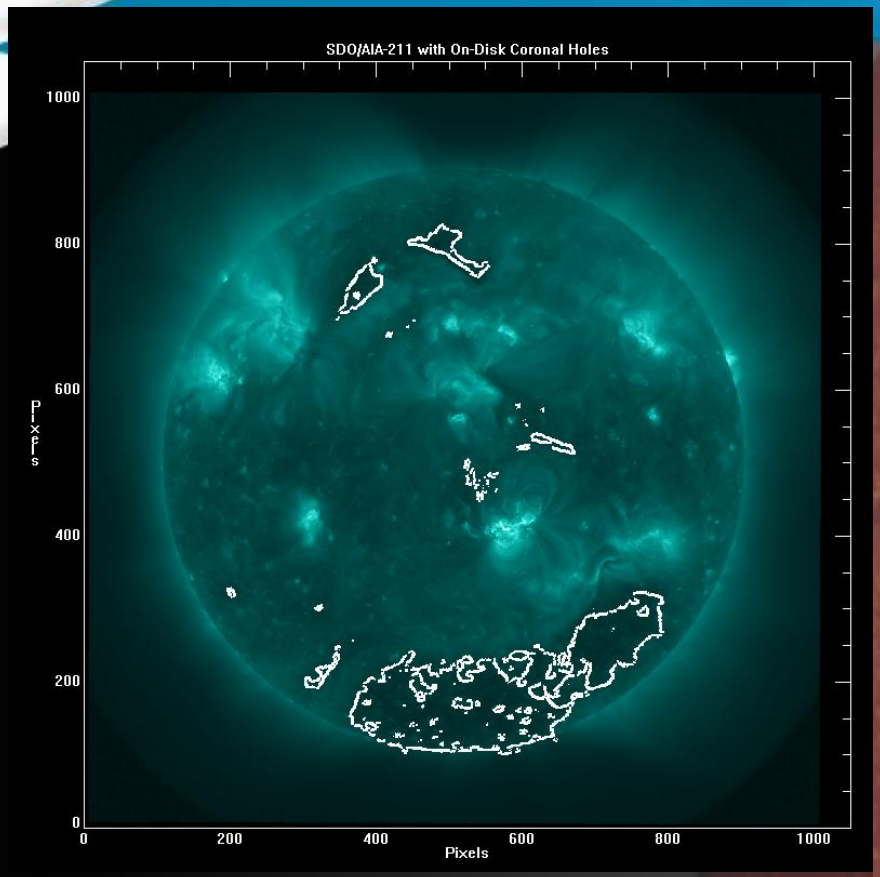
Rigler *et al.*, 2012 (in preparation)

AIA proxy data and corresponding thematic map

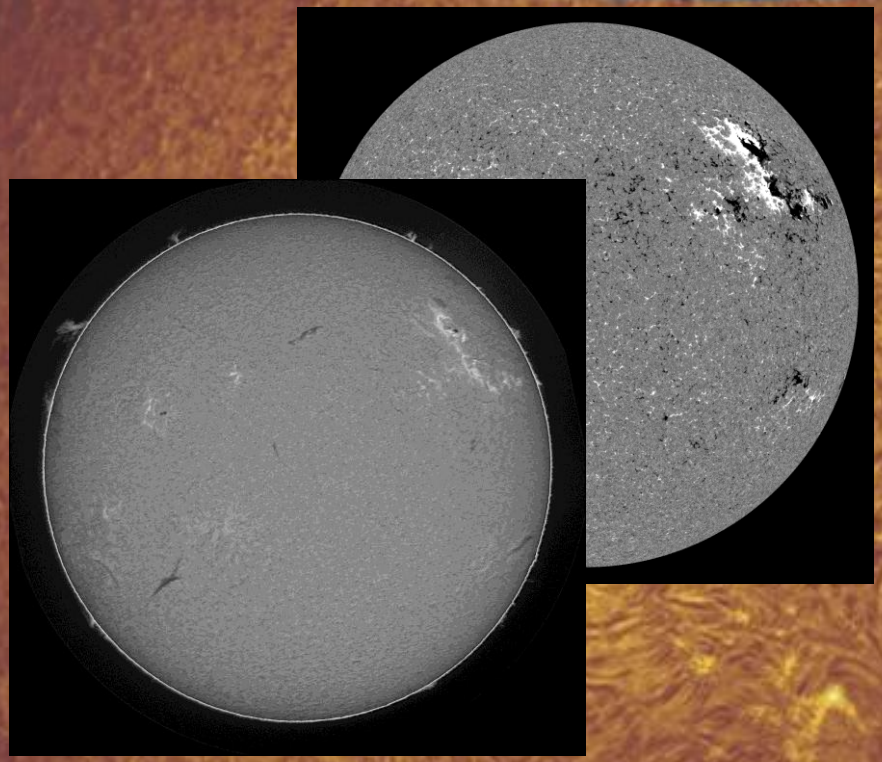
Proving Ground

- Space Weather Proving Ground will put Thematic Maps in front of forecasters in near real time by summer.
- Using AIA synoptic data at 3 min cadence.
- Processed in pseudo-operational mode (no 24x7 support)
- Will be presented in GRIB2 format and displayed in NAWIPS
- Forecaster evaluation will lead to further tuning of algorithm classification statistics

Future Steps



Automated feature identification and characterization



H-alpha and magnetogram "channels"

Summary

- GOES Role in Forecasting and Nowcasting
  - All GOES instruments provide a critical role in the chain of prediction and situational awareness
- NWS and WMO Product Integration
  - SWPC is integrating space weather – both GOES and non-GOES into the NWS enterprise
- Pilot Projects Building on Risk Reduction
  - Advanced products being developed for GOES-R are entering a trial phase.