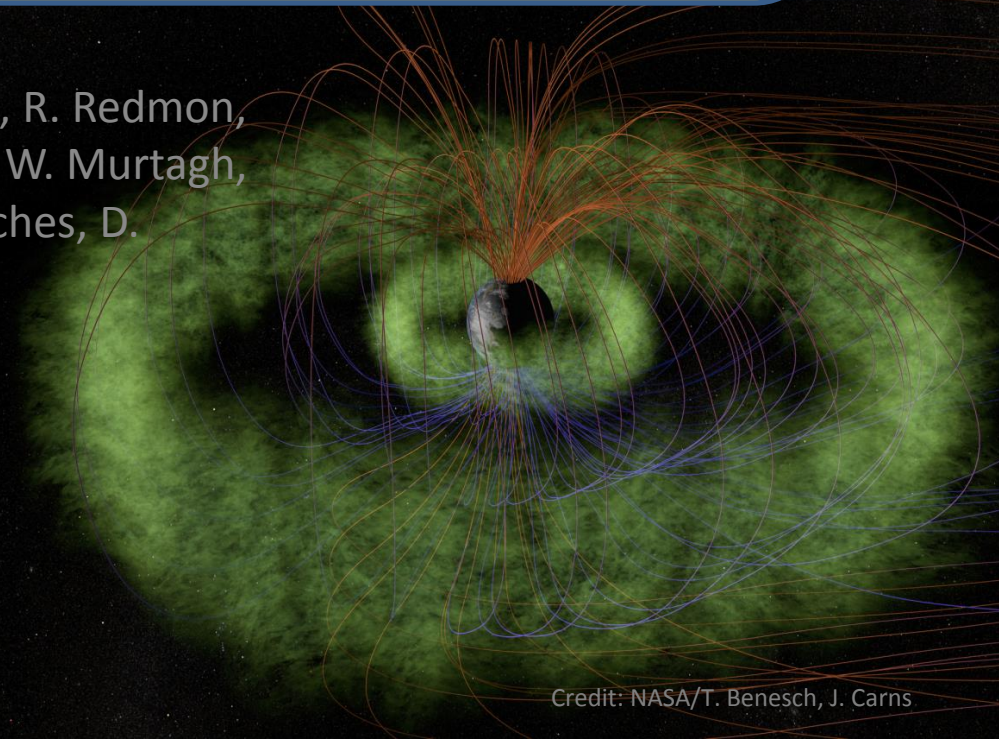


# NOAA resources for safeguarding the satellite infrastructure from space weather

Green, J.C., W. Denig, J. Rodriguez, R. Redmon,  
S. Codrescu, T. Onsager, H. Singer, W. Murtagh,  
R. Rutledge, J. Stankiewicz, J. Kunches, D.  
Wilkinson





# Outline

- Space Weather Radiation Effects on Satellites
- Challenges: Understanding, monitoring predicting space weather effects on satellites
- NOAA Resources
  - Anomaly analysis example: Visible Infrared Imaging Radiometer Suite (VIIRS)
- Future Directions
  - NOAA Satellite Anomaly Information Services data portal
  - Anomaly data base
- Other Activities



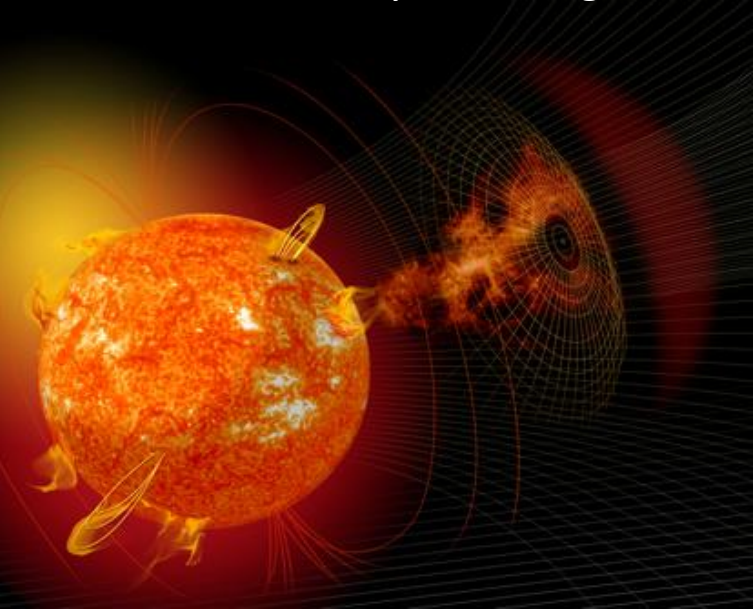
# Space Weather Effects on Satellites

My god Space is radioactive!



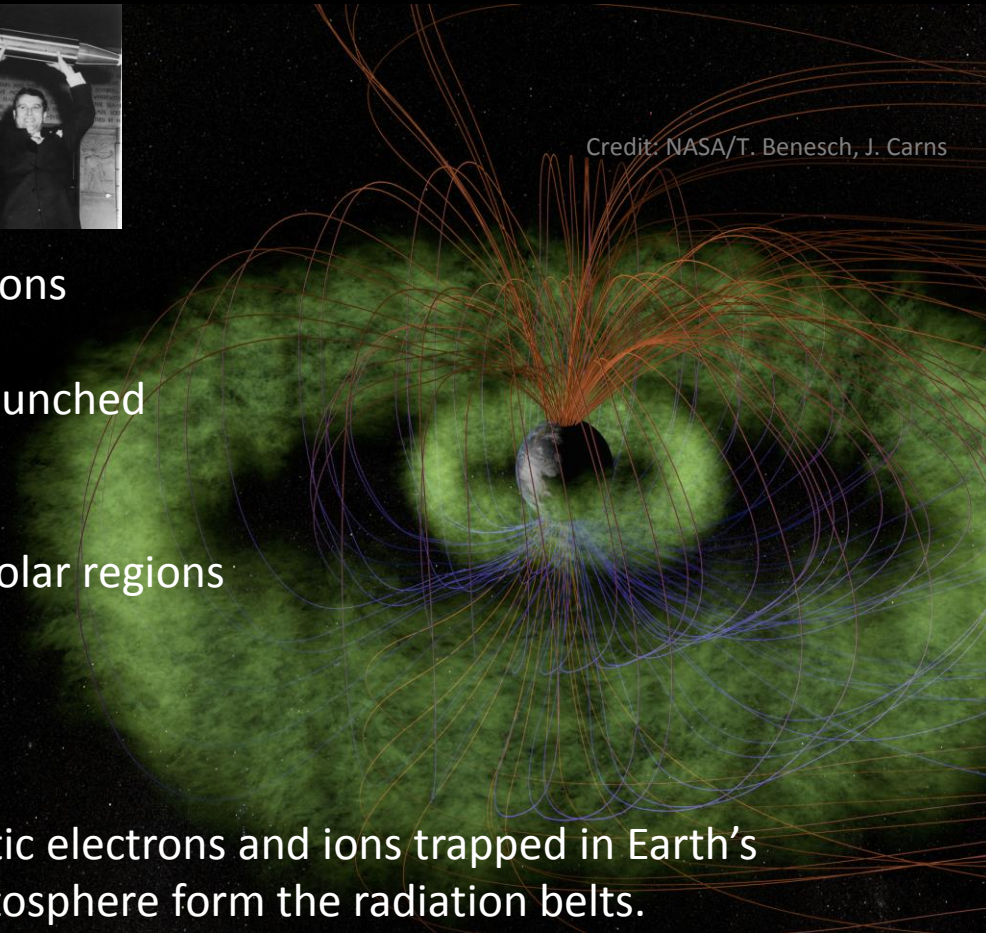
Energetic ions related to coronal mass ejections sporadically impact Earth.

- Reach Earth within hours after a CME is launched
- Occur ~100 times /solar cycle
- Duration is days
- Predominantly effect high altitudes and polar regions



Energetic electrons and ions trapped in Earth's magnetosphere form the radiation belts.

- Always present
- Intensity fluctuates with solar/geomagnetic activity.
- Peak intensity typically occurs on the declining phase of the solar cycle.



Credit: NASA/T. Benesch, J. Carns

# Space Weather Effects on Satellites

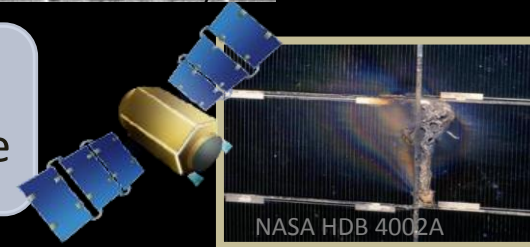
## Internal Charging

- High energy electrons collect internally until breakdown and discharge



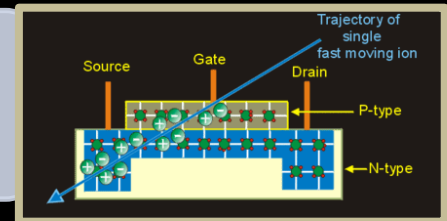
## Surface Charging

- Moderate energy protons/electrons collect on surfaces until sudden discharge



## Single Event Effects

- A single energetic ion causes a bit flip or burn out



## Total Dose Effects

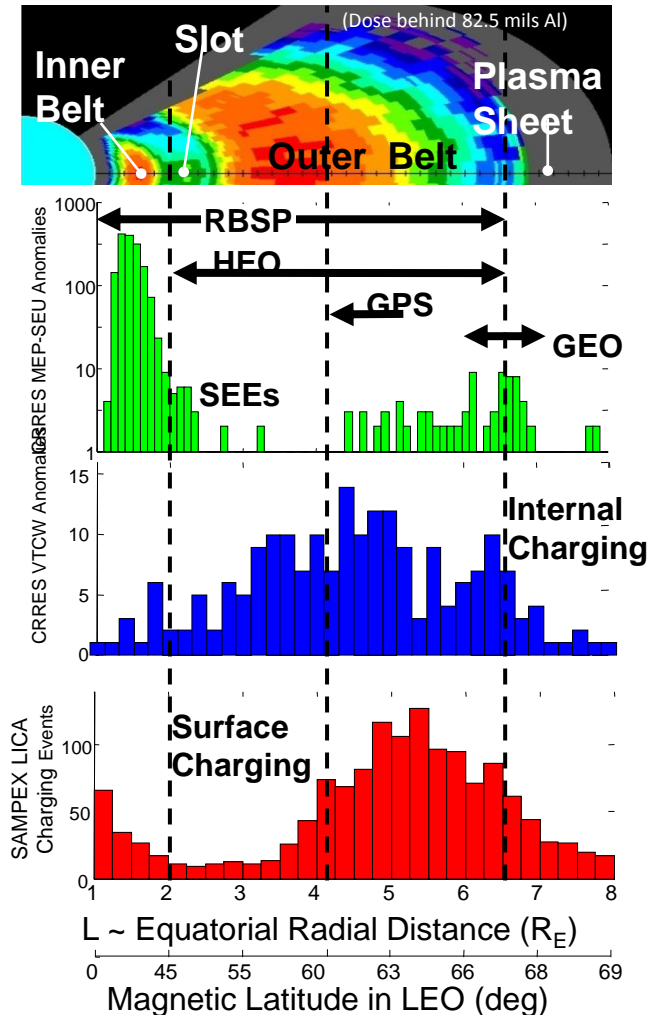
- Electronics and solar arrays performance degrade over time

# The Challenge

Monitoring, predicting, and connecting anomalies with space weather



- Different particles cause different types of anomalies
- Different particle energies cause different types of anomalies
- Different particles are observed at different locations
- Particle fluxes increase or decrease depending on different solar/geomagnetic drivers



# Radiation Environment Analysis



The best way to show the available NOAA data and tools is through examples

## LEO Example

- Visible Infrared Imaging Radiometer Suite (VIIRS)
- Suomi NPP



## GEO example

- [ftp://ftp.ngdc.noaa.gov/STP/publications/stp\\_presentations/presentations-oral/2011/WDenig\\_SWW\\_2011.pdf](ftp://ftp.ngdc.noaa.gov/STP/publications/stp_presentations/presentations-oral/2011/WDenig_SWW_2011.pdf)

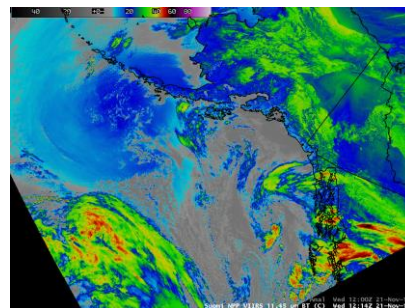






# VIIRS Anomaly Summary

VIIRS : measures cloud and aerosol properties, ocean color, sea and land surface temperature, ice motion and temperature, fires, and Earth's albedo on Suomi NPP



## Raytheon summary specifies 5 events

- 4 Events identical in behavior starting with loss of comm on both 1394 Bus A & Bus B
- Similar event with loss of comm on only 1394 Bus B

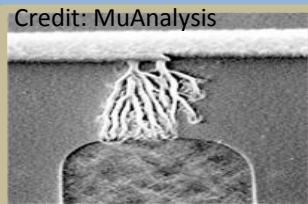
Investigation of this event pointed to code within the 1394 driver software which resides in the single board computer's DRAM. That memory unit is a commercial part and has known radiation susceptibility.

# VIIRS Anomaly

- Possible space weather related causes

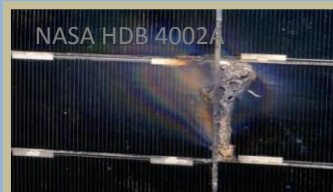
## Internal Charging

Credit: MuAnalysis

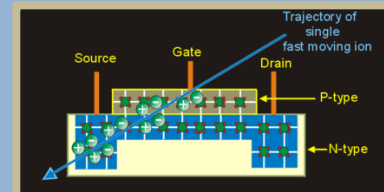


## Surface Charging

NASA HDB 4002A



## Single Event Effects



- Analysis method

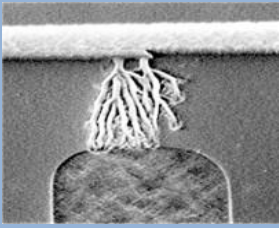
- Use NOAA Space Environment Monitor-2 from 5 POES and 1 MetOP-A satellite
- Available in real time at <https://www.ngdc.noaa.gov/stp/satellite/poes/dataaccess.html>

POES Constellation  
July 1, 2007  
13:30 - 17:30 UT





Credit: MuAnalysis



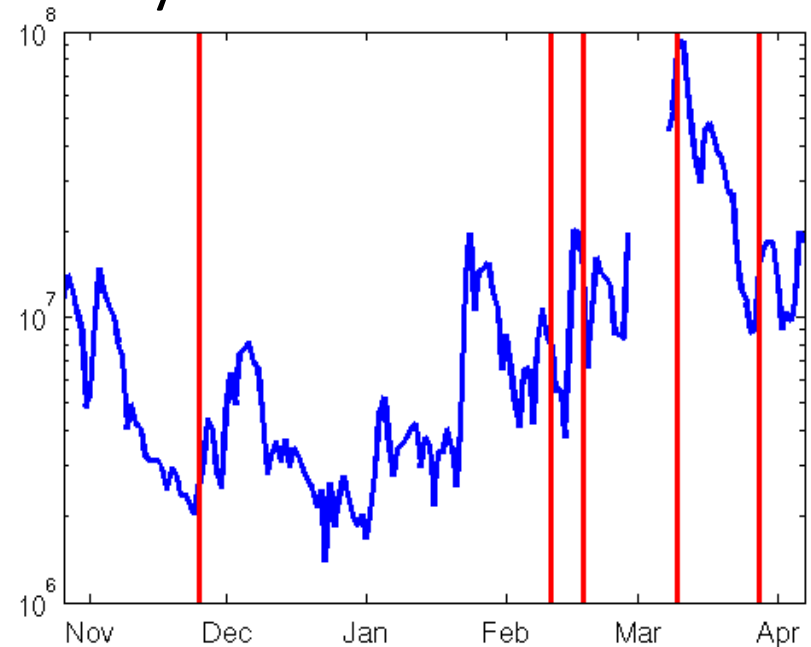
# Internal Charging Analysis



SEM-2 measures high energy electron flux (>300keV)

Flux is not enhanced in any systematic way prior to the events

Daily >300 keV electron fluence



Anomalies shown in red



# Surface Charging Analysis



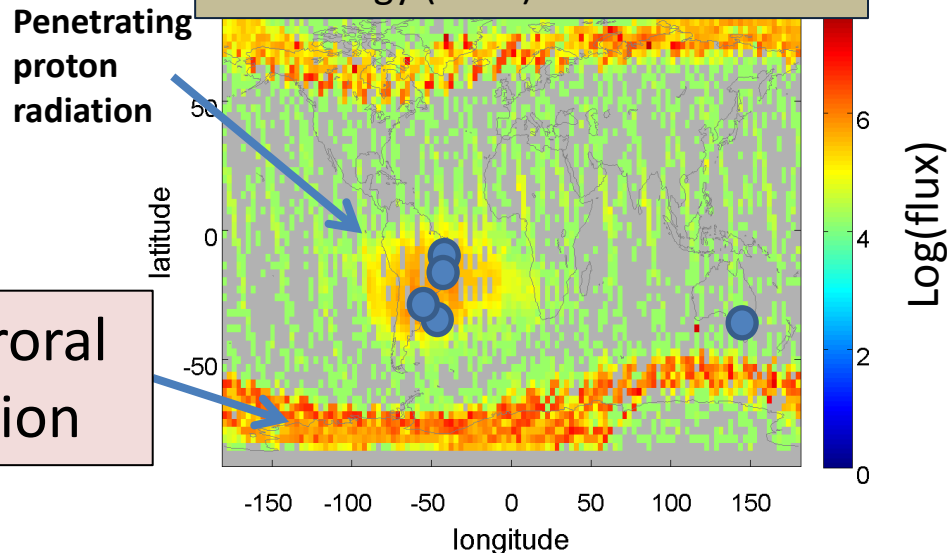
SEM-2 measures protons and electrons 50 eV -30 keV

No events in auroral region where low-medium energy proton/electrons are seen

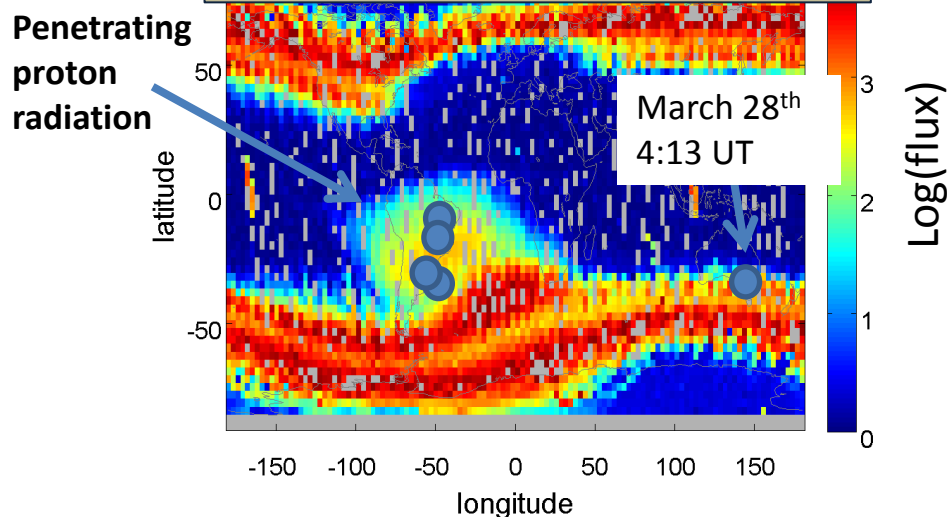
One event (Mar 28<sup>th</sup>) is located where medium energy electrons are present but at low levels

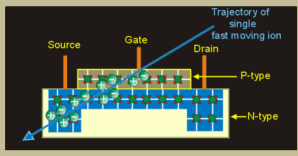
Auroral region

Low Energy (8keV) Auroral Electrons



Medium Energy (30 keV) Electrons





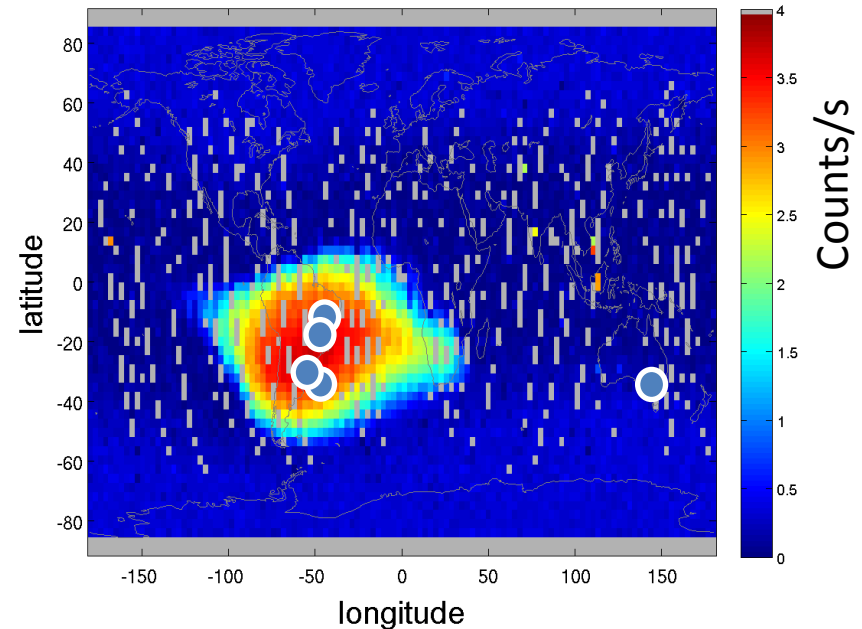
# Single Event Effects Analysis

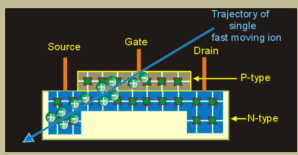


SEM-2 measures high energy proton flux

4 events occur in the South Atlantic Anomaly where high energy protons can cause single event upsets

>35 MeV Proton Flux

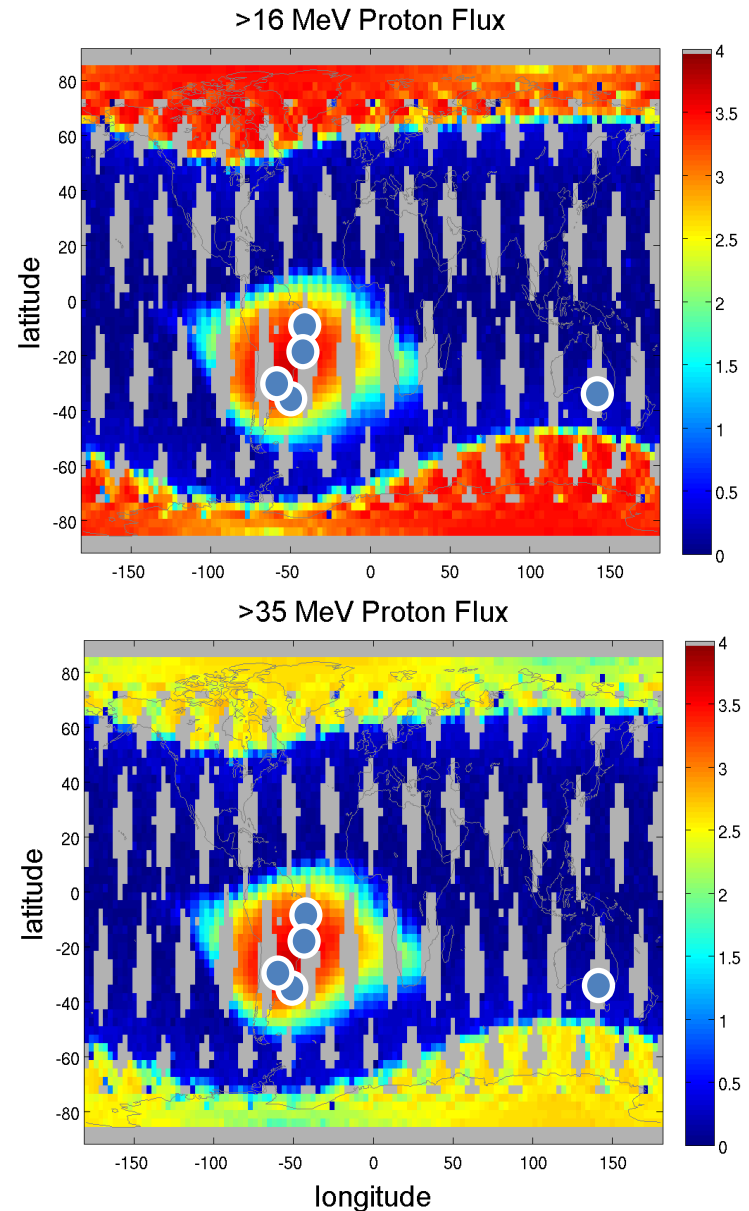




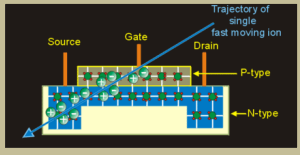
# Single Event Effects Analysis

Likely susceptibility to  
>35 MeV protons

All 4 solar proton events had >16 MeV flux levels comparable to those in the SAA but the >35 MeV flux levels were lower than in the SAA.

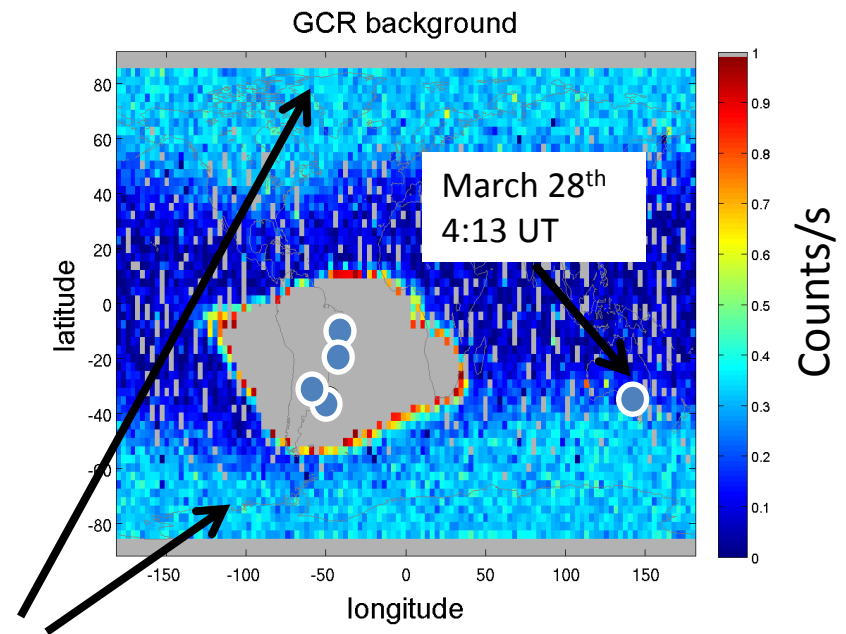






# Single Event Effects Analysis

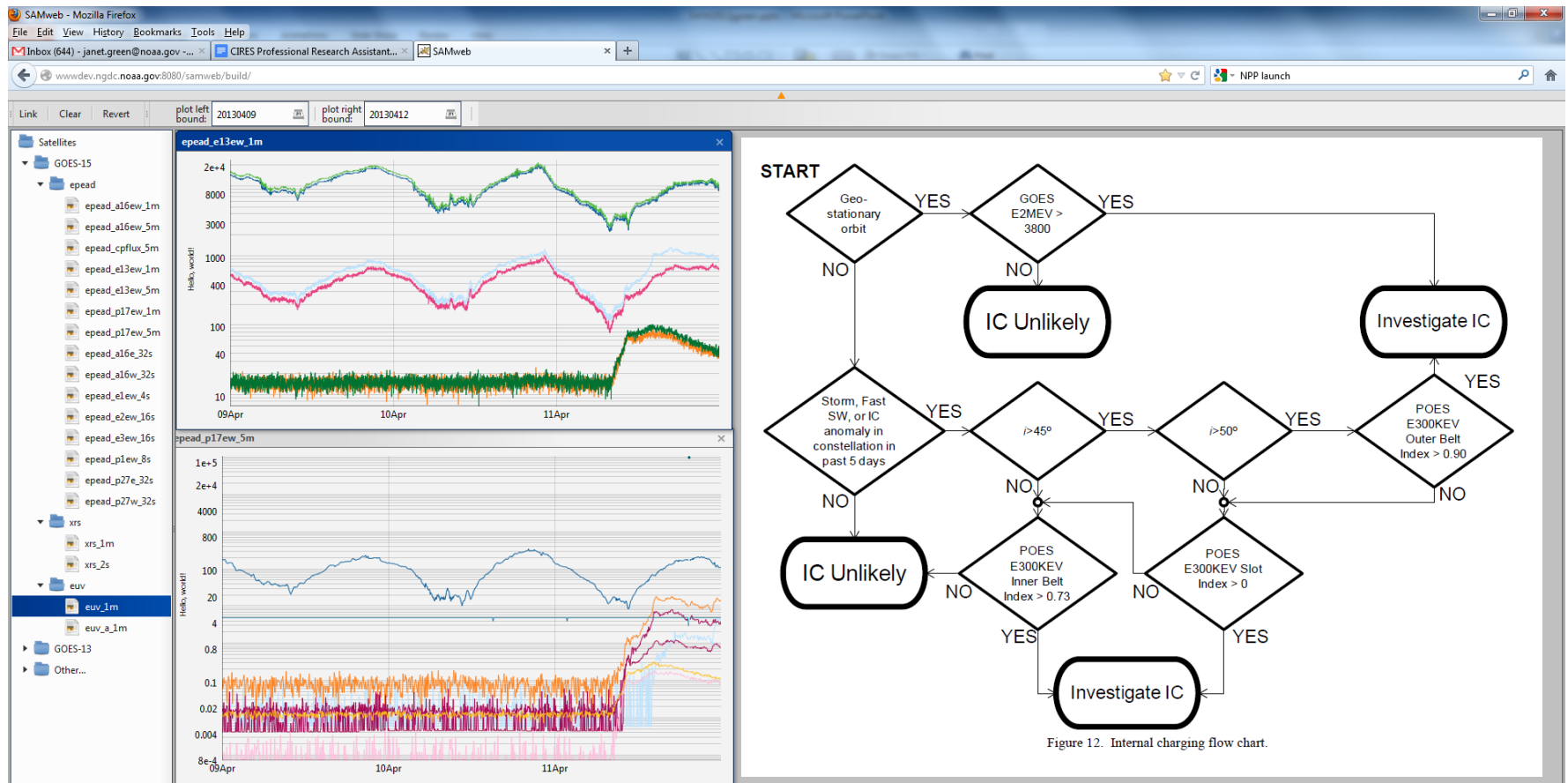
1 anomaly occurred in the region where Galactic Cosmic Rays are present that can cause single event effects



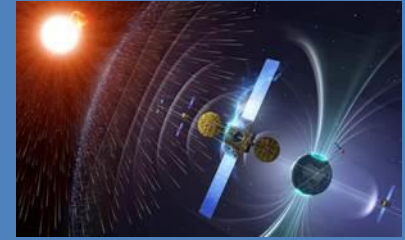
GCR background

# NOAA SAIS: Satellite Anomaly Information Services

- A one stop shop for data to quickly determine if an anomaly is related to the space environment
- The portal provides a standard palette that can be customized by the user and gives links to the data



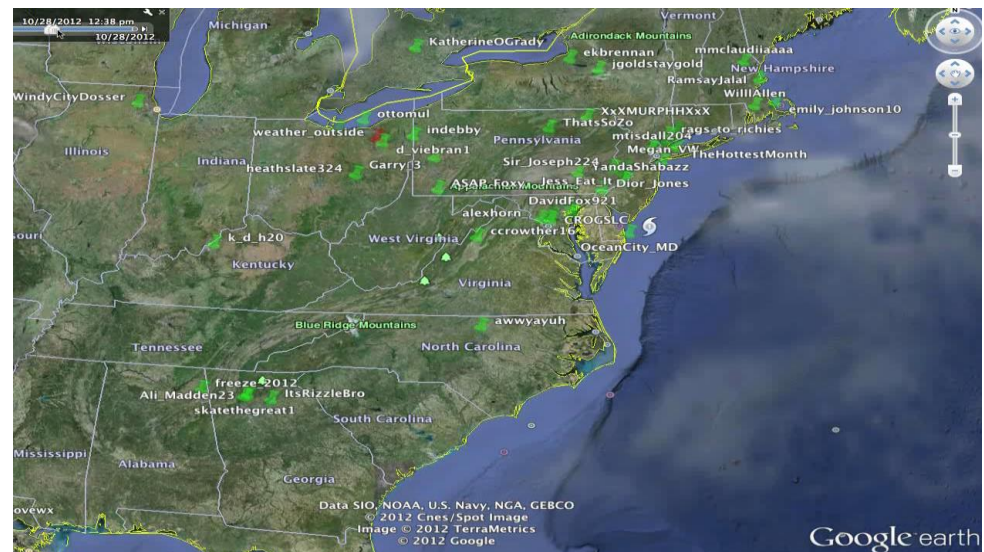
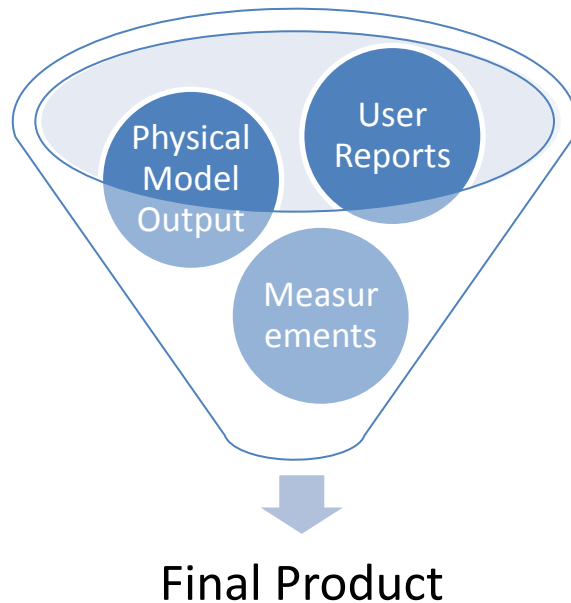
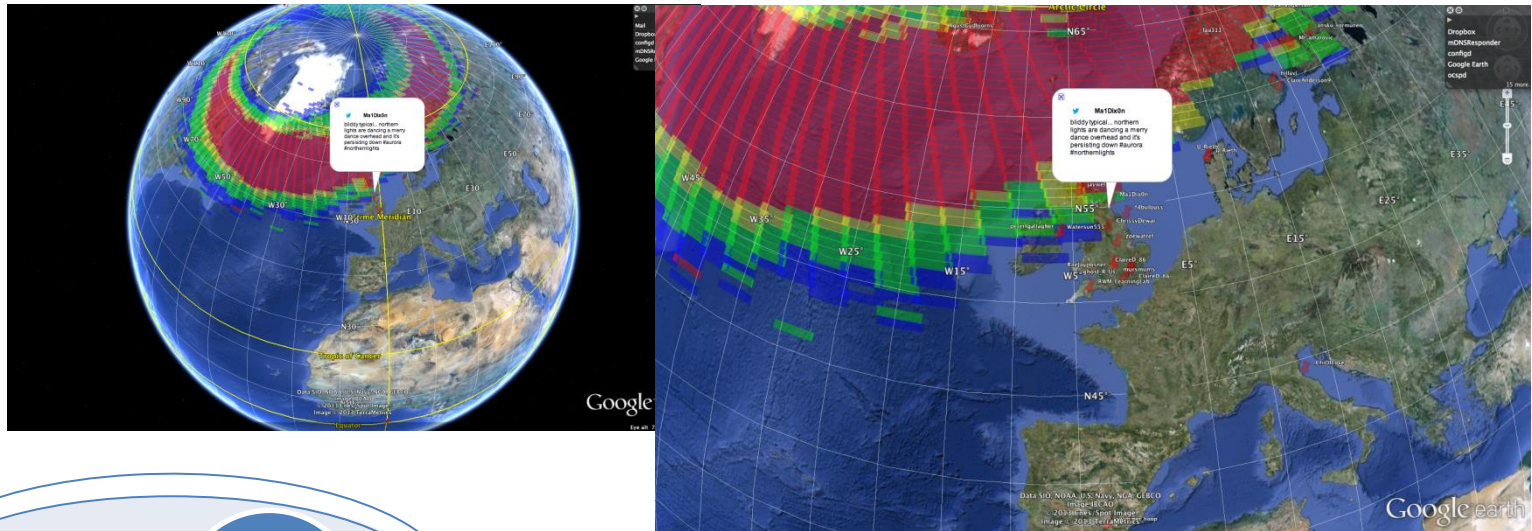
# Anomaly Database



- Community has requested an anomaly database
  - To develop models to predict when anomalies are likely
  - For designers to identify and correct space weather vulnerabilities
  - NGDC previously maintained a database
- NOAA SAIS will provide mechanism for reporting anomalies and accessing anomaly database
- Anomaly reports could be included with data and models as a real world validation

# People Empowered Products (PeEP)

Incorporates user reports into NOAA real time and retrospective weather products





# Other Activities

- United Nations Committee On the Peaceful Uses of Outer Space (UNCOPUOS)
  - Drafting guidelines and best practices
- ISO effort to generate a general satellite charging standard and worst case surface charging environment for design
  - team led by Dale Ferguson at AFRL





# Summary



- NOAA has many resources for understanding space weather effects on satellites
- Suggestions for other needed tools or products and ideas for collaboration are welcome ([sam@noaa.gov](mailto:sam@noaa.gov))