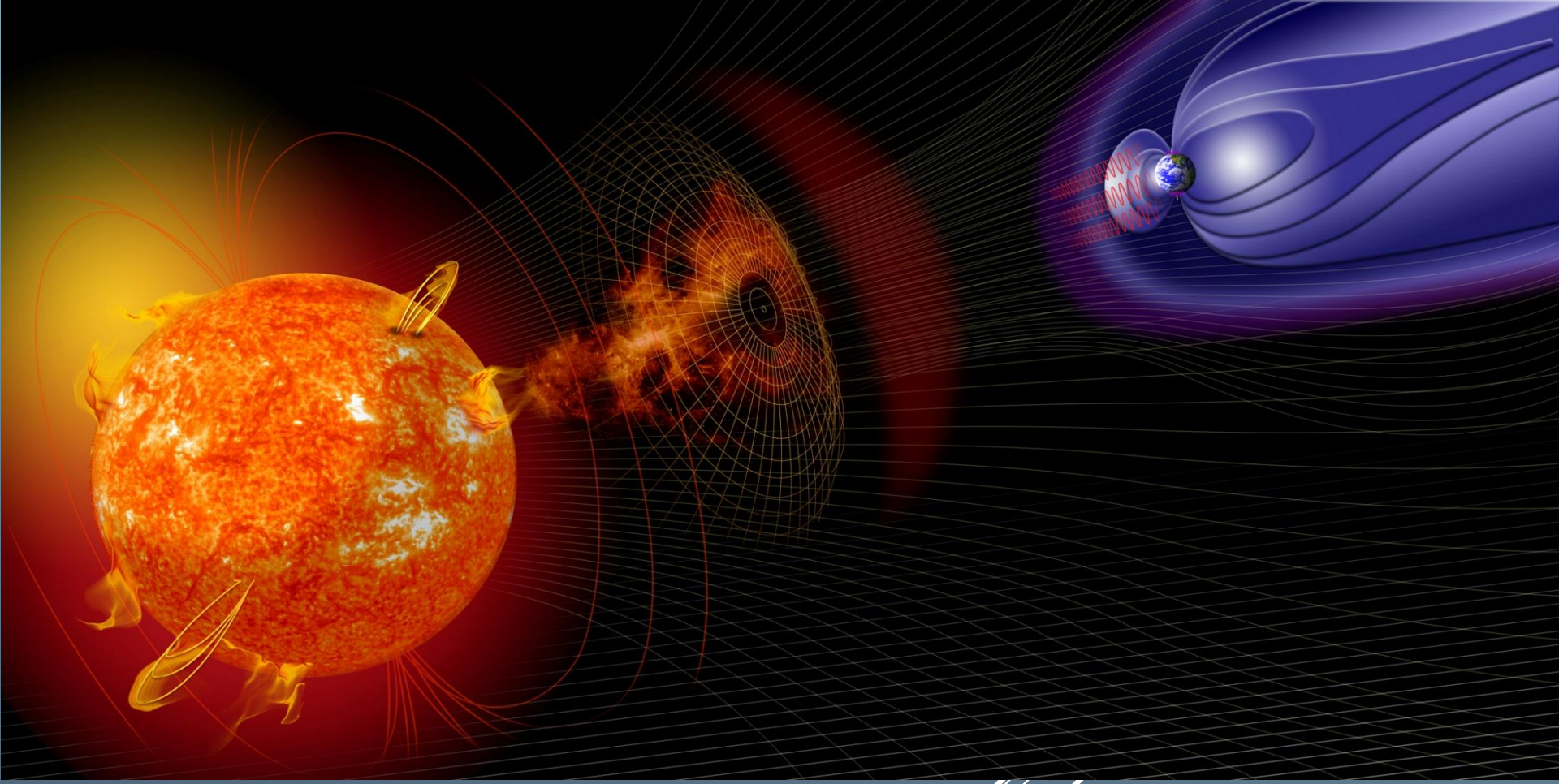


Overview of NASA MSFC and UAH Space Weather Modeling and Data Efforts

Dr. Linda Neergaard Parker, Jacobs ESSSA Group

Deputy for Space Weather, Space Plasma, and Spacecraft Charging to NASA Space Environment Tech Fellow

Outline

- Overview of capabilities
- Research / model development
- Applied space weather support
- Testing capabilities

Overview

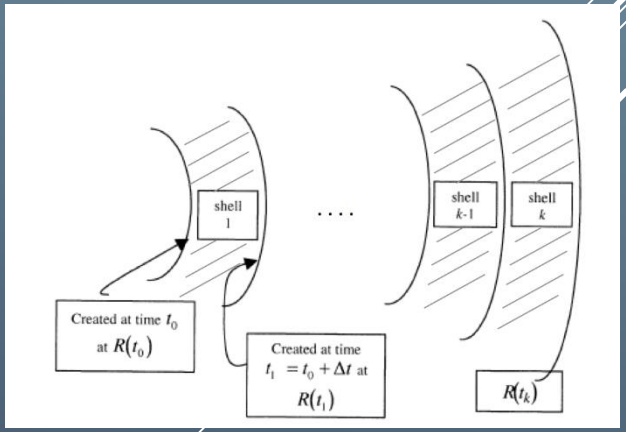
- Support all phases of the mission cycle for space weather and space environments.
  - Research
  - Testing
  - Model development
  - Design
    - Environment definition
    - Radiation, charging analyses
  - Launch availability - LCC
  - Anomaly investigation
  - Operations

Particle Acceleration and Transport in the Heliosphere (PATH) Model

- A dynamical time-dependent model of particle acceleration at a propagating, evolving interplanetary shock developed to understand solar energetic particle (SEP) events in the near-Earth environment – from 0.1 AU to several AU
- Instantaneous particle spectra at the shock front are obtained by solving the transport equation using the total diffusion coefficient κ_{ij}, which is a function of the parallel and perpendicular diffusion coefficients.

$$\frac{\partial f}{\partial t} + \underbrace{v_{w,i}\frac{\partial f}{\partial x_i}}_{\text{convection}} - \underbrace{\frac{\partial}{\partial x_i}\kappa_{ij}\frac{\partial f}{\partial x_j}}_{\text{diffusion}} + \underbrace{v_{D,i}\frac{\partial f}{\partial x_i}}_{\text{drift}} - \underbrace{\frac{1}{3}\frac{\partial v_{w,i}}{\partial x_i}\frac{\partial f}{\partial \ln p}}_{\text{energy change}} = \underbrace{Q}_{\text{source term}}$$

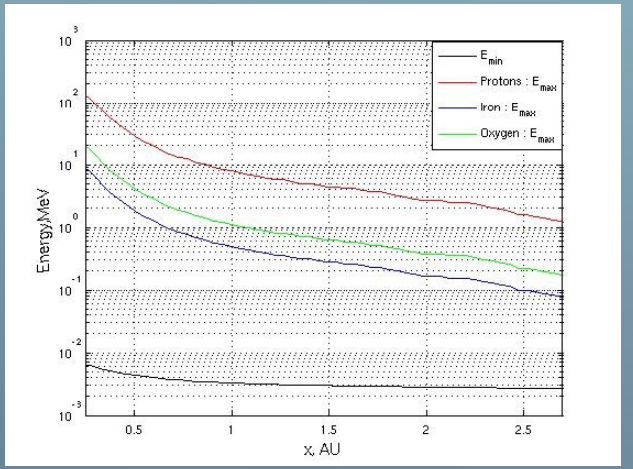
- Numerical shock is generated to represent a CME driven shock.
- Nest shells evolve (expand adiabatically and experience convection)
- At each point in time, tk, model can determine:
  - Particle injection energy (via diffusive shock acceleration mechanism) and injection rate,
  - Emax, diffusion coefficient, wave intensity velocity, density, temperature, shock compression ratio, etc.
  - Energetic particle spectra at all spatial and temporal locations,
  - Dynamical distribution of particles that escape upstream and downstream from the evolving shock complex



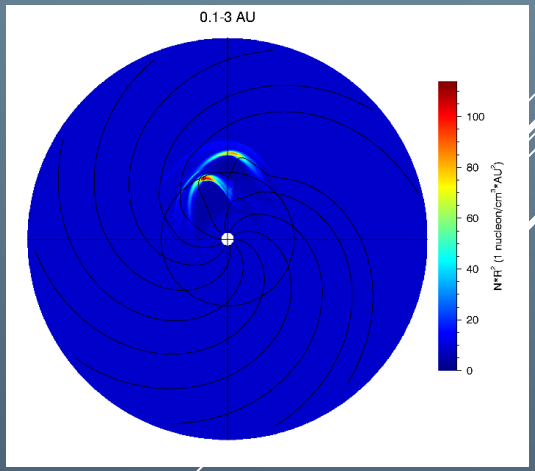
Gary Zank, UAH / CSPAR
Space Science Department

PATH Model

- A time-dependent model of shock wave propagation (1- and 2-D), local particle injection, Fermi acceleration at the shock, and non-diffusive transport in the IP medium does remarkably well in describing observed SEP events: This includes spectra, intensity profiles, anisotropies.
- Can model heavy ion acceleration and transport in gradual events, even understanding differences in Fe / O ratios, for example.
- We have begun to model mixed events to explore the consequences of a pre-accelerated particle population (from flares, for example) and have also related this to the timing of flare – CME events.
- Incorporates:
  - incorporates both solar flare and shock-accelerated solar wind suprathermal particles.
  - Arbitrary theta Bn and r (shock strength),
  - particle transport as they escape from the shock,
  - protons and heavy ions



SEP Event # 215 (shock arrival at ACE: Sept. 29, 2001, 09:06 UT) , Verkhoglyadova et al. 2007



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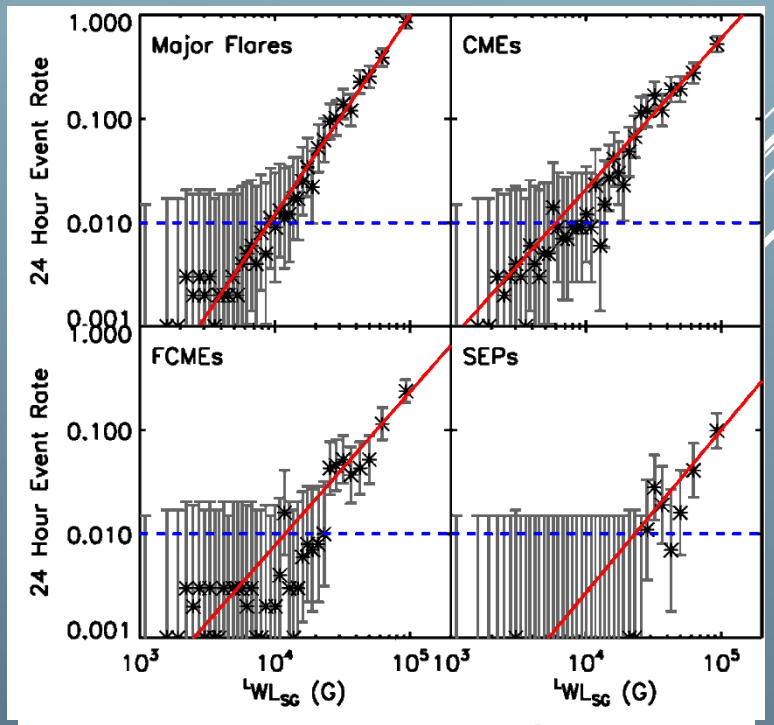
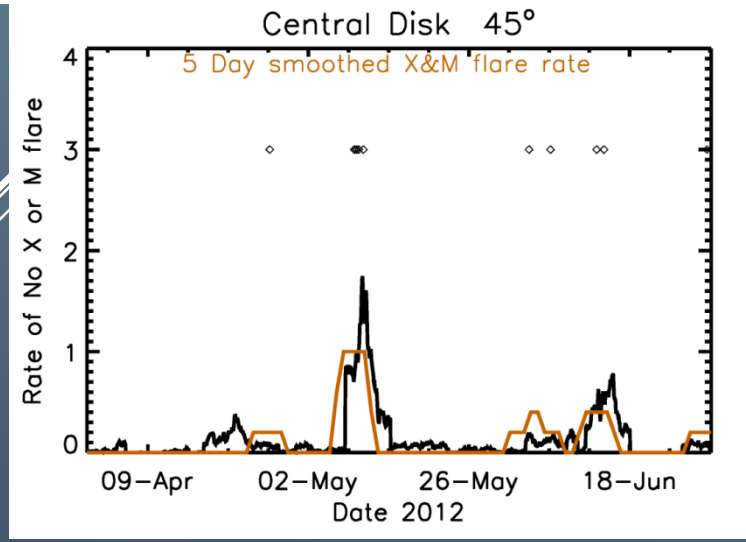
MAG4 (Magnetogram Forecast)

- MAG4 is a R20 project developing space weather forecast tool for NASA/SRAG, with access to NOAA, Air Force, and CCMC.
- It downloads HMI LOS or vector magnetograms, as well as recent flare history.
- It measures a free-energy proxy.
- The free-energy cannot be measured accurately with present instrumentation.
- The model uses empirically derived forecast curve to predict event rates.
- It presents the predicted event rates graphically, and in output files.
- Graphical on next slide



- Predicted X&M-class flare rate versus actual smoothed rate.



David Falconer, UAH/CSPAR

Comparison of Safe and Not Safe Days

June 26, 2013

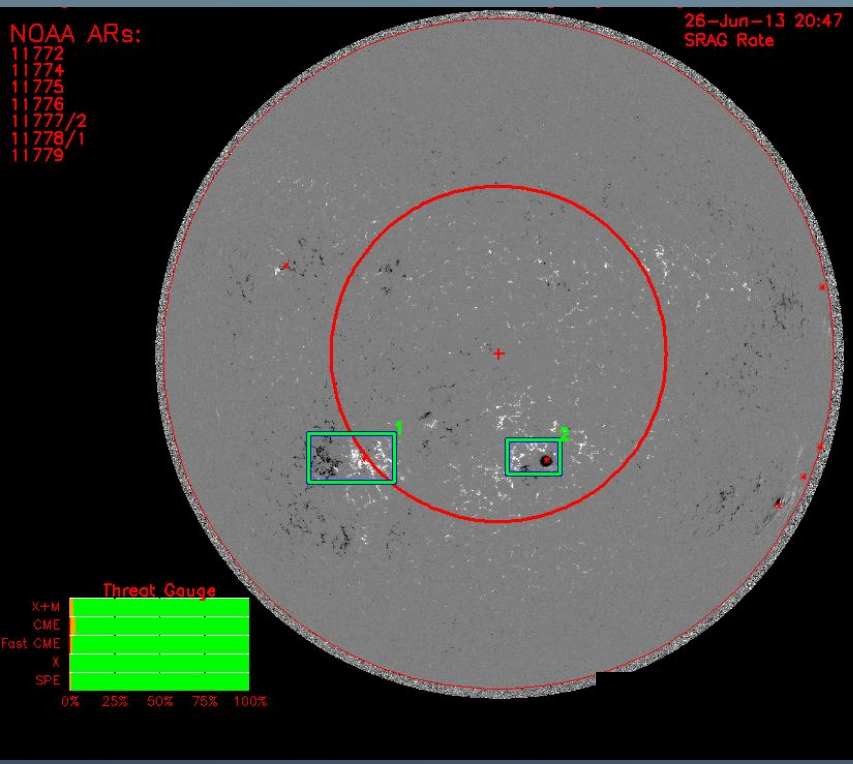
C1, C1.5 flares

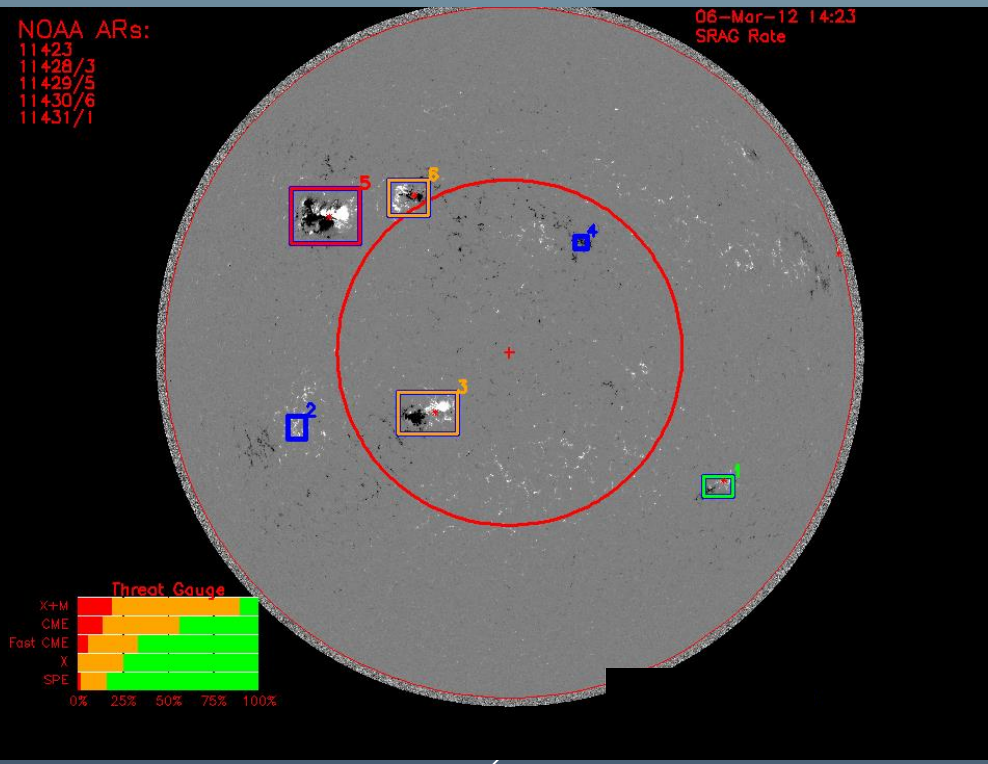
March 7, 2012

X5.4, X1.3, C1.6

CME 2684, 1825 km/sec,

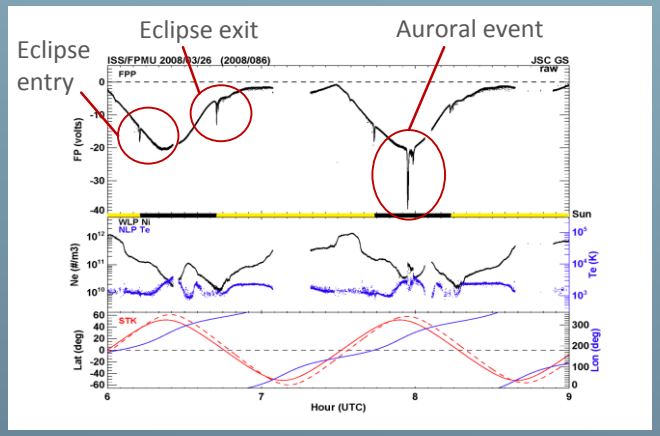
Solar Energetic Proton Event reaches 6530 particle flux unit >10MeV

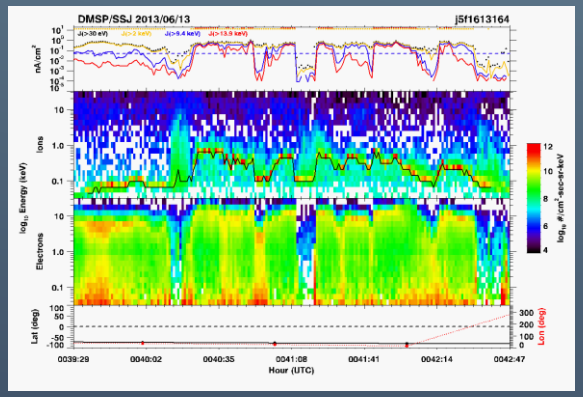


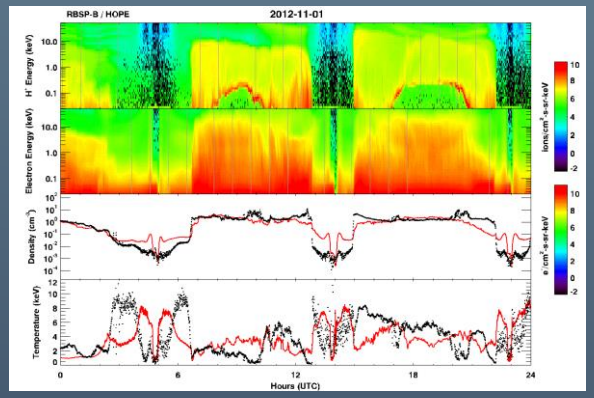


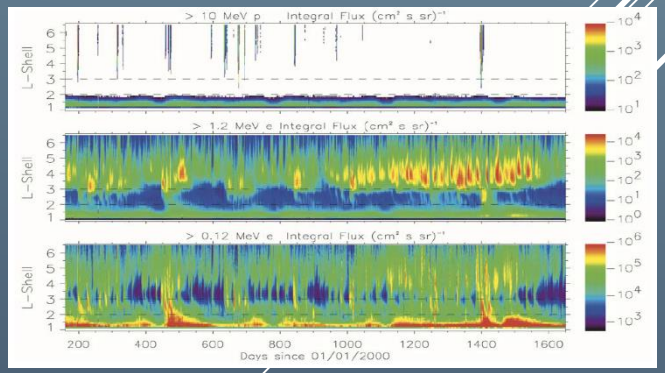
Marshall/EV44 Applied Space Weather Support

- Environment Definition for Spacecraft Design
- Modeling and Analysis
- Applied Space Weather Support
  - Anomaly investigations
  - Operational Support
- Routinely use observations for: polar, radiation belts, GEO, LEO, and interplanetary environments







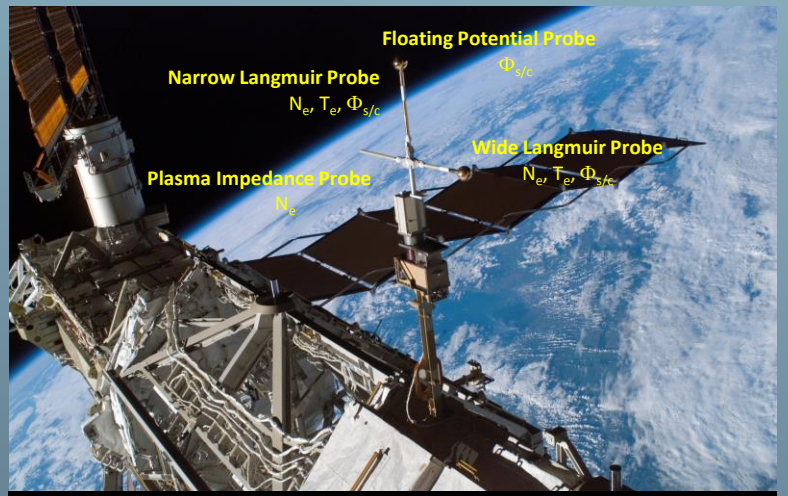


Brautigam et al., 2004

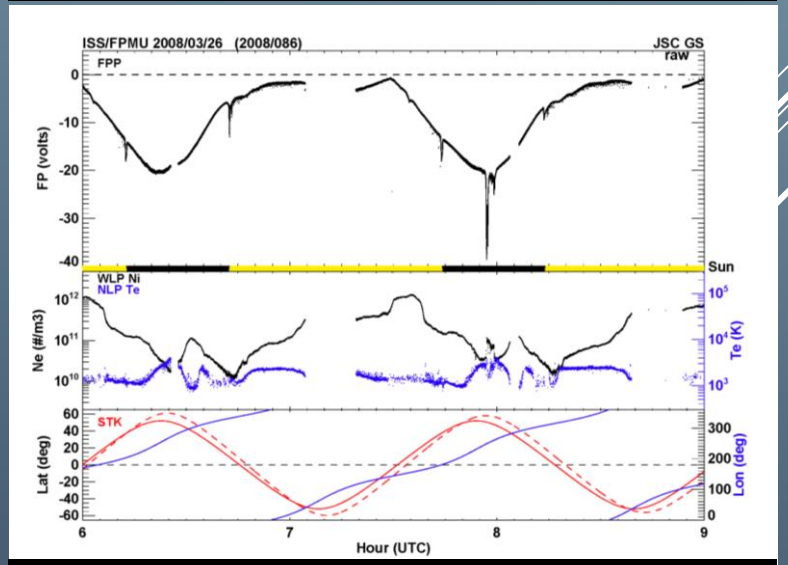
Applied Space Weather Support - ISS

- International Space Station (ISS) Floating Potential Measurement Unit (FPMU)
  - Instrument suite for monitoring ISS charging, plasma environments
  - Monitor visiting vehicle and payload charging
  - Characterize US high voltage (160V) solar array interactions with LEO plasma environment
  - Anomaly investigation
- Try to collect ISS charging data during geomagnetic storm periods in order to have information for the extreme environments

  Requires a strategy to improve odds of operating FPMU during geomagnetic storm periods.



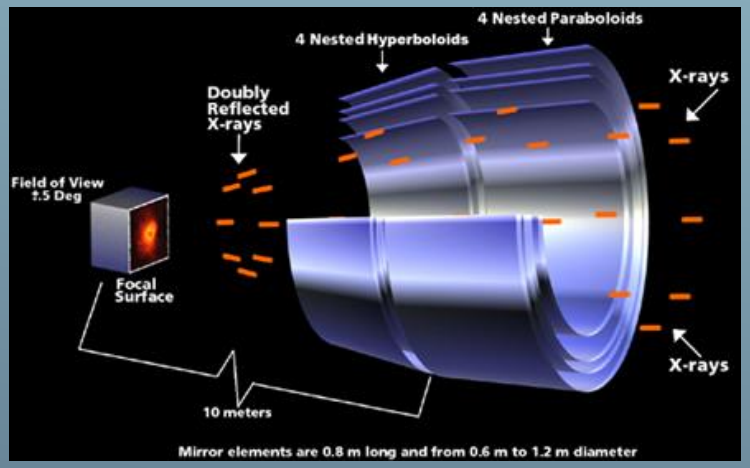
FPMU designed and built by Space Dynamics Laboratory (Logan, UT) on contract to NASA JSC



26 March 2008: FPMU captures auroral charging data during operations in support of STS-123 ISS and ATV docking

Applied Space Weather Support – Chandra

- Mitigation strategy for ACIS degradation issue
  - Schedule observations in low proton flux environments
- Chandra Radiation Model
  - Uses data from Geotail (EPIC/ICS instrument) and Polar (CEPPAD/IPS) spacecraft to populate the model.



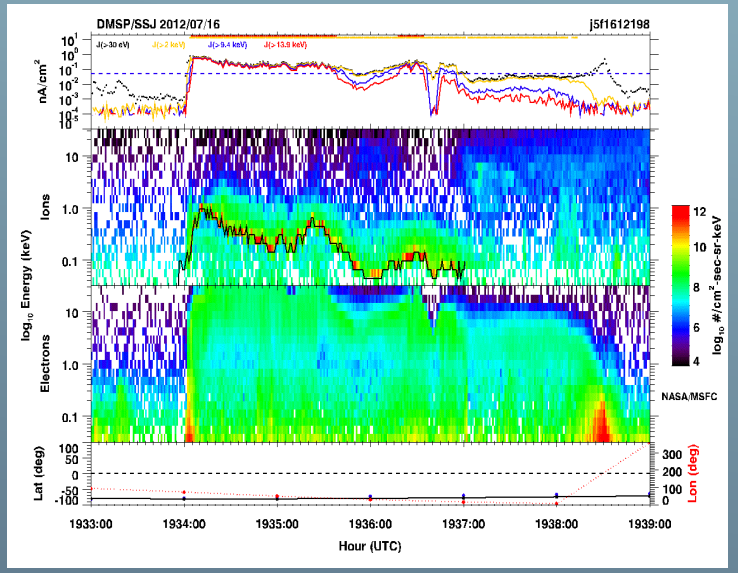
	Geotail		Polar			
P3/H+	77.3 - 107.4		6/H+	87.7	102.0	75.9	88.4
P4/H+	107.4 - 154.3		7/H+	118.0	138.0	103.0	121.0
P5/H+	154.3 - 227.5		8/H+	161.0	188.0	142.0	168.0
			9/H+	221.0	259.0	198.0	234.0

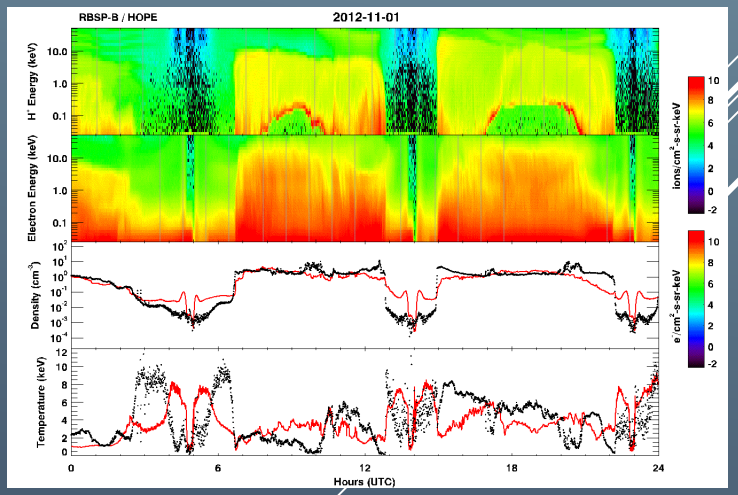
- ACE/EPAM real time monitoring
  - The ACE/EPAM RTSW records are the only real-time data for detecting ~100-200 keV proton events in interplanetary space that impact the ACIS instrument

ACE (NASA)	P3'	H+	115 – 195 keV	NOAA real time (5 min), manual

Applied Space Weather Support – phenomena characterization

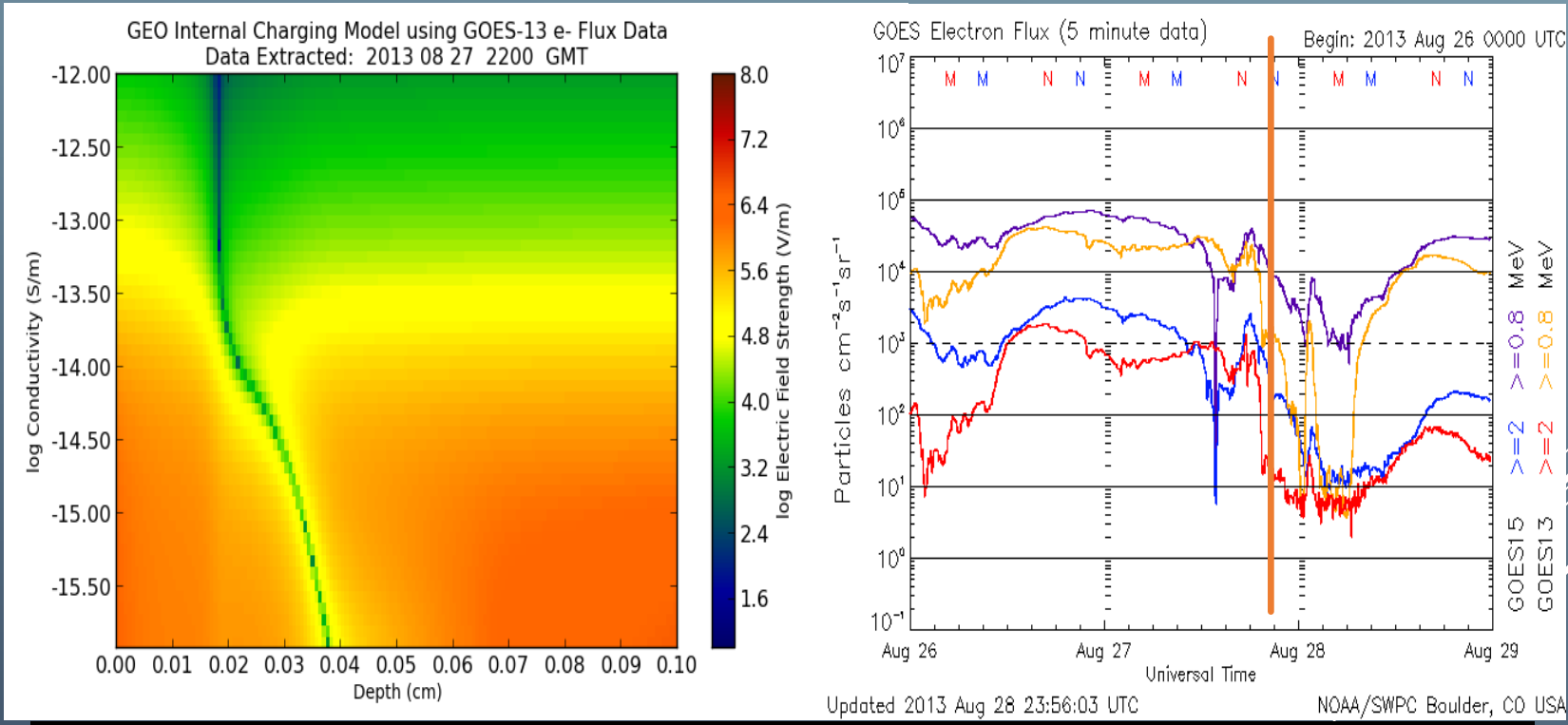
- **DMSP and RBSP surface charging**
  - MSFC developed software tools for working with DMSP SSJ and SSIES sensor data (F6 – F18)
  - Developing automated charging event identification algorithms, useful for "charging indices"
  - Characterize extreme charging to support spacecraft design, polar orbit operations
- Developing a statistical database to understand the location, duration, magnitude, etc. of surface charging events.





Real Time Space Environmental Effects Tools

- **Developing prototype engineering tools for evaluating effects of space environments on satellite systems**
  - Geostationary orbit single event upset tool (real time version of CREME96)
  - Geostationary orbit internal charging tool

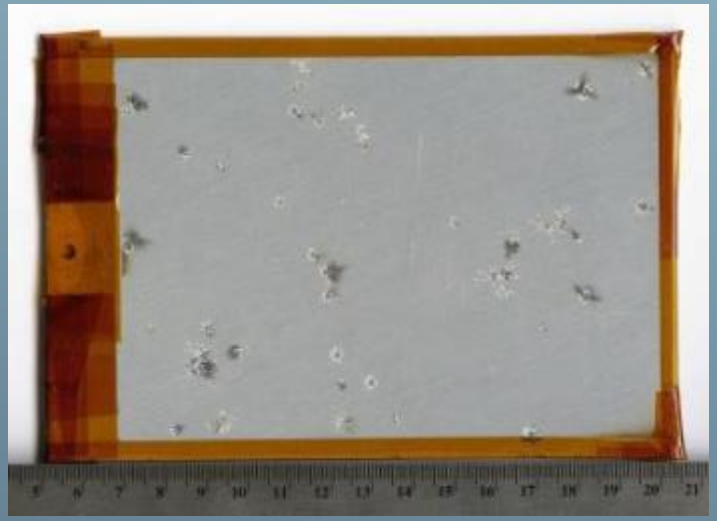


Electric fields resulting from internal (deep dielectric) charging as function of depth in dielectric material and electrical conductivity. Fields are updated at 5 minute intervals using NOAA GOES >0.8 MeV, >2.0 MeV electron data.

Space Environment Effects Testing and Calibration

Space environmental effects testing for broad spectrum of environments and effects:

- Energetic electron, ion radiation
- Ultraviolet (UV) radiation
- High intensity solar simulator
- Spacecraft charging (surface, internal)
- Atomic oxygen
- Thermo-optical properties
- Solar array interaction with space plasma, radiation environments
- Hypervelocity (meteor/orbital debris) impacts
- Thermo/vacuum/vibration
- Contamination/outgassing



Electrostatic discharge arc damage of ISS thermal control coatings

Low Energy Electron and Ion facility (LEEIF)

- Charged particle instrument calibration for particle energy, mass, flux, and angular acceptance
- Supports iterative design, build, and testing of space plasma instruments for variety of environments
- Electron/ion/UV sources, ISO 7 tent, ISO 5 bench, vacuum chamber, and data acquisition and analysis

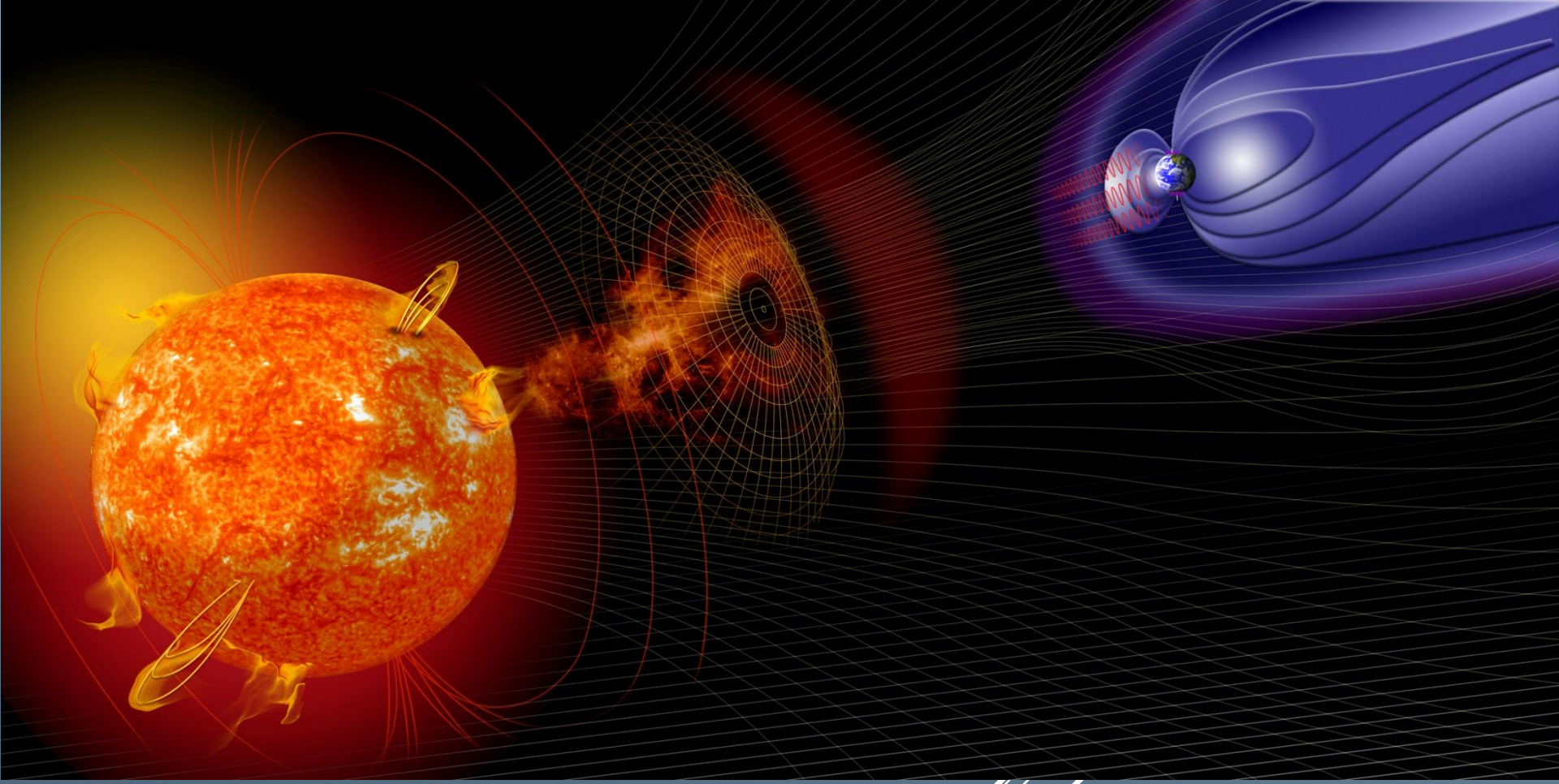
LEEIF chamber with test device in mount

Summary

- MSFC and UAH are active in the modeling and development of space weather tools for R2O.

- Data from all regions of geo to interplanetary space are used for
  - Research and model development
  - Environment definition for design
  - Phenomena characterization
  - Anomaly investigation
  - Operations
  - Modeling/analysis

- Broad spectrum for space environments testing



Questions?