Ongoing Collaborations within the Integrated Solar Energetic Particle (ISEP) Warning System Project

Janet E. Barzilla, Ph.D.[1]; Edward Semones[2]; Maria Kuznetsova, Ph.D.[3]; M. Leila Mays, Ph.D.[3]; Kerry Lee, Ph.D.[2]; A. Steve Johnson, Ph.D.[1]; Philip Quinn, Ph.D.[1], Kathryn Whitman, Ph.D.[4]

[1]Leidos Exploration and Mission Support, Houston, TX; [2]NASA Johnson Space Center, Houston, TX; [3]NASA Goddard Space Flight Center, Greenbelt, MD; [4]University of Houston, Houston, TX

ISEP Collaboration

Purpose:

To transition space weather models of interest in human spaceflight from research to operational (R2O) use to support forecasting needs for exo-LEO missions

ISEP Collaboration

- **Space Weather Forecasting Needs for Human Spaceflight**
- Human Spaceflight Applications with the ISEP Project
- Collaborations in Support of the ISEP Project

Space Weather Concerns for Human Spaceflight – A Quick Summary

- X-Ray Flare
  - No Impact
  - Can be associated with SPE/ESPE
- Geomagnetic Storm
  - Impact *only* if there is an increase in solar energetic particles (SEP)
  - Can 'compress' Earth's geomagnetic field/ protection
- Solar Particle Event (SPE)
  - Definition: >10MeV proton flux >10pfu (GOES)
  - Minimal impact unless crew is EVA
  - Low energy particles do not penetrate vehicle
- Energetic Solar Particle Event (ESPE)
  - Definition: >100MeV proton flux >1pfu (GOES)
  - Concern – SRAG monitors closely and makes recommendations to Flight Control Team (FCT)
  - Crew may be asked to avoid lower-shielded areas or shelter in highly-shielded areas of vehicle

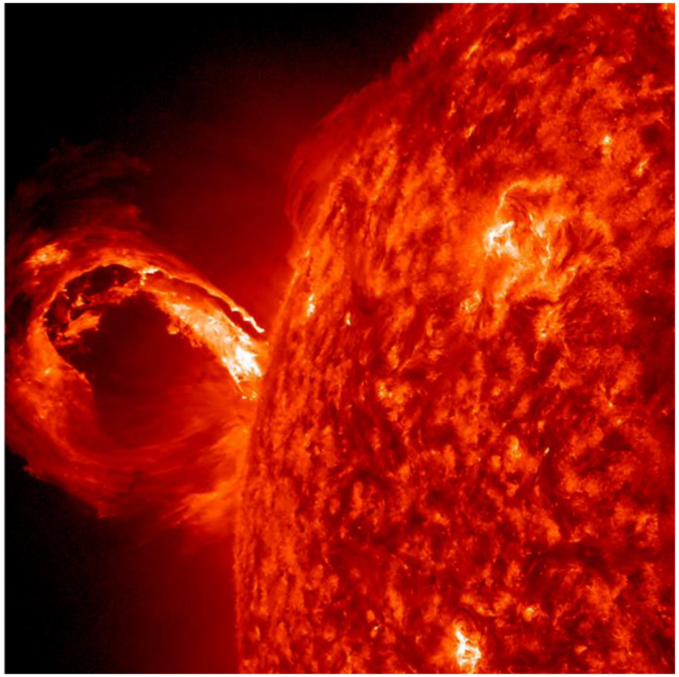


Image of Coronal Mass Ejection (CME) taken by NASA's Solar Dynamics Observatory (SDO) on May 1, 2013.
From: https://sdo.gsfc.nasa.gov

SRAG – Current Roles and Responsibilities

- SRAG provides 24/7 mission support for ISS
- Focus on ALARA – As Low As Reasonably Achievable
- "Big Three" questions the Console Operator always fields:
  - **Will there be an event (SEP)?**
  - **How 'intense' will it be?**
  - **How long will it last?**
- The console operator's ability to answer the "Big Three" questions is limited by current technology
  - Daily briefings provided by NOAA/SWPC to gain situational awareness
  - When large X-ray flare or SPE observed, SRAG is alerted by SWPC as well as own internal systems
  - Space weather models are available to assess possible impacts; this approach is best described as 'now-casting'

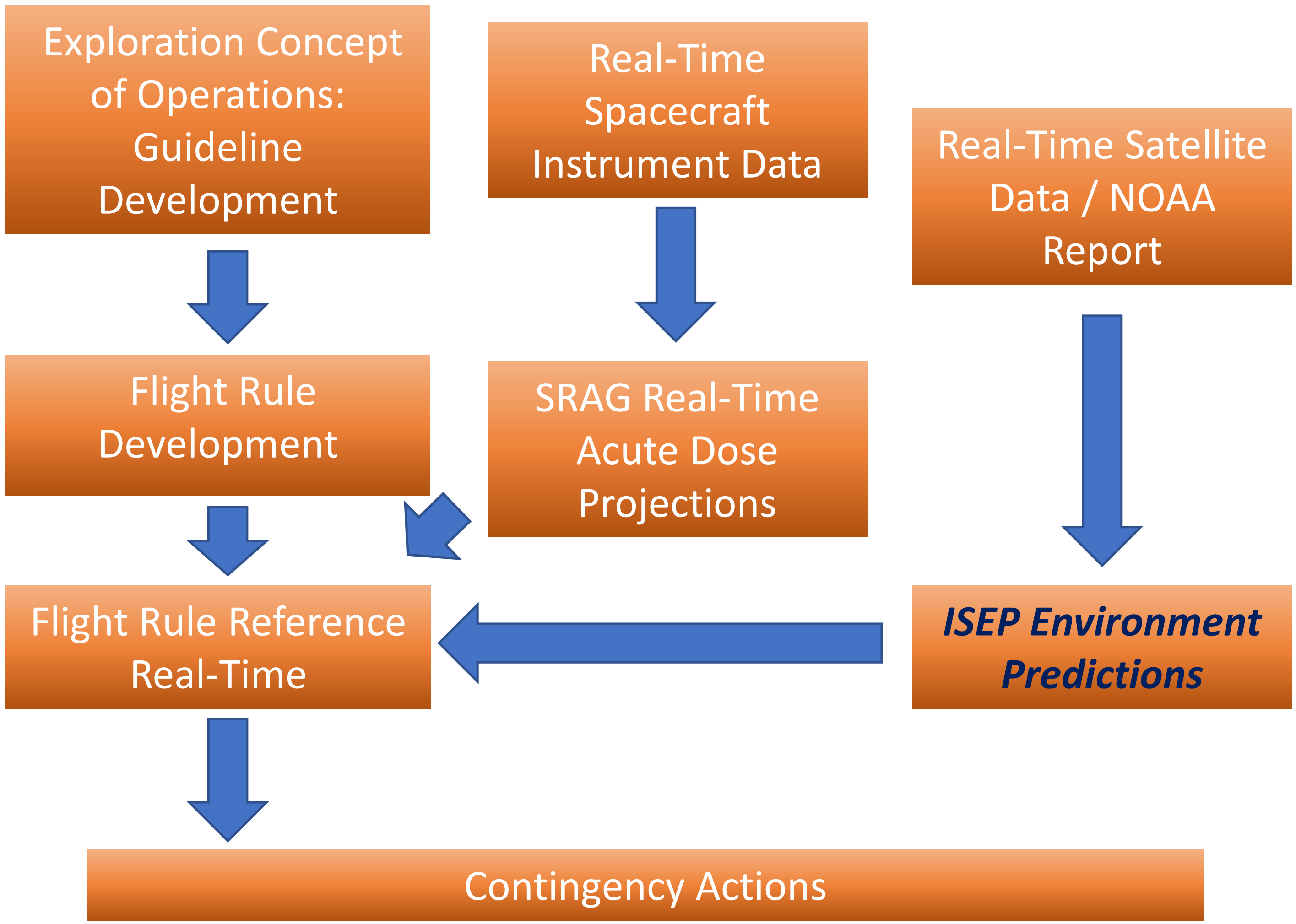
Mission Support for Exo-LEO Missions

- SRAG will continue 24/7 mission support for ISS, but there are complications
  - Free space missions
  - Communication capability
- Free space mission → crew cannot use protection from Earth's geomagnetic field
  - Vehicle design process incorporates advances in particle transport modeling and shielding technologies
  - Improvements to space weather forecasting capability (modeling) needed to give FCT information to act upon when making crew recommendations
  - Crew cannot shelter continuously for days; they need to know when they can exit shelter
- Reduced communications capability → FCT will need a longer lead time to determine recommendations for crew action
  - A 12-24 hour lead time would give the FCT more ability to act prior to communication blackout periods
- Ideal alert/warning system
  - Maximizes true event predictions
  - Minimizes false positive / true negative event predictions

ISEP Collaboration

- Space Weather Forecasting Needs for Human Spaceflight
- **Human Spaceflight Applications with the ISEP Project**
- Collaborations in Support of the ISEP Project

Operational Schema for Exo-LEO Missions



‘Big Three’ – Model Focus

1) Will there be an event (SEP)?

   Probability Scoreboard

2) How ‘intense’ will it be?

   Proton Peak Flux Scoreboard

3) How long will it last?

   Flux Time Series Scoreboard

Research Model Investments to Operational Tools

- Focus on two paths
  - Statistical-based models:
    - Models will be integrated to run as an ensemble output for peak SEP fluence.
  - Physics-based models:
    - Higher complexity over statistical models
    - Less mature
    - Build on past agency investment in forecasting temporal evolution.

- Leverage current capabilities
  - Multiple models previously developed under SMD
  - ISEP infrastructure funded under STMD FY12-FY14
  - Current SMD data streams
  - GSFC/CCMC and JSC/SRAG expertise and functionality to develop ensemble techniques and operational architectures

ISEP Collaboration

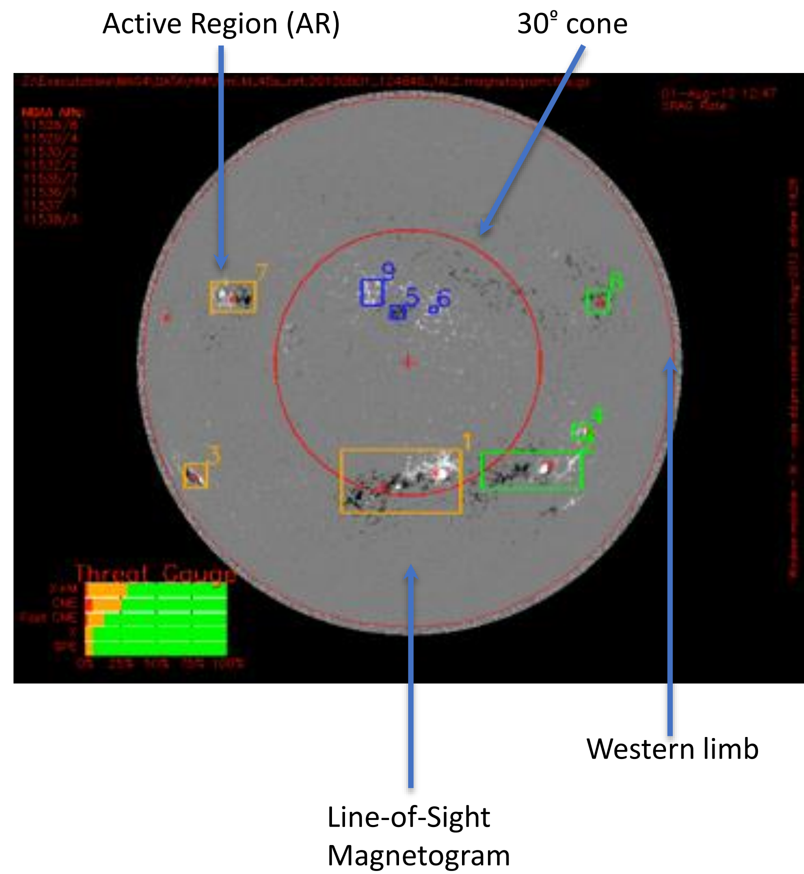
- Space Weather Forecasting Needs for Human Spaceflight
- Human Spaceflight Applications with the ISEP Project
- **Collaborations in Support of the ISEP Project**

Current Collaborations: Overview

Model	Description	Collaboration	NASA Investment
CORHEL	CORona-HELiosphere – coronal model developed by Predictive Science	Joint: Small business / University	NASA SBIR Phase I (HEOMD), SMD/LWS, STTR (collaboration with UNH)
EPREM	Particle transport through the heliosphere	Joint: Small business / University	SMD/LWS, STTR (collaboration with PSI)
iSWA	Integrated Space Weather Analysis system	NASA	SMD; CCMC to add connectivity models
Mag4	All-Clear forecast for x-ray flares, SEPs and CMEs using magnetogram imagery. University of Alabama Huntsville and MSFC.	University	HEOMD/SRAG investment since 2009. SMD investment through LWS.
SEPMOD	SEP model; moving shock source is specified, transport calculation gives related time profile sampled by stationary observer (at 1AU)	University	SMD/LWS; Funded in FY19
REleASE	Relativistic Electron Alert System for Exploration: Prediction of proton fluence at L1 via prompt arrival of energetic electrons. HESPERIA continued development effort	University (EU)	SMD, funded by AES in FY19
UMASEP	Prediction of time interval where >10 MeV protons will exceed threshold of 10 pfu, and >100MeV protons will exceed threshold of 1pfu. HESPERIA continued development effort (>500MeV)	University (EU)	Funded by AES in FY19
Richardson	Prediction of peak flux	NASA / University	GSFC-based developer
ADAPT, WSA, ENLIL, PFSS	These models will be used to derive magnetic field line footpoints on the photosphere	NASA / University	CCMC connectivity models: No additional funding planned for FY19

Magnetogram Forecast (MAG4)
Probability Scoreboard

Developer	**University of Alabama Huntsville** (PI: D. Falconer)
Summary	Probabilistic forecasting tool that uses SOHO/MDI and SDO/HMI magnetogram data to project likelihood of solar flares, CMEs and SPEs
FY19 Work	• Derive and implement forecast curves for X+M-flares, X-flares and SPEs using historic HMI data • Study and report on forecast curves for CMEs/fCMEs using historic HMI data • Improve model robustness • Deliver code to SRAG/CCMC
FY20 Work	Continue to provide expertise for improving model robustness
Of Note	Also used for All-Clear projection



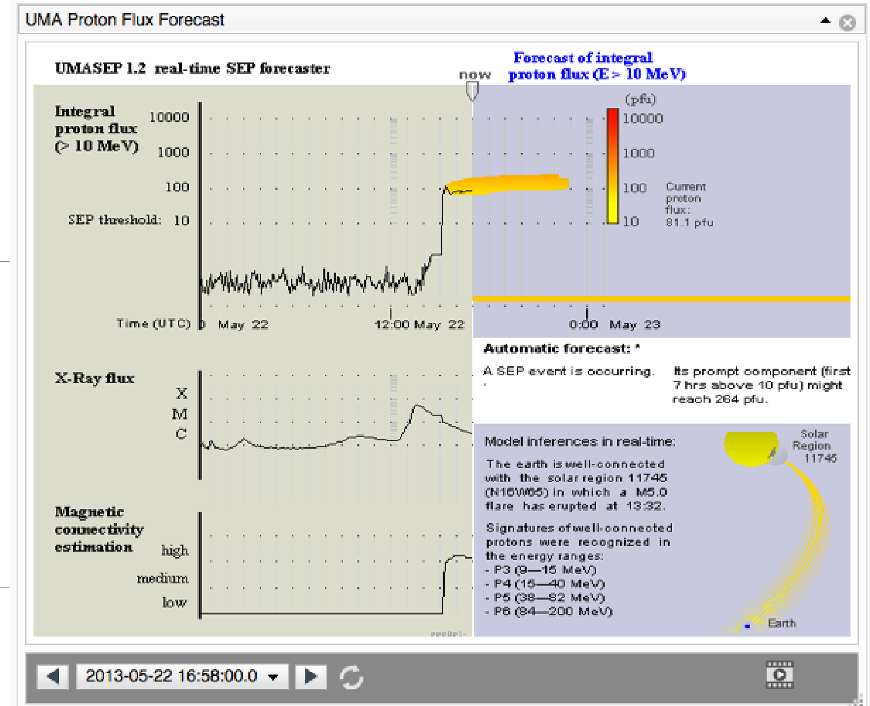
MAG4 image

BACK

University of MAlaga Solar Energetic Particles (UMASEP)

Proton Peak Flux Scoreboard

Developer	University of Malaga (PI: M. Nunez)
Summary	Using GOES SXR and differential proton flux data, assesses connectivity and provides projection of event onset and intensity. Versions exist for >10MeV (-10), >100MeV (-100) and GLEs (-500)
FY19 Work	• Update output displays for operational use • Update model output format per CCMC request • Deliver code to SRAG/CCMC and help CCMC implement
FY20 Work	• Continue working with CCMC on implementation • UMASEP-30/UMASEP-50 development • Event comparison tool
Of Note	• Also used for All-Clear projection • UMASEP-500 part of HESPERIA collaboration (HORIZON 2020 program)



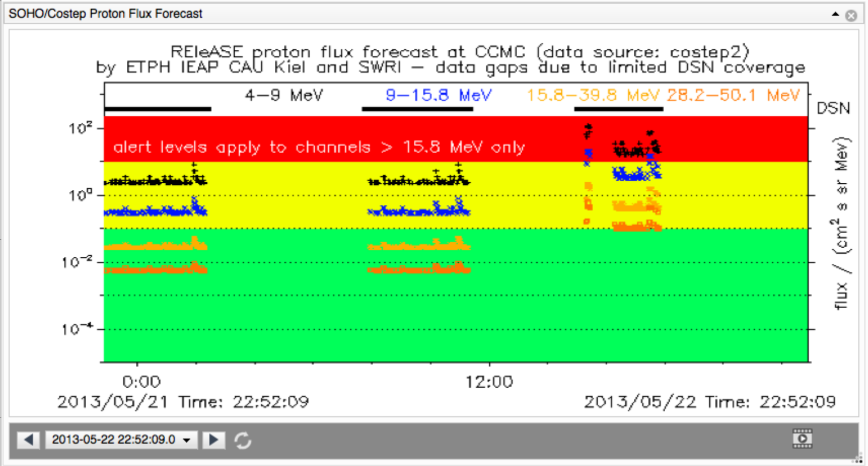
(current UMASEP model running in real-time at CCMC)

BACK

Relativistic Electron Alert System for Exploration (REleASE)

Proton Peak Flux Scoreboard

Developer	**University of Kiel / National Observatory of Athens** (PI: O. Malandraki)
Summary	Using electron measurements from SOHO/COSTEP/EPHIN and ACE/EPAM, forecast proton flux at 15.8-39.8MeV and 28.2-50.1 energy bands
FY19 Work	• Update output displays for operations • Update model output format per CCMC request
FY20 Work	• Deliver code to SRAG/CCMC and help CCMC implement
Of Note	• Original version developed by A. Posner and used COSTEP data • Model hosted at CCMC (iSWA) • Can be used in All-Clear forecast product • Current version (**HESPERIA**) developed in collaboration with HORIZON 2020 program



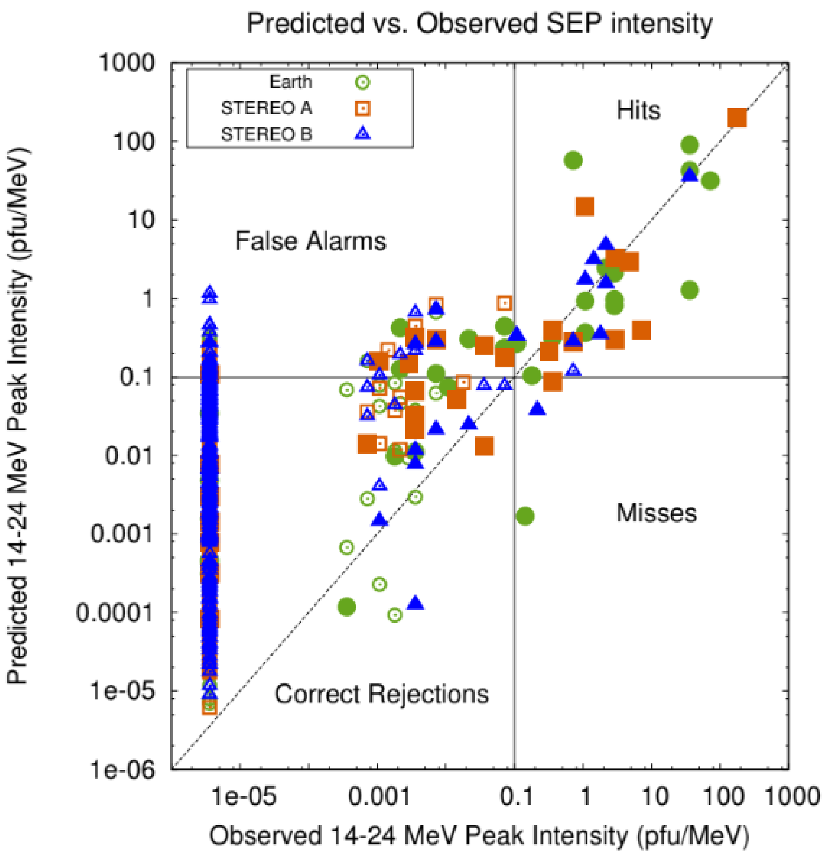
(current ReLEASE model running in real-time at CCMC)

BACK

SEP Predictions inspired by STEReo (SEPSTER)

Proton Peak Flux Scoreboard

Developer	NASA GSFC / **University of Maryland College Park** (PI: I. Richardson)
Summary	Using observed CME speed and connection angle (based on solar wind speed and CME longitude), forecasts peak proton flux at 14-24MeV and time to reach peak
FY19 Work	• Derive method to predict peak proton intensities at different energy ranges (>10MeV, >30MeV, >50MeV, >100MeV) • Create and deliver the SEPSTER code to be hosted at CCMC
FY20 Work	• Host model on operational server • Continued work on expansion of model to different energy ranges possible • Continued validation possible
Of Note	• Simple empirical model • Robust and reliable • Fully automated, running hourly at CCMC



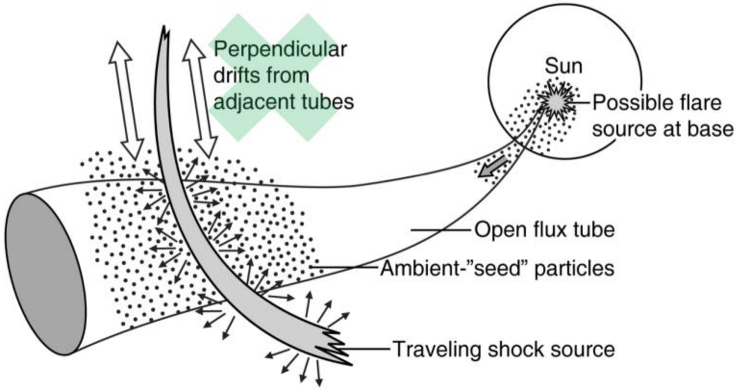
Richardson et al, Space Weather (2018)

BACK

ENLIL + SEP MODel (SEPMOD)

Flux Time Series Scoreboard

Developer	**University of California Berkeley** (PI: J. Luhmann)
Summary	Coupled to ENLIL (CME/solar wind MHD model), SEPMOD accelerates particles from shock to observer along solar wind magnetic field lines. Model originally predicted 1-100MeV proton flux time profile (user-specified ranges).
FY19 Work	• Extended output energy range to 500MeV (>100MeV and >300MeV provided) • Explore coupling of SEPMOD to WSA model (coronal reflection)
FY20 Work	• Validation work planned with ISEP and **CU Boulder CIRES/NOAA SWPC** • Complete WSA model incorporation • Test use of a cluster of several field line start points around observer • Test inclusion of SEPMOD 'flare' source option
Of Note	• Can predict SPE time profile over broad energy range



(Presented at GSFC Space Weather Workshop, 2017)

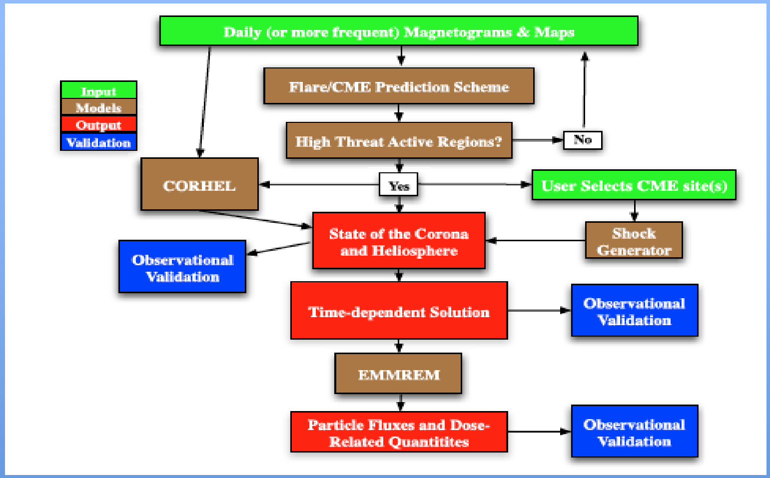
BACK

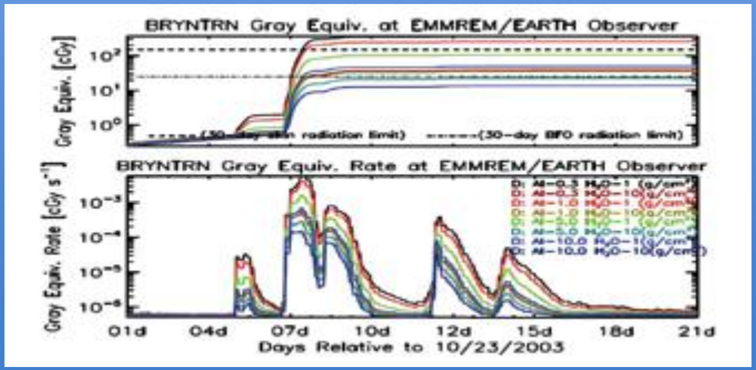
SPE Threat Assessment Tool (STAT)

Flux Time Series Scoreboard

Developer	**Predictive Sciences, Inc / University of New Hampshire** (PI: J. Linker)
Summary	STAT couples CORHEL/MAS (CME formation and eruption) and EPREM (particle transport in heliosphere) to provide >10MeV, >50MeV and >100MeV proton flux time profile.
FY19 Work	• Improved model design • Simulation of 3 historical CMEs for inclusion in output database
FY20 Work	• Incorporation of STAT into Scoreboard interface • Operational use of STAT database
Of Note	• STAT currently simulates historic events only

Predictive Science, Inc: Results of Phase I SBIR showed effective coupling of models to apply to forecasting time profile (evolution) of fluence and subsequent dose.





BACK

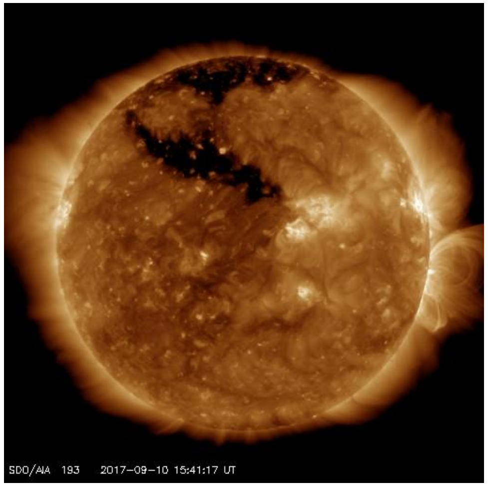
New Directions: Machine/Deep Learning

- June 2019: Working meeting – Applying Machine Learning / Artificial Intelligence Technology to forecasting of Solar Proton Events
- September 2019: Began collaboration with **Georgia State University** for initial steps in application of ML technology to SPE forecasts
- More to come…

ISEP Support for Exo-LEO Missions

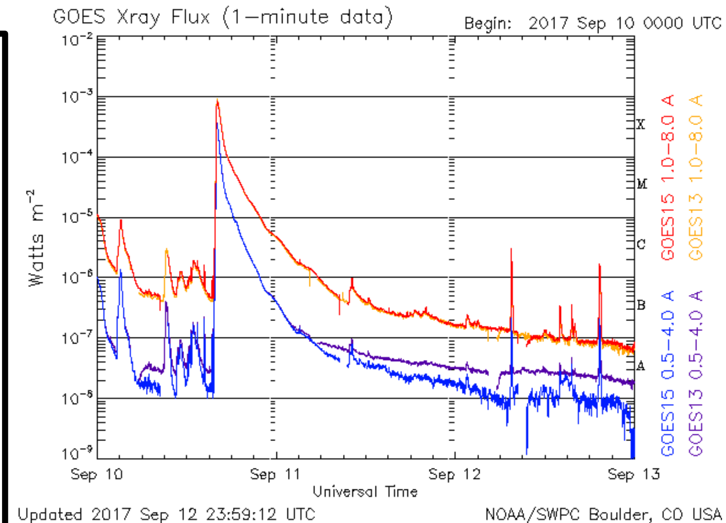
- SRAG current forecasting capabilities for ISS support lags capabilities required for exo-LEO missions
- ISEP will fill the gaps, giving SRAG tools needed to better assess impacts of changes to the space environment
- With a better idea of (1) **If** an SPE will occur, (2) **How big** will the event be and (3) **How long** will it last, SRAG can better recommend crew action to support both ALARA and mission-critical task completion

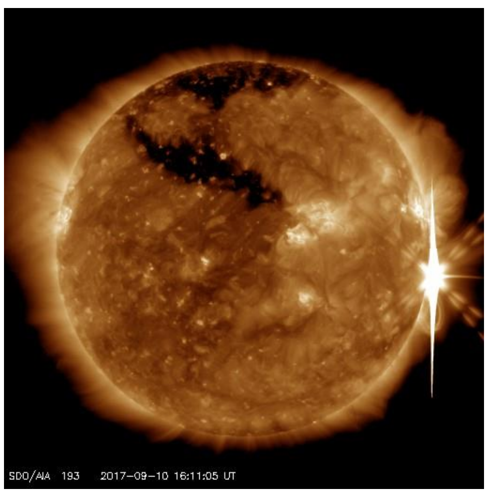
Questions?

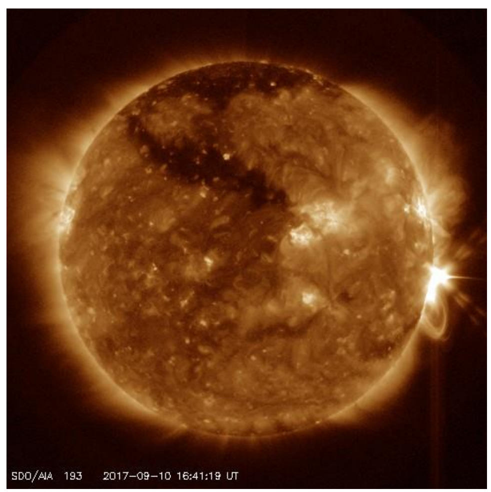


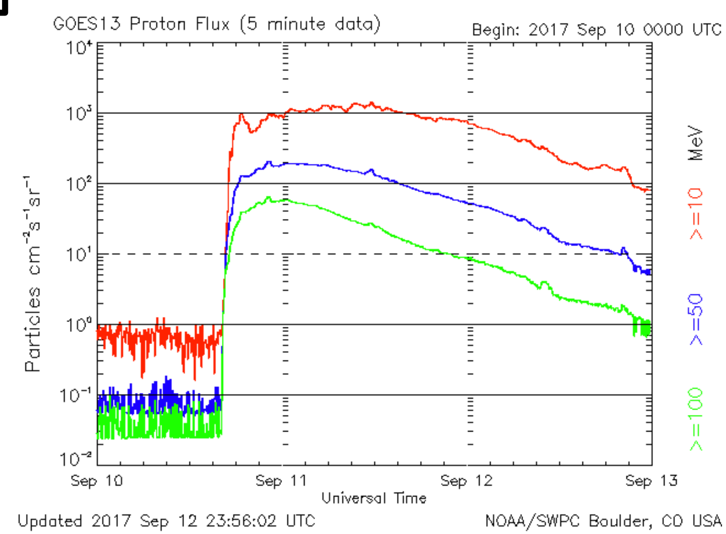
Sept 10, 2017 Event

15:53 GMT
X-ray flux > M5
16:06 GMT
X-ray peak @ X8.2
16:25 GMT
100MeV protons > 100pfu
16:45 GMT
10MeV protons > 10pfu









Imagery: sdo.gsfc.noaa.gov

GOES data charts: swpc.noaa.gov

MAG4 Detailed Overview

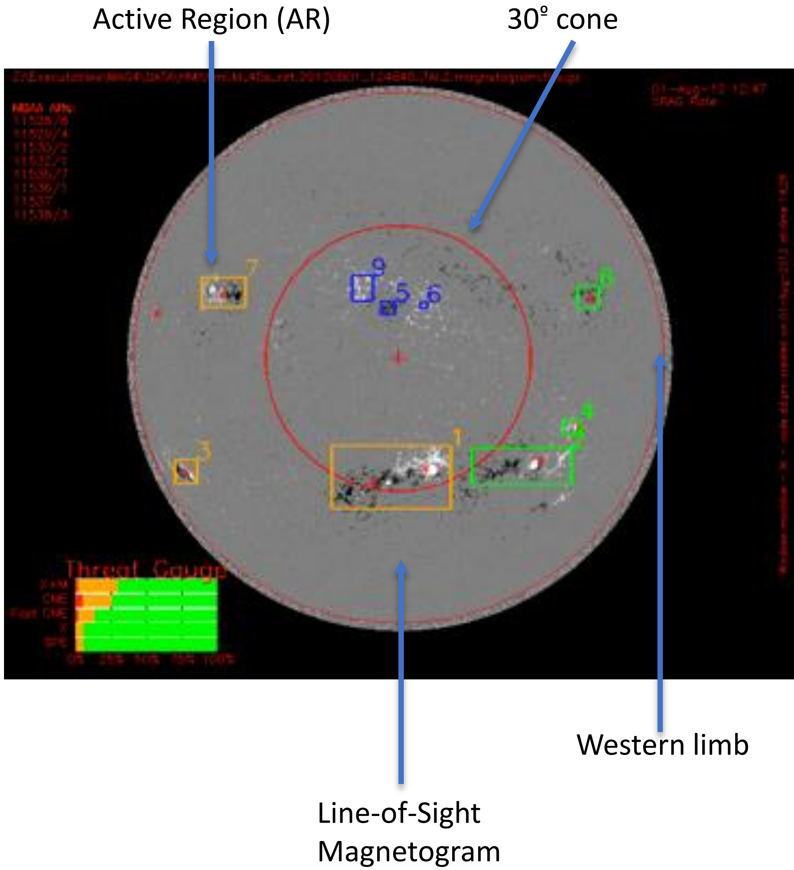
<u>Model Developers</u>

- MAG4: University of Alabama at Huntsville (D. Falconer)
- Solarscape: GSFC (P. MacNeice)

<u>Methodology</u>

- MAG4 – Probabilistic forecast
  - Input: Solar magnetograms
  - Assesses strength and characteristics of region magnetic field
  - Output: M/X, X, CME, fast CME, SEP probabilities
- Current Line-of-Sight magnetograms limit forecast to regions that lie inside 30° cone.
  - With inclusion of SDO in SMD observational suite, increased vector magnetogram resolution could facilitate expansion to 60° cone.
  - Historically, some of the most intense events for Earth occurred when regions were on the western solar limb
- ISEP: MAG4 model improvements in FY18/FY19
  - Improve robustness and statistics
  - Examine use of SDO/HMI vs SOHO/MDI imagery

- Solarscape – Estimate of connectivity of the Sun-Earth magnetic field line.
  - Provides input on magnetic field configuration of Active Regions (ARs) in the solar photosphere.

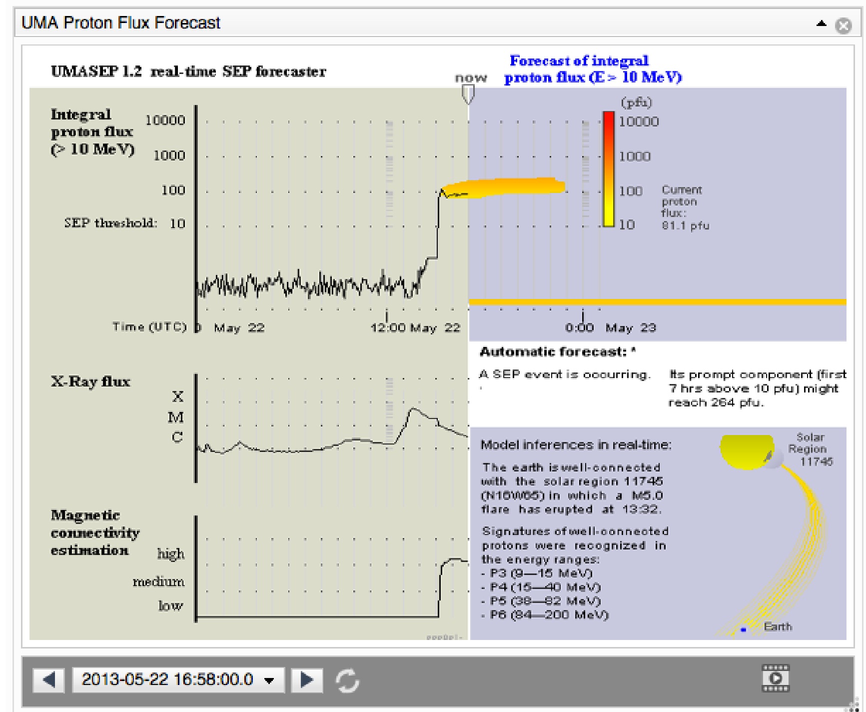


MAG4 image

UMASEP Detailed Overview

Model Developers
- University of Malaga (M. Nunez)

Methodology
- Empirical model - estimates lag between Soft X-Ray (SXR) and differential proton flux to find magnetic connection between SPE origin and observer
- Partial version running at CCMC; hosted remotely
  - Current models: >10MeV and >100MeV protons
  - HESPERIA 2020 project (EU) updated model to include >500MeV protons / Ground-Level Events (GLEs)
  - ISEP: Model provision and hosting at CCMC
- Input:
  - SXR (GOES)
  - Differential proton flux (GOES)
- Output:
  - Observed and forecasted integral proton flux
  - All-clear period (if applicable)
  - Observed X-ray flux
  - Magnetic connectivity estimation (low/medium/high)
  - Real-time forecast
  - Model inferences in real time (includes AR information, if available, from SWPC database)



(current UMASEP model running in real-time at CCMC)

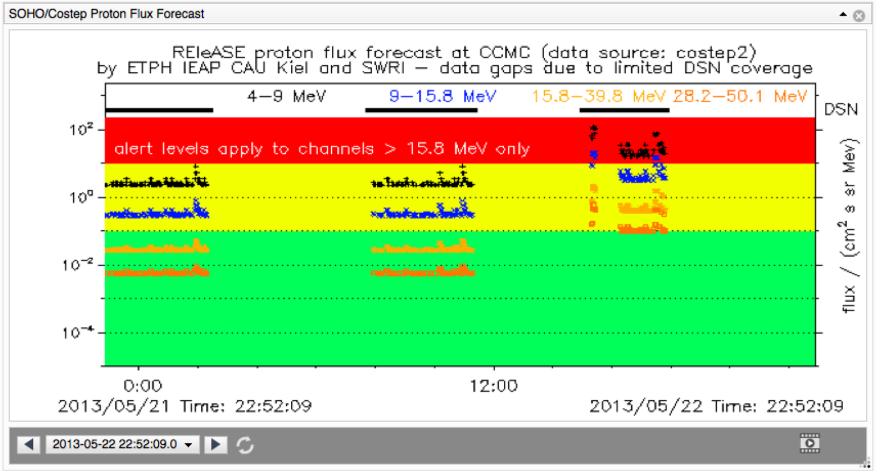
ReLEASE Detailed Overview

Model Developers

- NASA (A. Posner)
- National Observatory of Athens (O. Malandraki)

Methodology

- Near-relativistic electrons travel faster than protons
  - Actual electron flux
  - Observed increases in previous 30/60/90 minutes
- Running at CCMC
  - Model updated through HESPERIA 2020 project (EU)
  - ISEP: Updated model provision for hosting at CCMC
- Input:
  - SOHO / Electron Proton Helium Instrument (EPHIN) data (Posner)
  - ACE / Electron, Proton, Alpha Monitor (EPAM) (Malandraki)
- Output:
  - Proton differential flux (4-9MeV, 9-15.8MeV, 15.8-39.8MeV, 28.2-50.1MeV)
  - HESPERIA generates alerts for 15.8-39.8MeV and 28.2-50.1MeV
  - Lead time of 30, 60, and 90 minutes



(current ReLEASE model running in real-time at CCMC)

All statistical models will undergo V&V both as individual models to identify 'single-point' forecast capability and as an ensemble system

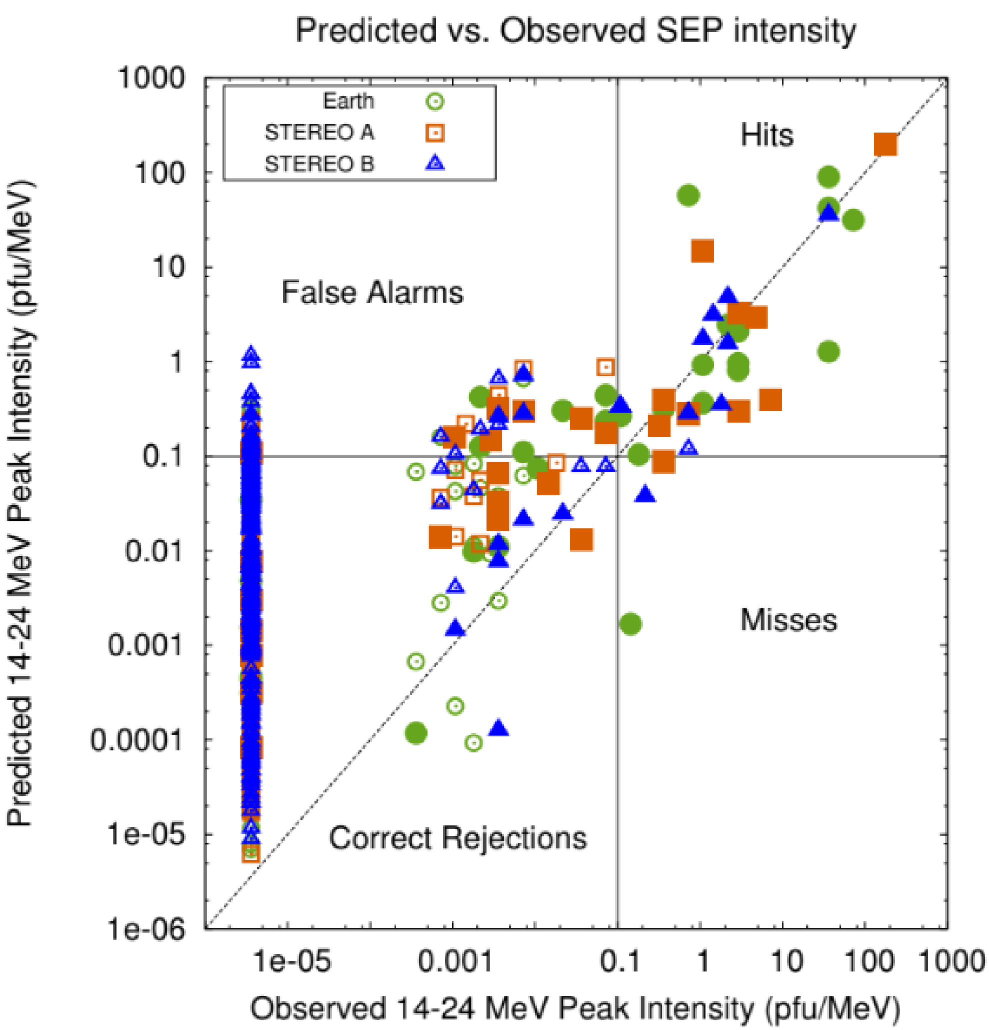
SEPSTER Detailed Overview

Model Developers

- University of Maryland (I. Richardson)

Methodology

- Empirical model
  - Input: CME speed, connection angle (phi) and mean CME width.
  - Output: SEP probability, peak (14-24 MeV) proton differential flux.
- Assumption: SEPs produced by CMEs
  - Leads to false positives (see Figure).
  - Tends to over-project peak flux, especially at lower peak flux values.
  - Possible use of radio emission data (Type II/III) to filter results.
- For ISEP
  - Implement model at CCMC.
  - Will examine applicability to higher energy protons (>50MeV) of interest to operations.



Richardson et al, Space Weather (2018)

BACK

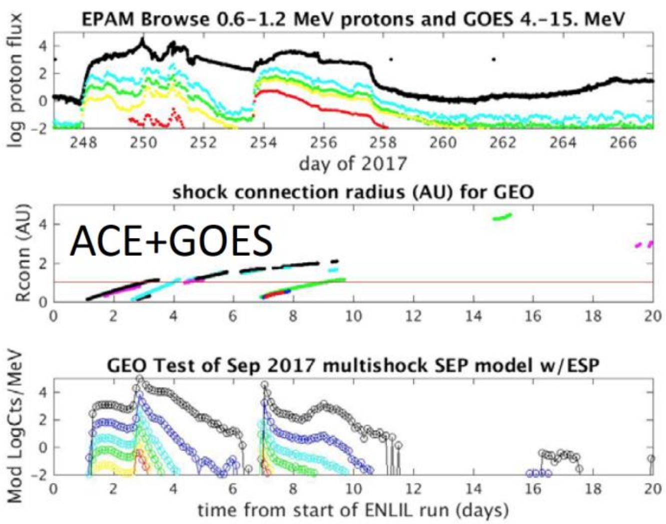
ENLIL+SEPMOD Detailed Overview

Model Developers

- ENLIL: University of Colorado at Boulder (D. Odstrcil)
- SEPMOD: University of California at Berkeley (J. Luhmann)

Methodology

- ENLIL provides a time-dependent 3D magnetohydrodynamic (MHD) model of the heliosphere then solves for the solar wind conditions and propagates CME shock.
- SEPMOD assumes that interplanetary shocks are the source for observed SEPs (currently ~1-100MeV) and transports protons from the evolving CME shock along magnetic field lines into the heliosphere.
- For ISEP, UCB will improve the performance of SEPMOD in real-time (hosted at CCMC), extend the predicted energy range to GeV (protons) and incorporate coronal reflection upgrades.

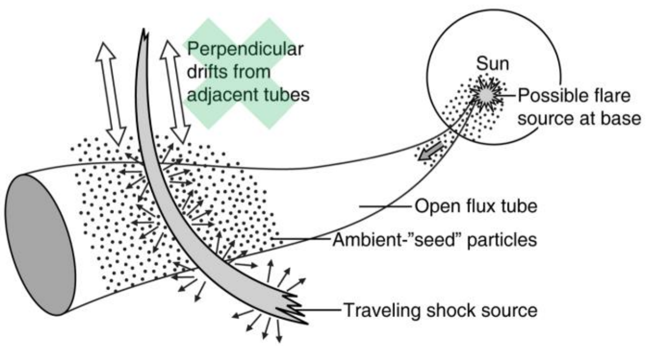


Top panel: ACE/EPAM and GOES observations for Sept 2017 event.

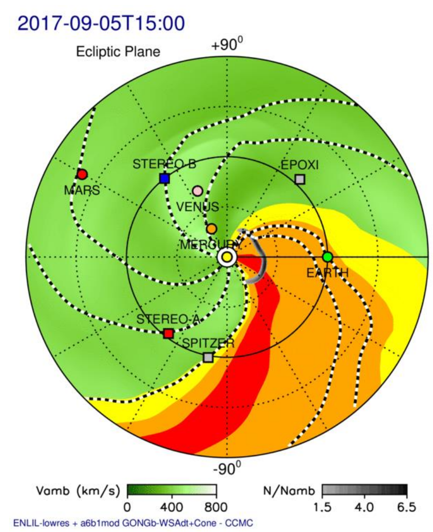
Middle panel: ENLIL results for the simulated interplanetary coronal mass ejection shocks during this period.

Bottom panel: The predicted SEPMOD proton flux vs time for September 2017. The model time series are for the SEPMOD default energy "channels" at 1.2, 2.6, 5.1, 8.6, 17, and 26 MeV.

(Results presented at SHINE 2018)



(Presented at GSFC Space Weather Workshop, 2017)



Far Left: Propagation of energetic particles away from the expanding shock front

Left: ENLIL output (Sept 2017)

BACK

CORHEL+EPREM (STAT) Detailed Overview

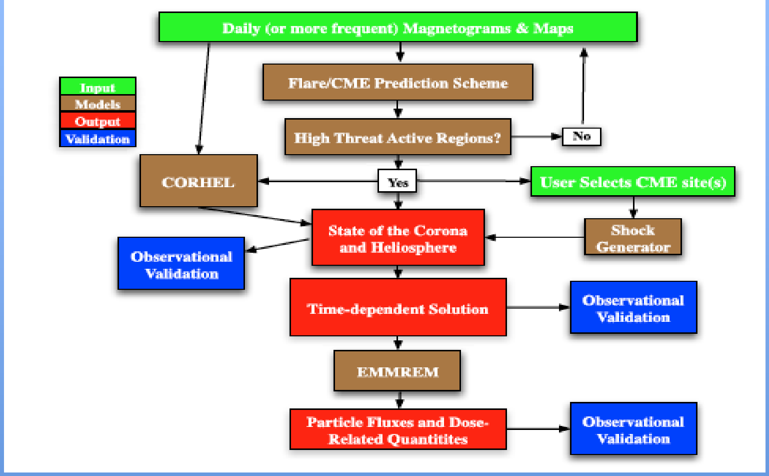
Model Developers

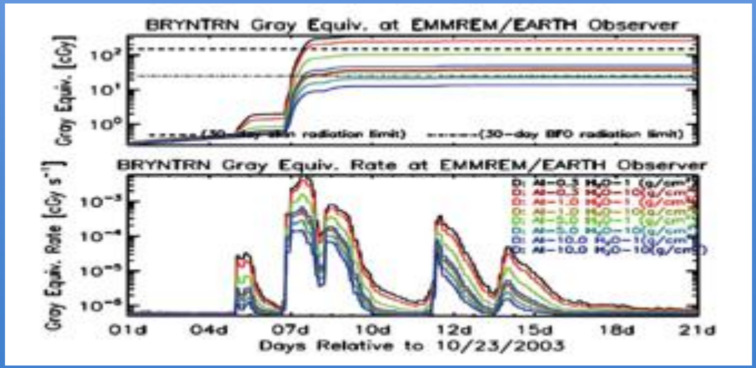
- CORHEL: Predictive Sciences Inc (J. Linker)
- EPREM: University of New Hampshire (N. Schwadron)

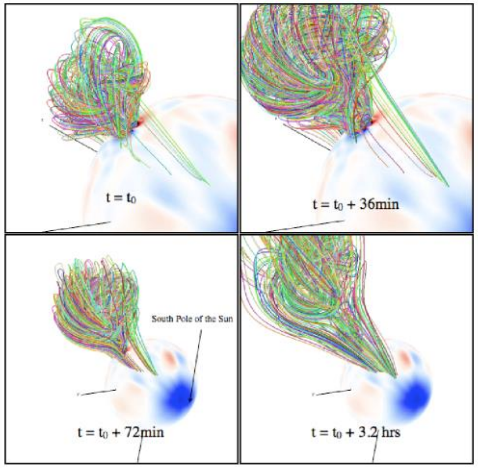
Methodology

- Generally accepted that particle acceleration starts at the solar corona and expected that most models will require CME shock parameters as input
- CORHEL model requires input at the corona and is used to inject particles into the heliosphere for propagation
- Propagation via coupling with EPREM has been proven in SBIR Phase I and is further pursued via STTR in FY19 as a collaboration with University of New Hampshire

Predictive Science, Inc: Results of Phase I SBIR showed effective coupling of models to apply to forecasting time profile (evolution) of fluence and subsequent dose.







Magnetic field lines and propagation away from Sun for May 1997 CME

BACK

Forecast of Temporal Evolution of Proton Fluence: CORHEL+EPREM (STAT)

CORHEL
(Corona-Heliosphere)

- Supports two coronal models
  - MAS (MHD model)
  - WSA (empirical model)
- Supports two heliospheric models
  - Enlil (MHD model)
  - MAS (heliospheric version)
- Inputs:
  - Maps of Sun's photospheric magnetic field (from magnetograms)
  - Available from six different observatories
- Outputs:
  - Solar coronal temperature
  - Plasma pressure
  - Density
  - Velocity
  - Magnetic fields
- Available through CCMC and PSI
- Long time required to run
  - Project will create database of pre-simulated events
  - Comparison to current events to determine proton flux at Earth

EPREM (Energetic Particle Radiation Environment Module)

- 3D time-dependent, physics-based particle transport model
- Forms basis of other models, including EMMREM and PREDICCS
- Inputs include:
  - Simulation resolution
  - Solar wind parameters (speed, density, magnetic field strength)
  - Particle parameters (mass, charge, scattering mean free path)
- Outputs include information on:
  - Solar wind
  - Interplanetary magnetic field
  - Particle distribution
  - Heliospheric location
  - Temporal history
- Provides distribution function
  - Number of particles per location, velocity
  - Function of time, location, velocity and pitch-angle

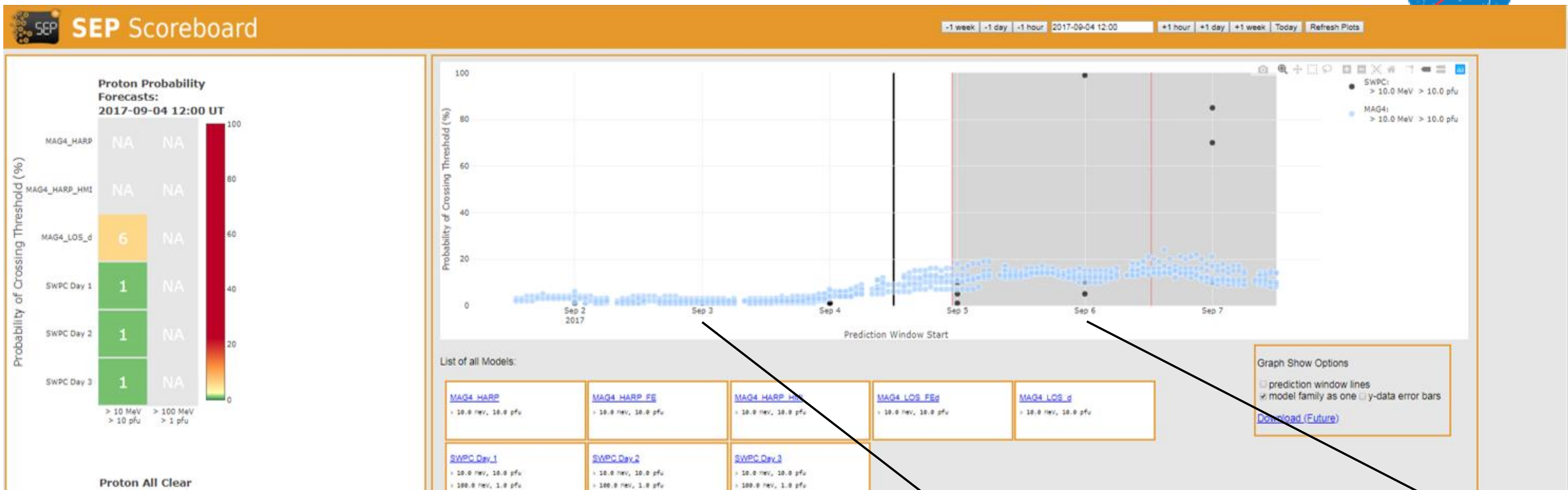
BACK

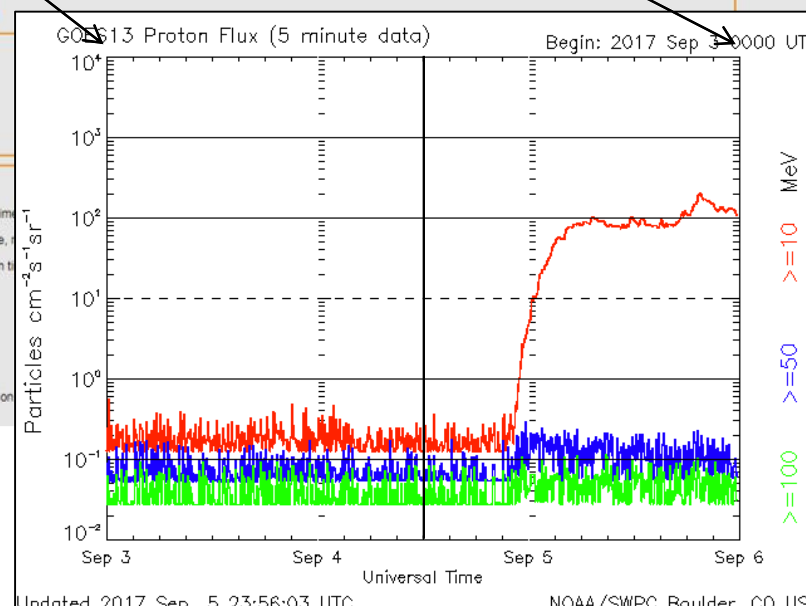
Space Weather Models Currently in Development

- Scoreboards will utilize:
  - Model projections
    - Corona
    - Solar wind propagation
    - Solar magnetic field
    - Interplanetary magnetic field
  - Satellite Data
    - Magnetogram observations (SDO and GONG)
    - CME observations (STEREO and SOHO)
    - Solar wind observations (ACE/DSCOVR)
    - STEREO EUV1 observations
    - SDO AIA observations
    - Solar synoptic magnetograms
    - X-ray and radio burst observations

Model	Description	NASA Investment
CORHEL	CORona-HELiosphere – coronal model developed by Predictive Science	NASA SBIR Phase I (HEOMD), SMD/LWS, STTR (collaboration with UNH)
EPREM	Particle transport through the heliosphere	SMD/LWS, STTR (collaboration with PSI)
iSWA	Integrated Space Weather Analysis system	SMD; CCMC to add connectivity models
Mag4	All-Clear forecast for x-ray flares, SEPs and CMEs using magnetogram imagery. University of Alabama Huntsville and MSFC.	HEOMD/SRAG investment since 2009. SMD investment through LWS.
SEPMOD	SEP model; moving shock source is specified, transport calculation gives related time profile sampled by stationary observer (at 1AU)	SMD/LWS; Funded in FY19
REleASE	Relativistic Electron Alert System for Exploration: Prediction of proton fluence at L1 via prompt arrival of energetic electrons. HESPERIA continued development effort	SMD, funded by AES in FY19
UMASEP	Prediction of time interval where >10 MeV protons will exceed threshold of 10 pfu, and >100MeV protons will exceed threshold of 1pfu. HESPERIA continued development effort (>500MeV)	Funded by AES in FY19
Richardson	Prediction of peak flux	GSFC-based developer
ADAPT, WSA, ENLIL, PFSS	These models will be used to derive magnetic field line footpoints on the photosphere	CCMC connectivity models: No additional funding planned for FY19

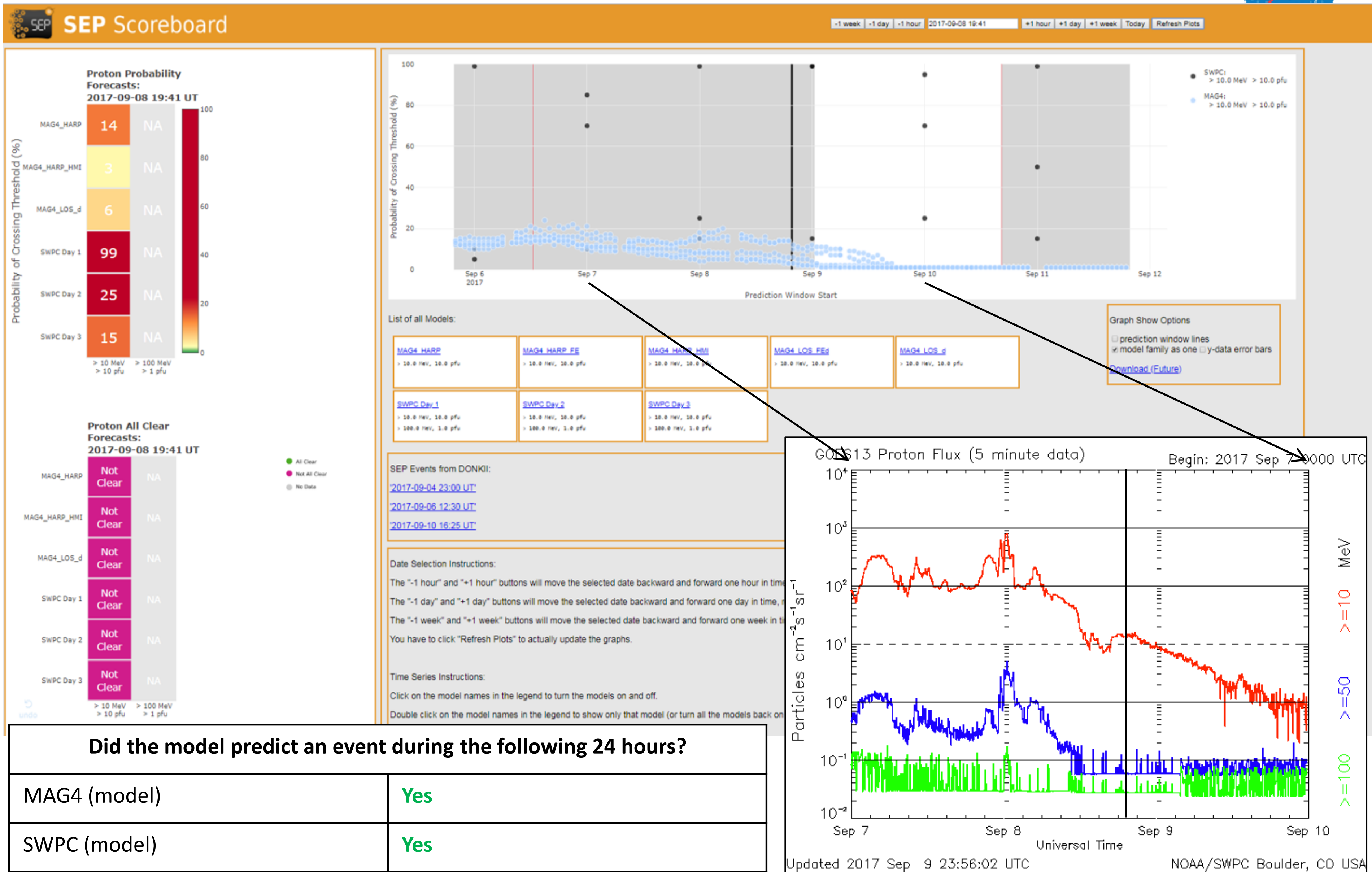
Scoreboard ‘A’ Design / Probability Models
September 04, 2017





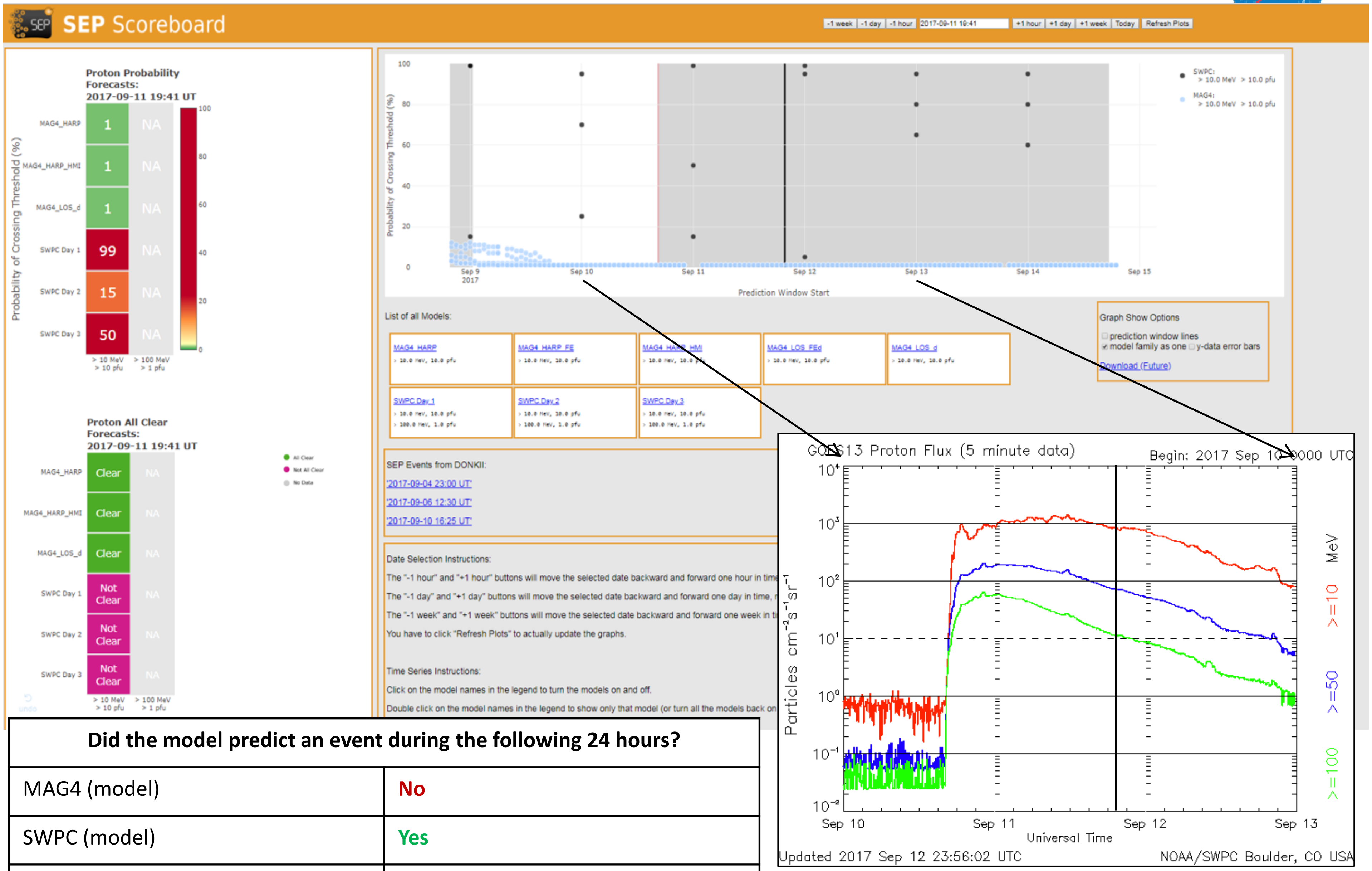
Did the model predict an event during the following 24 hours?	
MAG4 (model)	Yes
SWPC (model)	No
GOES 13 (data)	Yes

Scoreboard 'A' Design / Probability Models
September 08, 2017



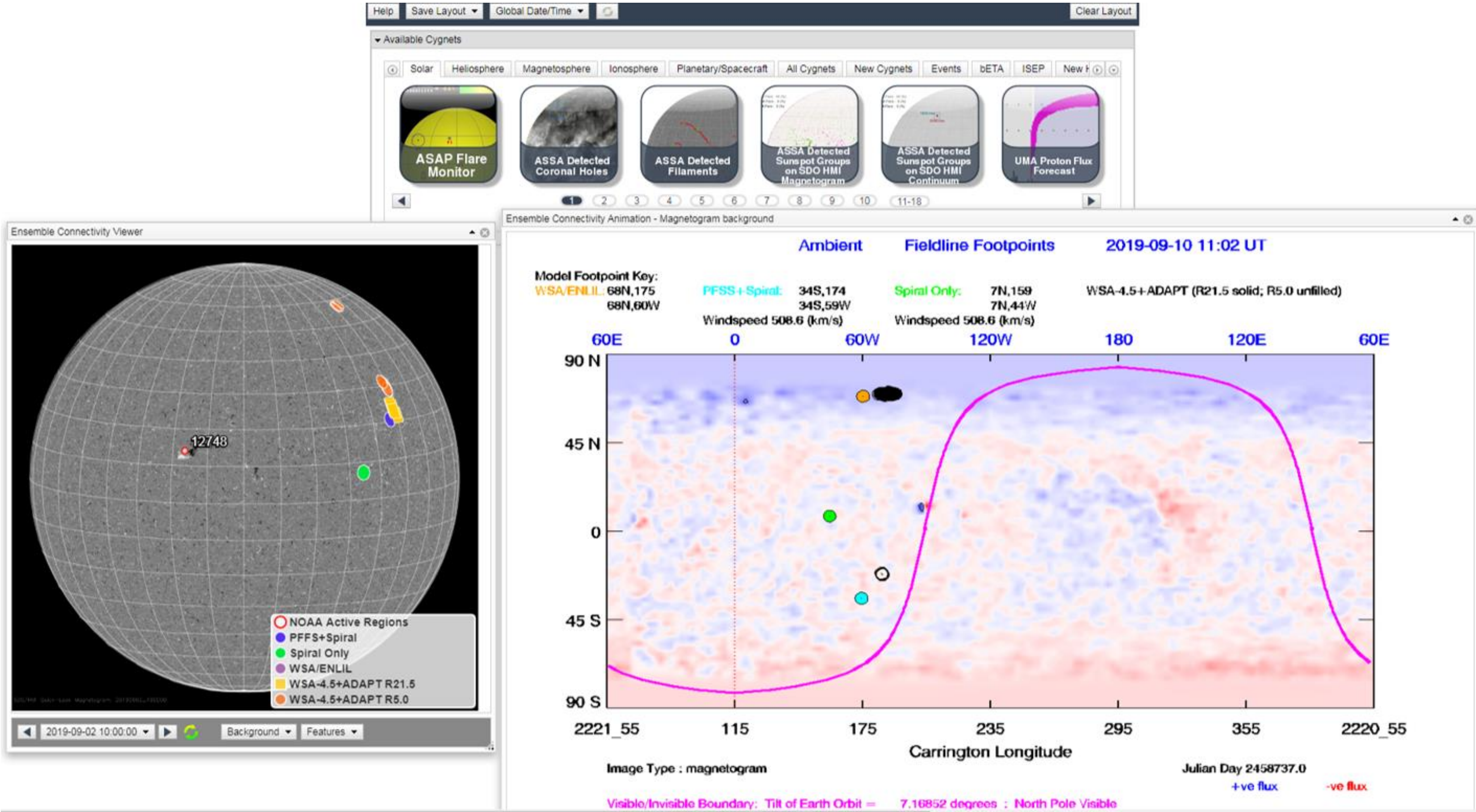
Did the model predict an event during the following 24 hours?	
MAG4 (model)	Yes
SWPC (model)	Yes
GOES 13 (data)	Yes

Scoreboard 'A' Design / Probability Models
September 11, 2017



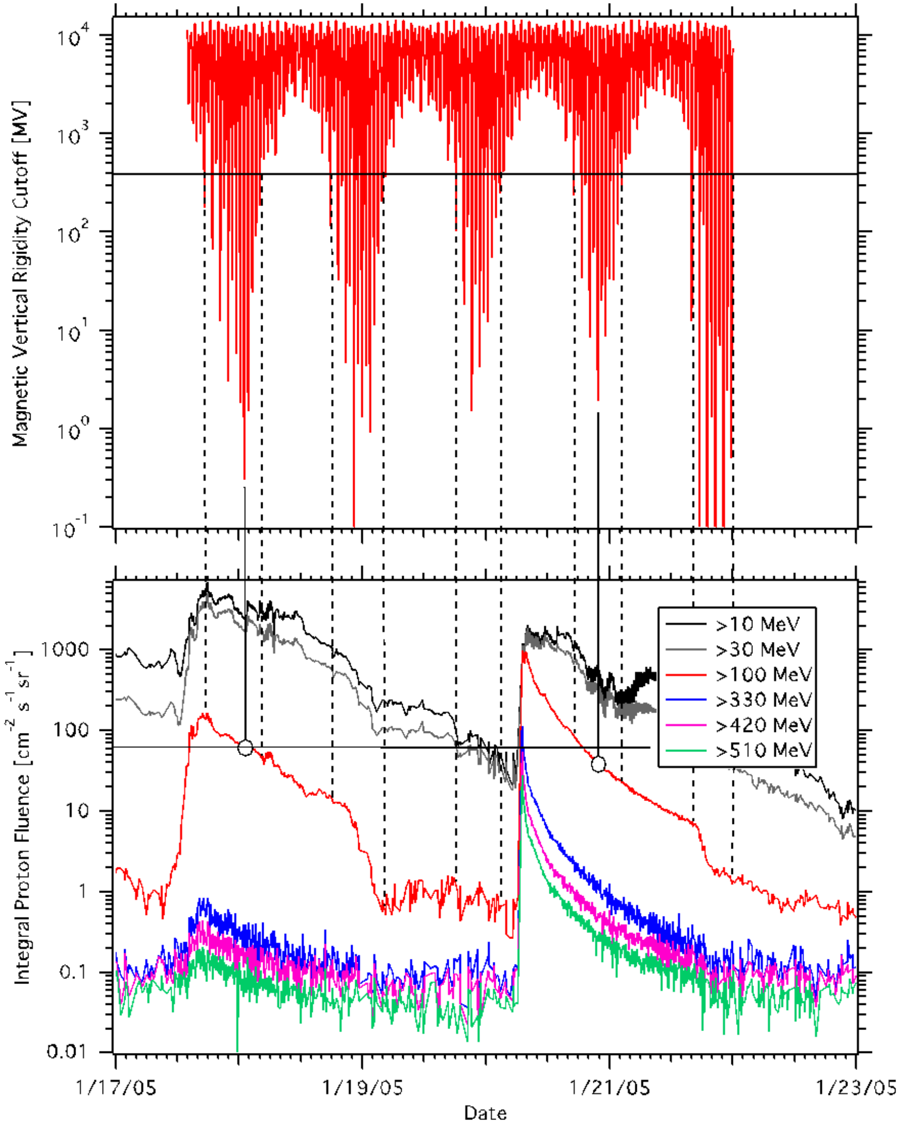
Did the model predict an event during the following 24 hours?	
MAG4 (model)	No
SWPC (model)	Yes
GOES 13 (data)	Yes

Management Demonstration: iSWA Connectivity Models
September 2019



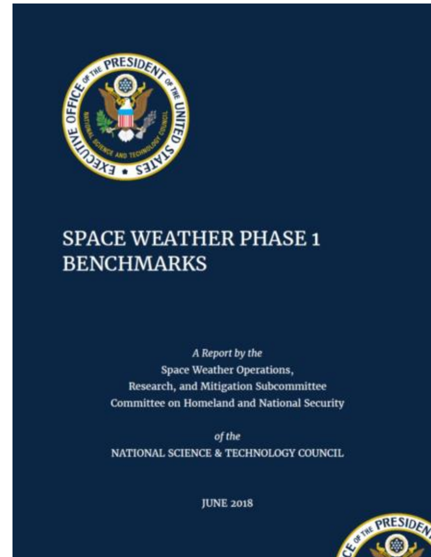
Role of Mission Proximity to Earth

- Low-Earth Orbit (LEO) missions, including ISS, take advantage of Earth's geomagnetic field for protection during majority of impact due to large SPEs/ESPEs.
- If shelter is recommended, crew is notified when vehicle enters and leaves 'areas of high-risk orbital alignment' (10-15min/orbit)
- No impact to crew when vehicle is outside these areas
- All recommendations worked through FCT, considering other high-priority mission activities



Space Weather Forecasting for Long-Duration Missions Beyond LEO – Programmatic Level

- National Space Weather Action Plan (SWAP) and National Space Weather Strategy (2015)
  - National Science and Technology Council products
  - Details six goals to prepare for space weather effects on multiple systems; includes associated deliverables and timeline
  - Phase 1 Benchmarks released in June 2018
  - Updated Space Weather Strategy and Action Plan in March 2019
- Space Weather Enterprise Forum (2018)
  - Meeting among information user groups
  - Description of risks associated with space weather
  - Implementation of activities to protect critical infrastructure
- Continued Support for Space Weather Strategy in Legislature
  - H.R.3086 (2017)
  - S.141 (2017)
  - S.881 (2019)


SPACE WEATHER PHASE 1 BENCHMARKS

A Report by the
Space Weather Operations,
Research, and Mitigation Subcommittee
Committee on Homeland and National Security

of the
NATIONAL SCIENCE & TECHNOLOGY COUNCIL

JUNE 2018


NATIONAL SPACE WEATHER STRATEGY AND ACTION PLAN

Product of the
SPACE WEATHER OPERATIONS, RESEARCH, and MITIGATION WORKING GROUP
SPACE WEATHER, SECURITY, and HAZARDS SUBCOMMITTEE
COMMITTEE ON HOMELAND and NATIONAL SECURITY
of the
NATIONAL SCIENCE & TECHNOLOGY COUNCIL

March 2019

Congressional Activity

115th Congress (2017-18)

- H.R. 3086 introduced (2017)
  - Originally co-sponsored by Rep. Ed Perlmutter (D-CO) and then-Rep. Jim Bridenstine (R-OK)
- S. 141 introduced/passed by Senate (2017)
  - ‘Space Weather Coordination Act’
  - Co-sponsored by Sen. Gary Peters (D-MI) and Sen. Cory Gardner (R-CO)
  - Similar to House bill
  - Directs Office of Science and Technology Policy (OSTP) to coordinate effort “to improve the nation’s ability to prepare, avoid, mitigate, respond to, and recover from potentially devastating impacts of space weather events.”
- S. 141 approved by the House (July 24)
  - New text provided by Rep. Perlmutter and Rep. Mo Brooks (R-AL)
  - Re-assigned coordination role to National Space Council
  - Added focus to private sector efforts
  - Created National Committee for Space Weather Observation and Forecasting

116th Congress (2019-20)

- S. 881 introduced (March 26)
  - ‘Space Weather Research and Forecasting Act’
  - Intent similar to that of bills from 115th Congress
  - Co-sponsored by Sen. Gary Peters (D-MI) and Sen. Cory Gardner (R-CO)
  - April 03 – Reported without amendment favorably

Space Weather Science Applications Project (SnAP)

- Managed by Heliophysics Division
  - Purpose is to transition results of heliophysics research to operational products (R2O)
- Three Goals
  - Improve current technology/observation capability as well as R2O, i.e., through the SBIR process
  - Enhance current capabilities (CCMC)
  - Provides response to National Space Weather actions (SWAP and Space Weather Operations , Research and Mitigation – SWORM)
- Multi-agency collaborations
  - NSF
  - NOAA
  - DoD