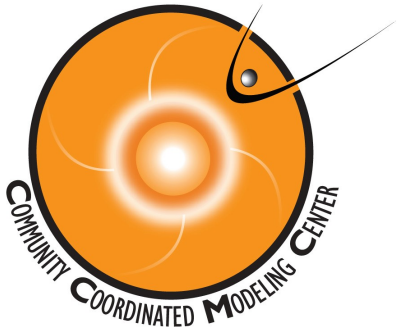
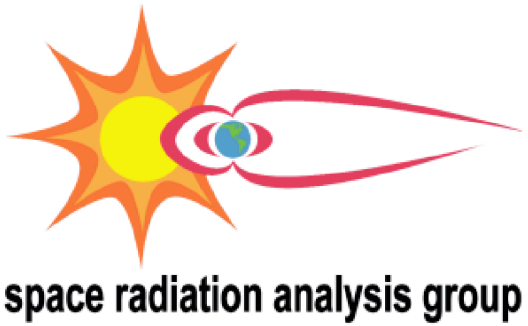
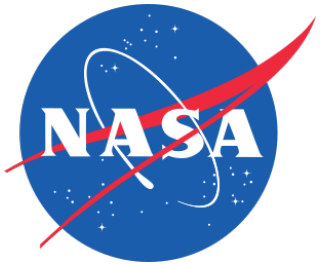
# Models on the  Scoreboard



M. Leila Mays, Joycelyn Jones, and the CCMC team



# SEP Scoreboard

https://ccmc.gsfc.nasa.gov/challenges/sep.php

- Planning for the SEP Scoreboard started in 2016 (led by BIRA-IASB, GSFC, UK Met Office)
- Builds upon the flare scoreboard and CME arrival time scoreboard
- Automated system; model developers can routinely upload their predictions to an anonymous ftp. Forecast data will be parsed and stored in a database which accessible to anyone via an API
- SEP forecasts can be roughly divided into three categories:


- The SEP scoreboard will focus on real-time forecasts (first and second categories) and will collect: proton intensity profile, threshold crossing probability, onset time, and duration.
- The SEP scoreboard team will also coordinate with the SEP Working Team for historical comparisons, particularly for those physics-based models in the third category that are not ready or relevant for real-time modeling.


Continuous/ Probabilistic

Continuous Probabilistic:
SWPC
UK Met Office
**MAG4 (Falconer)**
FORSPEF (NOA)
SPRINTS

Continuous Profile:
PREDICCS (UNH)

Non Near Real-Time/ Complex

**STAT: MAS+EPREM (PSI and UNH)**
EPREM+ENLIL (UNH + Odstricil)
iPATH (Li)

**SEPMOD (Luhmann)**
SPARX (Dalla, Marsh)
SWMF FLAMPA (UMich)
Zhang Model (FIT)

Solar Event Triggered

Flare:
AFRL PPS
COMESEP SEPForecast (BIRA)
FORSPEF (NOA)
SPARX (Dalla, Marsh)

Flare and CME:
COMESEP SEPForecast
FORSPEF (NOA)
SOLPENCO (Arans)

Flare and proton intensity:
**UMASEP (Núñez)**

CME:
**SEPSTER (Richardson)**
St. Cyr (Mauna Loa CME)

Electron intensity:
**HESPERIA REleASE**

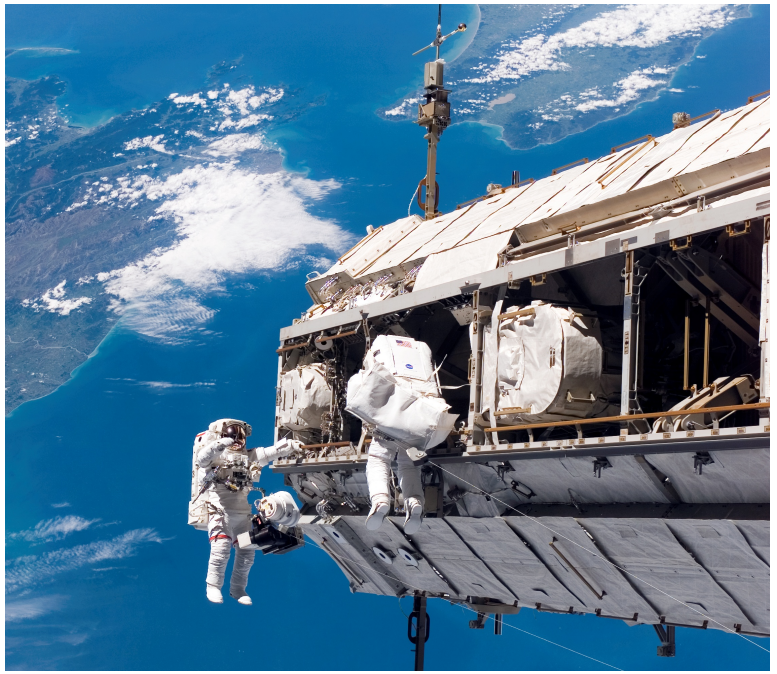
Flare, Radio, H-alpha:
SWPC PPM

Flare, Radio:
Laurenza Model

Radio:
AER SEP Model (Winter)

# CCMC SEP Scoreboard Collaboration with NASA Johnson Space Center: Astronaut Safety

- In 2018 CCMC started a 3 year project (ISEP) with SRAG to **transition 6 research Solar Energetic Particle models to operations**: including MAG4, UMASEP, RELeASE, SEPSTER, SEPMOD, STAT
- These **models were chosen by SRAG** based on their operational requirements, other models may be considered in later years.
- Models transitioned, and **SEP Scoreboard displays** built by CCMC will be used operationally by SRAG for human missions beyond LEO starting in 2022.




Continuous/ Probabilistic

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SEP modeling w/EUHFORIA

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SOLPENCO (Arans)

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Boubrahimi model

CME:
**SEPSTER (Richardson)**
St. Cyr (Mauna Loa CME)

Electron intensity:
**HESPERIA REleASE**

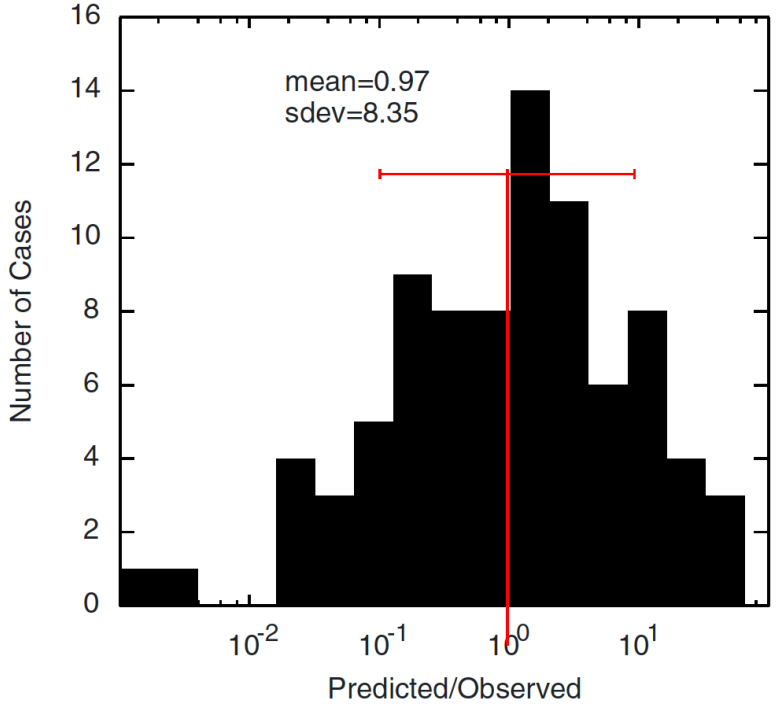
Flare, Radio, H-alpha:
SWPC PPM

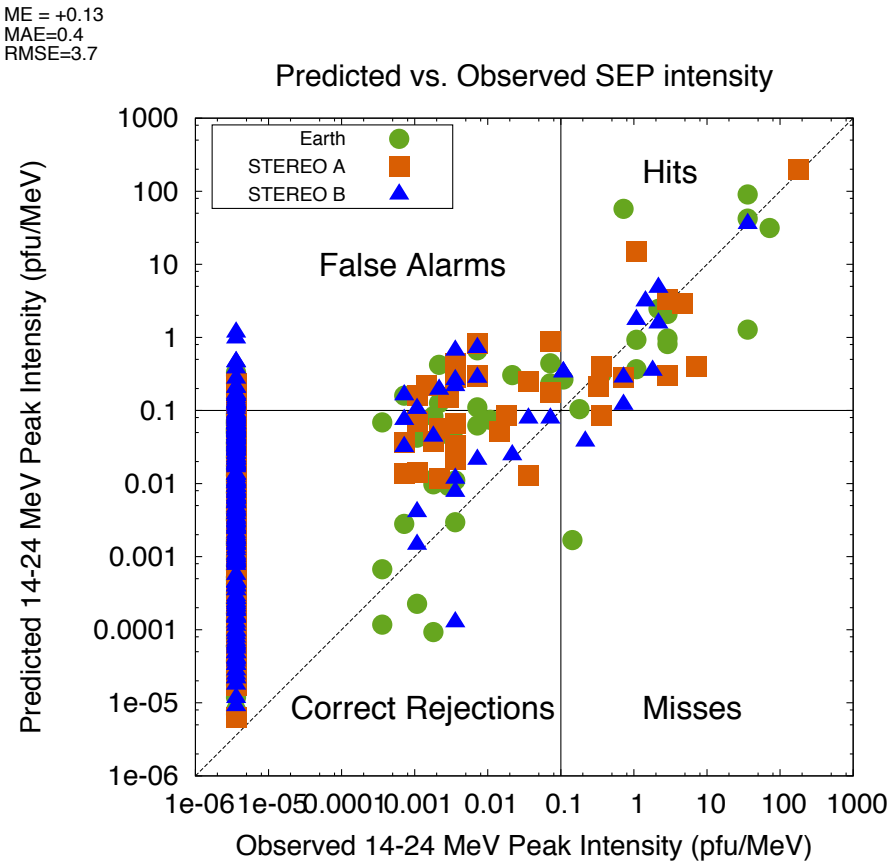
Flare, Radio:
ESPERTA (Laurenza)

Radio:
AER SEP Model (Winter)

# SEP prediction inspired by STEREO observations (SEPSTER)

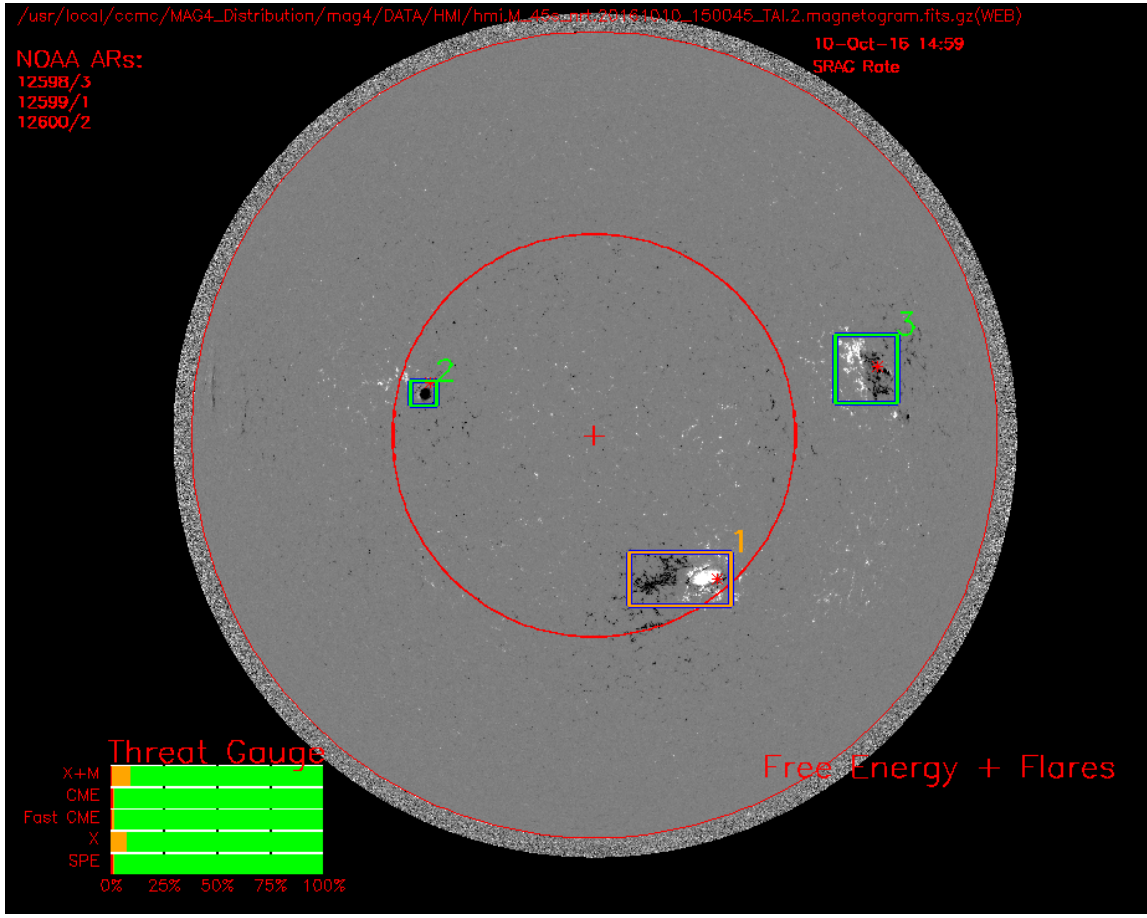
- Uses empirical relationship based on observed three spacecraft events (SOHO, STEREO A and STEREO B) to predict peak intensity
- Event triggered inputs: CME speed, width, and connection angle between the CME and observer magnetic footpoint



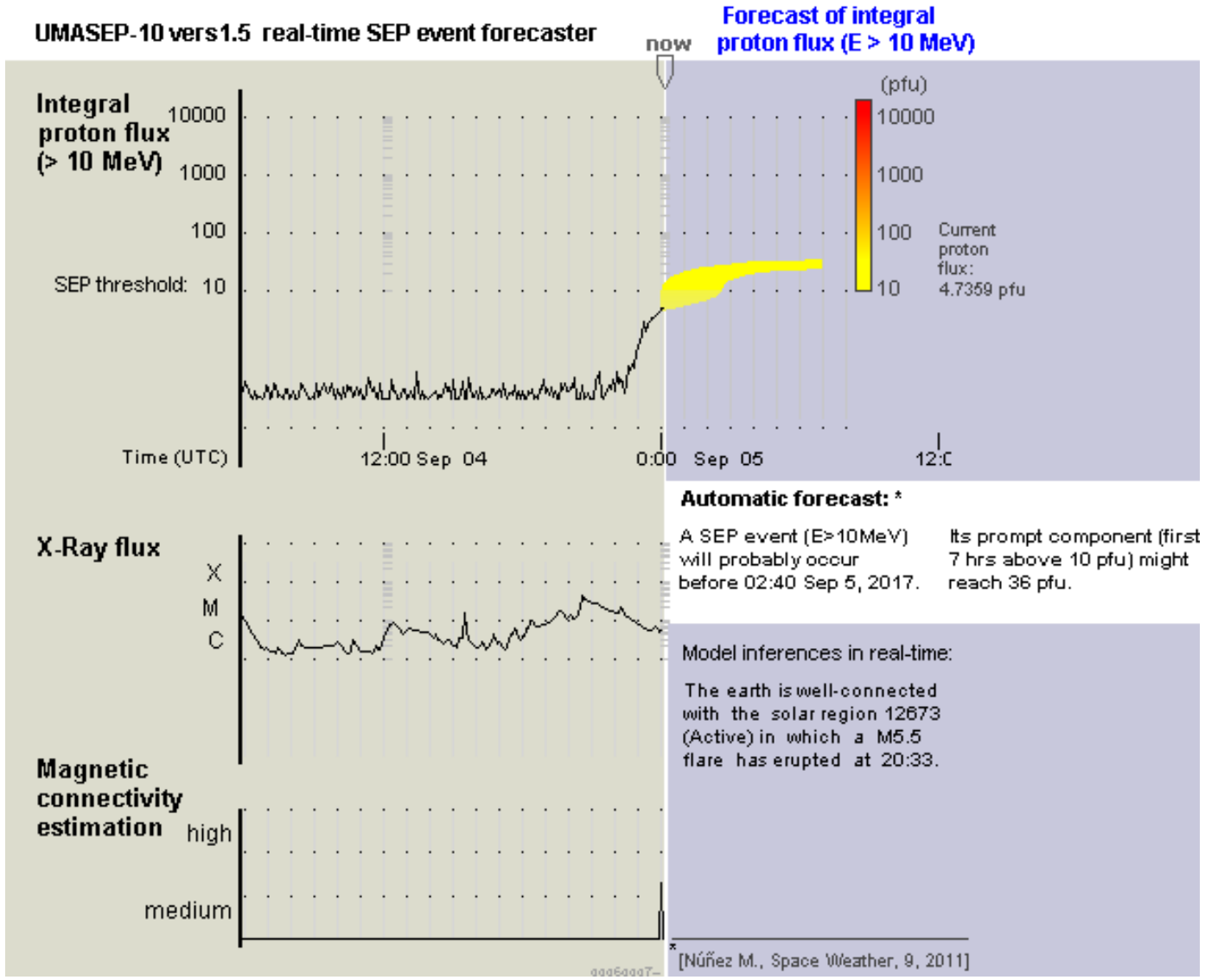
# Magnetogram Forecast (MAG4)

| MAG4 Variants | magnetogram type | Instrument used to compute forecast curve | uses previous flare history |
|---|---|---|---|
| MAG4 HMI SHARP FE+F | vector | HMI | yes |
| MAG4 SHARP FE+F | vector | MDI | yes |
| MAG4 HMI LOS FE+F | line-of-sight | MDI | yes |
| MAG4 HMI LOS FE | line-of-sight | MDI | no |
| MAG4 SHARP FE | vector | MDI | no |



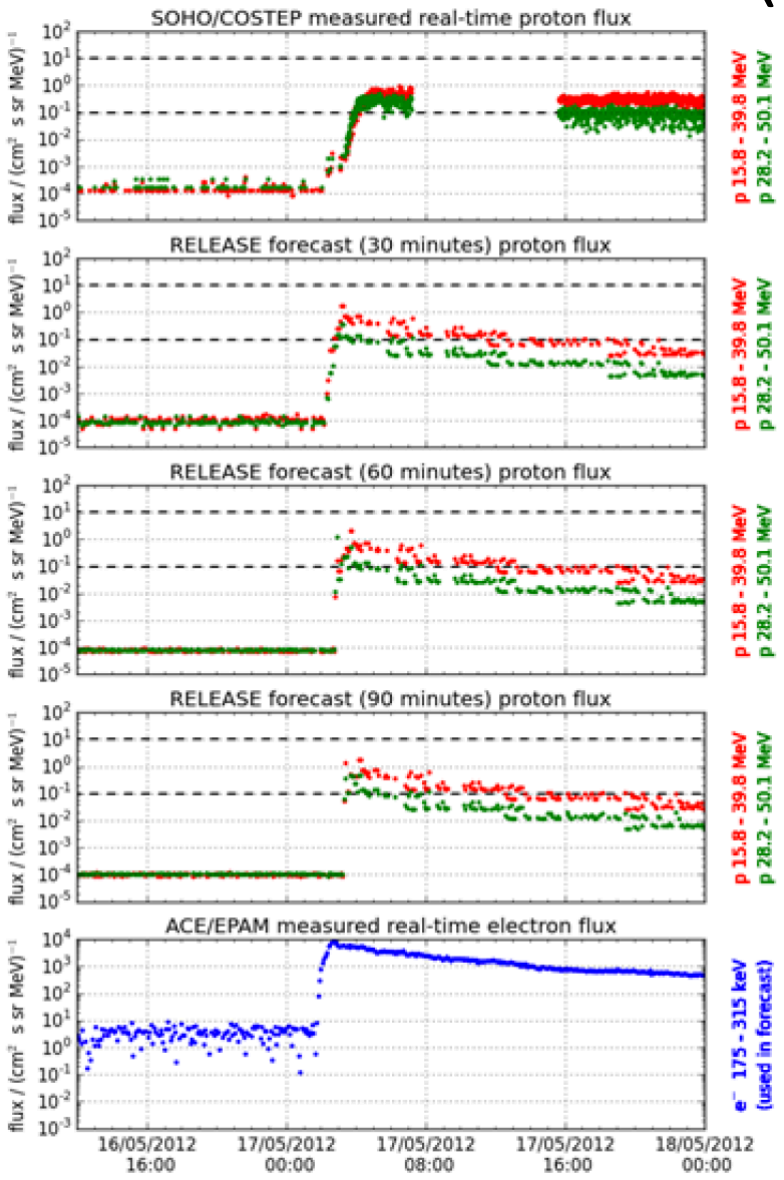

- Uses solar magnetic field measurements to compute the active region magnetic free energy and forecasts the probability of flares, CMEs, and SEPs based on historical event rates

# University of Malaga SEP Model (UMASEP)



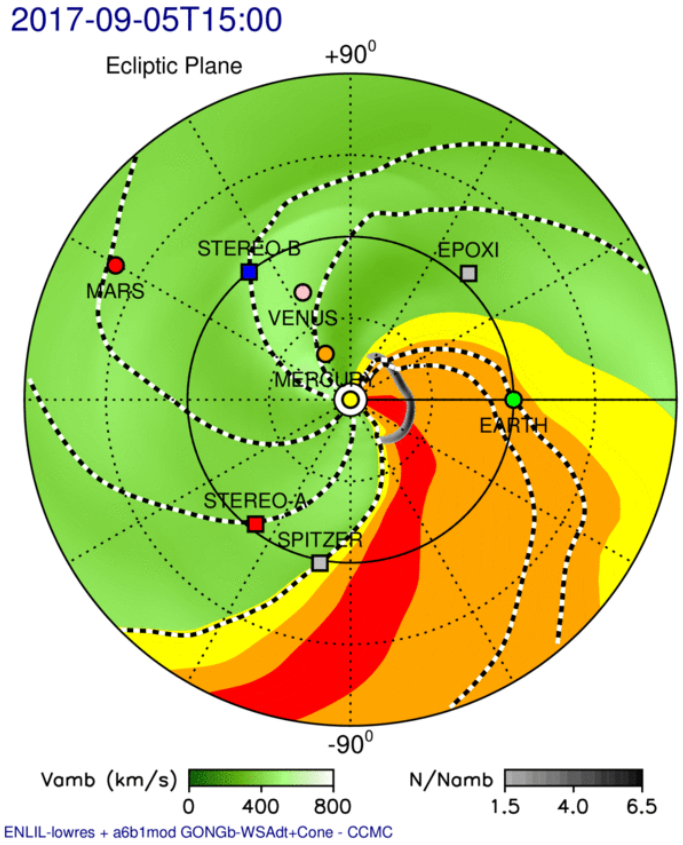

- Uses a lag-correlation of the solar electromagnetic flux with the particle flux at near-earth.
- Analyzes soft X-ray, differential and integral proton flux data
- Divides forecasts into well-connected SEP events, poorly-connected SEP events, and "all-clear" situations

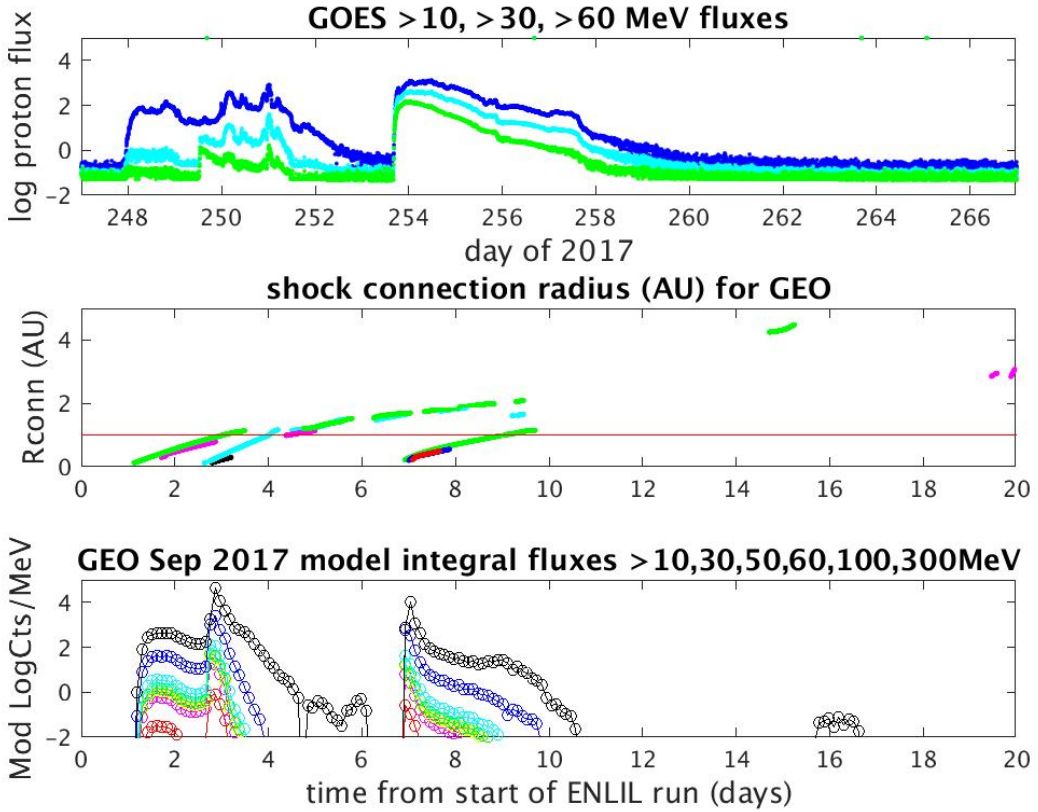
# Relativistic Electron Alert System for Exploration (HESPERIA RELeASE)




- Uses the fact that near relativistic electrons travel faster than ions to predict the proton flux
- Uses the actual electron flux from ACE/EPAM and the increase of the electron flux in the last 30, 60, or 90 minutes.
- Developed as part of the HESPERIA Horizon 2020 European Union Project

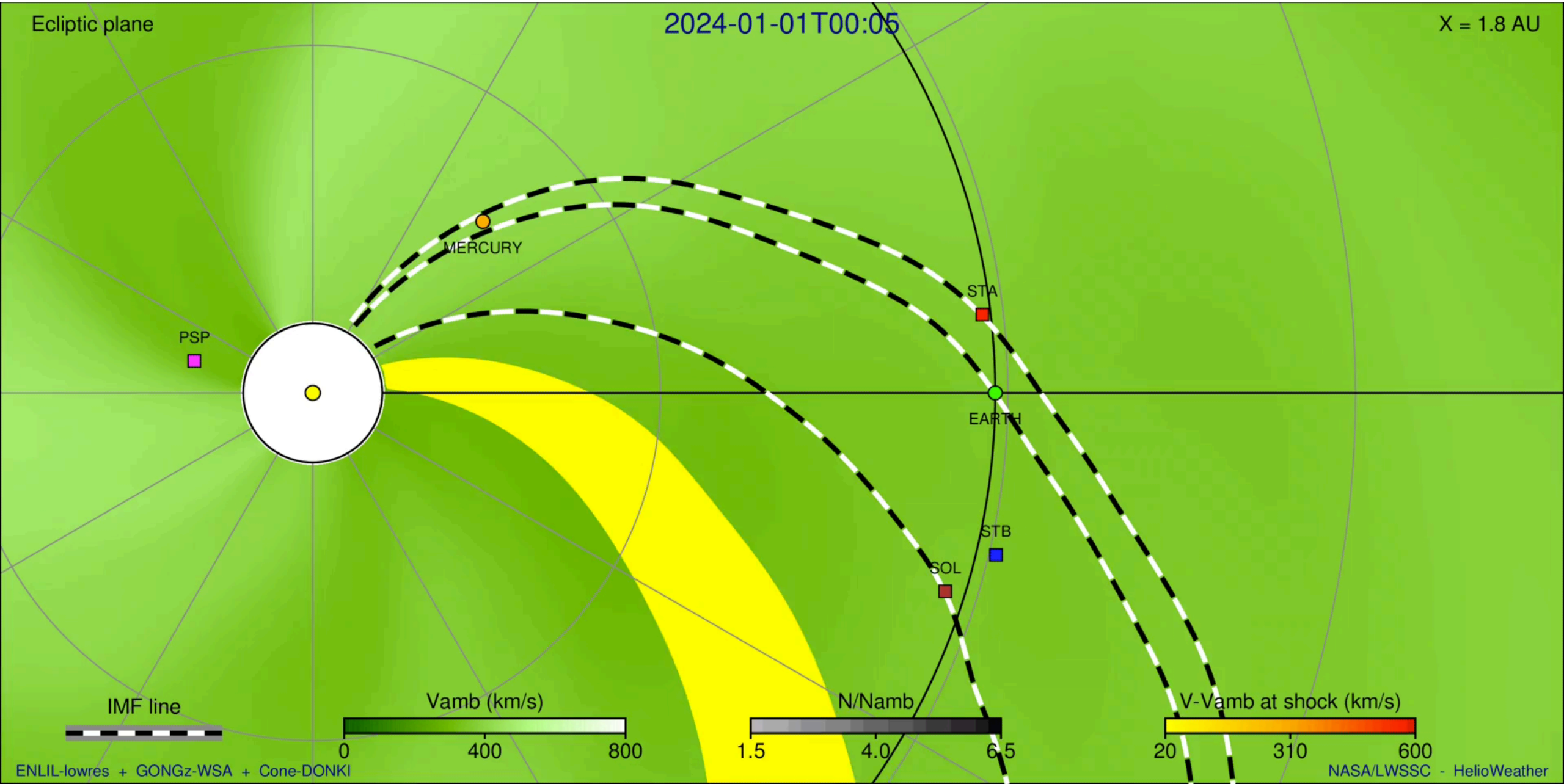
# SEP Model (SEPMOD)



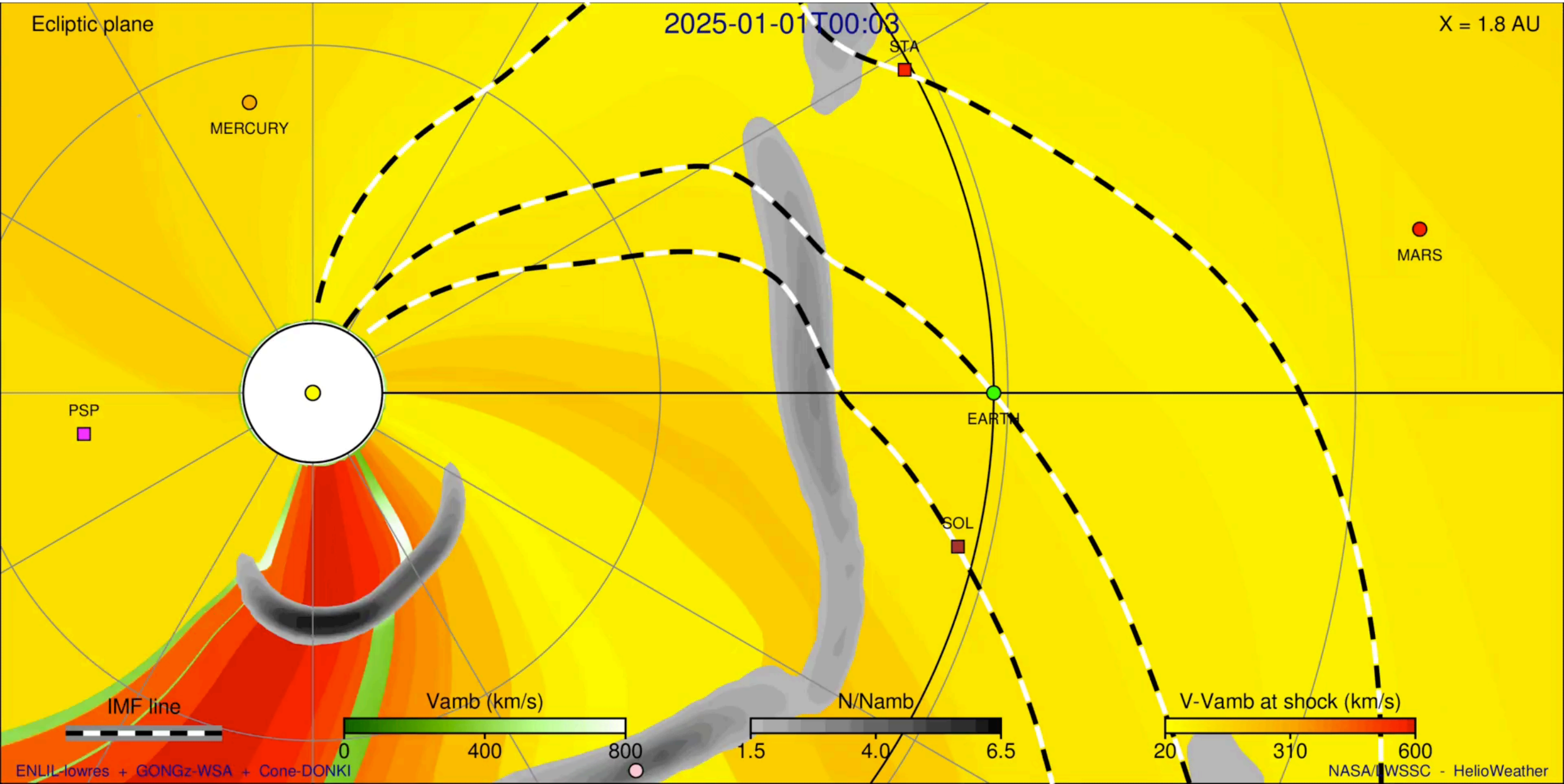




- Runs coupled with the heliospheric WSA-ENLIL model starting at 0.1 AU (outer corona)
- Simulates the time series of SEP fluxes at any inner heliosphere observer location
- Assumes that interplanetary shocks are locations where a small fraction of solar wind protons are accelerated to high energies to produce SEPs

# WSA-ENLIL shock strength: early 2024 estimate



# WSA-ENLIL shock strength: early 2025 estimate

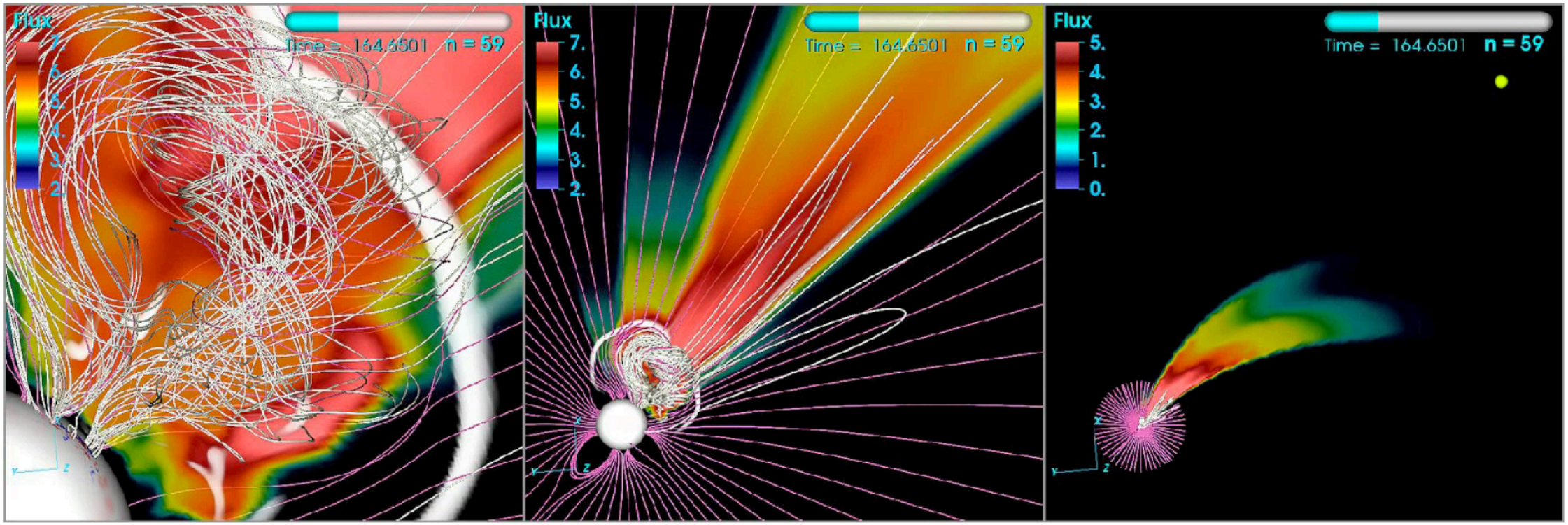


# SPE Threat Assessment Tool (STAT)

- Coupled Coronal Mass Ejection - Solar Particle Event Simulations

STAT=CORHEL (Corona-Heliosphere) + EPREM (Energetic Particle Radiation Environment Module

- Models SEP acceleration low in the corona which requires detailed physical models



# SEP Scoreboard Goals

- Uniform input format and scoreboard displays so multiple models can be viewed and compared together
- Displays should be easy for SRAG operator to understand and take action on, but contain all necessary information

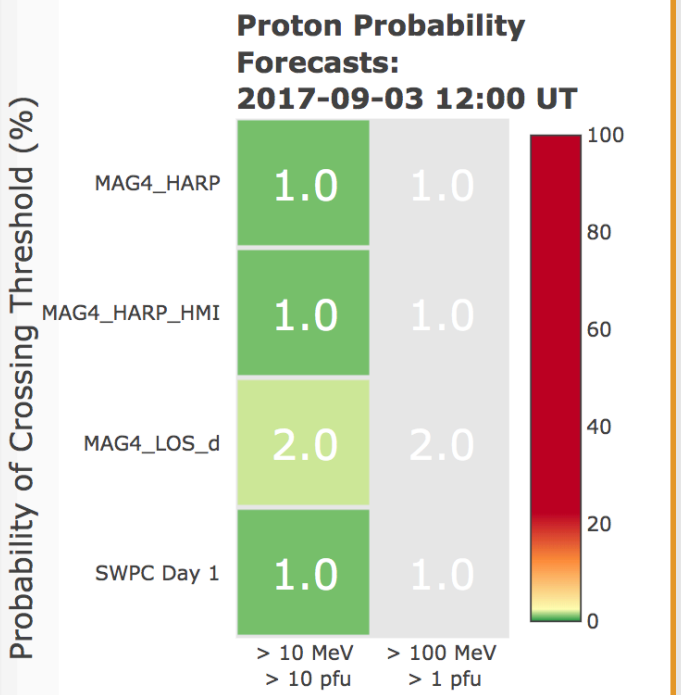
# SEP Forecast Types

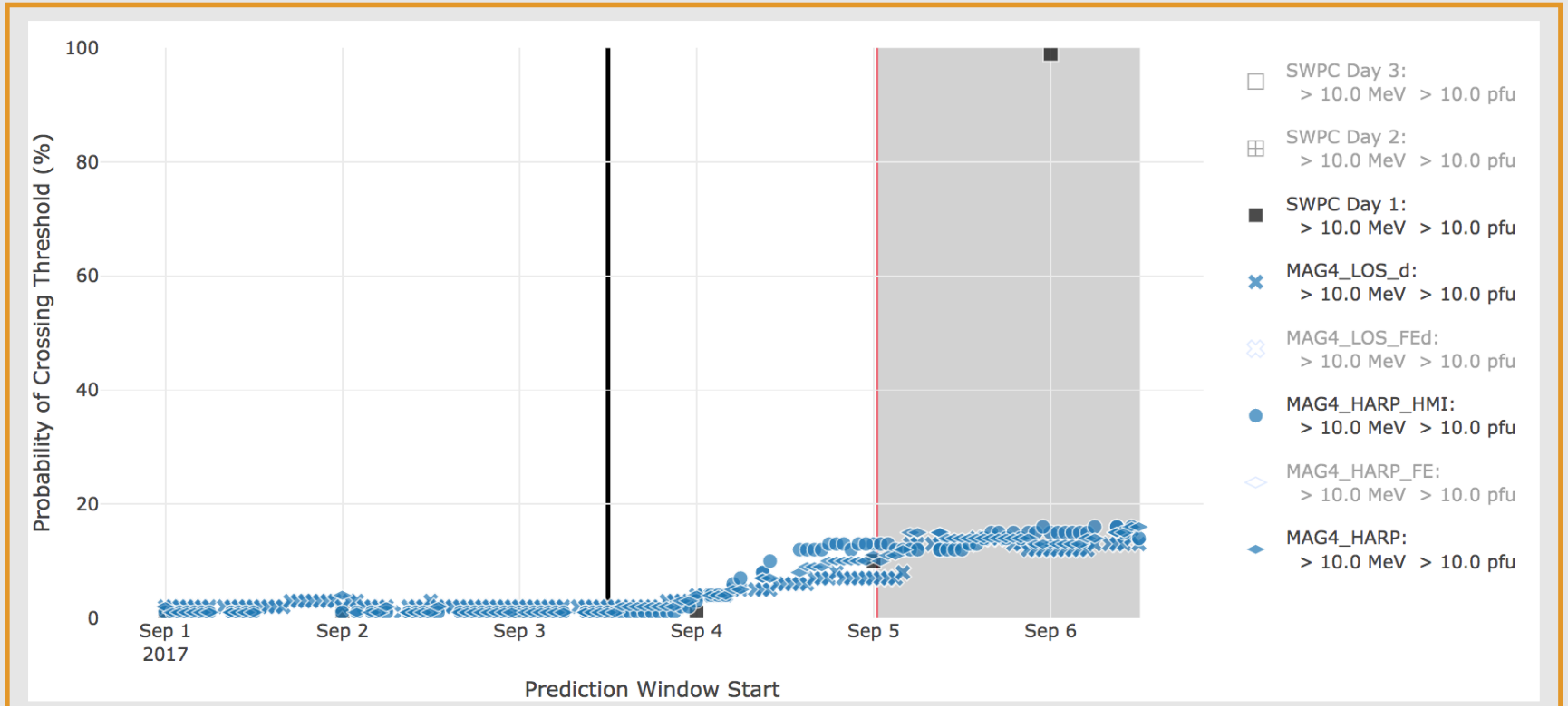
For different energy ranges/thresholds models may forecast:

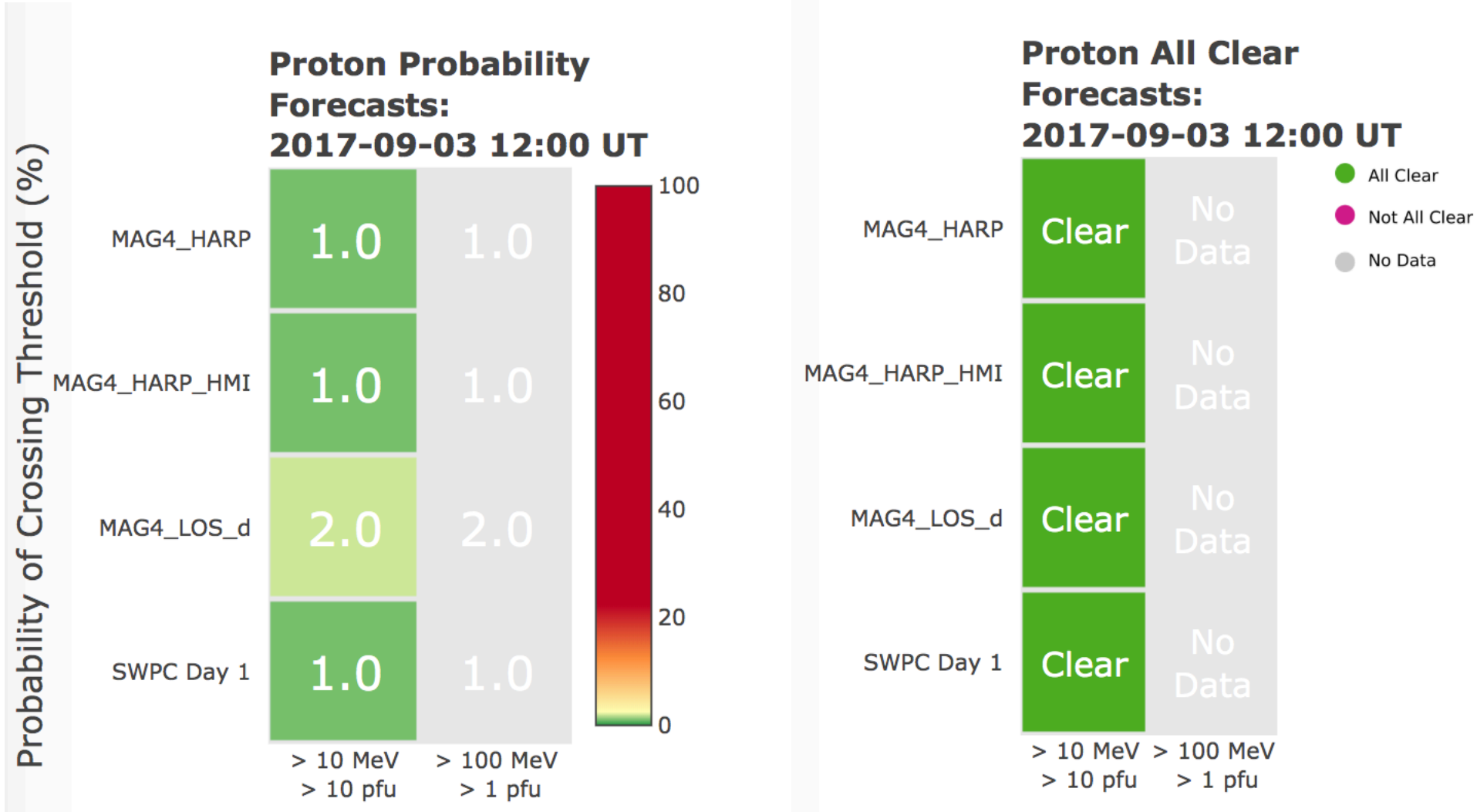
- Continuous threshold crossing probabilities
- Continuous intensity
- Peak intensity for event
- Peak intensity with the next x hours
- and others

# SEP Scoreboard

-1 week | -1 day | -1 hour | 2017-09-03 12:00 | +1 hour | +1 day | +1 week | Today | Refresh Plots

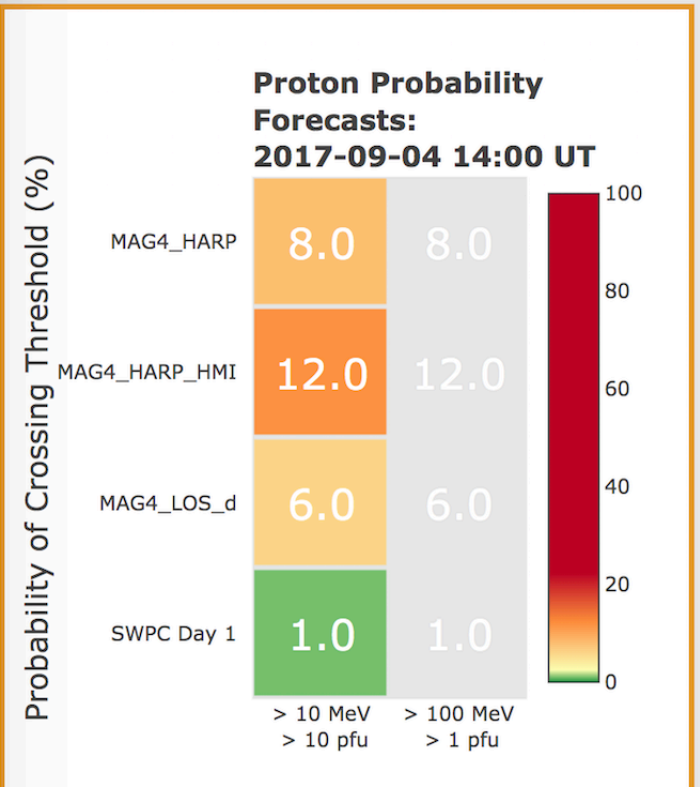


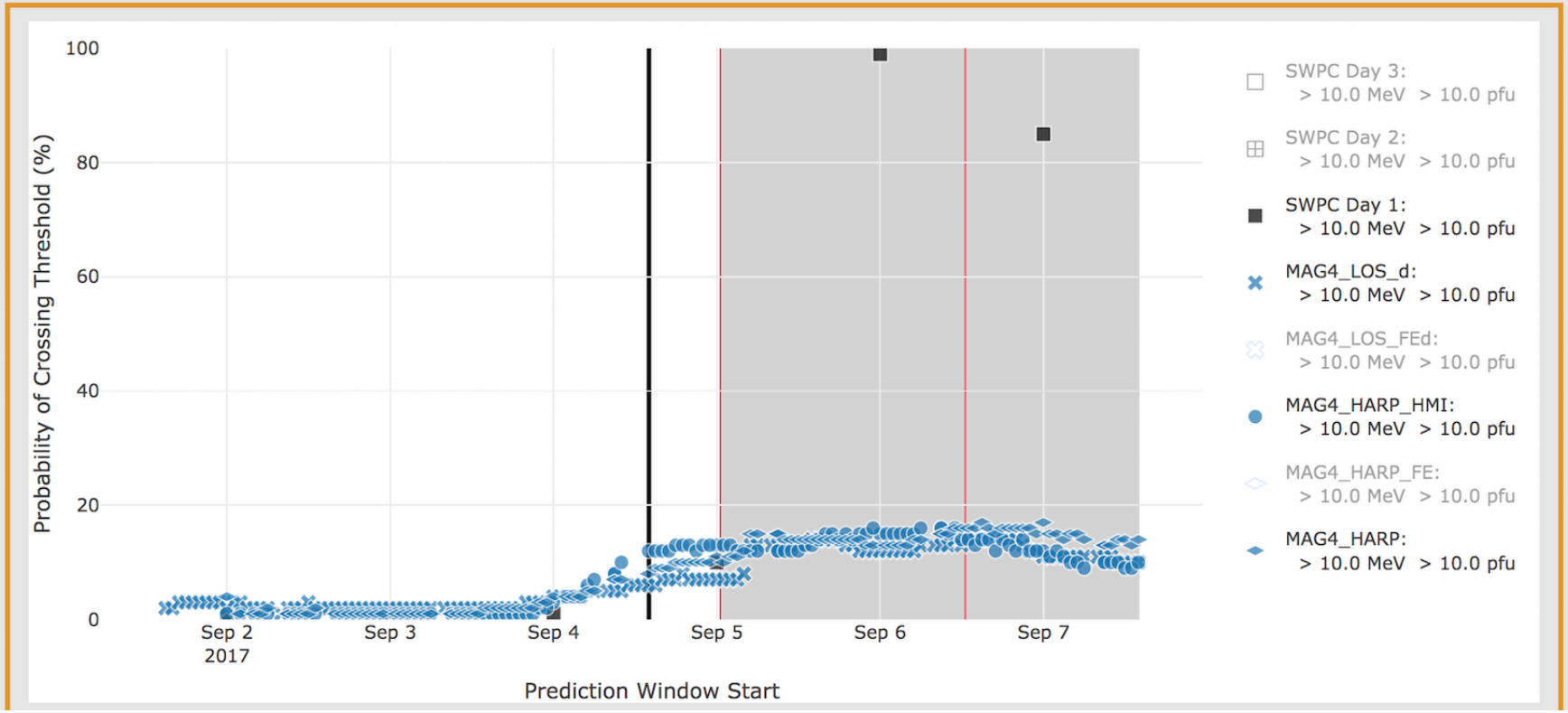




Proton Probability Forecasts:
2017-09-03 12:00 UT
Probability of Crossing Threshold (%)
MAG4_HARP
MAG4_HARP_HMI
MAG4_LOS_d
SWPC Day 1
1.0
1.0
1.0
2.0
1.0
2.0
1.0
1.0
100
80
60
40
20
0
> 10 MeV
> 10 pfu
> 100 MeV
> 1 pfu
Proton All Clear Forecasts:
2017-09-03 12:00 UT
MAG4_HARP
MAG4_HARP_HMI
MAG4_LOS_d
SWPC Day 1
Clear
Clear
Clear
Clear
No Data
No Data
No Data
No Data
All Clear
Not All Clear
No Data
> 10 MeV
> 10 pfu
> 100 MeV
> 1 pfu

# SEP Scoreboard

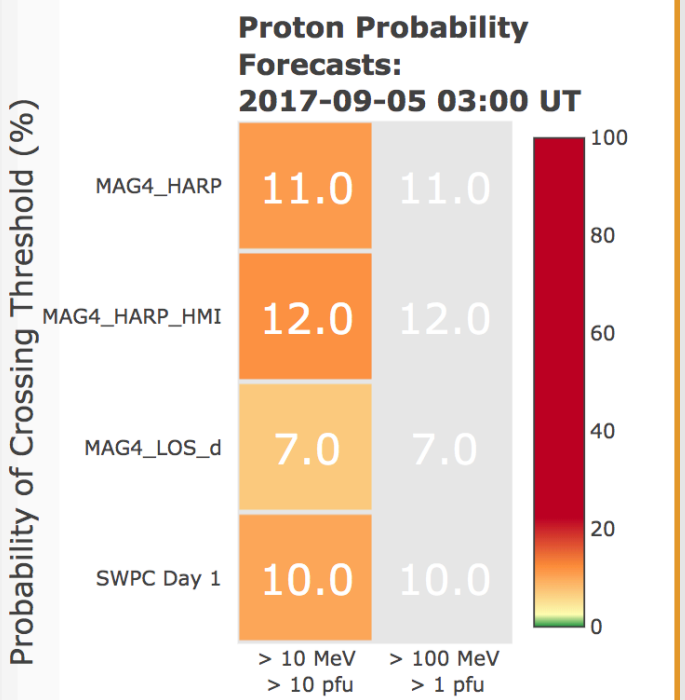
-1 week | -1 day | -1 hour | 2017-09-04 14:00 | +1 hour | +1 day | +1 week | Today | Refresh Plots

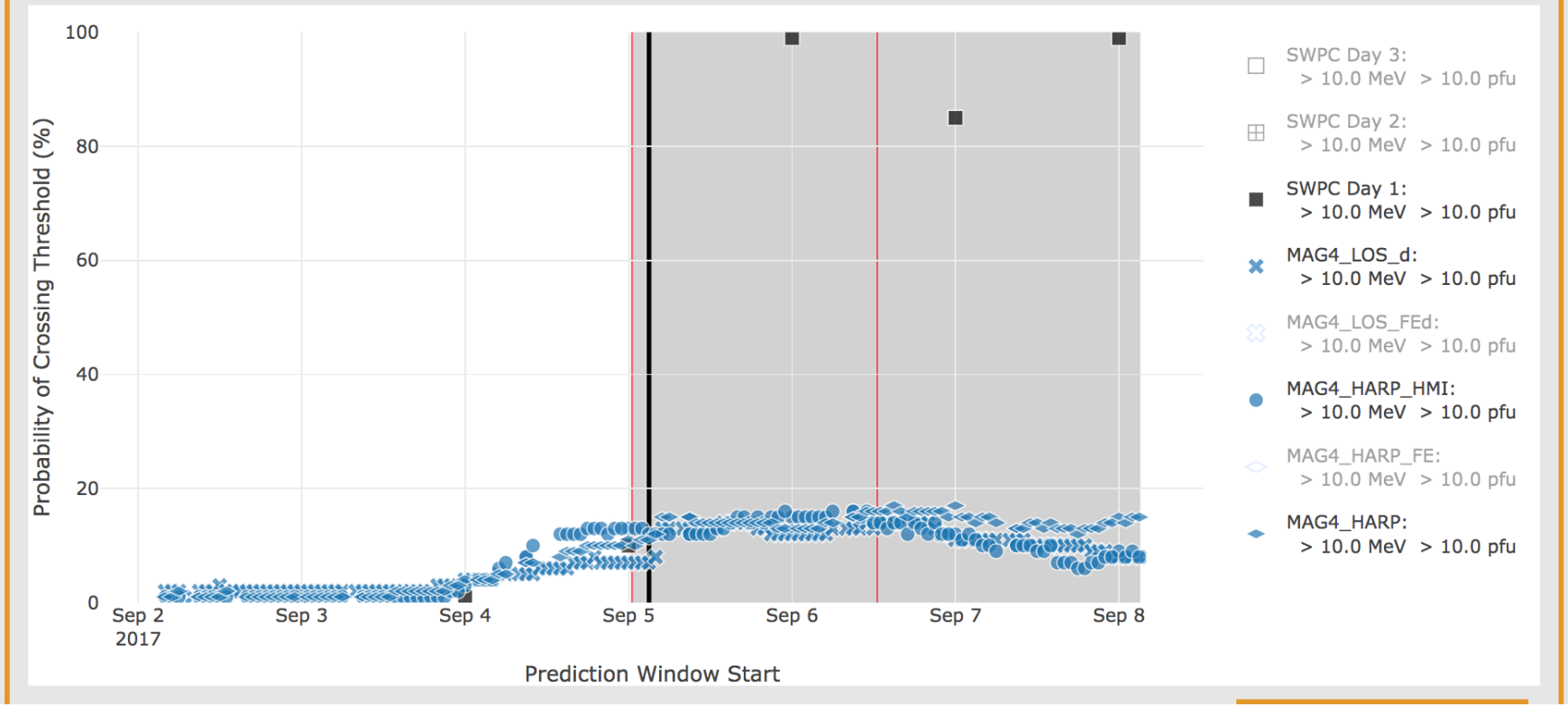


# SEP Scoreboard

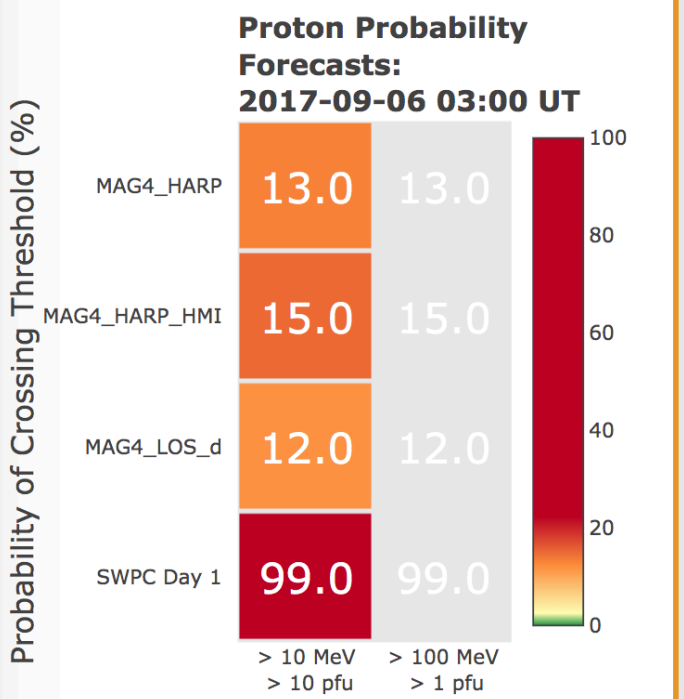
-1 week | -1 day | -1 hour | 2017-09-05 03:00 | +1 hour | +1 day | +1 week | Today | Refresh Plots

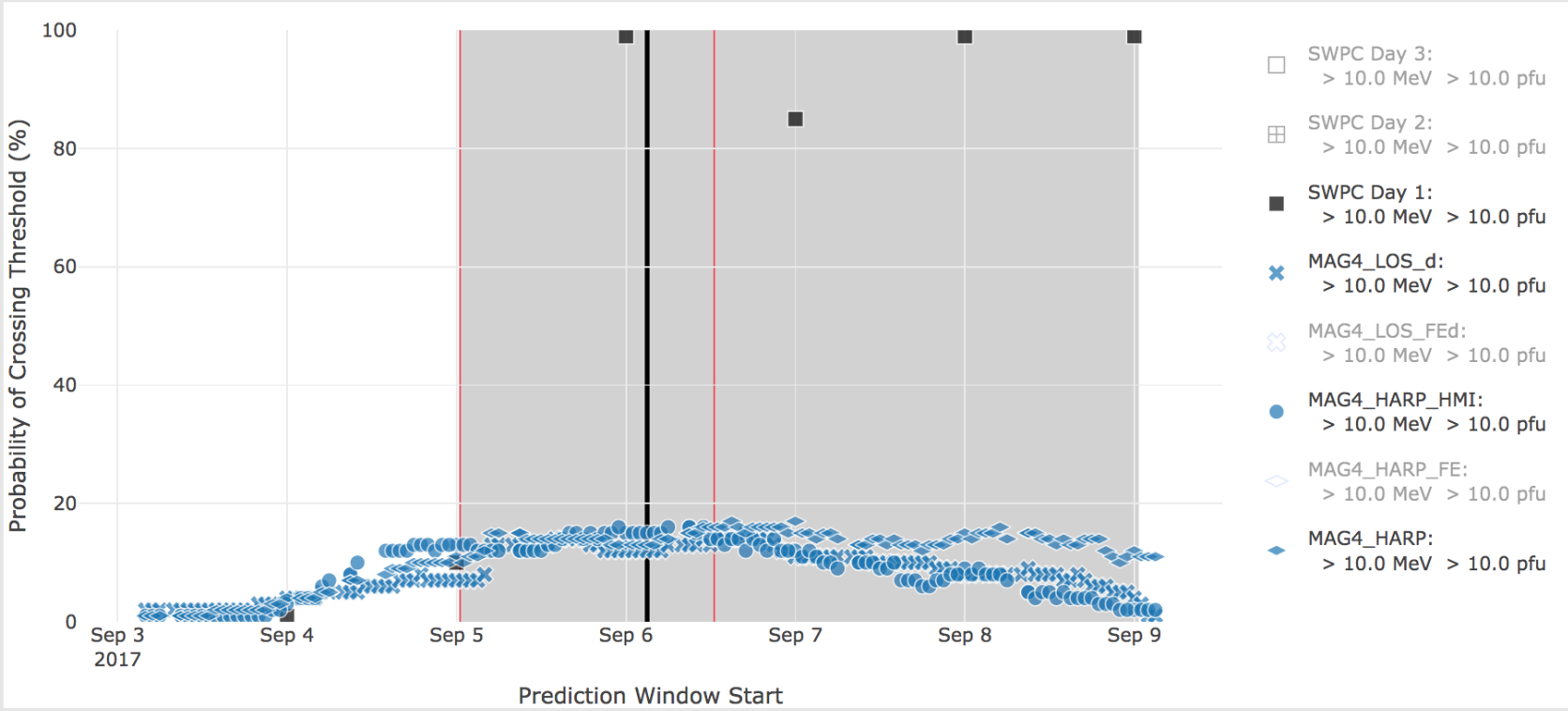


# SEP Scoreboard

-1 week | -1 day | -1 hour | 2017-09-06 03:00 | +1 hour | +1 day | +1 week | Today | Refresh Plots



# SEP Scoreboard

-1 week | -1 day | -1 hour | 2019-10-01 00:00 | +1 hour | +1 day | +1 week | Today | Refresh Plots

Probability of Crossing Threshold (%)

## Proton Probability Forecasts: 2019-10-01 00:00 UT

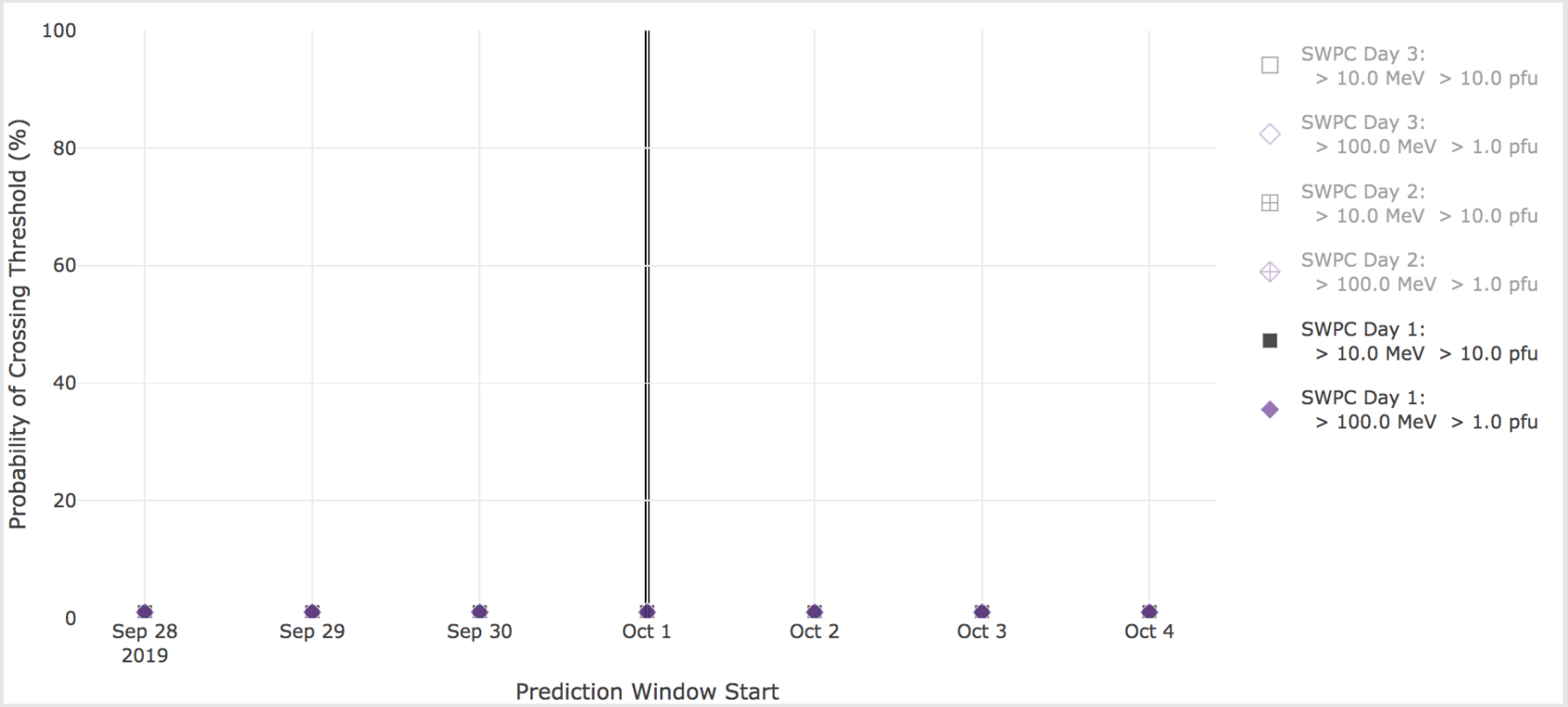
| | > 10 MeV > 10 pfu | > 100 MeV > 1 pfu |
|---|---|---|
| SWPC Day 1 | 1.0 | 1.0 |

100 / 50 / 0

## Proton All Clear Forecasts: 2019-10-01 00:00 UT

| | > 10 MeV > 10 pfu | > 100 MeV > 1 pfu |
|---|---|---|
| SWPC Day 1 | Clear | Clear |

All Clear
Not All Clear
No Data




List of all Models:

Graph Show Options

# SEP Scoreboard Displays


Display will be built for multiple forecast types/stages

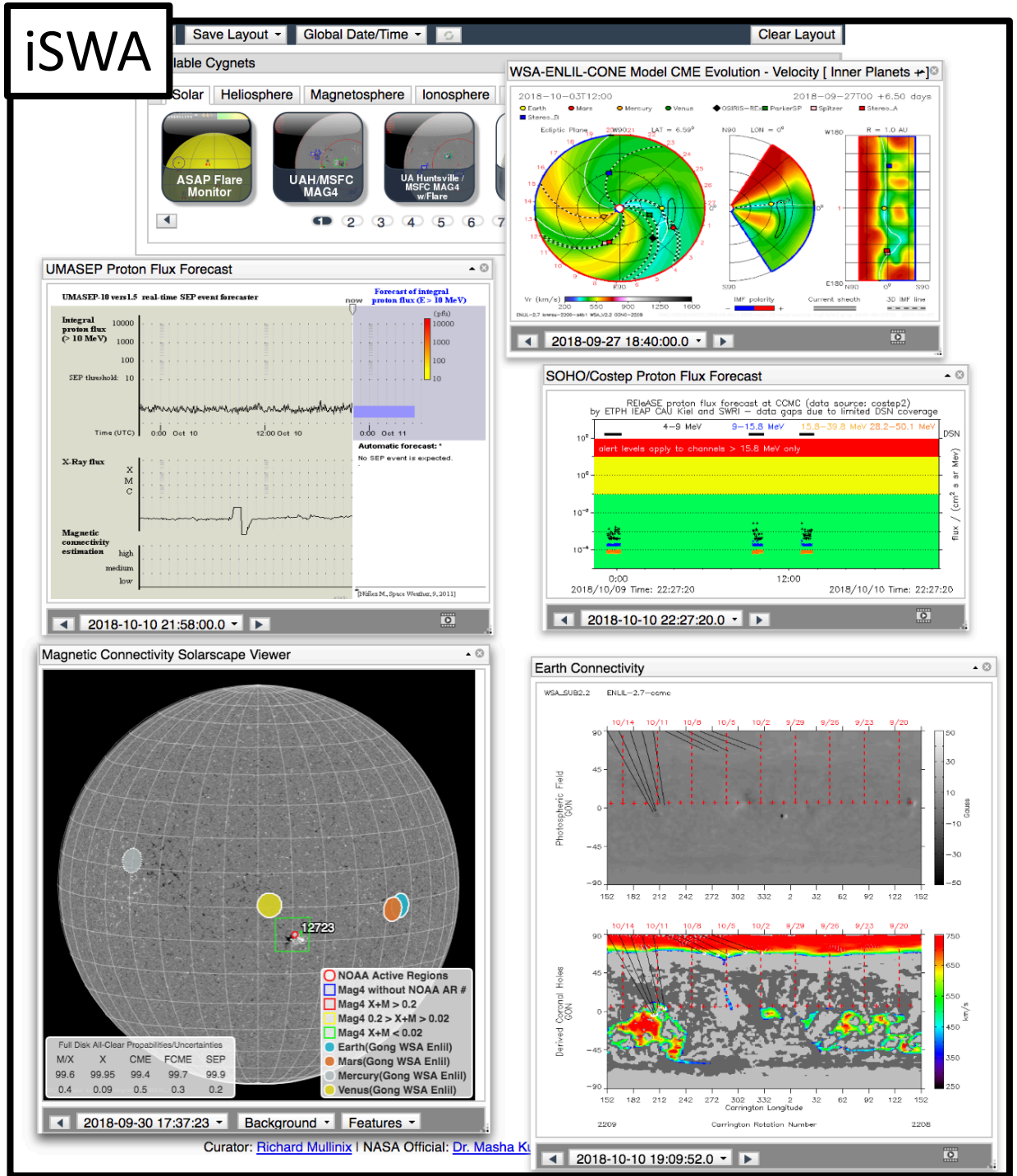
- (A) probability heat map and time series (MAG4)
- (B) peak intensity heat map (SEPSTER, UMASEP, REleASE, SEPMOD)
  - SEPSTER peak intensity is for entire event not including ESP
  - UMASEP peak intensity is for the next 7, 3, 1 hours
  - REleASE peak intensity is for next 30, 60, 90 min; derive from the timeseries
  - SEPMOD peak derived from the timeseries
- (C) intensity time series (REleASE, SEPMOD, UMASEP, STAT)
  - REleASE time series: next 30, 60, 90 min
  - UMASEP timeseries: next 7, 3, 1 hours
  - SEPMOD timeseries: next 7 days
- (D) all-clear forecast time series: MAG4, UMASEP, REleASE, SEPSTER, SEPMOD, STAT

# SEP Scoreboard: Model energy ranges


- MAG4: >10 MeV
- REleASE: 15.8–39.8 MeV, 28.2–50.1 MeV
- SEPSTER (Richardson):
  14-24 MeV; expanded to >10 MeV, >100 MeV proxy
- SEPMOD: 10-100 MeV; expanded to 1 GeV
  custom differential and integral channels possible
- STAT: 1-2 GeV
  custom differential/integral channels possible
  including >10 MeV, > 50MeV, >100 MeV
- UMASEP: >10 MeV, >100 MeV, >500 MeV

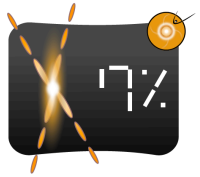
# SEP Scoreboard Connections

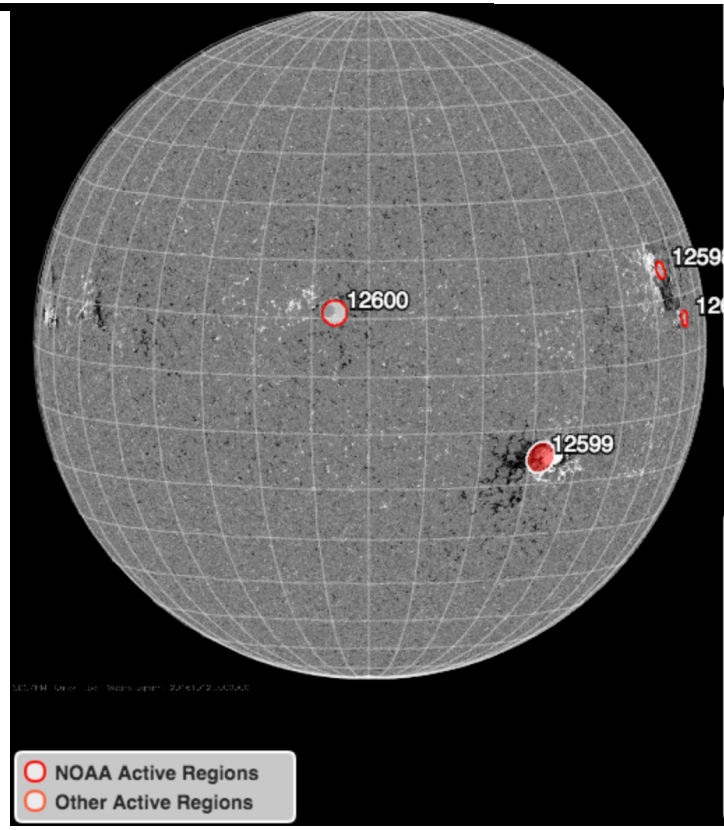
## iSWA




Curator: Richard Mullinix | NASA Official: Dr. Masha K

## Flare Scoreboard




**S15W32 Region Flare Predictions (24 hour)**

| | | | |
|---|---|---|---|
| BoM_flare1 | | M+: 1% | X : 1% |
| AMOS_v1 | C+: 27% | M+: 5% | X : 0% |
| NOAA_1 | C : 20% | M : 1% | X : 1% |
| Averages | C : 20% | M : 1% | |
| | C+: 27% | M+: 3% | X : 1% |

**Region Location Details**

**BoM_flare1**
NOAA AR#: 12599 (S15W32), R: 1.88, Beta

**AMOS_v1**
NOAA AR#: 12599 (S15W32), R: 1.88, Beta
AMOS_v1 AR#: 1 (S15W32, 2016-10-12 00:00:00.0)

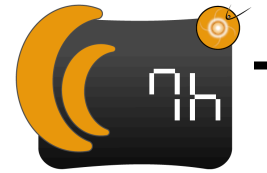
**NOAA_1**
NOAA AR#: 12599 (S15W32), R: 1.88, Beta

**Full Disk Predictions (24 hour)**

| | | | |
|---|---|---|---|
| BoM_flare1 | | M+: 1% | X : 1% |
| ASSA_24H_1 | C : 84% | M : 31% | X : 6% |
| AMOS_v1 | C+: 36% | M+: 6% | X : 0% |
| NOAA_1 | | M : 1% | X : 1% |
| UFCORIN_1 | C+: 0% | M+: 0% | X : 0% |
| MO_TOT1 | | M : 5% | X : 1% |
| Averages | C : 84% | M : 12% | |
| | C+: 18% | M+: 2% | X : 1% |

## DONKI:

CCMC's real-time SW Event Catalog




## CME Scoreboard