Validation: SEP Working Team & Scoreboard TDM

Agenda: 1) TDM introduction [2 min]

2) SEP Working Team and Scoreboard Status [13 min]

3) SEP Working Team Community Campaign Events [60 min]
10 September 2017; 23 July 2017

Empirical(ish)

- Athanasios Papaioannou – FORSPEF [12 min]
- Mark Dierckxsens – SEPForecast [12 min]
- Monica Laurenza – ESPERTA [12 min]
- Ian Richardson – SEPSTER [12 min]
- Olga Malandraki – REleASE [12 min]
- Mike Marsh - UK Met Office operational probabilistic forecast
- Marlon Núñez - UMASEP-10

Physics-based

- Silvia Dalla – SPARX

General Discussion:

- What are the challenges?
- How to establish performance benchmarks for models in a systematic, controlled way and for much longer time periods.

Grey: Not attending ESWW but sent model event results

SEP Working Team Goals

- (1) Evaluate how well different models/techniques can predict historical SEP events throughout the heliosphere;
- (2) Establish community metrics; and
- (3) Provide a benchmark against which future models/model updates can be assessed against.

SEP Working Team Update From iLWS-CCMC 2017 workshop

Many SEP quantities to validate, e.g.:

- Onset time and threshold crossing time
- Event duration (above a threshold)
- Fluence, peak intensity and peak timing (energy dependent)
- Flare/CME-SEP prediction (i.e., when will a flare/CME erupt, and will it be associated with SEPs?).
- Energy spectrum, anisotropy, profile shape ESP

Observations (calibration is important)

- GOES (dataset cross-calibrated with IMP/GME), STEREO, SOHO, ACE, PAMELA, Wind, IMP-8

Examples of different user requirements:

- Satellite launchers: Use **GOES >10 MeV proton** intensity for radiation-based go/no go decisions. Would like forecasts of SEP intensity several days in advance;
- Aviation community: Need reliable, few hours lead time, **forecasts of 100s of MeV/n SEPs** that penetrate to aircraft altitudes and to low geomagnetic latitudes. Forecasts of >10 MeV proton events/fluxes are not useful.

Overlapping user needs:

- a few **standard energy ranges** relevant to user groups (more than just GOES 10 MeV, 100 MeV protons)
- a few **standard thresholds** (to define SEP event, and duration time) relevant to **user groups**
- Include **heavy ions**
- Make sure a **few key metrics** amongst science metrics are targeting users

CCMC community scoreboards

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

Leads: **Trinity College Dublin** (S. Murray), **ROB** (J. Andries)

Leads: **BIRA-IASB** (M. Dierckxsens, N. Crosby), **GSFC** (I. Richardson), **UK Met Office** (M. Marsh)

Leads: **CCMC** (L. Mays), **UK Met Office**

Leads: **GSFC** (N. Savani), **PredSci** (P. Riley), **CCMC** (L. Mays)

- Scoreboards collect forecast before event is observed
- Allow a consistent **real-time** comparison of various operational and research forecasts. Complementary to non-real time model assessments.

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 flux 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.
- 2018: A version of the SEP Scoreboard is being developed for Johnson Space Center's Space Radiation Analysis Group starting with the initial set of 6 models.

Continuous/ Probabilistic

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

Continuous Profile:
PREDICCS (UNH)

Non Near Real-Time/ Complex

COMMUNITY COORDINATED MODELING CENTER

CSWEPA 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
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SOLPENCO (Arans)

Flare and proton flux:
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CME:
Richardson SEP formula
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Electron flux:
REleASE

Flare, Radio, H-alpha:
SWPC PPM

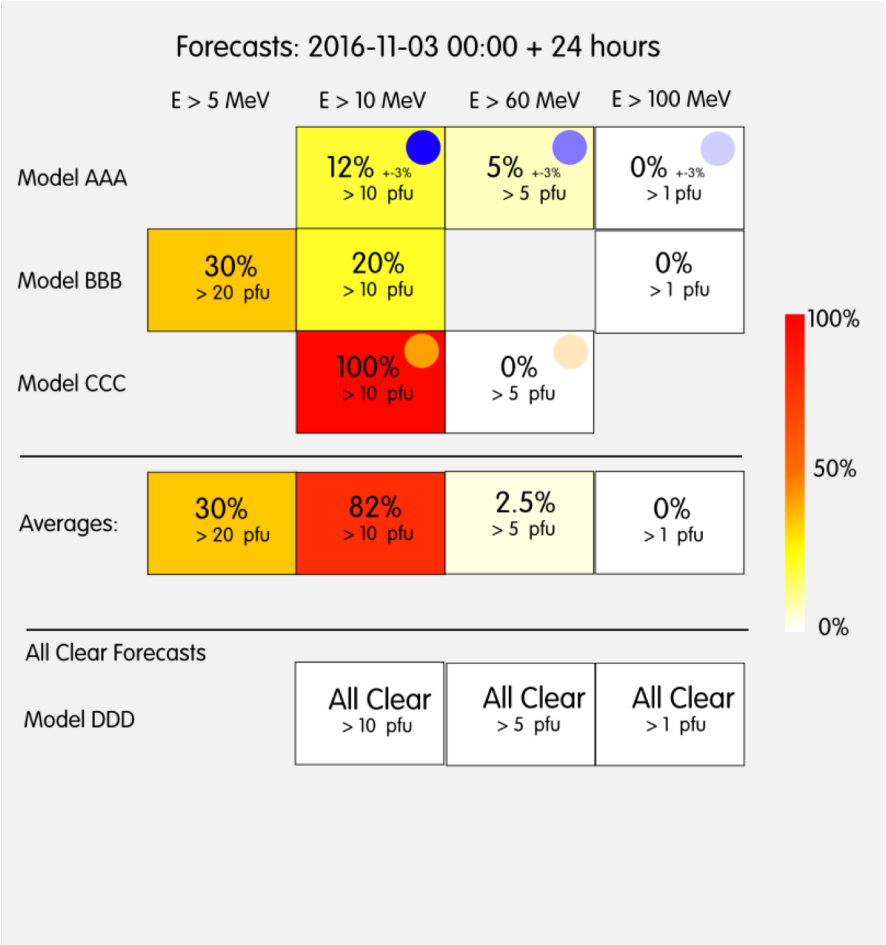
Flare, Radio:
Laurenza Model

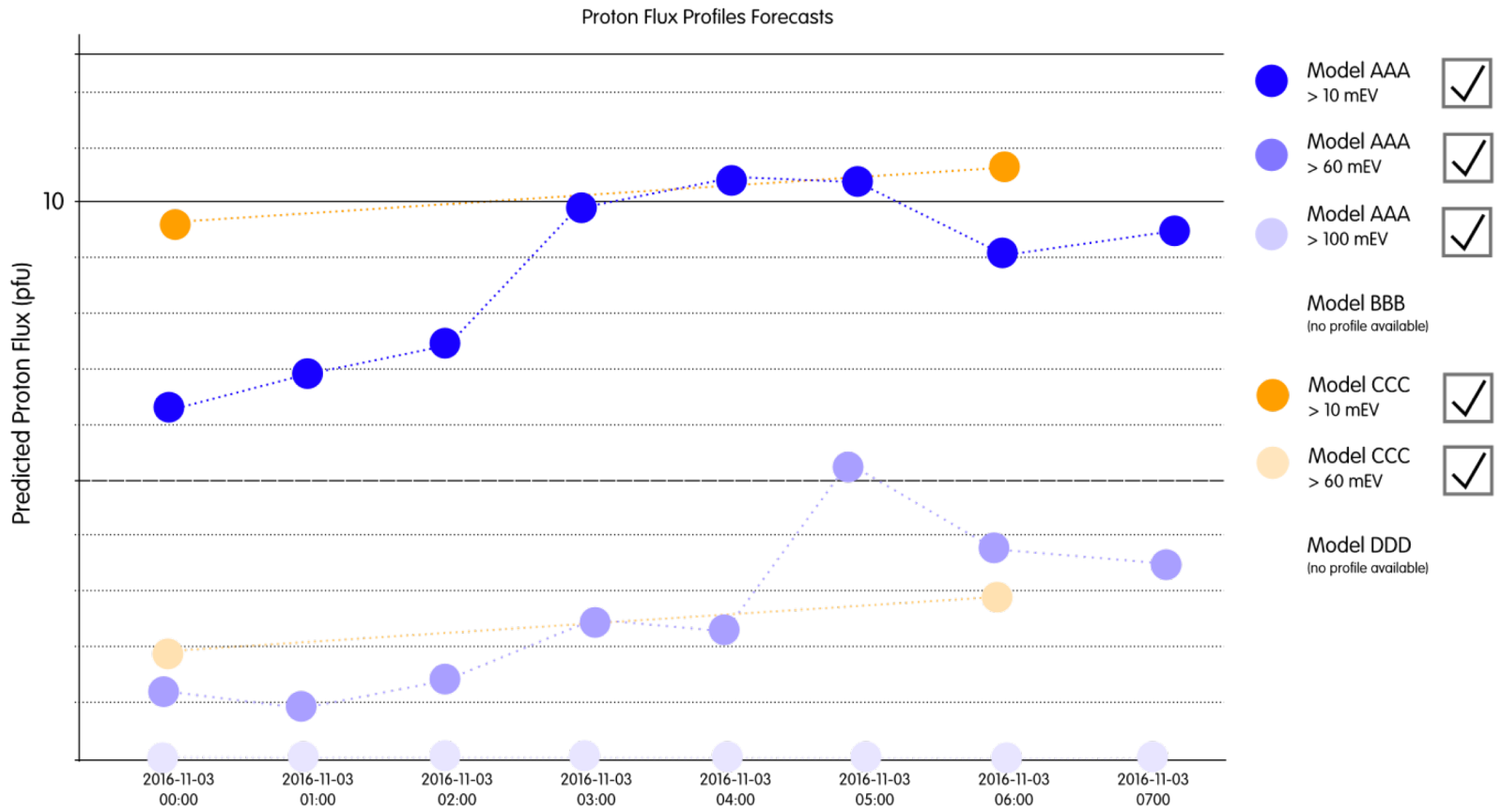
Radio:
AER SEP Model (Winter)

SEP Scoreboard Planning

Display ideas

SEP Scoreboard





Probability heat map at a single time

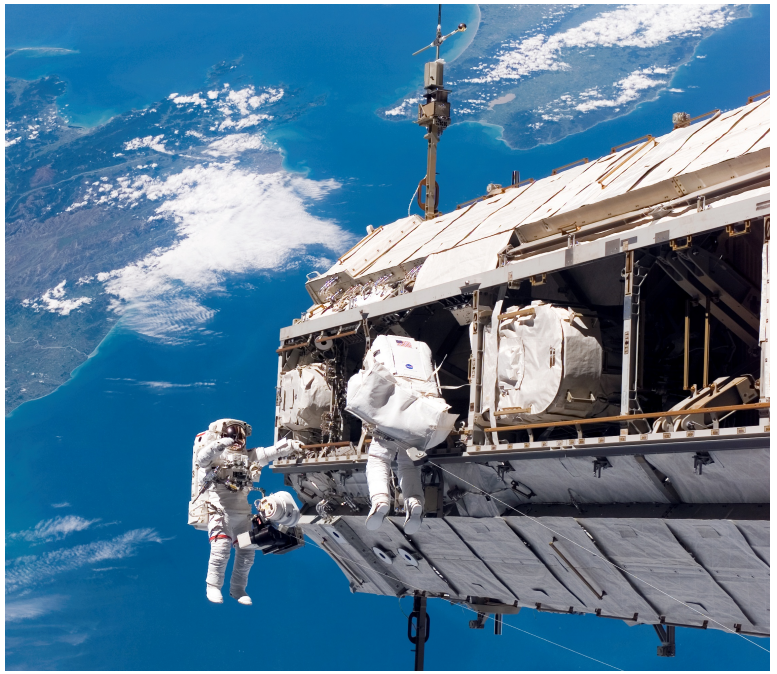
https://ccmc.gsfc.nasa.gov/challenges/sep.php

Predicted proton flux time-series

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

space radiation analysis group

- This year CCMC has started a 3 year project with SRAG to **transition a few research Solar Energetic Particle models to operations** including MAG4, UMASEP, SEPSTER, SEPMOD, STAT
- These **models were chosen by SRAG** based on their operational requirements, other models may be considered in later years.
- They need to know the **likelihood of an energetic particle event** over the next few days. Or, given a flare or coronal mass ejection event, will there be solar energetic particles? How intense will they be? How long will they last? What will be the impact on crew health?
- Models transitioned, and **SEP Scoreboard displays** built by CCMC will be used operationally by SRAG for human missions beyond LEO starting in 2022.



Draft XML Schema for Scoreboard

- XML Schema draft presented 2016-2017 to handle as wide a variety of forecasts as possible
- Currently being updated and finalized by February 2019
- May switch from XML to JSON
- Header element providing details on the model and validity of the forecast
- Issued forecast element(s) providing:
  - description, reference, species, location, confidence
  - event length & threshold
  - strength (storm level, peak flux, fluence)
  - probability
  - energy range
  - flux profile (time series)

XML Schema	Type	Comments
sepforecast		
header		
sender	string	optional
email	string	optional
model	string	
forecasttype	string	restrictions[1]
issuetime	datetime	
predictionwindow		optional
starttime	datetime	
endtime	datetime	
inputdata	string	optional, >1 possible
issued_forecast		at least 1
description	string	
source_id	string	optional
source_url	string	optional, >1 possible
species	string	restrictions[2]
location	string	restrictions[3]
confidence	decimal	[0.0,1.0]
event_length		optional
onset_time	datetime	
end_time	datetime	optional
event_threshold		optional
threshold	decimal	
units	string	
time	datetime	
strength		
storm_level	integer	optional, [0,5]
peak_flux		optional
flux	decimal	>0.0
units	string	
time	datetime	
fluence	decimal	optional, >0.0
fluence	decimal	>0.0
units	string	
probability		optional
value	decimal	[0.0,1.0]
uncertainty	decimal	optional
value_lower	decimal	optional, [0.0,1.0]
value_upper	decimal	optional, [0.0,1.0]
energy_range		
energy_min	decimal	default 0.0
energy_max	decimal	default -1.0 = infinity
sep_profile		optional
units	string	
flux_point		>1 possible
time	datetime	
flux	decimal	>0.0

SHINE 2018 Workshop sessions related to Working Team: SEP Models in the Community

(SHINE: July 30—August 3, 2018)

Sessions:

Coupled heliospheric and solar energetic particle models

Organizers: Christina Lee (UC Berkeley), Janet Luhmann (UC Berkeley), M. Leila Mays (NASA/GSFC)

Predicting solar energetic particles: community campaign

Organizers: M. Leila Mays (NASA GSFC), Hazel Bain (NOAA SWPC), Ian Richardson (UMD/NASA GSFC)

Is Understanding Magnetic Field Connectivity Crucial for Understanding Solar Energetic Particle Events?

Organizers: Hazel Bain (NOAA SWPC), Ian Richardson (University of Maryland/GSFC)

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Flare, Radio:
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Radio:
AER SEP Model (Winter)

SHINE 2018:
Predicting solar energetic particles: community campaign

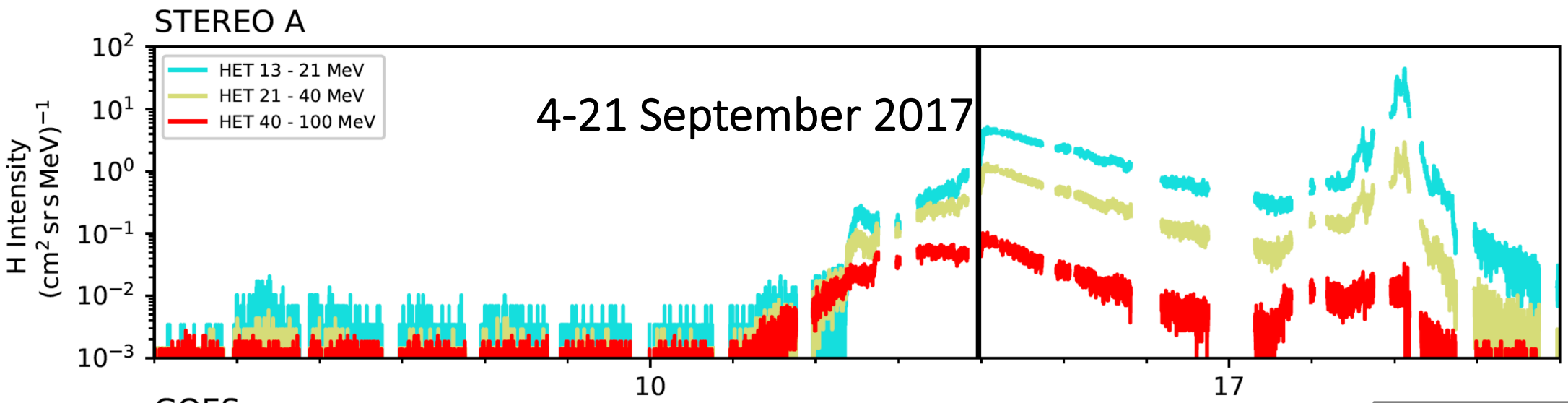
All contributing slides available at: https://drive.google.com/open?id=1ZMdcSEA0rVJFLX8041vSQjjuq8tqXrP_

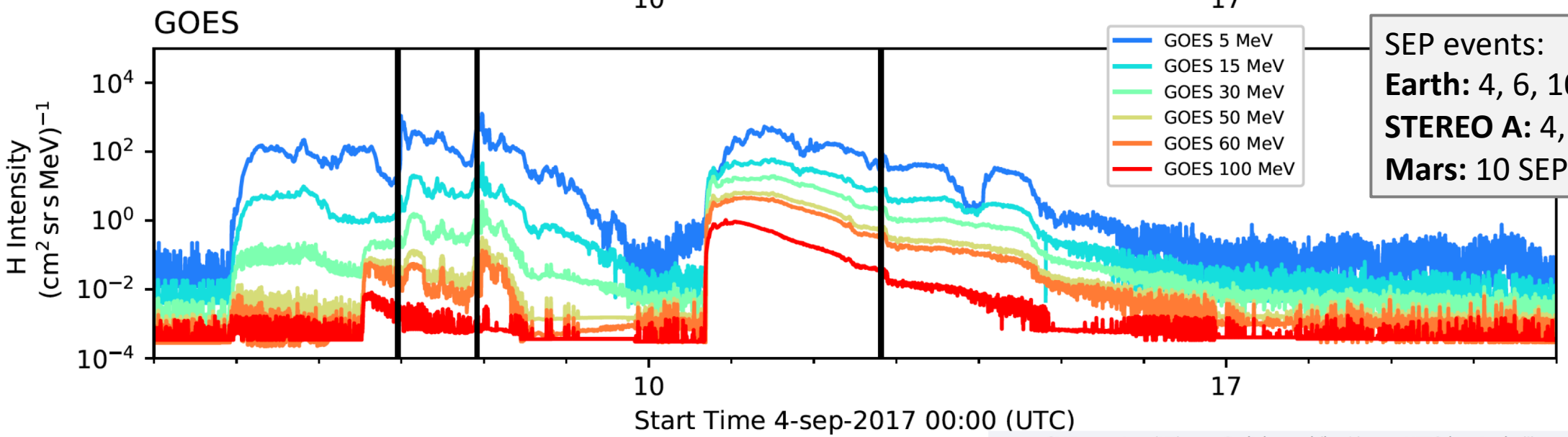
Physics-based

- Dmitry Borovikov – SWMF
- Silvia Dalla – SPARX
- Junxiung Hu - iPATH
- Janet Luhmann – SEPMOD
- Ming Zhang - Zhang model

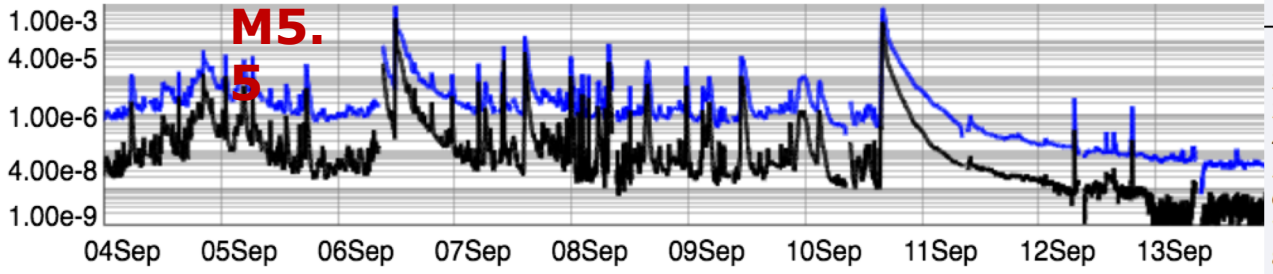
Empirical(ish)

- Stephen White & Steve Kahler - AFRL PPS
- Arik Posner – REleASE
- Hazel Bain – PROTONS & SWPC operational forecast
- Marlon Núñez - UMASEP-10
- *Ian Richardson – Richardson formula*
- *Alex Engell & David Falconer - MAG4 and SPRINTS*
- *Athanasios Papaioannou – FORSPEF*
- *Mark Dierckxsens - SEPForecast*
- *Mike Marsh - UK Met Office operational probabilistic forecast*
- *Monica Laurenza - ESPERTA*

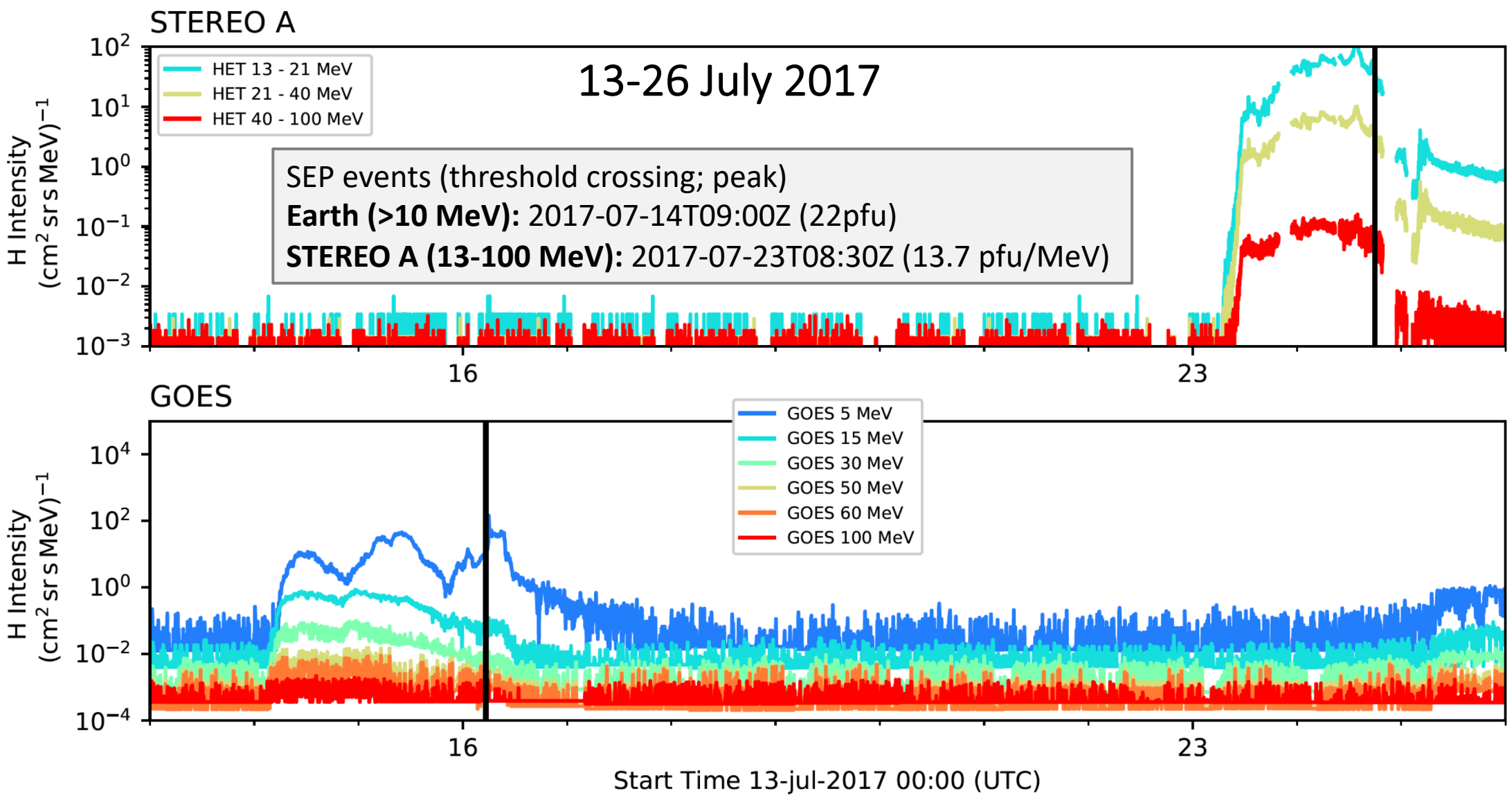


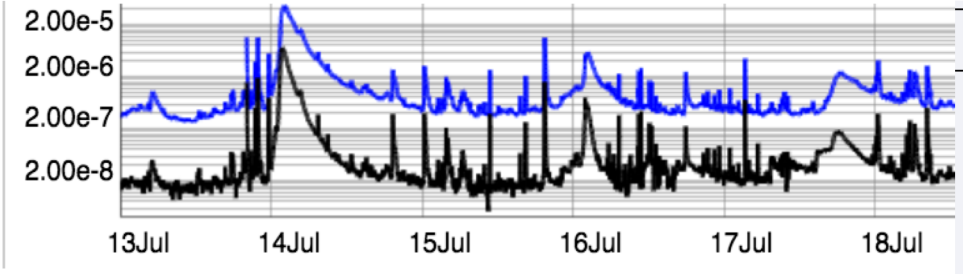


SEP events:
Earth: 4, 6, 10 SEP 2017
STEREO A: 4, 11, 18 SEP 2017
Mars: 10 SEP 2017

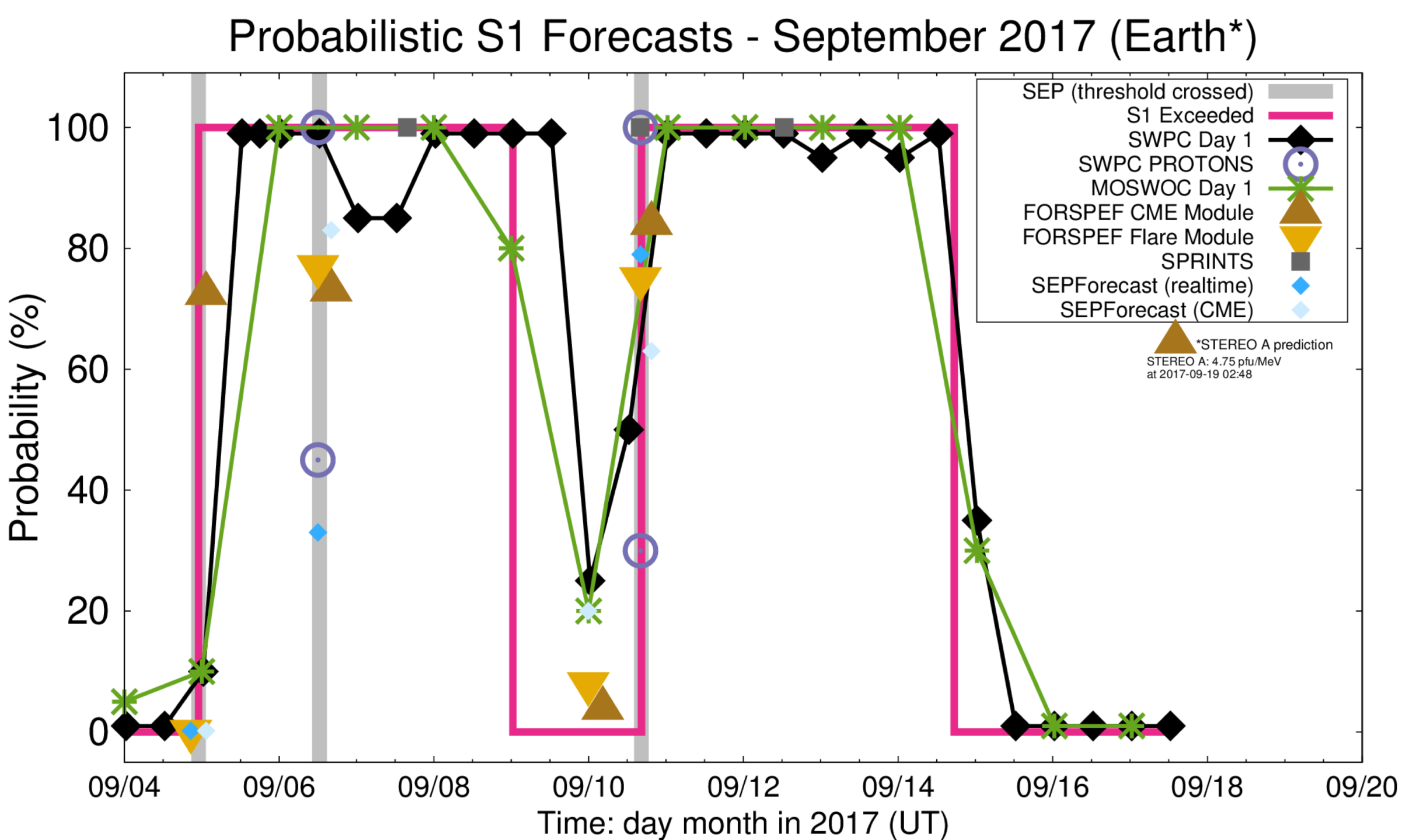


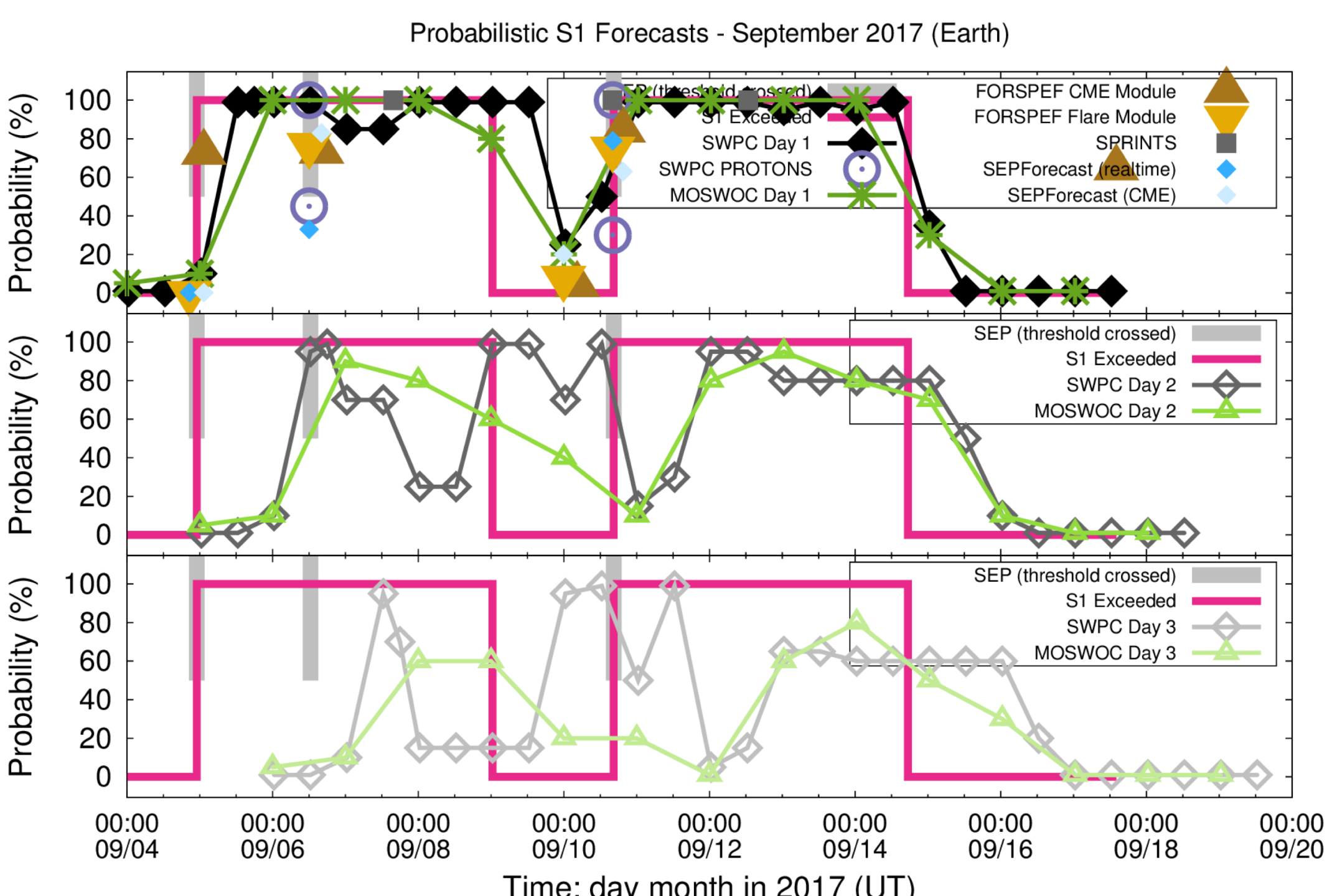
	CME start time (UT)	Radial speed (km/s)	HEEQ longitude (°)	HEEQ latitude (°)	Half-width (°)
1	2017-09-04 20:36	1,325	4	−8	52
2	2017-09-04 19:39	830	23	−8	28
3	2017-09-06 12:24	1,850	24	−15	50
4	2017-09-06 13:09	1,180	99	−4	30
5	2017-09-09 16:48	480	100	−10	33
6	2017-09-09 23:12	700	105	5	41
7	2017-09-10 16:09	2,500	108	−9	90[a]
8	2017-09-17 12:09	1,600	−155	−5	54

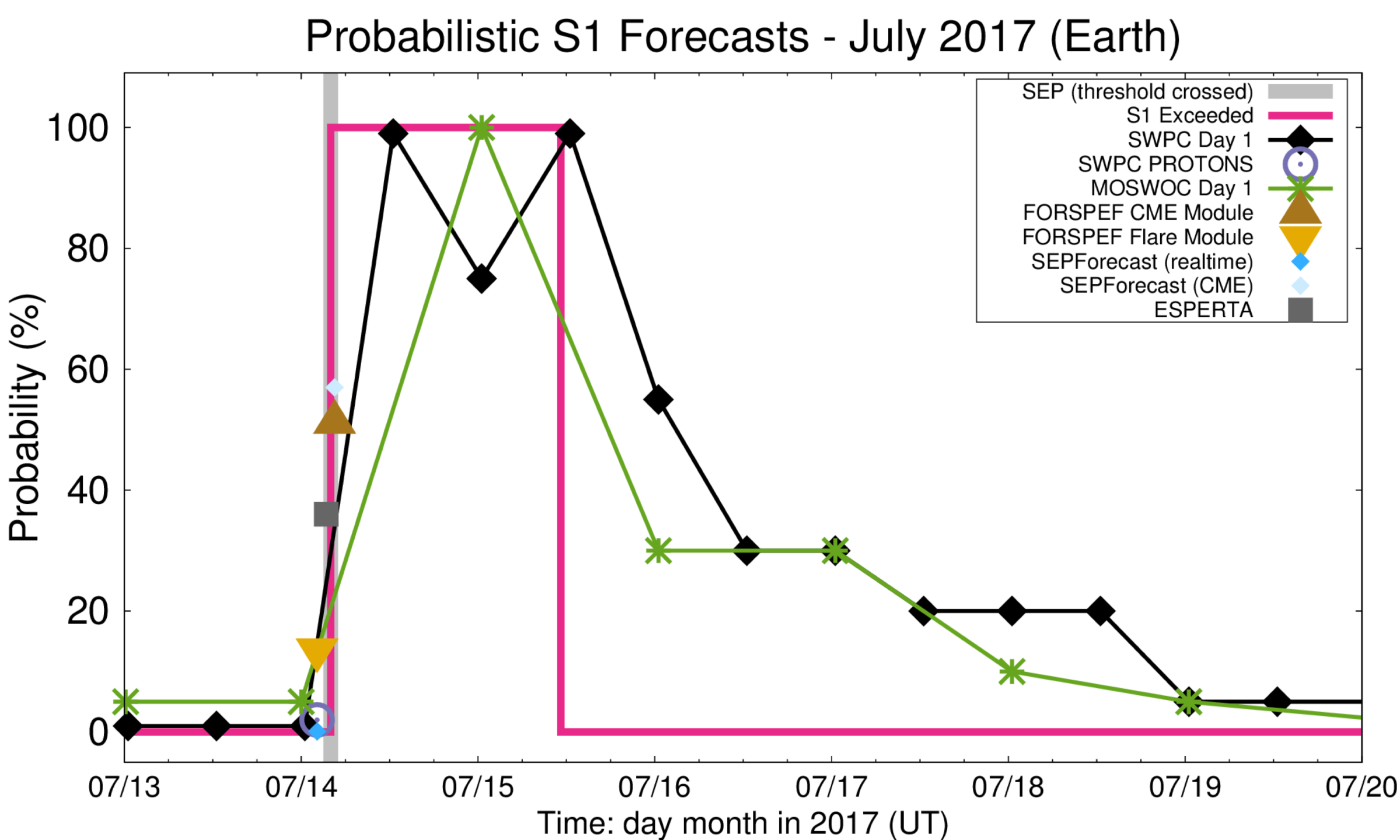


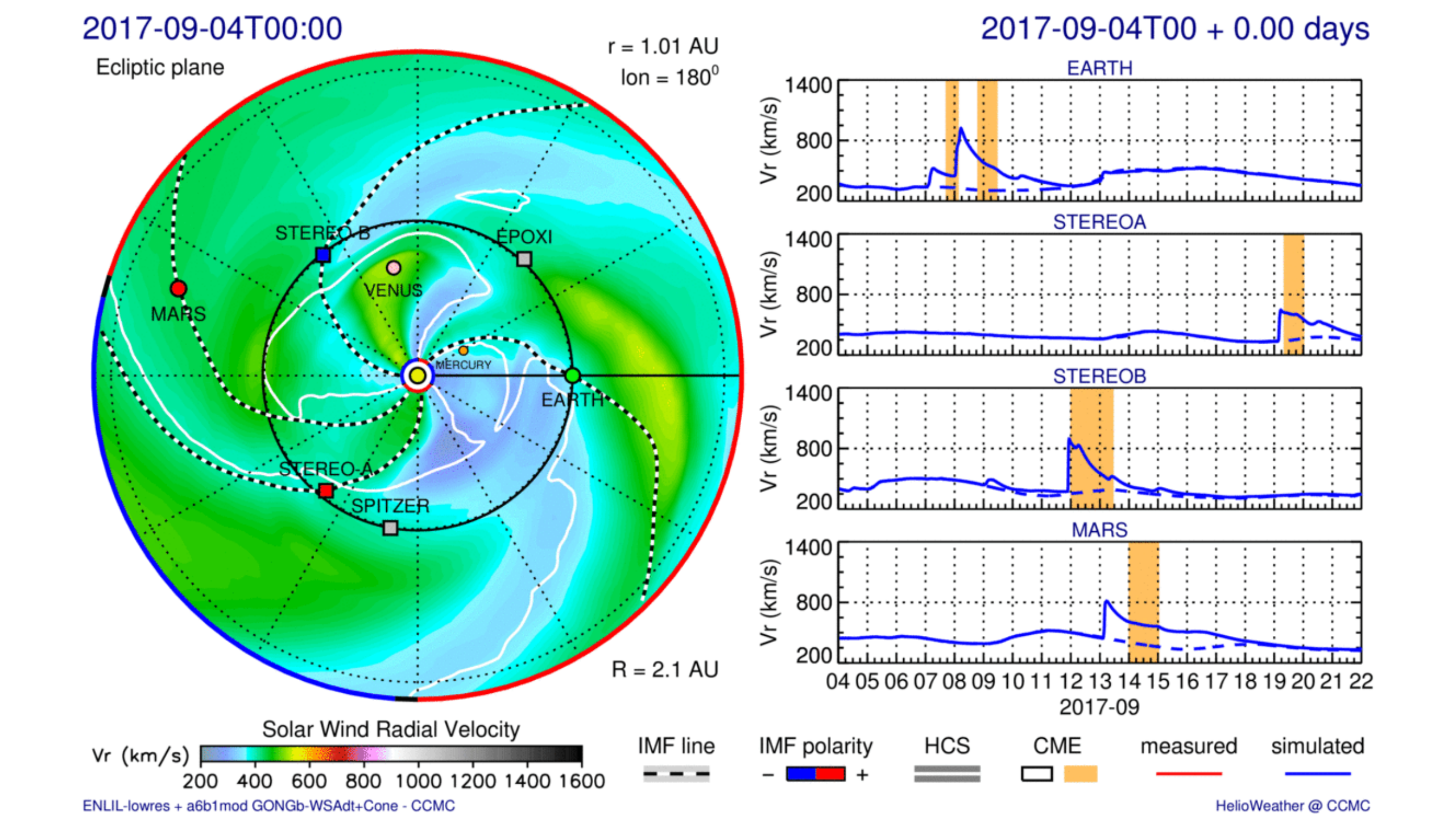


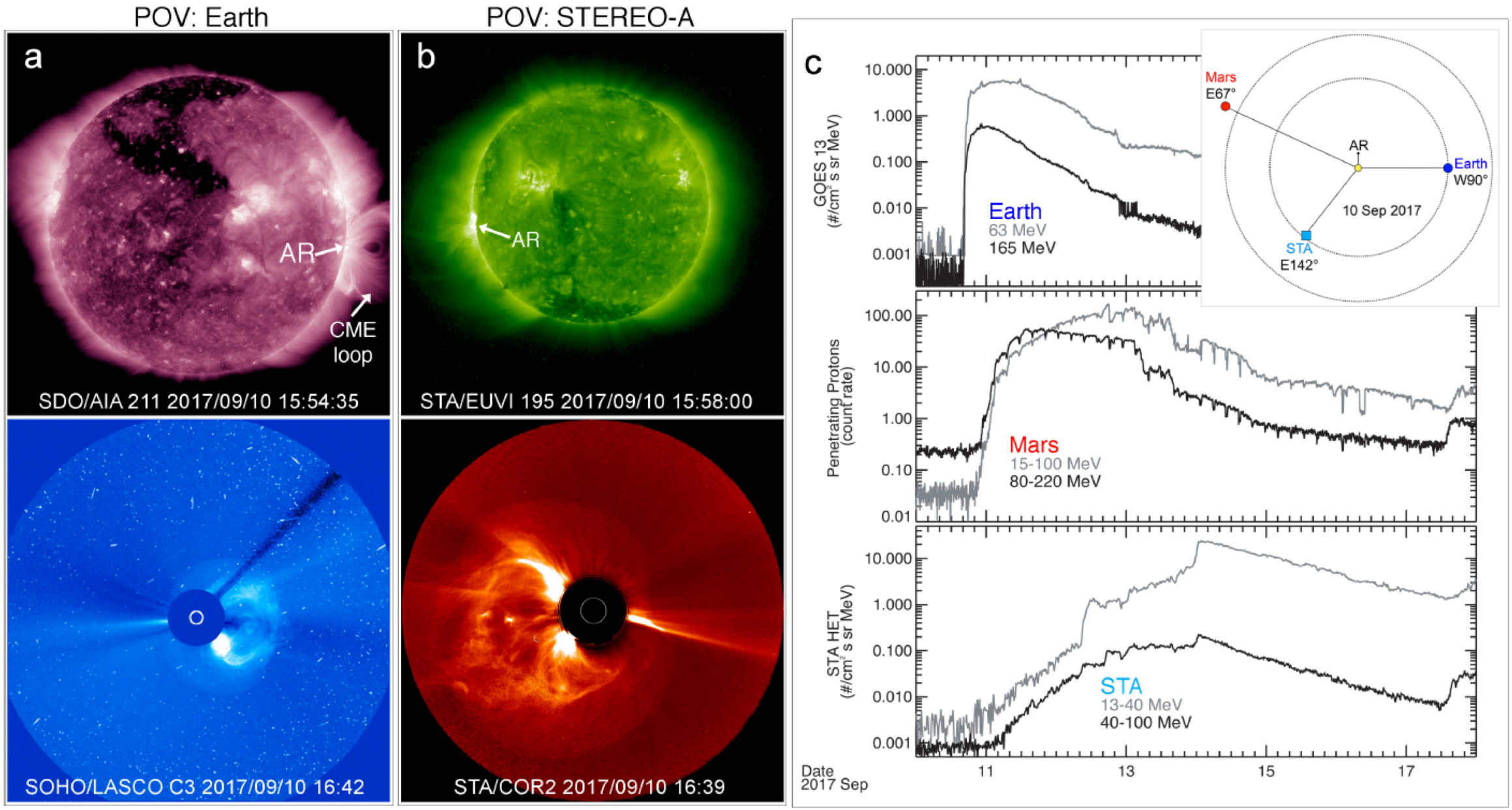
	CME start time (UT)	Radial speed (km/s)	HEEQ longitude (°)	HEEQ latitude (°)	Half-width (°)
1	2017-07-12 14:00	430	27	8	37
2	2017-07-14 01:36	1,300	38	-8	54
3	2017-07-23 01:36	1,080	149	15	36
4	2017-07-23 04:39	1,900	−165	−12	58
5	2017-07-28 05:36	880	−131	5	41


Probabilistic S1 Forecasts - September 2017 (Earth*)
Probability (%)
100
80
60
40
20
0
09/04
09/06
09/08
09/10
09/12
09/14
09/16
09/18
09/20
Time: day month in 2017 (UT)
SEP (threshold crossed)
S1 Exceeded
SWPC Day 1
SWPC PROTONS
MOSWOC Day 1
FORSPEF CME Module
FORSPEF Flare Module
SPRINTS
SEPForecast (realtime)
SEPForecast (CME)
*STEREO A prediction
STEREO A: 4.75 pfu/MeV
at 2017-09-19 02:48

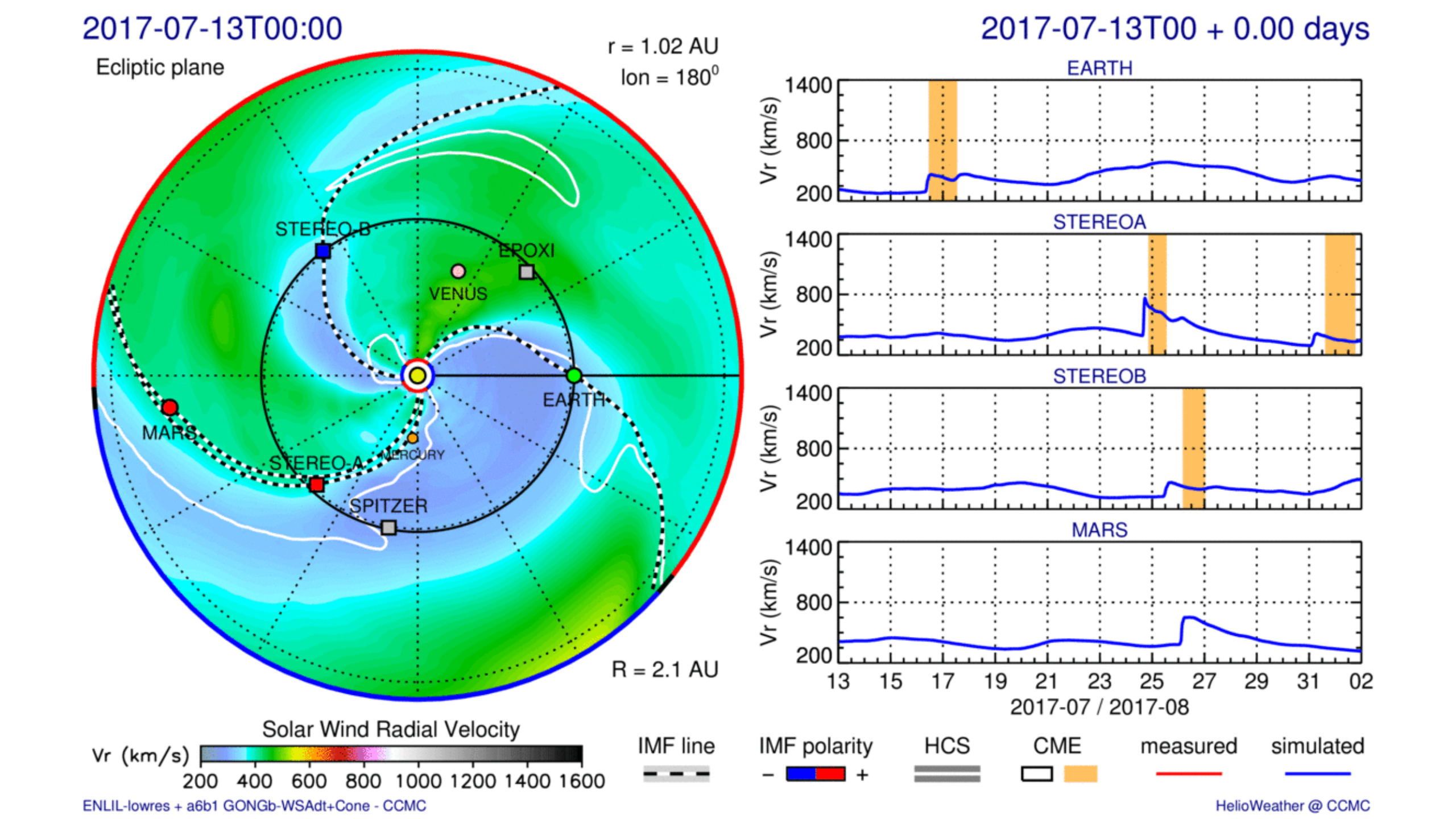

Probabilistic S1 Forecasts - September 2017 (Earth)
Probability (%)
100
80
60
40
20
0
SEP (threshold crossed)
S1 Exceeded
SWPC Day 1
SWPC PROTONS
MOSWOC Day 1
FORSPEF CME Module
FORSPEF Flare Module
SPRINTS
SEPForecast (realtime)
SEPForecast (CME)
SEP (threshold crossed)
S1 Exceeded
SWPC Day 2
MOSWOC Day 2
SEP (threshold crossed)
S1 Exceeded
SWPC Day 3
MOSWOC Day 3
00:00 09/04
00:00 09/06
00:00 09/08
00:00 09/10
00:00 09/12
00:00 09/14
00:00 09/16
00:00 09/18
00:00 09/20
Time: day month in 2017 (UT)


Probabilistic S1 Forecasts - July 2017 (Earth)
SEP (threshold crossed)
S1 Exceeded
SWPC Day 1
SWPC PROTONS
MOSWOC Day 1
FORSPEF CME Module
FORSPEF Flare Module
SEPForecast (realtime)
SEPForecast (CME)
ESPERTA
Probability (%)
100
80
60
40
20
0
07/13
07/14
07/15
07/16
07/17
07/18
07/19
07/20
Time: day month in 2017 (UT)


2017-09-04T00:00
Ecliptic plane
r = 1.01 AU
lon = 180⁰
STEREO-B
EPOXI
VENUS
MARS
MERCURY
EARTH
STEREO-A
SPITZER
R = 2.1 AU
2017-09-04T00 + 0.00 days
EARTH
STEREOA
STEREOB
MARS
Vr (km/s)
1400
800
200
04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22
2017-09
Solar Wind Radial Velocity
Vr (km/s)
200 400 600 800 1000 1200 1400 1600
IMF line
IMF polarity
–
+
HCS
CME
measured
simulated
ENLIL-lowres + a6b1mod GONGb-WSAdt+Cone - CCMC
HelioWeather @ CCMC



Lee et al. GRL, 2018 (accepted)


2017-07-13T00:00
Ecliptic plane
r = 1.02 AU
lon = 180⁰
STEREO-B
EPOXI
VENUS
EARTH
MARS
MERCURY
STEREO-A
SPITZER
R = 2.1 AU
2017-07-13T00 + 0.00 days
EARTH
STEREOA
STEREOB
MARS
Vr (km/s)
1400
800
200
13 15 17 19 21 23 25 27 29 31 02
2017-07 / 2017-08
Solar Wind Radial Velocity
Vr (km/s)
200 400 600 800 1000 1200 1400 1600
IMF line
IMF polarity
HCS
CME
measured
simulated
ENLIL-lowres + a6b1 GONGb-WSAdt+Cone - CCMC
HelioWeather @ CCMC