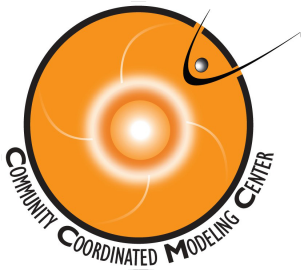
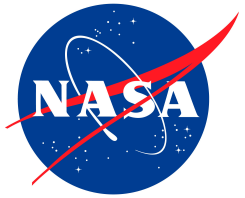
The Role of Community Solar Flare Predictions in Space Weather Forecasting

M. Leila Mays
and the CCMC team

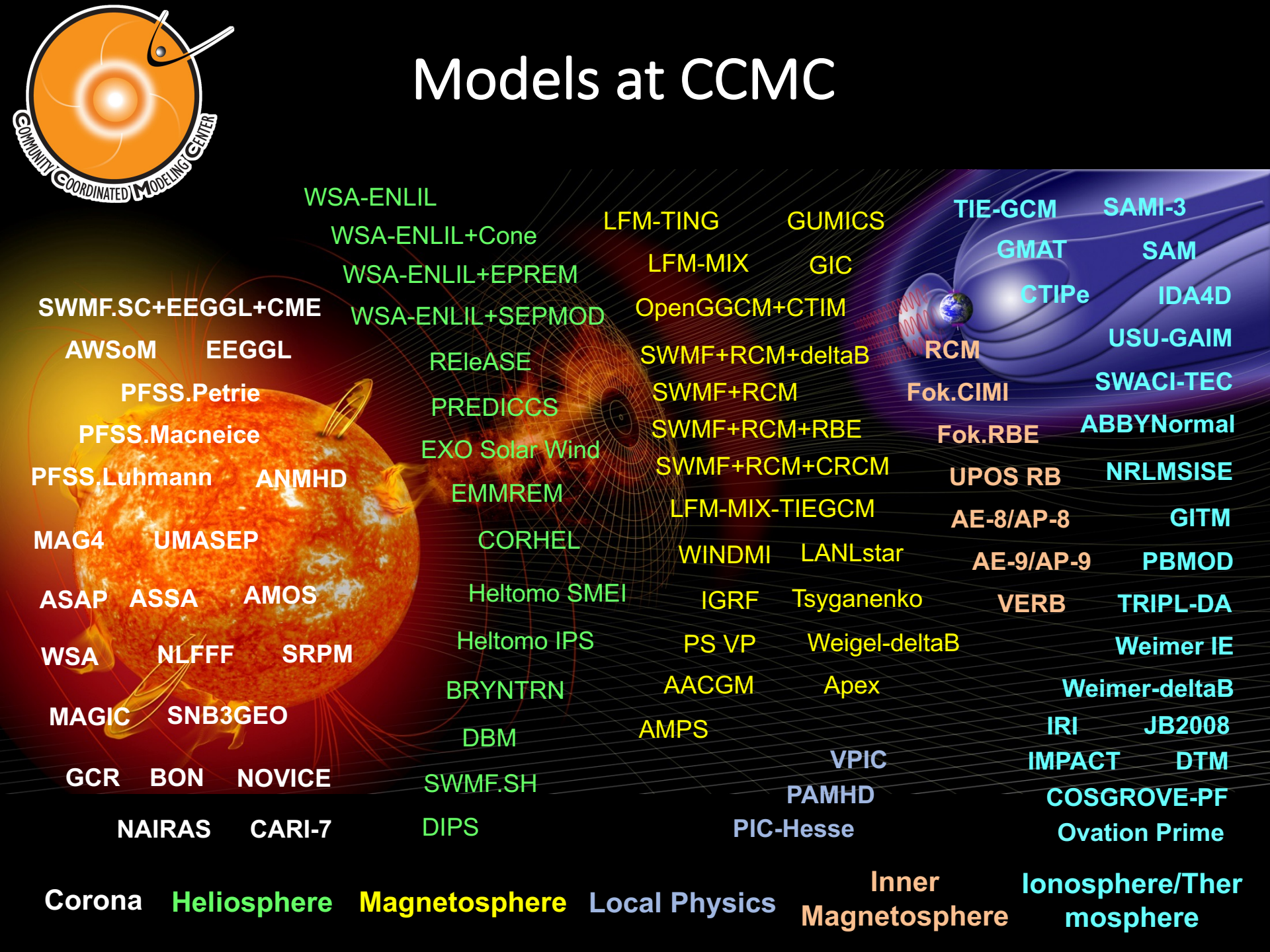
November 2017
ESWW14



http://ccmc.gsfc.nasa.gov



Models at CCMC



SWMF.SC+EEGGL+CME
AWSoM
EEGGL
PFSS.Petrie
PFSS.Macneice
PFSS.Luhmann
ANMHD
MAG4
UMASEP
ASAP
ASSA
AMOS
WSA
NLFFF
SRPM
MAGIC
SNB3GEO
GCR
BON
NOVICE
NAIRAS
CARI-7

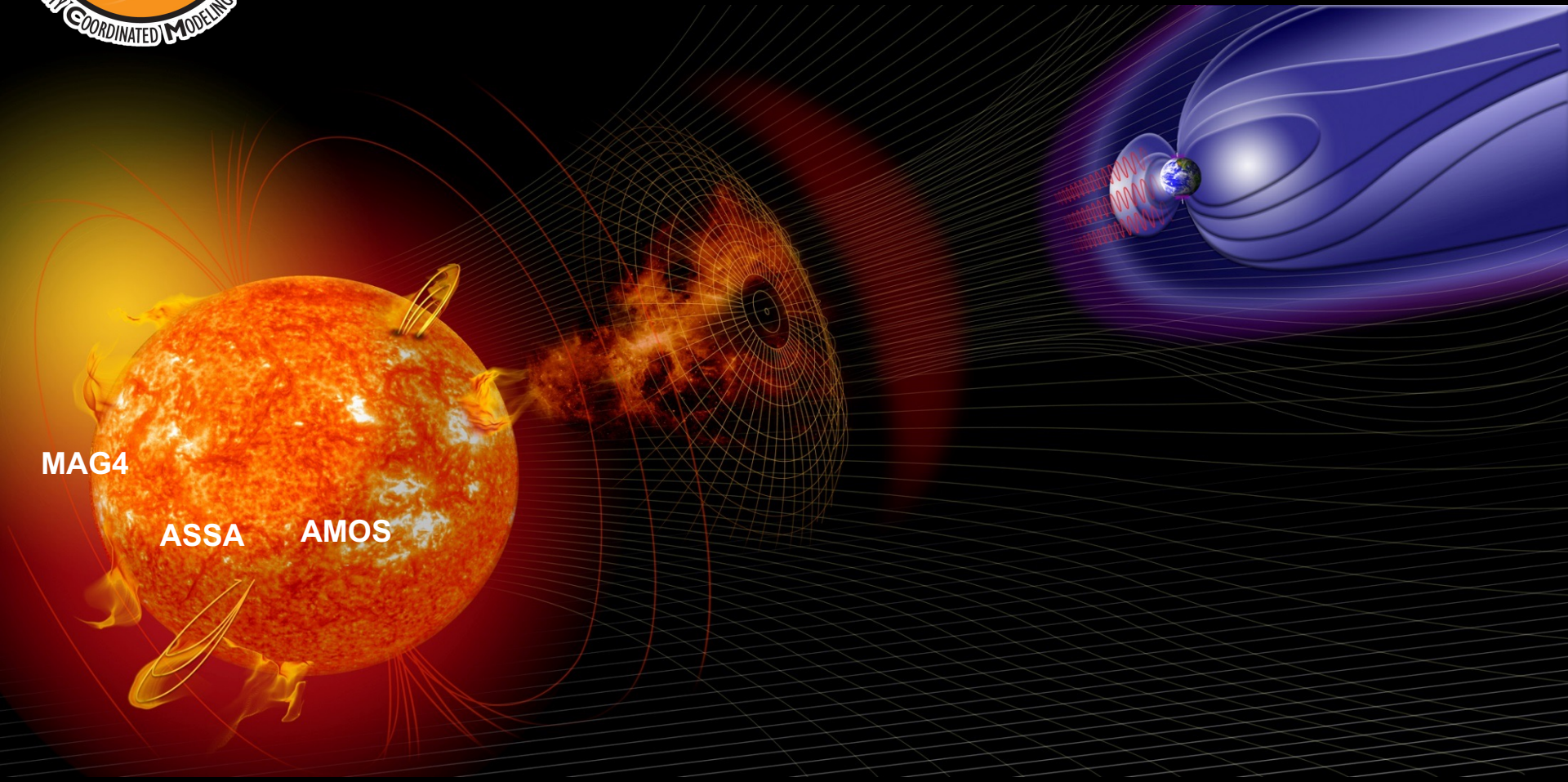
WSA-ENLIL
WSA-ENLIL+Cone
WSA-ENLIL+EPREM
WSA-ENLIL+SEPMOD
REIeASE
PREDICCS
EXO Solar Wind
EMMREM
CORHEL
Heltomo SMEI
Heltomo IPS
BRYNTRN
DBM
SWMF.SH
DIPS

LFM-TING
GUMICS
LFM-MIX
GIC
OpenGGCM+CTIM
SWMF+RCM+deltaB
SWMF+RCM
SWMF+RCM+RBE
SWMF+RCM+CRCM
LFM-MIX-TIEGCM
WINDMI
LANLstar
IGRF
Tsyganenko
PS VP
Weigel-deltaB
AACGM
Apex
AMPS
VPIC
PAMHD
PIC-Hesse

TIE-GCM
SAMI-3
GMAT
SAM
CTIPe
IDA4D
RCM
USU-GAIM
Fok.CIMI
SWACI-TEC
Fok.RBE
ABBYNormal
UPOS RB
NRLMSISE
AE-8/AP-8
GITM
AE-9/AP-9
PBMOD
VERB
TRIPL-DA
Weimer IE
Weimer-deltaB
IRI
JB2008
IMPACT
DTM
COSGROVE-PF
Ovation Prime

Corona
Heliosphere
Magnetosphere
Local Physics
Inner Magnetosphere
Ionosphere/Thermosphere

Models at CCMC

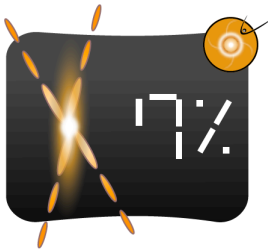


Corona | Heliosphere | Magnetosphere | Local Physics | Inner Magnetosphere | Ionosphere/Thermosphere

CCMC community scoreboards

- Fostering world-wide **community validation projects** that ultimately help researchers **improve** their CME, flare, and SEP forecasts and determine their **usefulness**.
- Allow a consistent **real-time** comparison of various operational and research forecasts. Complementary to non-real time model assessments such as the **International Forum for Space Weather Capabilities Assessment.**
- The flare and SEP system is **automated** such that model developers can routinely upload their predictions.
- Forecast data is parsed and stored in a **database** accessible to anyone via an **API**.

Flare Scoreboard



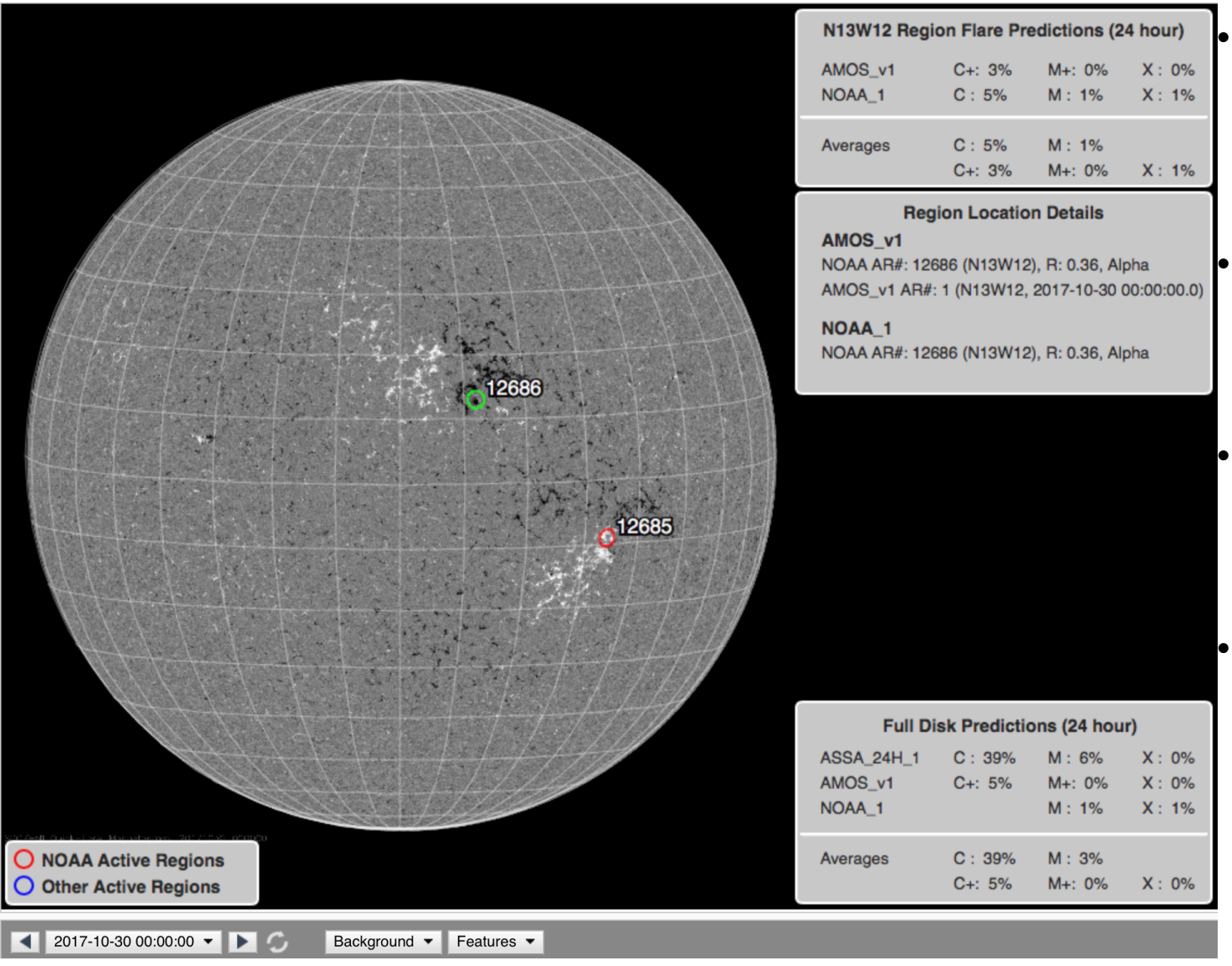
https://ccmc.gsfc.nasa.gov/challenges/flare.php

Currently registered models and particpating partners:

AMOS Automatic McIntosh-based Occurrence probability of Solar activity Korea Meteorological Administration KYUNG HEE UNIVERSITY	**ASAP** Automated Solar Activity Prediction UNIVERSITY of BRADFORD	**ASSA** Automatic Solar Synoptic Analyzer RRA KOREAN SPACE WEATHER CENTER
BoM Data-driven probabilistic flare forecast model Australian Government Bureau of Meteorology	**MAG4** MAG4 LOS and Vector Magnetogram Forecasts (four products) THE UNIVERSITY OF ALABAMA IN HUNTSVILLE	**Met Office** Space Weather Forecast (full disk) and Sunspot Region Summary Met Office
SIDC SIDC human operator moderated Royal Observatory of Belgium	**SolarMonitor.org** Flare Prediction System Trinity College Dublin The University of Dublin	**UFCORIN** Universal Forecast Constructor by Optimized Regression of INputs UFCORIN

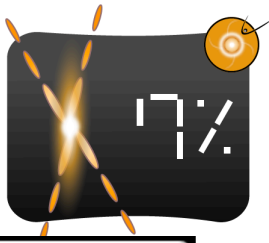
Flare Scoreboard

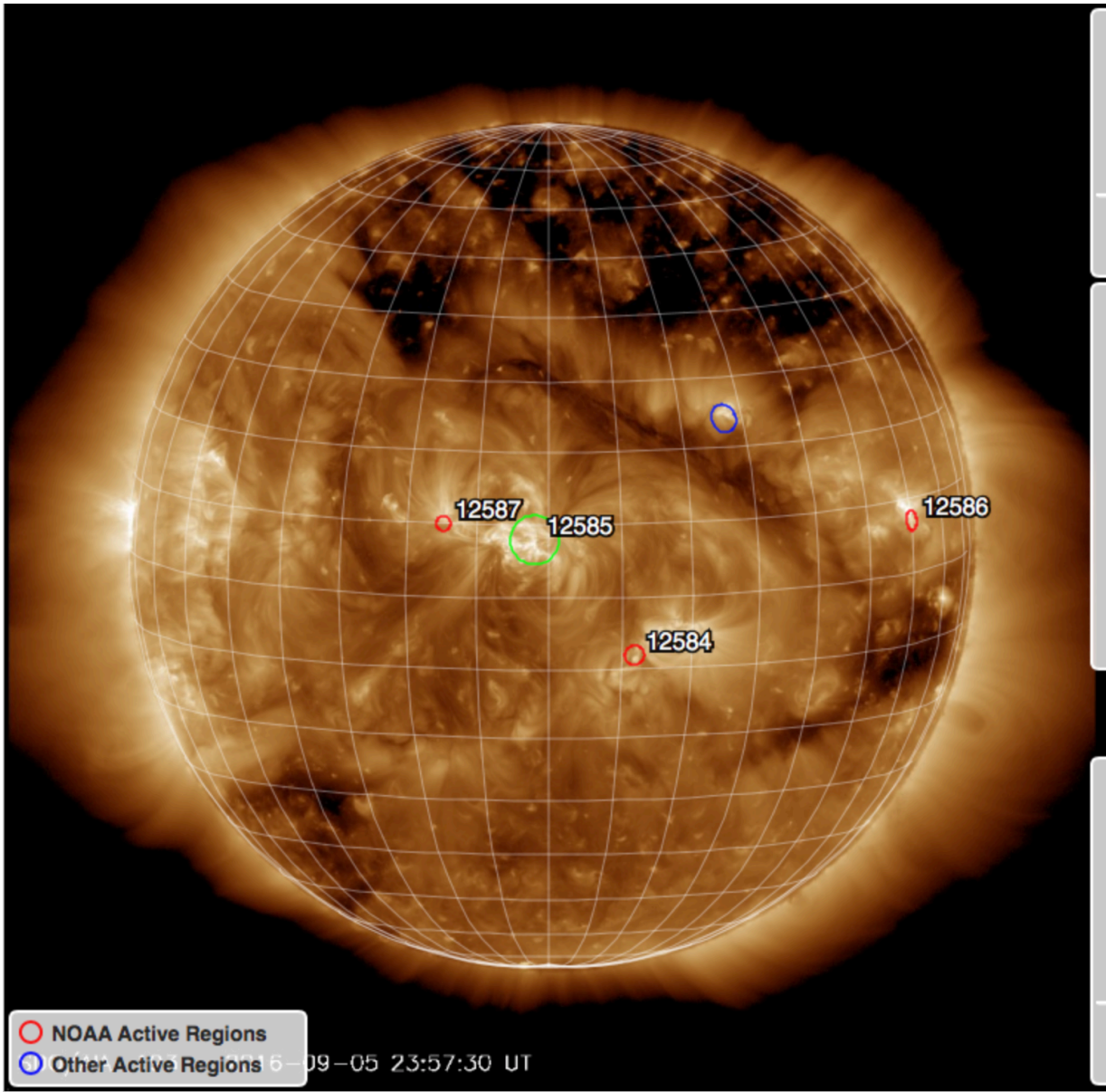
https://ccmc.gsfc.nasa.gov/challenges/flare.php



- Allows a consistent real-time comparison of various operational and research flare forecasts.
- Automated system; model developers can routinely upload their predictions to an anonymous ftp
- Forecast data is parsed and stored in a database which accessible to anyone via an API
- This project is led by Sophie Murray (TCD) and SIDC. The planning group includes expert scientists as well as operational space weather prediction centers.

Flare Scoreboard





N08E02 Region Flare Predictions (24 hour)

ASAP_1	C : 58%	M : 18%	X : 3%
BoM_flare1		M+: 5%	X : 1%
NOAA_1	C : 50%	M : 10%	X : 1%
AMOS_v1	C+: 61%	M+: 16%	X : 2%
Averages	C : 54%	M : 14%	
	C+: 61%	M+: 10%	X : 2%

Region Location Details

ASAP_1
ASAP_1 AR#: 2 (N06E02, 2016-09-06 00:00:00.0)

BoM_flare1
NOAA AR#: 12585 (N08E02), R: 2.35, Beta

NOAA_1
NOAA AR#: 12585 (N08E02), R: 2.35, Beta

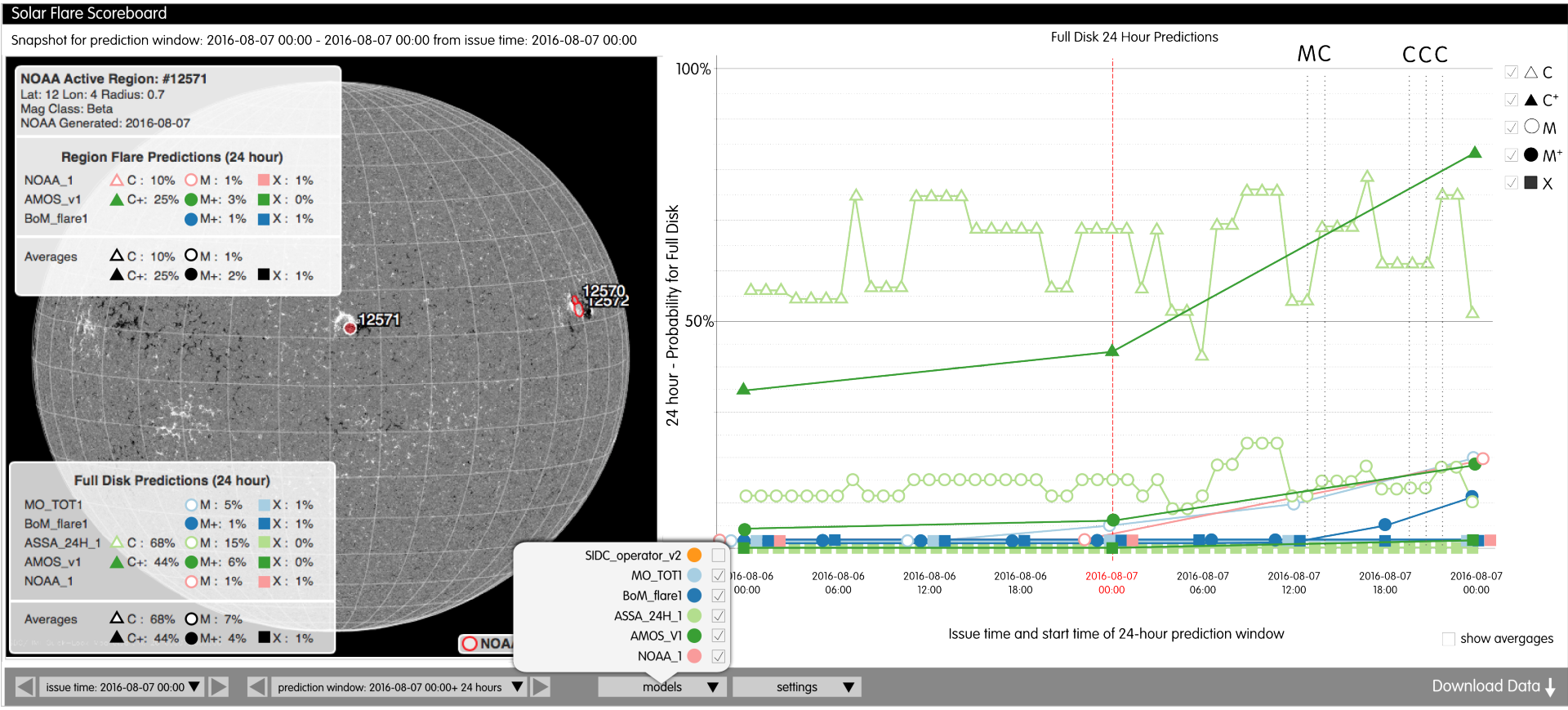
AMOS_v1
NOAA AR#: 12585 (N08E02), R: 2.35, Beta
AMOS_v1 AR#: 0 (N08E02, 2016-09-06 00:00:00.0)

Full Disk Predictions (24 hour)

BoM_flare1		M+: 5%	X : 1%
ASSA_24H_1	C : 81%	M : 29%	X : 6%
AMOS_v1	C+: 64%	M+: 17%	X : 2%
NOAA_1		M : 10%	X : 1%
UFCORIN_1	C+: 43%	M+: 0%	X : 0%
MO_TOT1		M : 5%	X : 1%
Averages	C : 81%	M : 15%	
	C+: 53%	M+: 7%	X : 2%

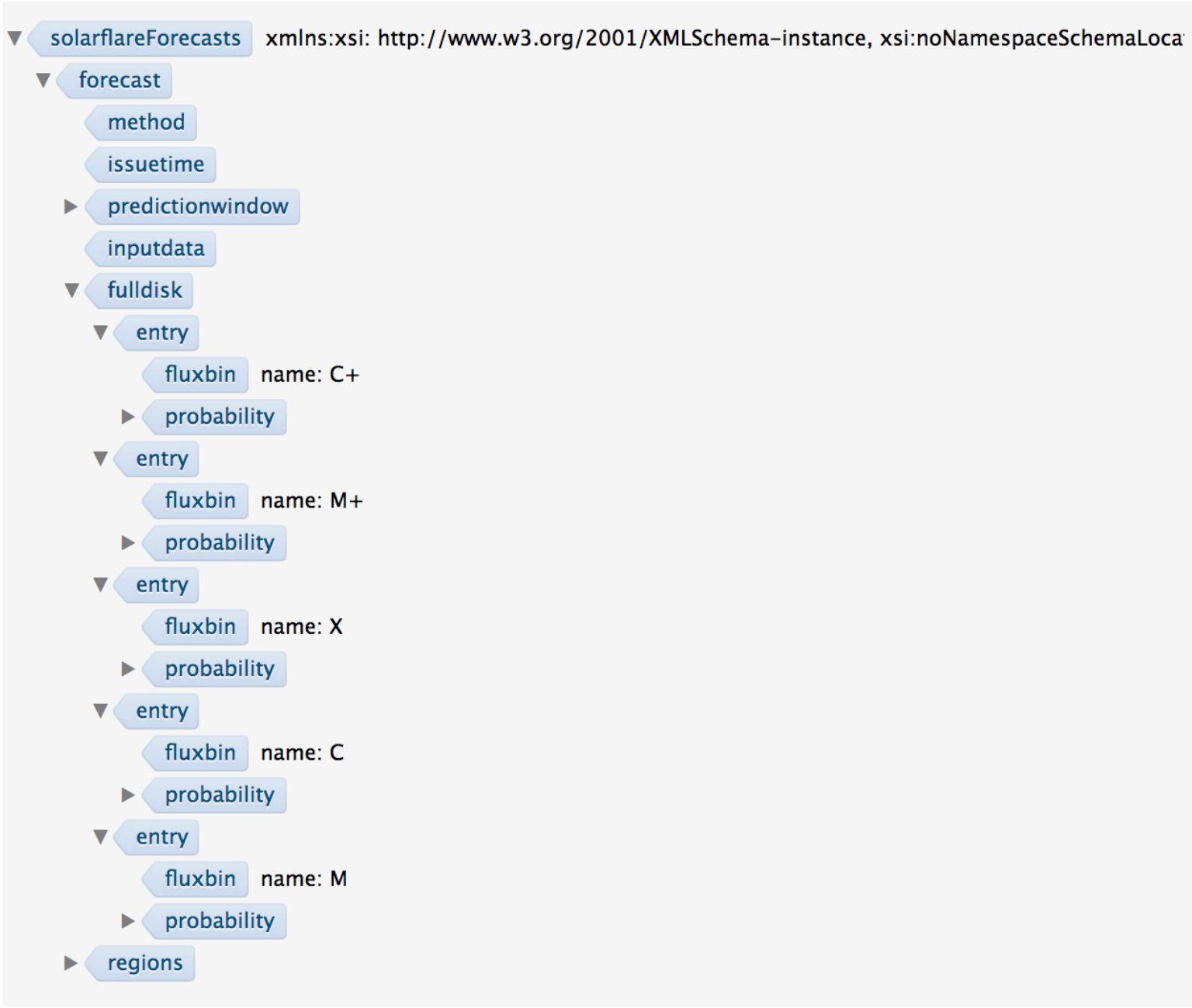
Flare Scoreboard: Future

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



The full disk and active region flare forecasts can currently be viewed on an interactive display overlaid on an SDO/AIA or HMI image of then Sun and will be dynamically paired with a graph of flare probability vs. time (coming soon)

https://ccmc.gsfc.nasa.gov/challenges/flareinfo/flareforecast_template_v1.0_example.xml



Solar Flare Scoreboard API - CATALOG

https://iswa.ccmc.gsfc.nasa.gov/IswaSystemWebApp/flarescoreboard/hapi/catalog


```
{
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 "catalog": [
  {
    "id": "SIDC_Operator_FULLDISK",
    "title": "SIDC human operator moderated",
    "type": "FULLDISK",
    "version": "2"
  },
  {
    "id": "SIDC_Operator_REGIONS",
    "title": "SIDC human operator moderated",
    "type": "REGIONS",
    "version": "2"
  },
  {
    "id": "MO_TOT1_FULLDISK",
    "title": "Met Office",
    "type": "FULLDISK",
    "version": "1"
  },
  {
    "id": "BoM_flare1_FULLDISK",
    "title": "Australian Bureau of Meteorology, Space Weather Services Flarecast automatic
forecast",
    "type": "FULLDISK",
    "version": "1"
  },
  …
```

Solar Flare Scoreboard API - INFO

https://iswa.ccmc.gsfc.nasa.gov/IswaSystemWebApp/flarescoreboard/hapi/info?&id=NOAA_1_FULLDISK


```
{
 "HAPI-API": "1.1",
 "parameters": [
  {
    "fill": null,
    "length": 22,
    "name": "start_window",
    "type": "isotime",
    "units": "UTC"
  },
  {
    "fill": null,
    "length": 22,
    "name": "end_window",
    "type": "isotime",
    "units": "UTC"
  },
  {
    "fill": null,
    "length": 22,
    "name": "issue_time",
    "type": "isotime",
    "units": "UTC"
  },
```

```
{
    "fill": null,
    "name": "M",
    "type": "double",
    "units": "probability"
  },
  {
    "fill": null,
    "name": "X",
    "type": "double",
    "units": "probability"
  }
 ],
 "startDate": "2016-05-
02T00:00:00.0",
  "status": {
   "code": 1200,
   "message": "OK"
 },
 "stopDate": "2017-11-
01T00:00:00.0"
}
```


Input Parameter:
id (required)

JSON returned:
startDate,
stopDate
parameters:
(start_window,
end_window,
M,C,X)

The Heliophysics Application Programmer's Interface (HAPI) data access specification is a RESTful API and streaming format specification for delivering digital time series data. The HAPI specification describes a minimum set of capabilities needed for a server to allow access to the time series data values within one or more data collections.

Solar Flare Scoreboard API – DATA (JSON)

```
https://iswa.ccmc.gsfc.nasa.gov/IswaSystemWebApp/flarescoreboard/hapi/data?
&id=NOAA_1_FULLDISK
&time.min=2017-10-25 00:00:00.0
&time.max=2017-10-31 00:00:00.0
&format=json
```


```
{
 "HAPI": "1.1",
 "data": [
  [
   "2017-10-25T00:00:00.0",
   "2017-10-26T00:00:00.0",
   "2017-10-22T22:00:00.0",
   0.1,
   0.01
  ],
  [
   "2017-10-25T00:00:00.0",
   "2017-10-26T00:00:00.0",
   "2017-10-24T22:00:00.0",
   0.01,
   0.01
  ],
  [
   "2017-10-26T00:00:00.0",
   "2017-10-27T00:00:00.0",
   "2017-10-24T22:00:00.0",
   0.01,
   0.01
  ],
  [
   "2017-10-27T00:00:00.0",
   "2017-10-28T00:00:00.0",
   "2017-10-24T22:00:00.0",
   0.01,
   0.01
  ]. . . ,
```

```
 ],
 "format": "json",
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  "type": "isotime",
  "units": "UTC"
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  "units": "UTC"
  },
  {
  "fill": null,
  "length": 22,
  "name": "issue_time",
  "type": "isotime",
  "units": "UTC"
  },
  {
  "fill": null,
  "name": "M",
  "type": "double",
  "units": "probability"
  },
   . . .
```


Input Parameter:
id (required)
time.min (required)
time.max(required)
format(csv or json)
parameters (optional)

JSON returned:
Data + Info

Solar Flare Scoreboard API – DATA (CSV)

```
https://iswa.ccmc.gsfc.nasa.gov/IswaSystemWebApp/flarescoreboard/hapi/data?
&id=NOAA_1_FULLDISK
&time.min=2017-10-25 00:00:00.0
&time.max=2017-10-27 00:00:00.0
&format=csv
```

CSV returned:
Data + Info

```
#{
# "HAPI": "1.1",
# "format": "csv",
# "parameters": [
#  {
#   "fill": null,
#   "length": 22,
#   "name": "start_window",
#   "type": "isotime",
#   "units": "UTC"
#  },
#  {
#   "fill": null,
#   "length": 22,
#   "name": "end_window",
#   "type": "isotime",
#   "units": "UTC"
#  },
#  {
#   "fill": null,
#   "length": 22,
#   "name": "issue_time",
#   "type": "isotime",
#   "units": "UTC"
#  },
#  {
#   "fill": null,
#   "name": "M",
#   "type": "double",
#   "units": "probability"
#  },
. . .
#  {
#   "fill": null,
#   "name": "X",
#   "type": "double",
#   "units": "probability"
#  }
# ],
# "startDate": "2016-05-02T00:00:00.0",
# "status": {
# "code": 1200,
# "message": "OK"
# },
# "stopDate": "2017-11-02T00:00:00.0"
#}
2017-10-25T00:00:00.0,2017-10-26T00:00:00.0,2017-10-22T22:00:00.0,0.01
2017-10-25T00:00:00.0,2017-10-26T00:00:00.0,2017-10-24T22:00:00.0,0.01
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2017-10-28T00:00:00.0,2017-10-29T00:00:00.0,2017-10-25T22:00:00.0,0.01
2017-10-27T00:00:00.0,2017-10-28T00:00:00.0,2017-10-26T22:00:00.0,0.01
2017-10-28T00:00:00.0,2017-10-29T00:00:00.0,2017-10-26T22:00:00.0,0.01
```

SEP Scoreboard

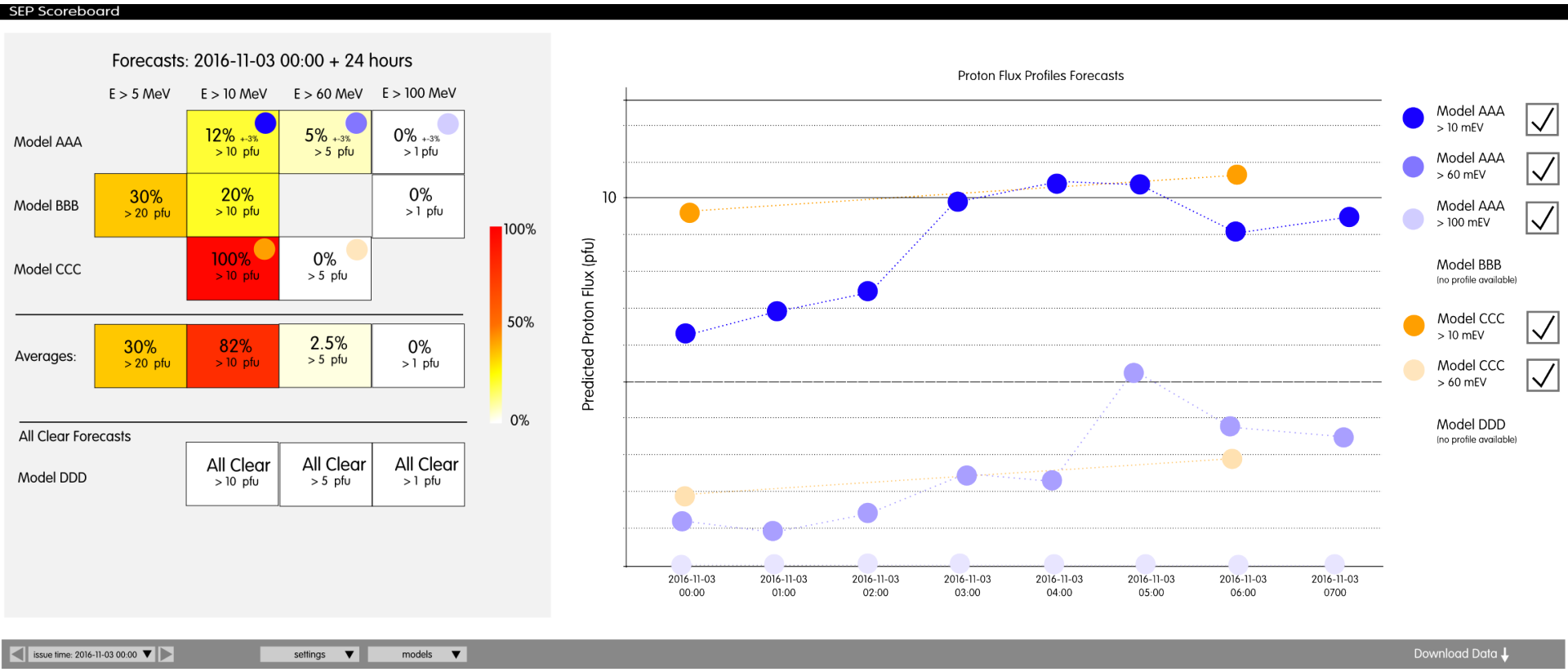
https://ccmc.gsfc.nasa.gov/challenges/sep.php

- Planning for the SEP Scoreboard has started (led by Mark Dierckxsens at BIRA-IASB and the Mike Mash at 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.
- Next steps for the SEP Working Team: SHINE session on model/data comparisons for 1-2 campaign events.

SEP Scoreboard Planning

Display ideas



Probability heat map at a single time

Predicted proton flux time-series

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

CME Arrival Time Scoreboard

Community predictions for the 6 Sep 2017 CME

CME: 2017-09-06T12:24:00-CME-001

Actual Shock Arrival Time: 2017-09-07T22:30Z

Observed Geomagnetic Storm Parameters:
Max Kp: 8.0
Dst min. in nT: -142
Dst min. time: 2017-09-08T02:00Z
CME Note: Associated with X9.3 flare from AR 12673.

Predicted Shock Arrival Time	Difference (hrs)	Confidence (%)	Submitted On	Lead Time (hrs)	Predicted Geomagnetic Storm Parameter(s)	Method
2017-09-08T06:00Z (-3.0h, +3.0h)	7.50	80.0	2017-09-07T05:00Z	17.50	Max Kp Range: 5.0 - 8.0	WSA-ENLIL + Cone (Met Office)
2017-09-08T06:00Z (-2.0h, +2.0h)	7.50	----	2017-09-07T16:30Z	6.00	----	Ooty IPS
2017-09-08T07:32Z (-5.0h, +6.0h)	9.03	----	2017-09-07T08:33Z	13.95	----	DBM
2017-09-08T08:00Z (-3.0h, +3.0h)	9.50	70.0	2017-09-07T05:40Z	16.83	----	DBM + ESWF
2017-09-08T10:16Z (-4.0h, +4.0h)	11.77	----	2017-09-07T09:00Z	13.50	----	EAM (Effective Acceleration Model)
2017-09-08T10:25Z	11.92	----	2017-09-07T02:13Z	20.28	----	SARM
2017-09-08T10:42Z	12.20	----	2017-09-07T15:55Z	6.58	----	SPM
2017-09-08T12:46Z	14.27	84.0	---	---	Max Kp Range: 4.33333 - 6.5	Average of all Methods
2017-09-08T13:00Z (-7.0h, +7.0h)	14.50	90.0	2017-09-07T08:25Z	14.08	Max Kp Range: 5.0 - 7.0	Other
2017-09-08T13:52Z	15.37	----	2017-09-07T15:46Z	6.73	----	SPM2
2017-09-08T15:48Z (-9.0h, +10.0h)	17.30	100.0	2017-09-07T14:53Z	7.62	Max Kp Range: 4.0 - 6.0	Ensemble WSA-ENLIL + Cone (GSFC SWRC)
2017-09-08T16:00Z	17.50	----	2017-09-09T12:59Z	-38.48	----	WSA-ENLIL + Cone (BoM)
2017-09-08T16:30Z (+14.0h)	18.00	----	2017-09-07T12:32Z	9.97	----	ElEvo
2017-09-08T17:00Z (-12.0h, +12.0h)	18.50	80.0	2017-09-06T22:40Z	23.83	Max Kp Range: 4.0 - 6.0	Other (SIDC)
2017-09-08T18:27Z (-7.0h, +7.0h)	19.95	----	2017-09-06T17:23Z	29.12	Max Kp Range: 3.0 - 5.0	WSA-ENLIL + Cone (GSFC SWRC)
2017-09-08T22:00Z	23.50	----	2017-09-06T23:24Z	23.10	Max Kp Range: 5.0 - 7.0	WSA-ENLIL + Cone (NOAA/SWPC)

https://kauai.ccmc.gsfc.nasa.gov/CMEscoreboard

All prediction methods are welcome and all are encouraged to participate.

Future:Linking the Scoreboards

Example of activities linked to a CME event in the CCMC DONKI database:
http://kauai.ccmc.gsfc.nasa.gov/DONKI

Coronal Mass Ejection
Catalog: SWRC_CATALOG
Start Time: 2015-03-15T02:00Z (SOHO: LASCO/C2)
All Detecting Spacecrafts:
SOHO: LASCO/C2
SOHO: LASCO/C3
Activity ID: 2015-03-15T02:00:00-CME-001 (version 4)
Source Location: S15W24
Active Region Number: 12297
Note: This CME is connected to the long duration C9.1 flare erupting, bright post-flare arcade later in AR 2297
Submitted on 2015-03-15T14:17Z by Karin Muglach

2015-03-15T01:15:00-FLR-001
FLR Type: C9.1

2015-03-16T07:36:00-SEP-001
SOHO: COSTEP 15.8-39.8 MeV

2015-03-17T04:05:00-IPS-001
Location: Earth

2015-03-17T06:00:00-GST-001
NOAA Kp: 6 (2015-03-17T09:00Z)
NOAA Kp: 6 (2015-03-17T12:00Z)
NOAA Kp: 8 (2015-03-17T15:00Z)
NOAA Kp: 8 (2015-03-17T18:00Z)
NOAA Kp: 7 (2015-03-17T21:00Z)
NOAA Kp: 8 (2015-03-18T00:00Z)
NOAA Kp: 6 (2015-03-18T03:00Z)
NOAA Kp: 6 (2015-03-18T18:00Z)

2015-03-17T06:23:00-MPC-001