Space Weather Outreach at the Community Coordinated Modeling Center (CCMC)

M. Leila Mays (NASA GSFC) and the CCMC team

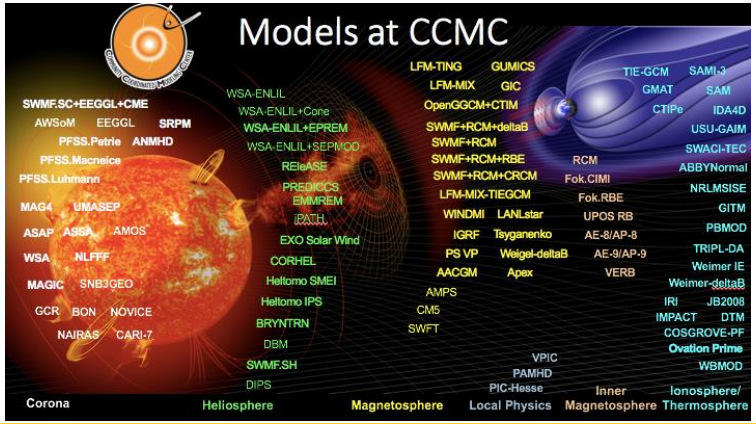
Deputy Director, CCMC

m.leila.mays@nasa.gov

International Space Weather Initiative Workshop (ISWI): 2 November 2021

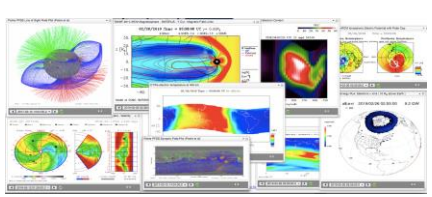
CCMC Assets & Functions

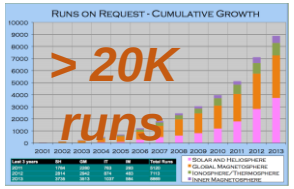
Models



Simulation

Services

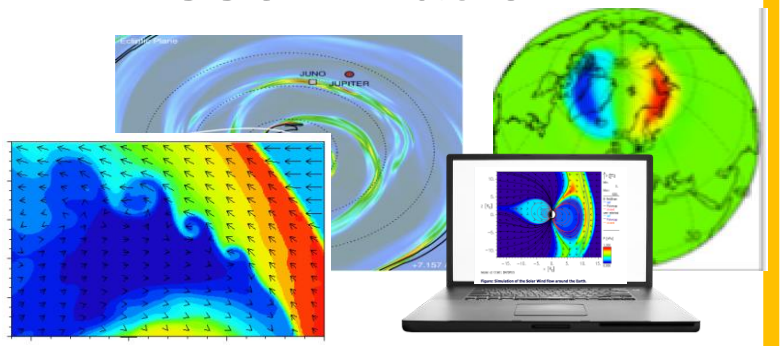




Runs-on-Request

Continuous Runs

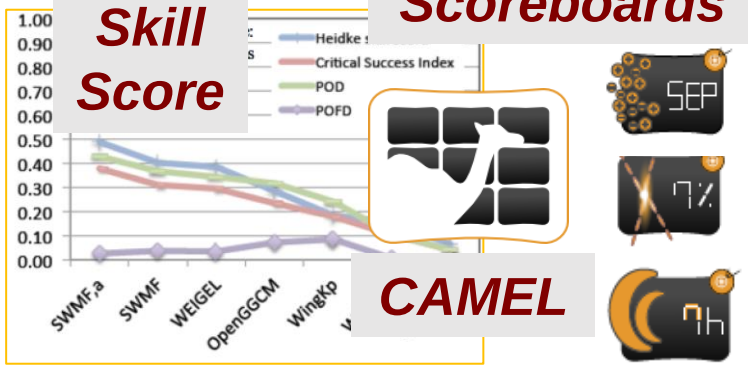
Visualization, Dissemination



Validation

Skill Score

Scoreboards

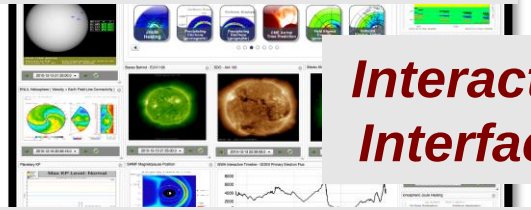


CAMEL

NASA Missions & Community Support

Information Architecture:

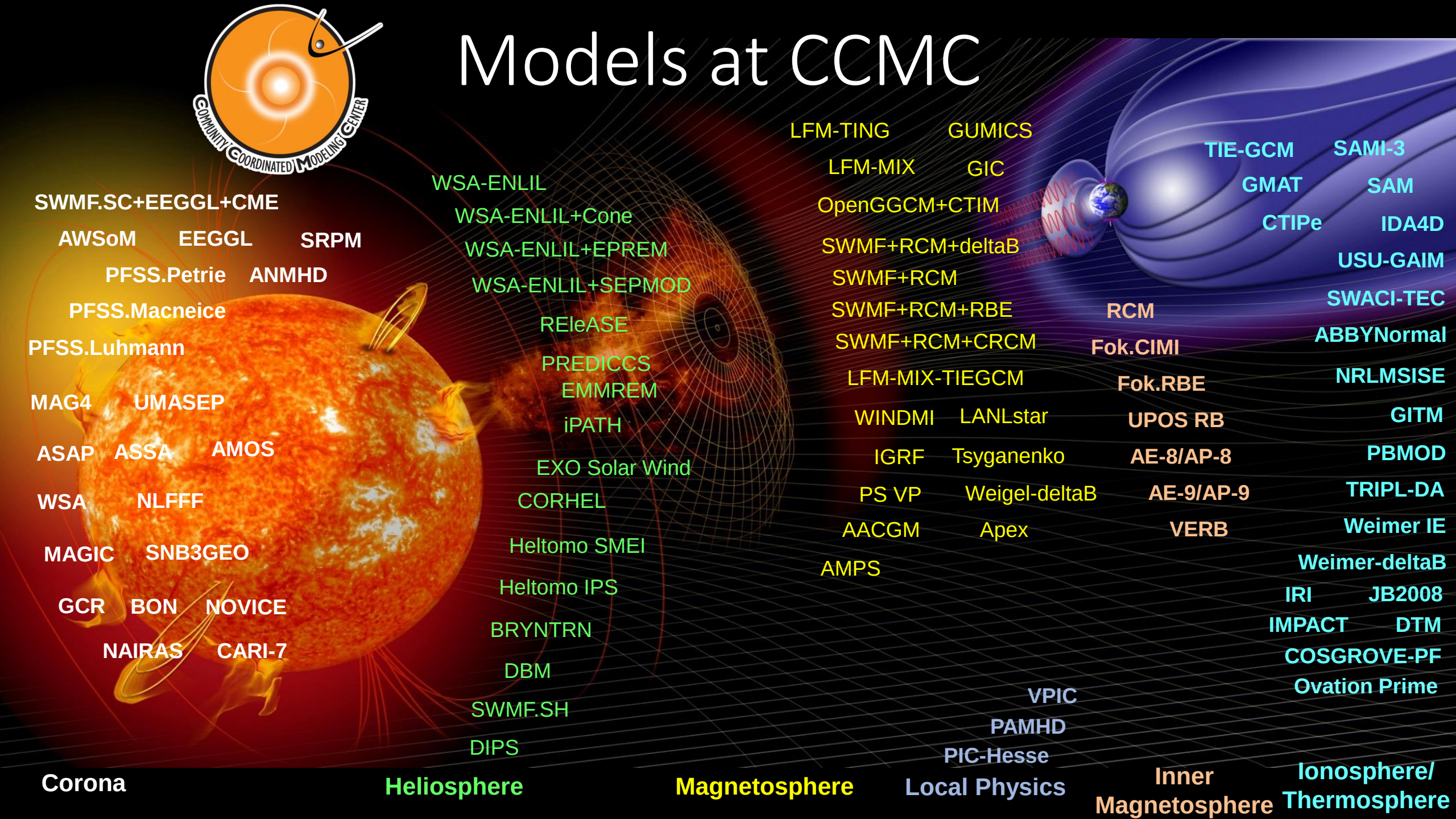
Perpetual Archives



Interactive Interfaces

(Meta)data Standards

Models at CCMC



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

WSA-ENLIL
WSA-ENLIL+Cone
WSA-ENLIL+EPREM
WSA-ENLIL+SEPMOD
REleASE
PREDICCS
EMMREM
iPATH
EXO Solar Wind
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

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

VPIC
PAMHD
PIC-Hesse

Corona
Heliosphere
Magnetosphere
Local Physics
Inner Magnetosphere
Ionosphere/ Thermosphere

CCMC Education & Outreach

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

Educational materials and activities

The CCMC organizes and supports educational activities, such as as Heliophysics and space weather summer schools and bootcamps, student internships, contests, research visits and exchanges.

We create and maintain an array of web-based tools and systems for space weather simulations, analysis, monitoring and experimental research forecasting, interactive visualization software, and produce and co-produce educatioinal modules, tutorials and other training materials.

Activities and events

- Space Weather REDI educational initiative

SW REDI Summer Internships at NASA

- 2018 Space Weather Forecasting summer internship
- 2018 SW Software Developement summer internship
- Past SW REDI internships | intern list | past intern experiences

Space Weather bootcamps and schools

- Space Weather forecasting training June 2019
- Space Weather REDI Bootcamp June 2018
- tutorials from the last (2017) SW REDI Bootcamp | past SW REDI Bootcamps
- Space Weather training at VarSITI General Symposium *(Russia, July 2017)*
- Introduction to Space Weather: Concepts and Tools school *(India, Jan 2016)*
- UAH Space Weather Summer School 2013

CCMC educational services and tools

- Runs-On-Request service | ROR tutorial
- Interactive On-Line Visualization of simulations results | Tutorial
- Kameleon access and interpolation library | Kameleon documentation
- Space Weather Explorer (3D visualization tool) | Tutorial

Tools and Systems in support of forecasting:

- integrated Space Weather Analysis System (iSWA)
  About iSWA *(PDF)* | iSWA webservices API | iSWA Cygnet Descriptions
  (iSWA is a web-based dissemination system for NASA-relevant space weather information).
- Database of Notifications Knowledge and Information (DONKI) | DONKI webservices API
  (DONKI is a database of space weather events and simulatons hosted by CCMC/SWRC).
- StereoCAT (Stereo CME Analysis Tool for measuring CMEs)
- CME Arrival Time Scoreboard | list of CME models
  (This is a research-based forecasting validation activity enabling community to compare CME forecasting methods).
- Flare Scoreboard
- SEP Scoreboard planning page
- Tool Pages for NOAA SWPC
- Tool Pages for AFWA

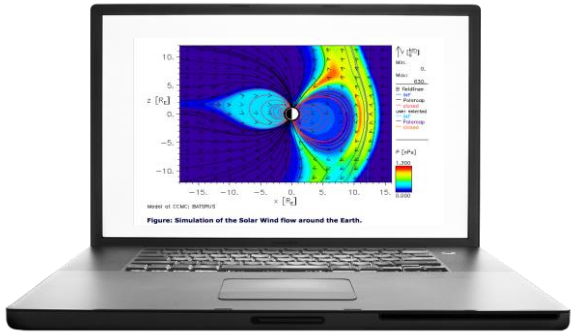
- NASA GSFC CDAW movie generator

Educational modules and tutorials

CCMC Education and Outreach: current focus

- Web-based tools and simulation services that can be used for space weather and space science research & education
- Specialized simulations, visualizations, and tutorials in support of space weather summer schools
- Interactive visualizations of simulations with OpenSpace

CCMC Simulation Services: Runs-on-Request

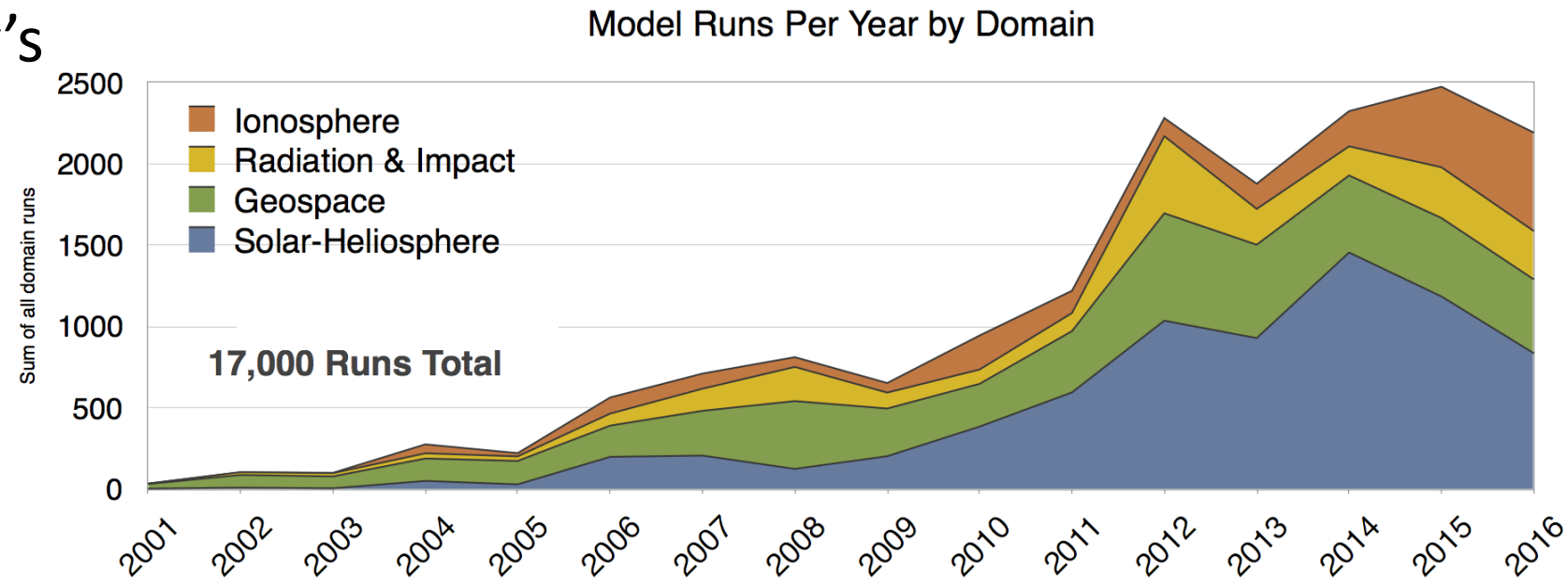


REQUESTS

RESULTS

Super Computing Clusters	**Searchable Simulation Archive (>20,000 runs)**
ccmc.gsfc.nasa.gov	
Peta-Bytes of Data Storage	**Online Visualization & Downloads**

- Advances the community's scientific research
- Mission science/planning support
- Model validation in a research setting
- Model delivery point



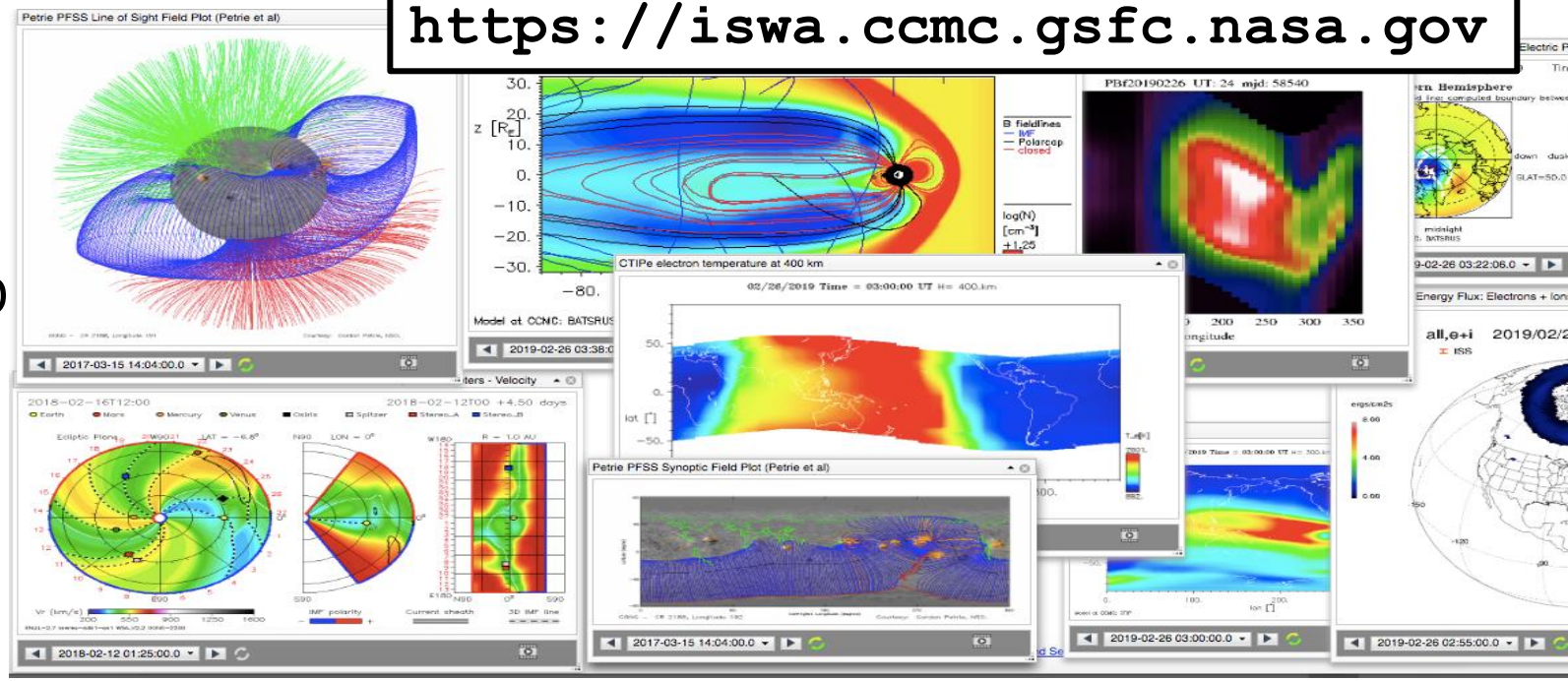
CCMC Simulation Services: Continuous Real Time Runs

- CCMC hosts ~100 models, 20 of which are also running in real time, including experimental model chains
- CCMC approach to finding model forecasting value: highlight the forecast possibilities while keeping in mind the model limitations. Experiment.
- Real time model outputs are available via iSWA displays and streaming

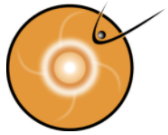
https://iswa.ccmc.gsfc.nasa.gov

Goals include:

- Validation in a real time setting
- Demonstration of operational potential and facilitate entry to R2O pipeline
- Mission science campaign support
- Feedback for the model developer on long term model performance
- Education and context for research



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



Run-On-Request System

Usage Statistics [charts | tables]

integrated Space Weather Analysis (iSWA) system

Space Weather Database Of Notifications, Knowledge, Information (DONKI)

Comprehensive Assessment of Models and Events using Library Tools (CAMEL) Framework

SWPC CME Analysis Tool Web Version (SWPC_CAT_Web)

Stereo CME Analysis Tool (StereoCat)

Flare Scoreboard

CME Arrival Time Scoreboard

SEP Scoreboard

Kamodo (Open Source Project)

Kameleon Software Suite

EEGGL tool: Eruptive Event Generator (Gibson and Low)

Traveling Space Weather Lectures

- SW Working Group at the Space Generation Forum 2.0, *Vienna, Austria, 06/2018*
- Space weather bootcamp hosted by the 2nd VarSITI General Symposium, *Irkutsk, Russia, 2017*
- Space weather school hosted by Science for Space Weather Workshop, *Goa, India, 2016*
- Training at the Kennedy Space Center, *Florida, USA, 2016*
- Space weather bootcamp at Istanbul Technical University, *Turkey, 2015*
- SW training at Korea Meteorological Administration, *Korea, 2013*

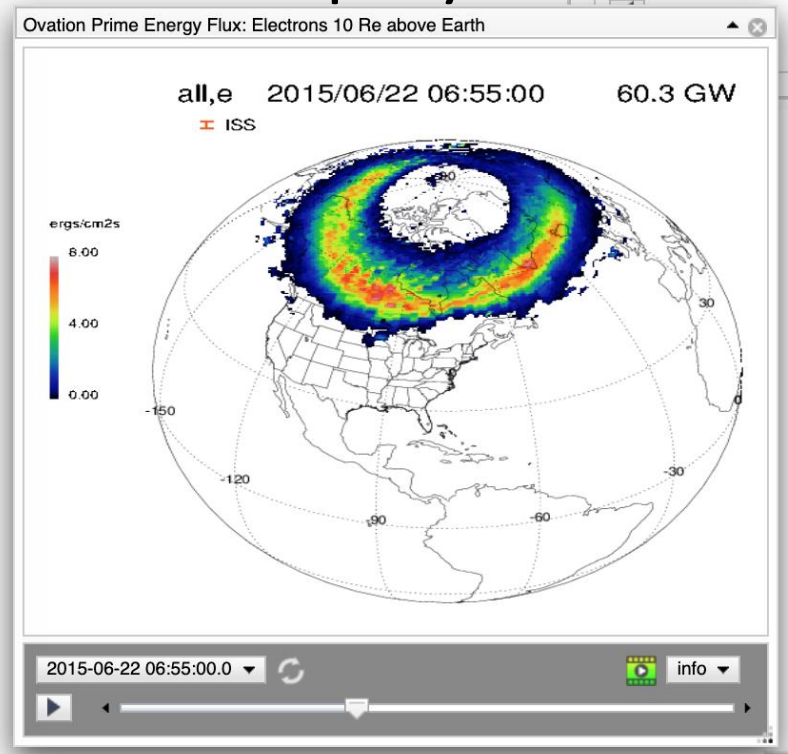
Example: iSWA in Heliophysics Summer School Exercises

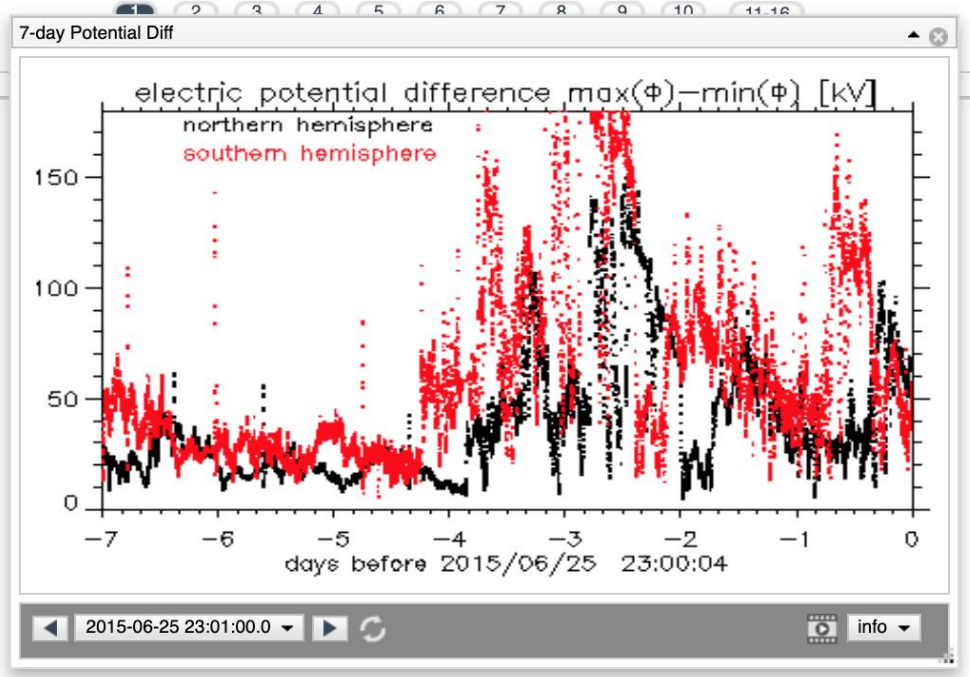
Lab questions

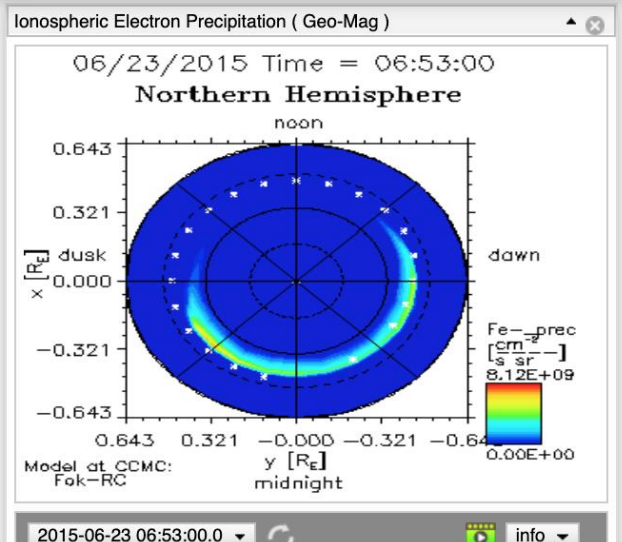
1) Do you see significant changes in the structure of the ionosphere as shown by these results? Describe these and identify the onset time for the changes.

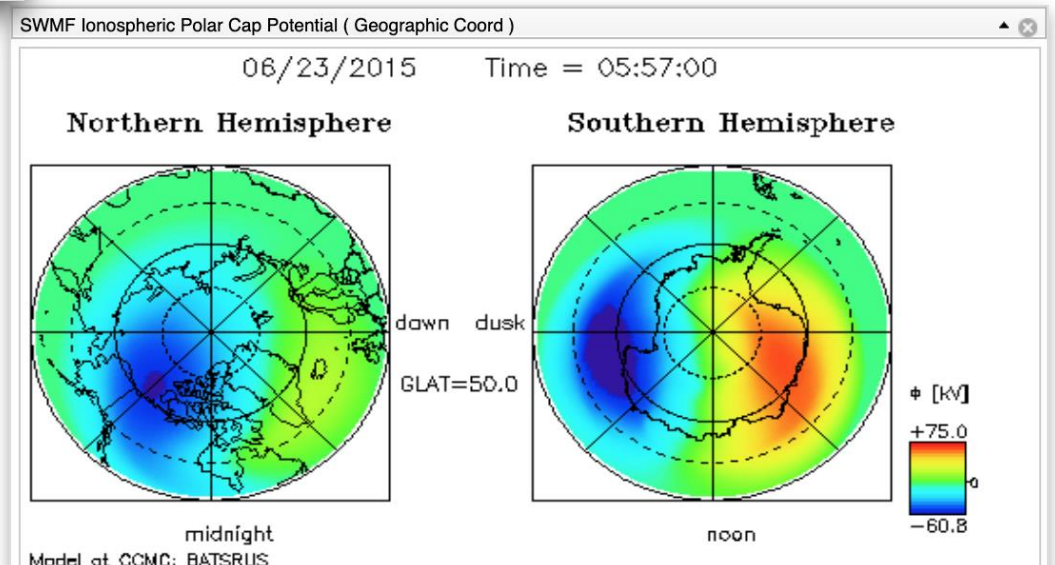
2) Does the structure of the ionosphere change significantly? (Pay careful attention to the color scales for the animation. Are they fixed or do they change?

3) Can you interpret parameters plotted? What could cause these changes and what effects might you expect there to be?

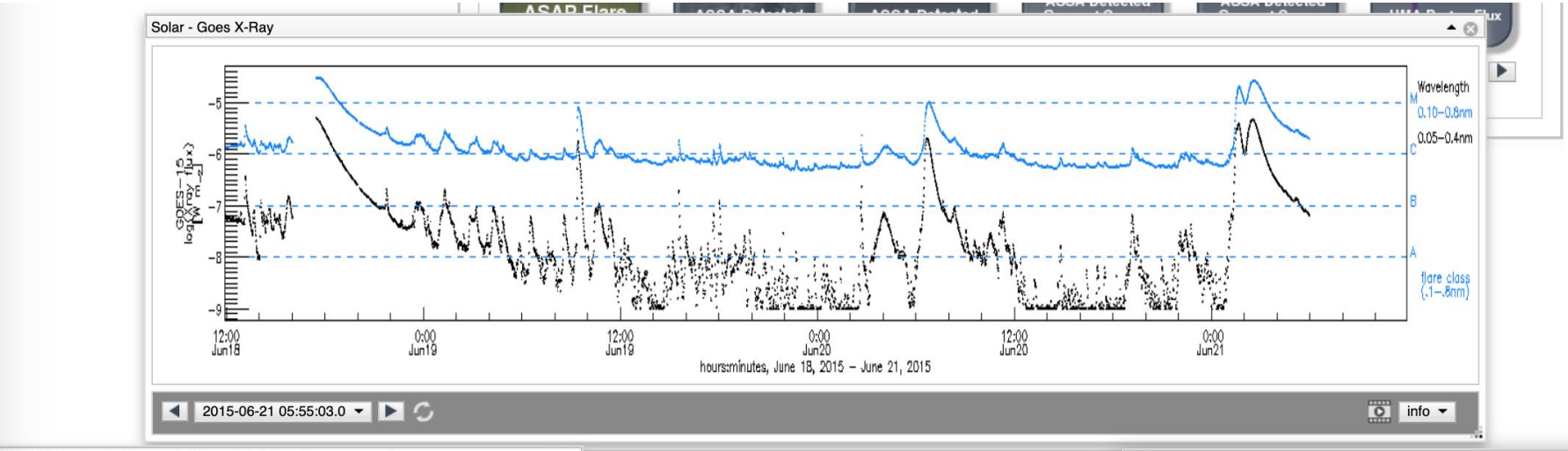


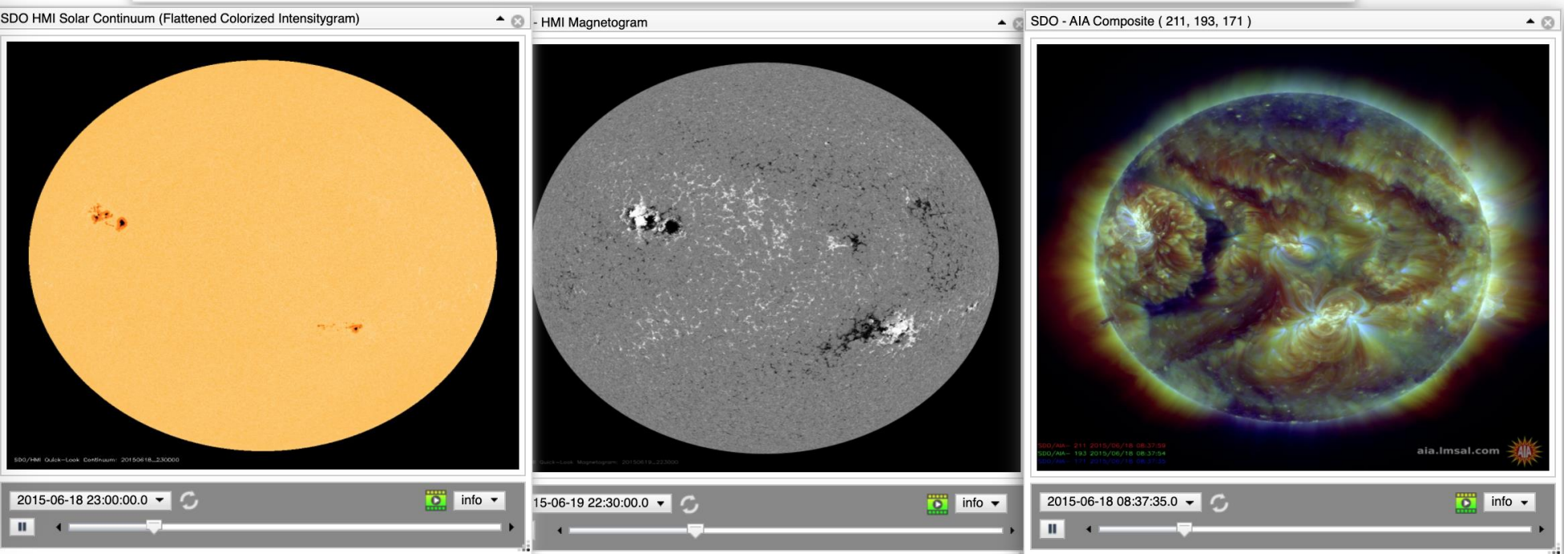






Example: iSWA in Heliophysics Summer School Exercises





Lab questions

1) Do all sunspots have active regions associated with them?

2) Are all active regions associated with sunspots?

3) How would you define an solar active region? What characteristics does it have?

4) When does a solar flare occur? What criteria do you use to define the solar flare event?

5) Is there another event you should not?

Heliophysics Summer Schools:
Demos and Tutorials of CCMC Runs-on-Request

CCMC Runs-on-request system: demo and hands-on

Sun to L1:

Heliosphere

Results of WSA-ENLIL Cone model simulations:

- Demo run and tutorial
- Runs

L1 to Geospace:

Magnetosphere

Results of SWMF model simulations:

- Demo run and tutorial
- Runs with artificial conditions
- Real event simulations

Inner Magnetosphere

Results of inner magnetospheric models simulations (Ring Current, Radiation Belt and CIMI models)

- Demo run and tutorial
- CIMI model run

Ionosphere

Results of CTIPe model simulations:

- Demo run and tutorial
- Runs with artificial conditions
- Real event simulations

Local Physics

Results of PIC-Hesse model simulation:

- Demo run

Example: CCMC Runs-on-Request Heliosphere tutorial

Generate a Plot with Default Selection

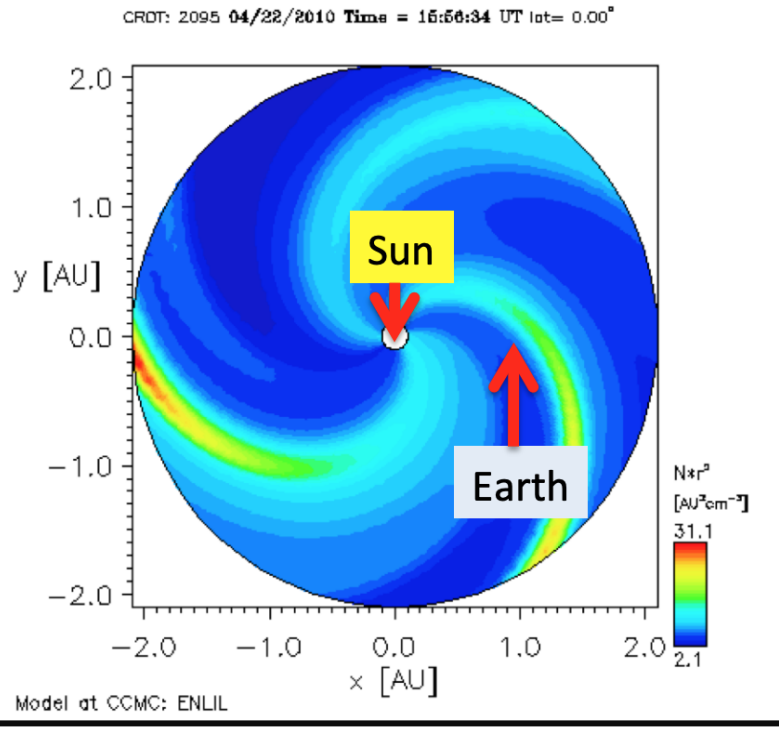
Click here

Update Plot *Update Plot* will update (generate) the plot with the chosen time and plot parameters below.
This will take some time (typically 10-30s) as data is read in and processed.

Choose data time:
Date: 2010/04/22 Time: 15:56:34

Color Contour 2D plot in solar equatorial plane (Lat=0) of Nr^2 (number density N scaled with r^2, r – radial distance in au)

Please wait - computation is estimated to take 0 minutes and 5 seco
A "." will appear for each 5 seconds elapsed.



Example:
Specialized simulations in support of space weather summer schools

Global Magnetosphere Simulations with Artificial Conditions

Quiet solar wind conditions at the Earth: Distance from the Sun = 1 au, Dipole Tilt = 11 deg, Vx = 400 km/s, T= 20000 keV, Vy=Vz=0, Bx=By=0

- The Earth's magnetosphere at different distances from the Sun for quiet solar wind conditions:
  At 1 au: Vx = 400 km/s, T= 20000 keV, Vy=Vz=0, Bx=By=0, N=5nT, Bz= - 5nT Normal Earth magnetic moment Dm_Earth, and dipole tilt equal to 11 deg:
- What if the Earth magnetic dipole had a different tilt angle?
- The role of ionosphere conductance
- What if the Earth magnetic moment differed from the normal value Dm_Earth?

DONKI

Database of Notifications, Knowledge, and Information

- Catalog of space weather phenomena.
- Chronicles the daily interpretations of space weather observations, simulation results, forecasting analysis, and notifications.
- Developed to address space weather needs of NASA missions, and as an O2R tool.
- Online tool for forecasts, notifications, and archiving event-focused information
- Intelligent linkages, relationships, cause-and-effects between space weather activities
- Comprehensive search functionality to support **anomaly resolution** and **space science research**:
  - Space weather activity archive (flares, CME parameters and simulation results, SEPs, geomagnetic storms, radiation belt enhancements) with links between activities
  - M2M space weather notification and weekly report archive
- Enables collaboration with students, world-wide partners, model and forecasting technique developers

Demo: http://kauai.ccmc.gsfc.nasa.gov/DONKI

Validation: CCMC community scoreboards

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

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

Leads: **NASA SRAG**, **CCMC** (L. Mays), **BIRA-IASB** (M. Dierckxsens)

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

Leads: **PredSci** (P. Riley), **University of Reading** (M. Owens)

PLANNING PHASE

- Scoreboards collect forecasts from the community before event is observed
- Allows a consistent **real-time** comparison of various operational and research forecasts
- Over time enough statistics are collected for validation studies
- Provides valuable feedback for model developers to make improvements

The COSPAR ISWAT initiative is a global hub for collaborations addressing challenges across the field of space weather.

S: Space weather origins at the Sun	H: Heliosphere variability	G: Coupled geospace system	Impacts
S1: Long-term solar variability	H1: Heliospheric magnetic field and solar wind	G1: Geomagnetic environment	Climate
S2: Ambient solar magnetic field, heating and spectral irradiance	H2: CME structure, evolution and propagation through heliosphere	G2a: Atmosphere variability	Electric power systems/GICs
S3: Solar eruptions	H3: Radiation environment in heliosphere	G2b: Ionosphere variability	Satellite/debris drag
	H4: Space weather at other planets/planetary bodies	G3: Near-Earth radiation and plasma environment	Navigation/ Communications
			(Aero)space assets functions
			Human Exploration

Overarching Activities:
Assessment Information Architecture Data Utilization Education/Outreach

https://iswat-cospar.org/

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.

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

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

CME Arrival Time Scoreboard

Community predictions for the 28 October 2021 CME

CME: 2021-10-28T15:53:00-CME-001

CME Note: Significant CME SW in COR2A and full halo in C2/C3. Source: X1.0 class flare from AR 2887 at S26W4 peaking at 2021-10-28T15:35Z and an associated significant eruption (with a EUV wave) seen in AIA 193/171 and EUVI A 195/304 starting 2021-10-28T15:25Z.

Predicted Shock Arrival Time	Difference (hrs)	Confidence (%)	Submitted On	Lead Time (hrs)	Predicted Geomagnetic Storm Parameter(s)	Method	Submitted By
2021-10-30T05:00Z	----	----	2021-10-29T02:00Z	27.00	----	WSA-ENLIL + Cone (BoM)	Duty Forecaster (ASFC)
2021-10-30T12:26Z (-9.0h, +9.0h)	----	----	2021-10-29T09:00Z	27.43	----	EAM (Effective Acceleration Model)	Evangelos Paouris (UoA)
2021-10-30T14:00Z	----	----	2021-10-29T04:00Z	34.00	----	WSA-ENLIL + Cone (NOAA/SWPC)	Robert Loper (M2M Office)
2021-10-30T16:00Z	----	----	2021-10-29T04:16Z	35.73	Max Kp Range: 5.0 - 8.0	WSA-ENLIL + Cone (Met Office)	Met Office (Met Office)
2021-10-30T16:54Z (-7.0h, +7.0h)	----	----	2021-10-29T12:07Z	28.78	Max Kp Range: 6.0 - 8.0	WSA-ENLIL + Cone (NASA M2M)	Robert Loper (M2M Office)
2021-10-30T17:15Z (-7.0h, +7.0h)	----	----	2021-10-28T19:13Z	46.03	Max Kp Range: 6.0 - 8.0	WSA-ENLIL + Cone (NASA M2M)	Anna Chulaki (M2M Office)
2021-10-30T18:55Z (-5.9h, +12.2h)	----	100.0	2021-10-29T05:54Z	37.02	Max Kp Range: 5.0 - 7.0	Ensemble WSA-ENLIL + Cone (NASA M2M)	Robert Loper (M2M Office)
2021-10-30T19:40Z (-12.0h, +12.0h)	----	90.0	2021-10-29T16:03Z	27.62	Max Kp Range: 4.0 - 8.0	Other (SIDC)	Robert Loper (M2M Office)
2021-10-30T20:20Z	----	----	2021-10-28T21:00Z	47.33	Max Kp Range: 6.0 - 7.0	SARM	Marlon Nunez (UMA)
2021-10-30T22:07Z	----	90.0	---	---	Max Kp Range: 5.42857 - 7.71429	Average of all Methods	Auto Generated (CCMC)
2021-10-31T03:07Z (-7.7h, +7.6h)	----	100.0	2021-10-29T08:41Z	42.43	----	DBM	Mateja Dumbovic (Hvar Obs)
2021-10-31T04:51Z (-9.0h, +9.0h)	----	----	2021-10-29T09:00Z	43.85	----	EAM (Effective Acceleration Model)	Evangelos Paouris (UoA)
2021-10-31T05:00Z	----	70.0	2021-10-29T08:23Z	44.62	Max Kp Range: 6.0 - 8.0	Cone+HAF (SEPC, NSSC, CAS)	Jingjing Wang (NSSC SEPC)
2021-10-31T07:58Z	----	----	2021-10-29T02:36Z	53.37	----	SPM2	Xinhua Zhao (NSSC CAS)
2021-10-31T11:28Z	----	----	2021-10-29T02:31Z	56.95	----	SPM	Xinhua Zhao (NSSC CAS)
2021-10-31T14:56Z	----	----	2021-10-29T08:07Z	54.82	----	CAT-PUMA	Jiajia Liu (QUB)

CME Scoreboard Validation: Riley et al., 2018 SWJ

AGU100 ADVANCING EARTH AND SPACE SCIENCE

Space Weather

RESEARCH ARTICLE
10.1029/2018SW001962

Special Section:
Space Weather Capabilities Assessment

Key Points:
- Current forecasts of the arrival time of CME-driven shocks have an average accuracy of ±10 hr, with a standard deviation of ±20 hr
- Most accurate model can forecast the arrival time of CME shocks with an average accuracy of −1 hr, and standard deviation of 15 hr
- Arrival time forecasts have not improved in accuracy during the previous 6 years

Forecasting the Arrival Time of Coronal Mass Ejections: Analysis of the CCMC CME Scoreboard

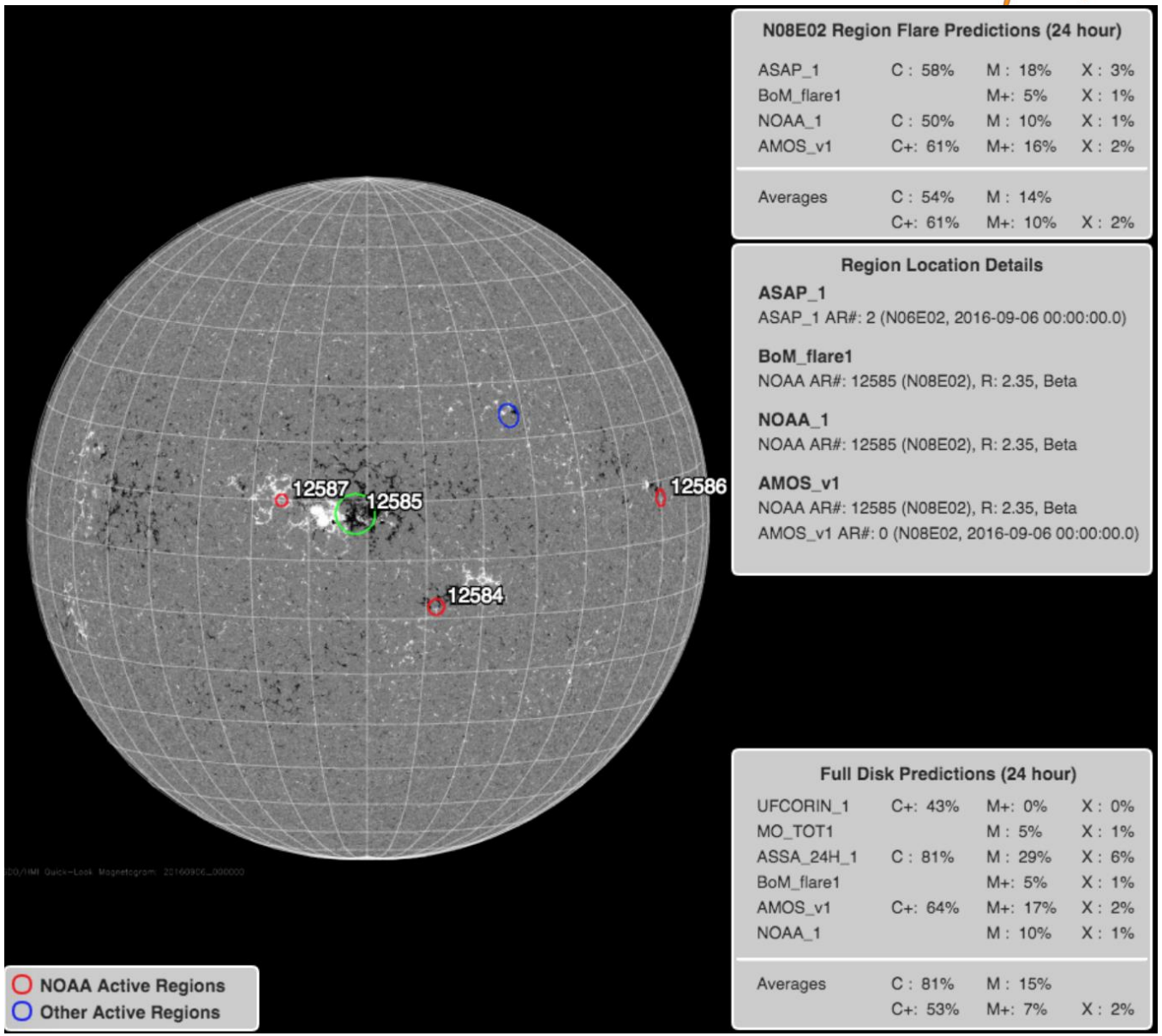
Pete Riley[1], M. Leila Mays[2], Jesse Andries[3], Tanja Amerstorfer[4], Douglas Biesecker[5], Veronique Delouille[3], Mateja Dumbović[6,7], Xueshang Feng[8], Edmund Henley[9], Jon A. Linker[1], Christian Möstl[4], Marlon Nuñez[1,10], Vic Pizzo[5], Manuela Temmer[4], W. K. Tobiska[1,11], C. Verbeke[1,2,12], Matthew J West[3], and Xinhua Zhao[6]

[1]Predictive Science Inc., San Diego, CA, USA, [2]NASA/GSFC, Greenbelt, MD, USA, [3]Solar-Terrestrial Center of ExcellenceRoyal Observatory of Belgium, Brussels, Belgium, [4]Space Research Institute, Austrian Academy of Sciences, Austria, [5]Space Weather Prediction Center, NOAA, Boulder, CO, USA, [6]Institute of Physics, University of Graz, Graz, Austria, [7]Hvar Observatory, Faculty of Geodesy, University of Zagreb, Zagreb, Croatia, [8]SIGMA Weather Group, State Key Laboratory of Space Weather, National Space Science Center, Chinese Academy of Sciences, Beijing, China, [9]Met Office, Devon, UK, [10]Department of Languages and Computer Sciences, Universidad de Málaga, Málaga, Spain, [11]Space Environment Technologies, Pacific Palisades, CA, USA, [12]Centre for Mathematical Plasma-Astrophysics, KU Leuven, Leuven, Belgium

Flare Scoreboard & Working Team

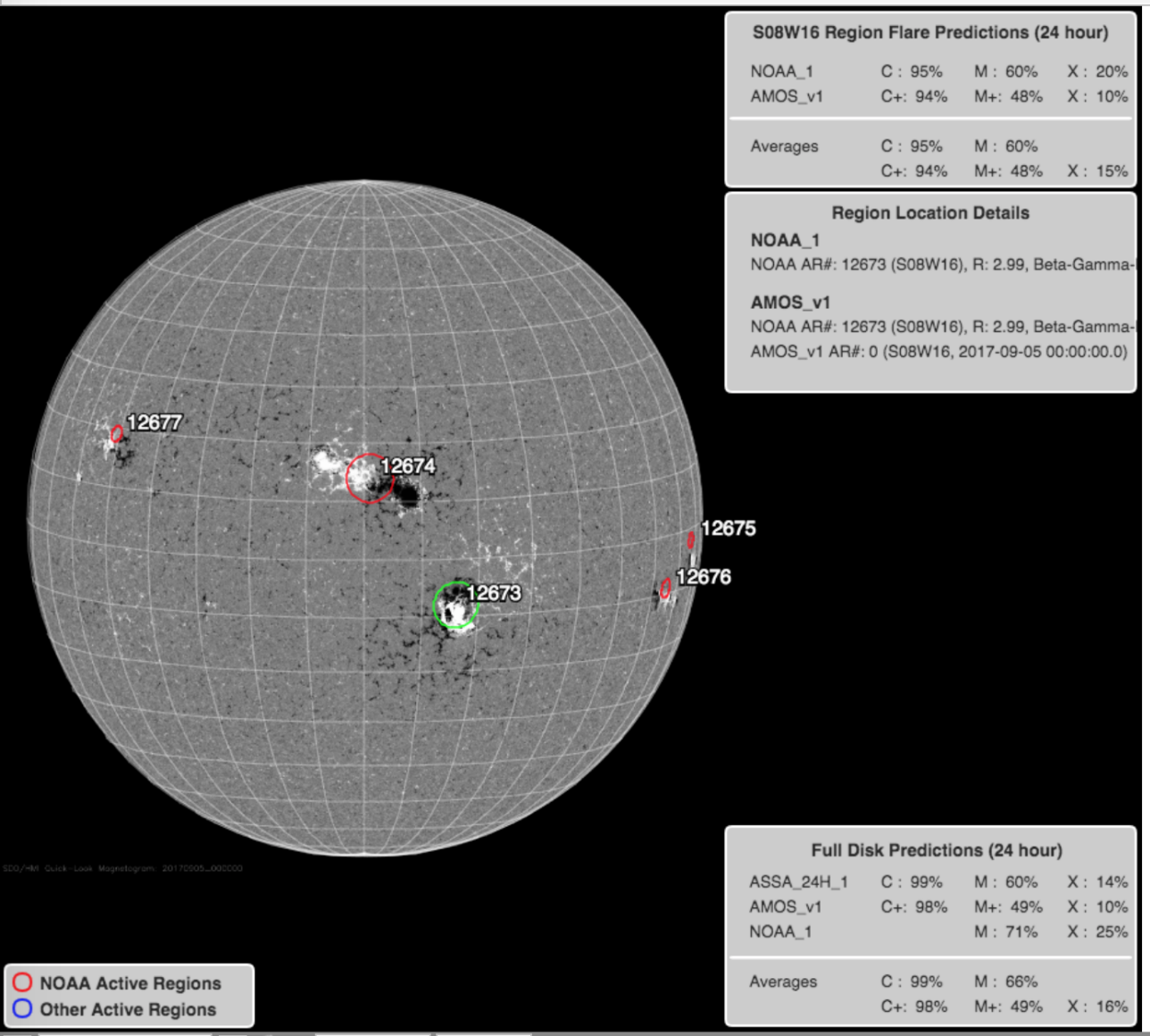
https://ccmc.gsfc.nasa.gov/challenges/flare.php

- 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 the planning group includes expert scientists as well as operational space weather prediction centers.
- Collaborating with ISEE/PSTEP "BenchMarks for Operational Flare Forecasts Workshop" study



Flare Scoreboard: Sep 2017

Solar Flare Scoreboard



S08W16 Region Flare Predictions (24 hour)

NOAA_1	C : 95%	M : 60%	X : 20%
AMOS_v1	C+: 94%	M+: 48%	X : 10%
Averages	C : 95%	M : 60%	
	C+: 94%	M+: 48%	X : 15%

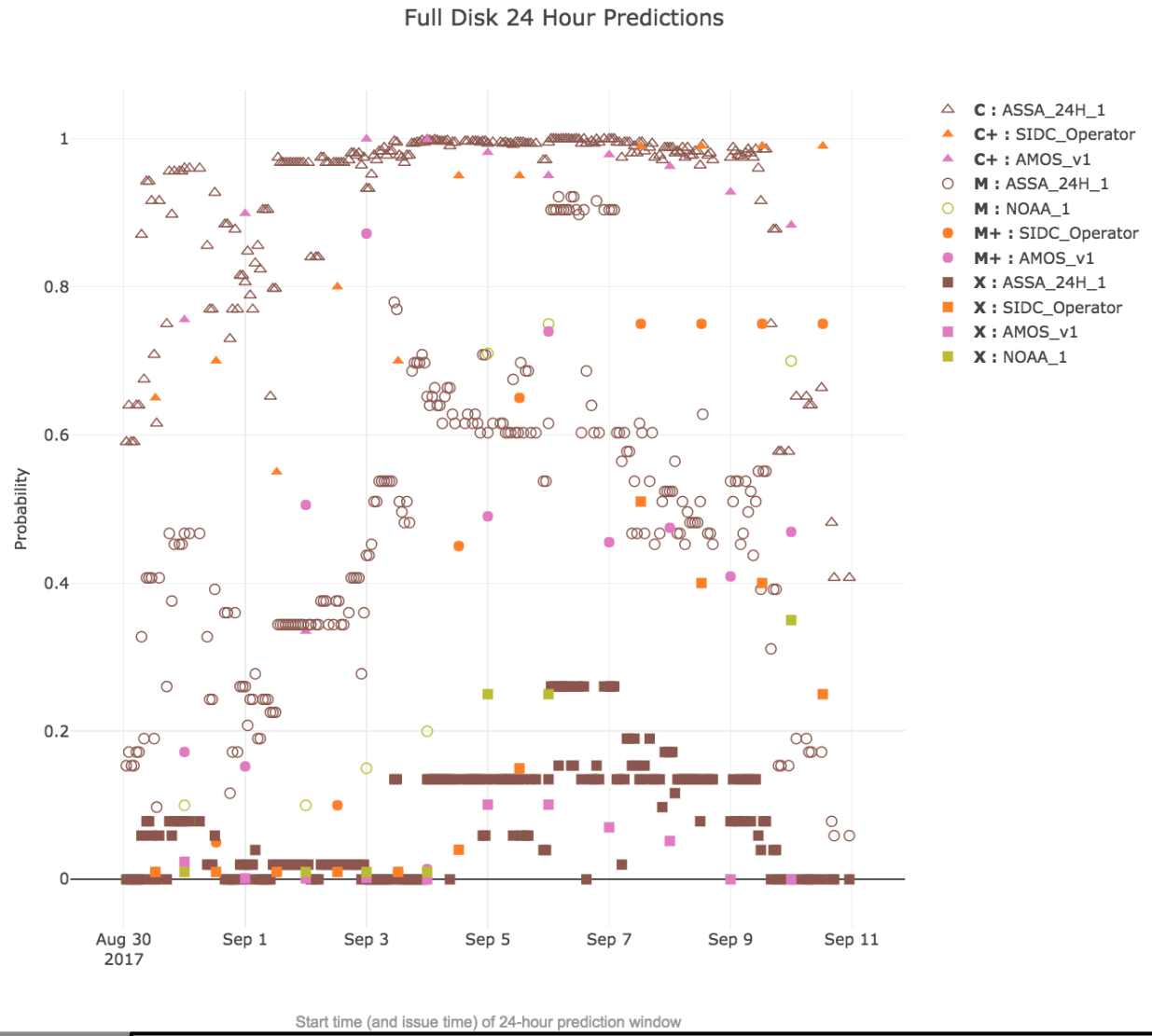
Region Location Details

NOAA_1
NOAA AR#: 12673 (S08W16), R: 2.99, Beta-Gamma-

AMOS_v1
NOAA AR#: 12673 (S08W16), R: 2.99, Beta-Gamma-
AMOS_v1 AR#: 0 (S08W16, 2017-09-05 00:00:00.0)

Full Disk Predictions (24 hour)

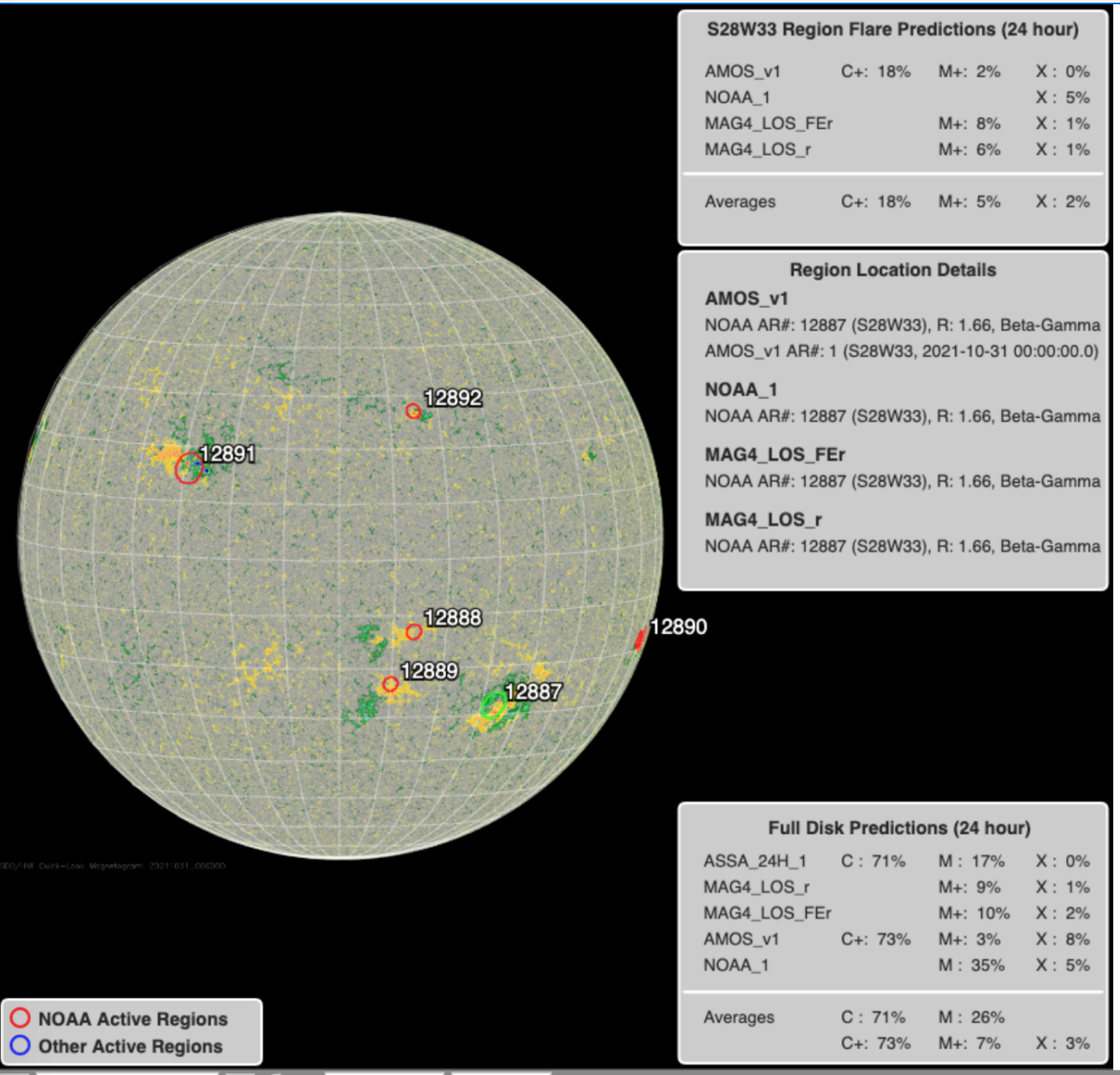
ASSA_24H_1	C : 99%	M : 60%	X : 14%
AMOS_v1	C+: 98%	M+: 49%	X : 10%
NOAA_1		M : 71%	X : 25%
Averages	C : 99%	M : 66%	
	C+: 98%	M+: 49%	X : 16%



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

Flare Scoreboard: October 2021

Solar Flare Scoreboard



S28W33 Region Flare Predictions (24 hour)

AMOS_v1	C+: 18%	M+: 2%	X : 0%
NOAA_1			X : 5%
MAG4_LOS_FEr		M+: 8%	X : 1%
MAG4_LOS_r		M+: 6%	X : 1%
Averages	C+: 18%	M+: 5%	X : 2%

Region Location Details

AMOS_v1
NOAA AR#: 12887 (S28W33), R: 1.66, Beta-Gamma
AMOS_v1 AR#: 1 (S28W33, 2021-10-31 00:00:00.0)

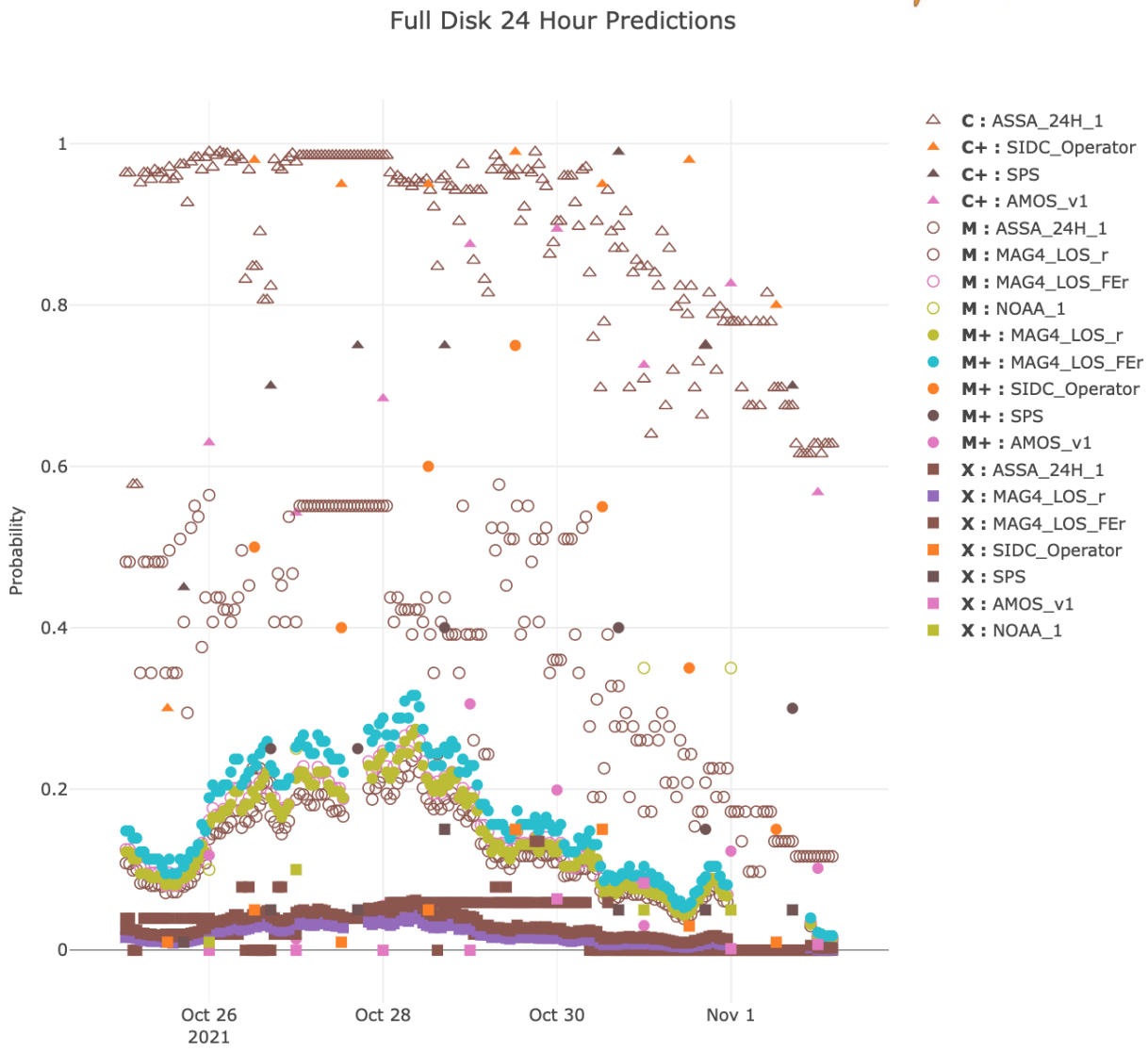
NOAA_1
NOAA AR#: 12887 (S28W33), R: 1.66, Beta-Gamma

MAG4_LOS_FEr
NOAA AR#: 12887 (S28W33), R: 1.66, Beta-Gamma

MAG4_LOS_r
NOAA AR#: 12887 (S28W33), R: 1.66, Beta-Gamma

Full Disk Predictions (24 hour)

ASSA_24H_1	C : 71%	M : 17%	X : 0%
MAG4_LOS_r		M+: 9%	X : 1%
MAG4_LOS_FEr		M+: 10%	X : 2%
AMOS_v1	C+: 73%	M+: 3%	X : 8%
NOAA_1		M : 35%	X : 5%
Averages	C : 71%	M : 26%	
	C+: 73%	M+: 7%	X : 3%

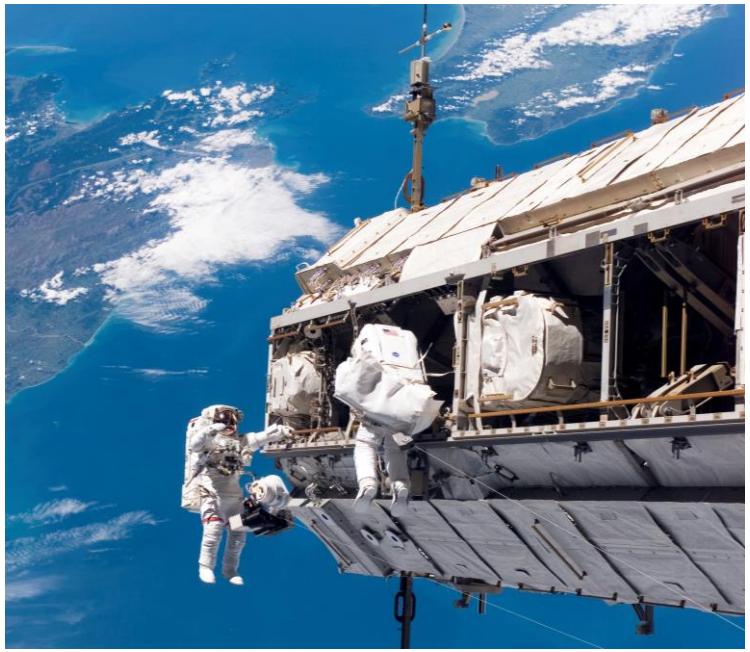


https://ccmc.gsfc.nasa.gov/challenges/flare.php

SEP Scoreboard: CCMC R2O Collaboration with NASA Johnson Space Center SRAG

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

- In 2018 CCMC started a multi year project (ISEP) with NASA Space Radiation Analysis Group to **transition research Solar Energetic Particle models to operations**
- **Project goals:**
  - identify, transition, and evaluate new models (R2O)
  - develop software tailored for SRAG
  - implement these capabilities within CCMC as a non-operational prototype.



- CCMC has transitioned 6+ real-time models and built **the SEP Scoreboard application** that will be used operationally by SRAG and M2M for human missions beyond LEO.
- The Scoreboard is already in use by SRAG for ISS support and will be used for ARTEMIS.

The Moon to Mars (M2M) Space Weather Office is a newly established effort in the Heliophysics Division to provide operational space weather support to SRAG for ARTEMIS missions

SEP Scoreboard

- Publicly available Dec 2020
- Supports SRAG console operators and M2M analysts
- Forecasts from multiple models are collected and uniformly displayed in real time
- Ability to go back in time
- Engages participation from the scientific community
- 6+ participating models

https://sep.ccmc.gsfc.nasa.gov/intensity/ https://sep.ccmc.gsfc.nasa.gov/probability/ https://sep.ccmc.gsfc.nasa.gov/allclear/

SEP Scoreboard

-1 week | -1 day | -1 hour | 2021-10-30 01:45 | +1 hour | +1 day | +1 week | Today

Refresh Plots

Proton Intensity Forecasts:

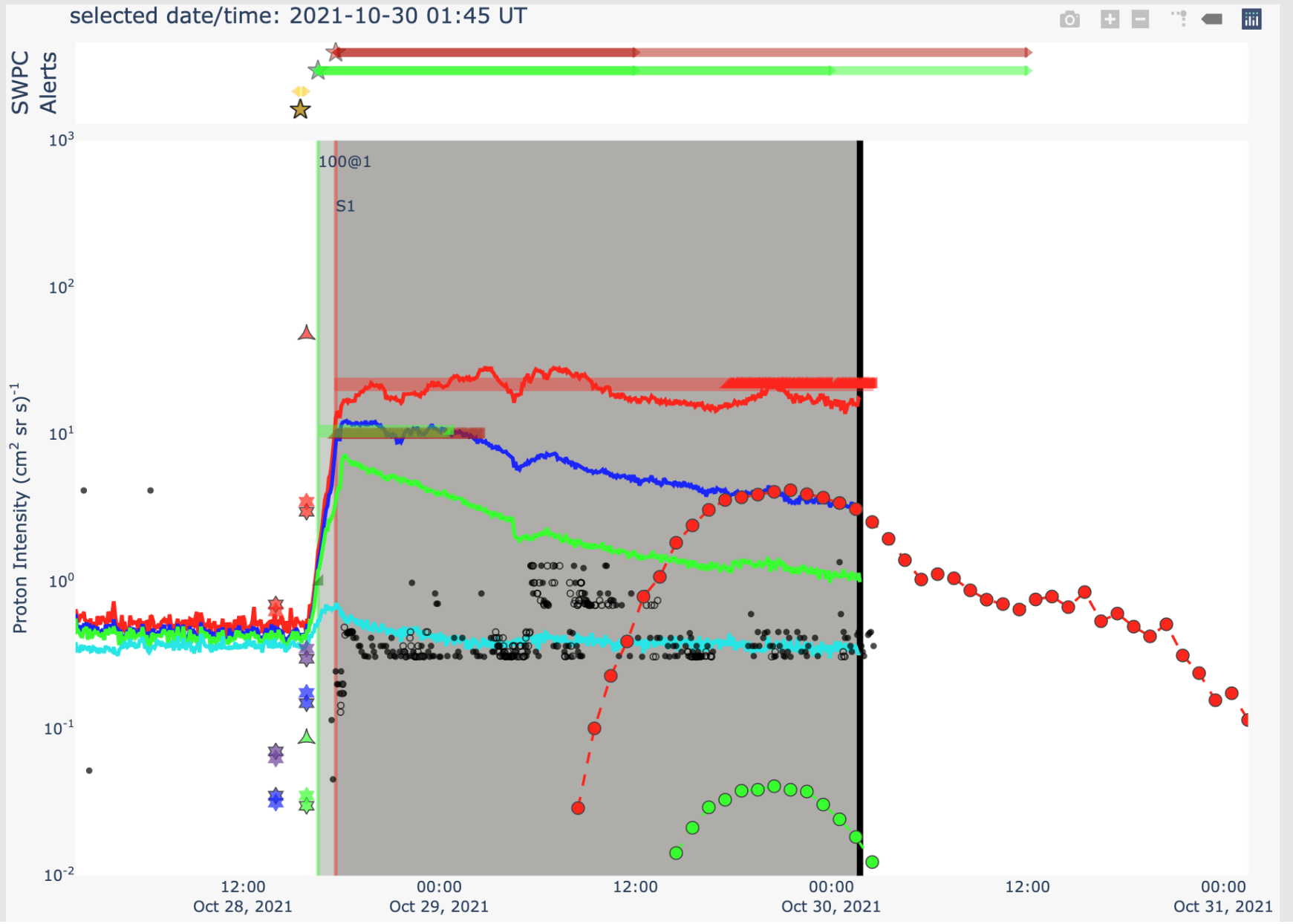
2021-10-301:45 UT

	> 10 MeV	> 100 MeV
GOES	17.3	0.99
SEPMOD	4.187	0.041
SEPSTER	No Data	No Data
SEPSTER2D	48.0	No Data
UMASEP	22.0 ± 5.0	In Event

pfu: 10^6, 10^5, 10^4, 10^3, 10^2, 10^1, 10^0, 10^{-1}, 10^{-2}, not c, clear, no d

pfu: 300, 200, 100, 50, 10, 1, 10^{-1}, 10^{-2}, 10^{-3}, not clear, clear, no data

Proton All Clear Forecasts:



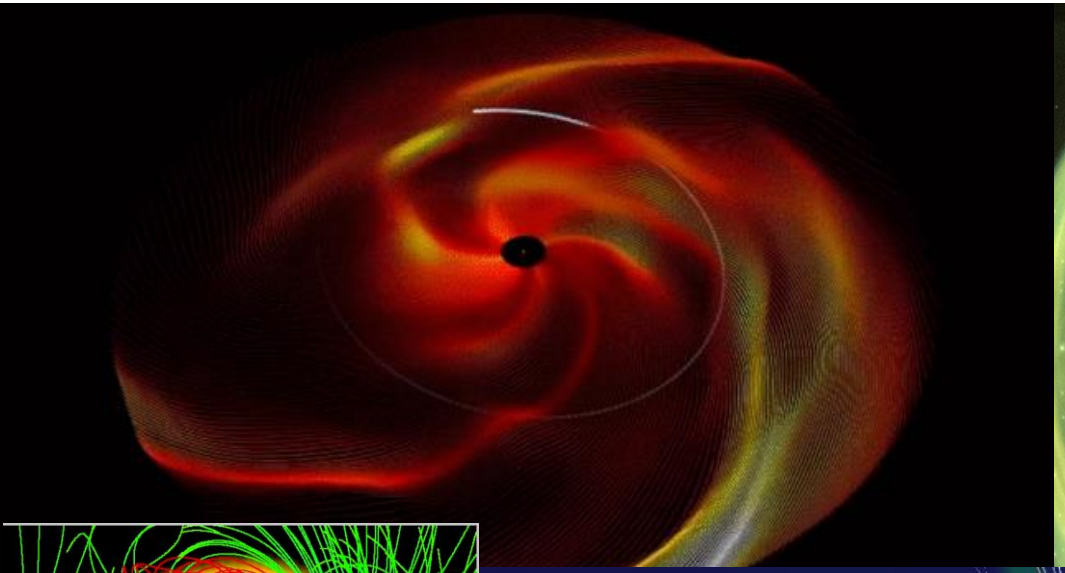
2021-10-29 00:00 UT

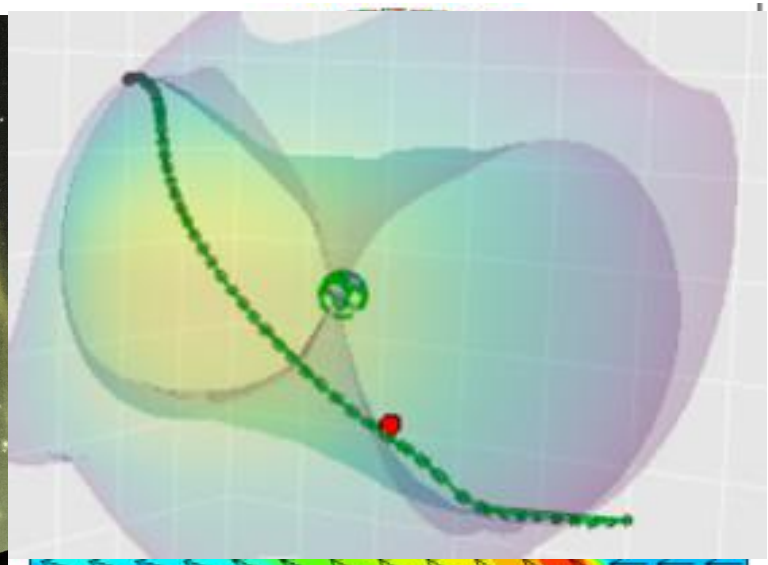
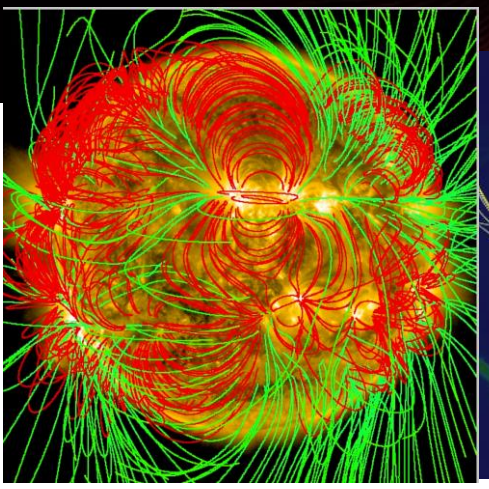
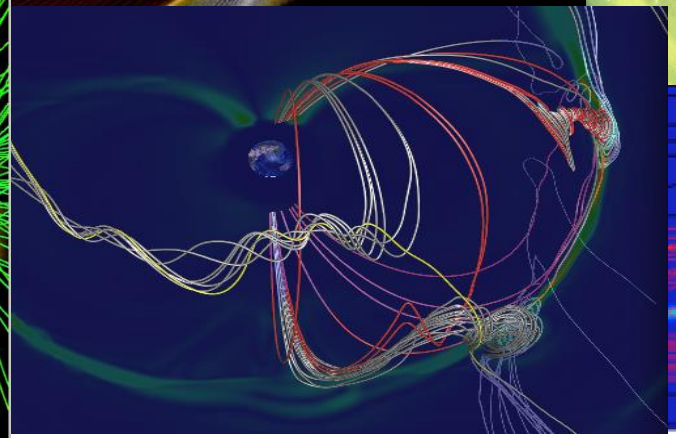
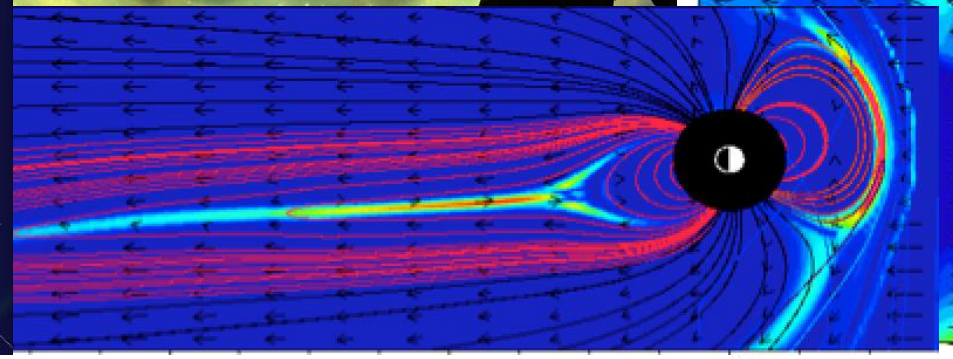
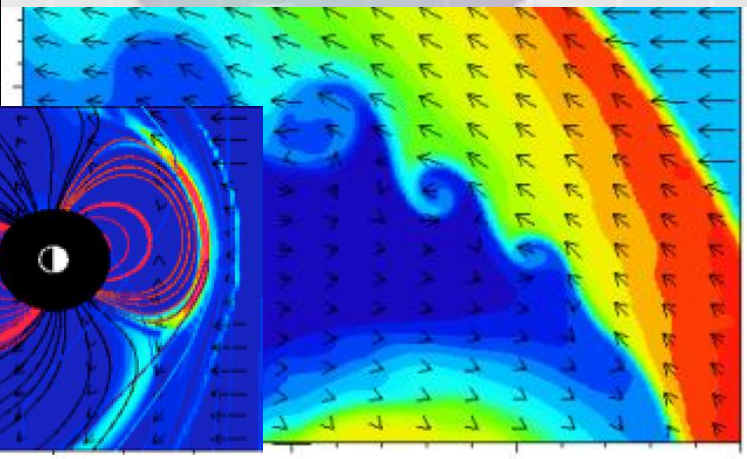
	GOES	SWPC Day 1	MAG4_SHARP_HMI	MAG4_SHARP	MAG4_LOS_r	SEPMOD	SEPSTER	SEPSTER2D	UMASEP
> 10 MeV	Not Clear	No Data	Clear	Clear	Not Clear	Not Clear	Clear	Not Clear	Not Clear
> 100 MeV	Not Clear	No Data	No Data	No Data	No Data	Clear	No Data	Clear	Not Clear
> 500 MeV	Clear	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Clear

All Clear

Not All Clear

Visualization



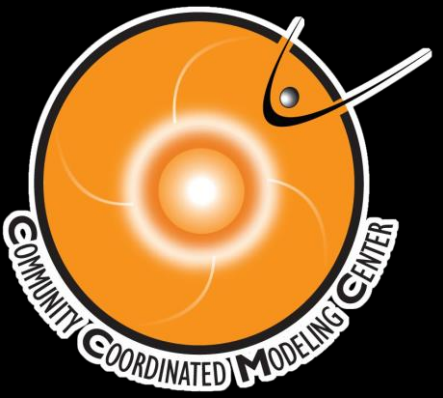
- ✓ Basic model output and derived quantities.
- ✓ User-ordered custom variables.
- ✓ Automated movie & time series generation

- ✓ Interfaces with Virtual Observatories.
- ✓ Interfaces with Planetariums.

OpenSpace is open source interactive data visualization software designed to visualize the entire known universe and portray our ongoing efforts to investigate the cosmos.

CCMC OpenSpace Planetarium Shows

https://www.openspaceproject.com/
https://www.amnh.org/research/hayden-planetarium



- June 27, 2017
  Sun Earth Connection
  https://youtu.be/rDDjcxBP6ag
- March 24, 2018
  Sun-Earth Interation
  https://youtu.be/VM_6XpLR3gw
- October 2, 2020
  Solar Storms
  https://youtu.be/iRt6rsYR_Sw
- October 18, 2020
  Simulating Risks of Solar Weather
  https://youtu.be/s1UaX0phI6I

Thank You!