

COMMUNITY COORDINATED MODELING CENTER (CCMC) SPACE WEATHER RESEARCH ANALYSIS – FORECASTING FOR NASA'S ROBOTIC MISSIONS

Yaireska (Yari) Collado-Vega

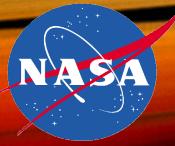
Community Coordinated Modeling Center (CCMC)

Space Weather Laboratory

Heliophysics Science Division

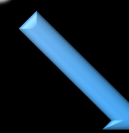
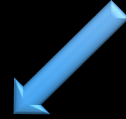


11th Space Exploration and Space Weather Workshop



The CCMC was established in 2000 as a multi-agency strategic investment in US space weather program

CCMC Goals



*Facilitate space weather
research & model development
to advance understanding and
to improve forecasting*

*Support
development & deployment
of new **operational**
space weather capabilities*

A long-term and flexible solution to the research to operations (R2O) transition.

In partnership with international research and operational communities.

CCMC FUNCTIONS

Models

Model input generation suite

EEGGL

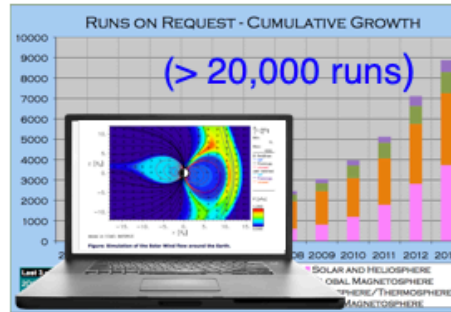
StereoCAT

Containers

Model display system

Models listed include: PFSS, Lohmann, SWMF, WINDM, LANLstar, UPOS RB, GITM, IGRF, Triggiano, AE-SWAP-8, PBMOD, PSVP, Weigand-default, AE-SWAP-3, TRPL-DA, Weimer IE, MAGIC, SWSO, Helios3 (SMEI), Helios3 (IPS), BRYNTRN, DDM, SWMF-SH, DIPS, Corona, Heliosphere, Magnetosphere, Local Physics, Magnetosphere, Thermosphere.

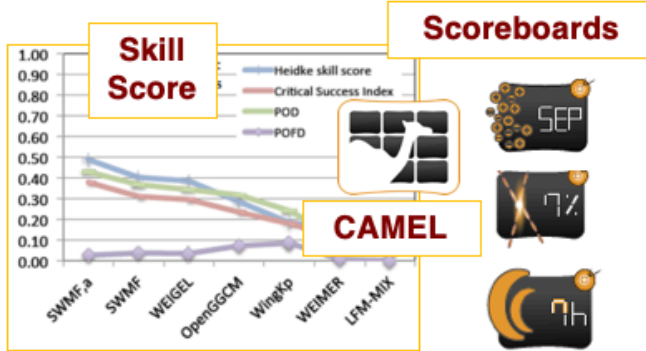
Simulation services



Visualization, dissemination

CCMC Kamodo analysis suite (open source)

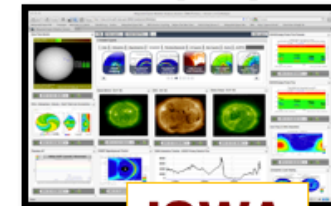
Evaluations, R20



NASA missions & community Support



Information architecture: perpetual archive



ISWA



DONKI

SOME CCMC TOOLS

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



INTEGRATED SPACE WEATHER ANALYSIS SYSTEM (iSWA)



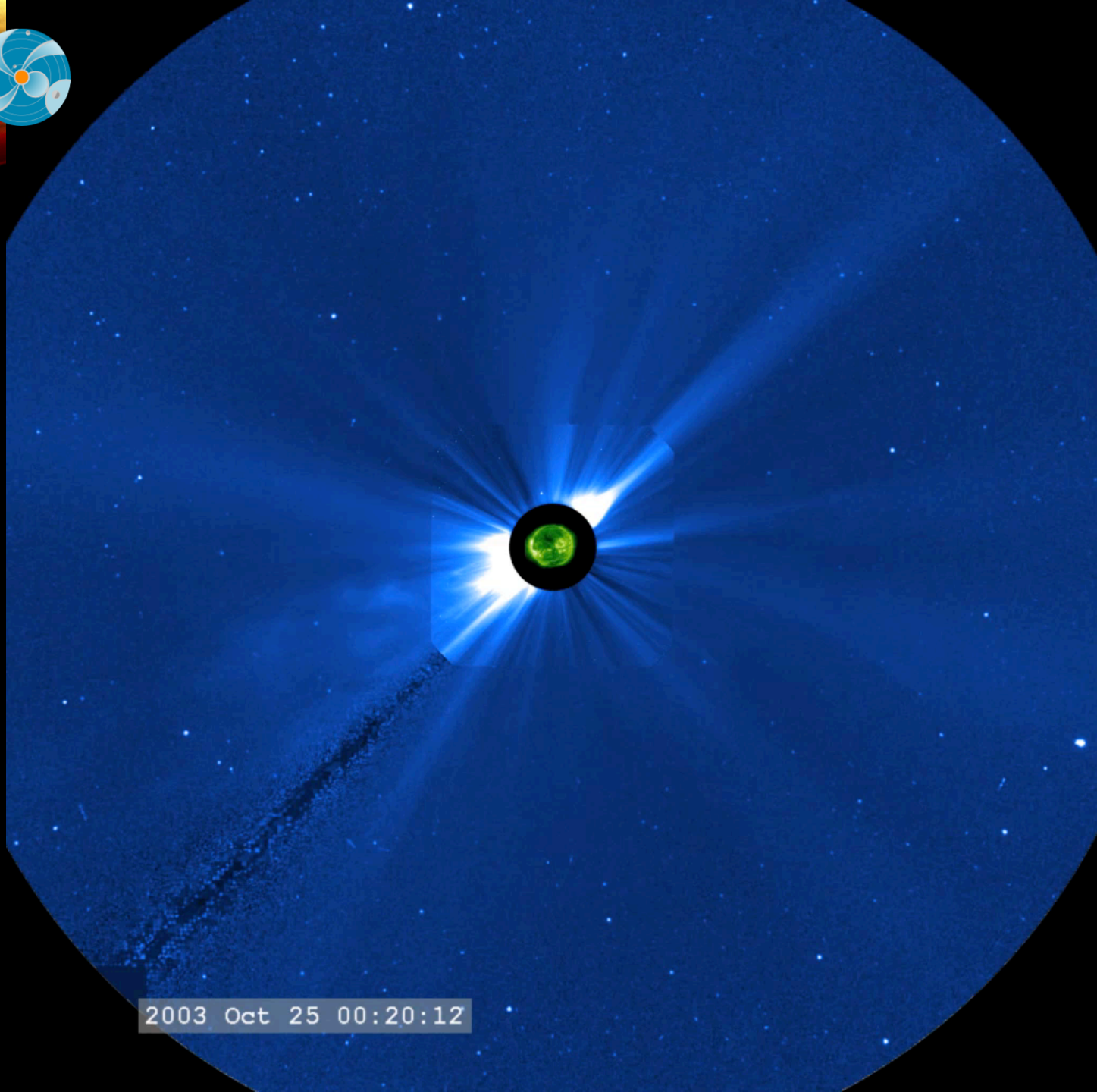
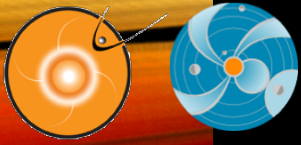
Space Weather Database Of Notifications, Knowledge, Information (DONKI)



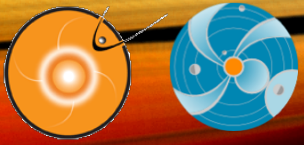
Stereo CME Analysis Tool (StereoCAT)



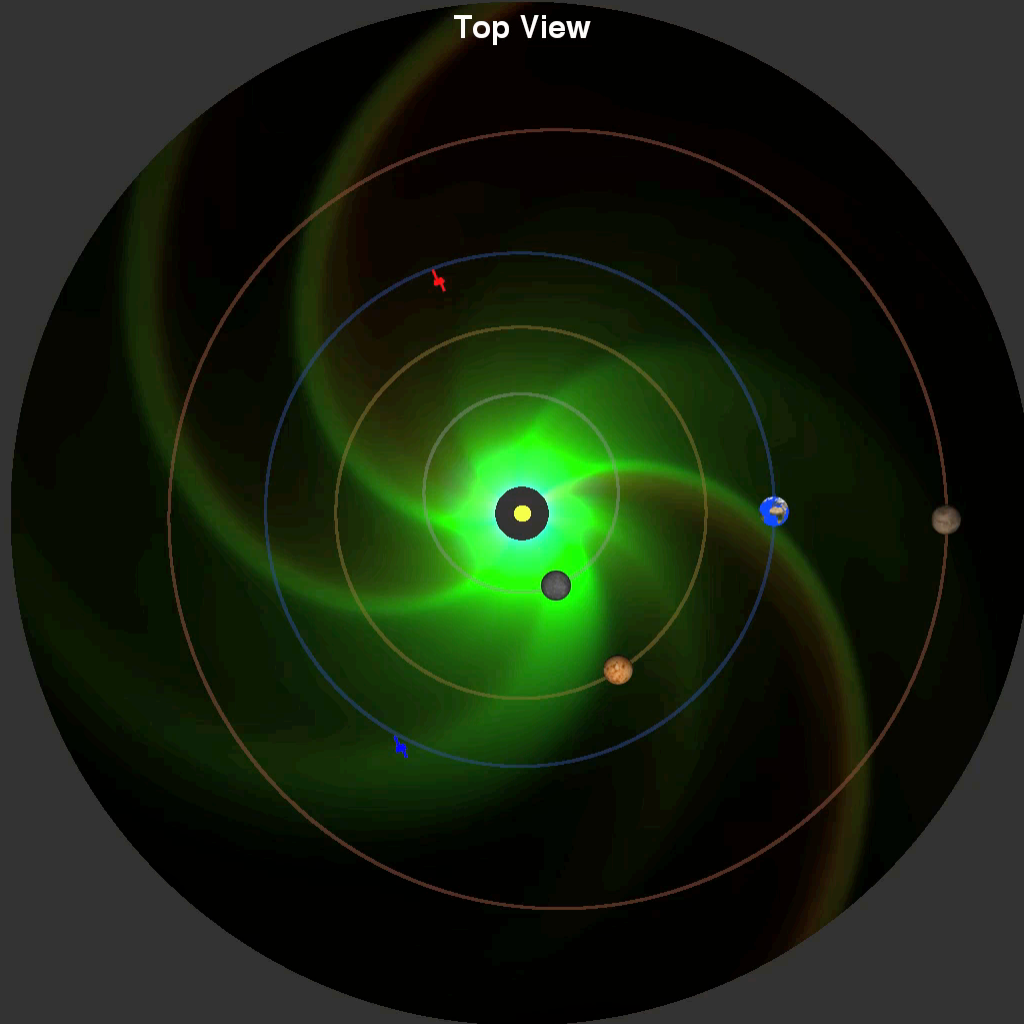
Comprehensive Assessment of Models and Events using Library Tools (CAMEL) Framework



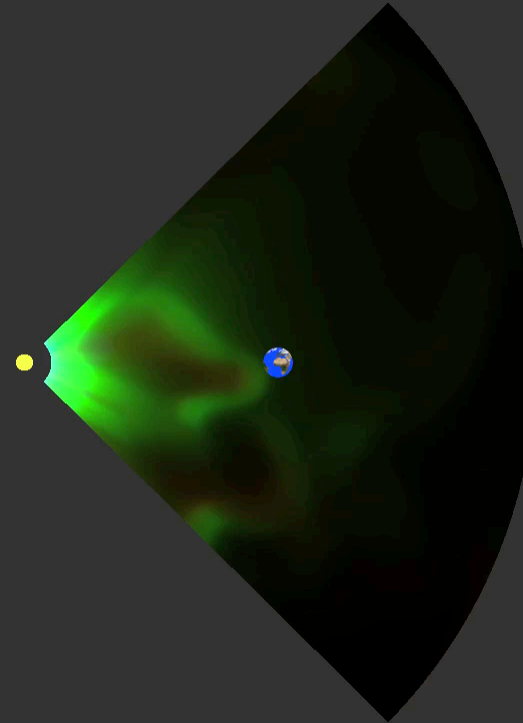
2003 Oct 25 00:20:12



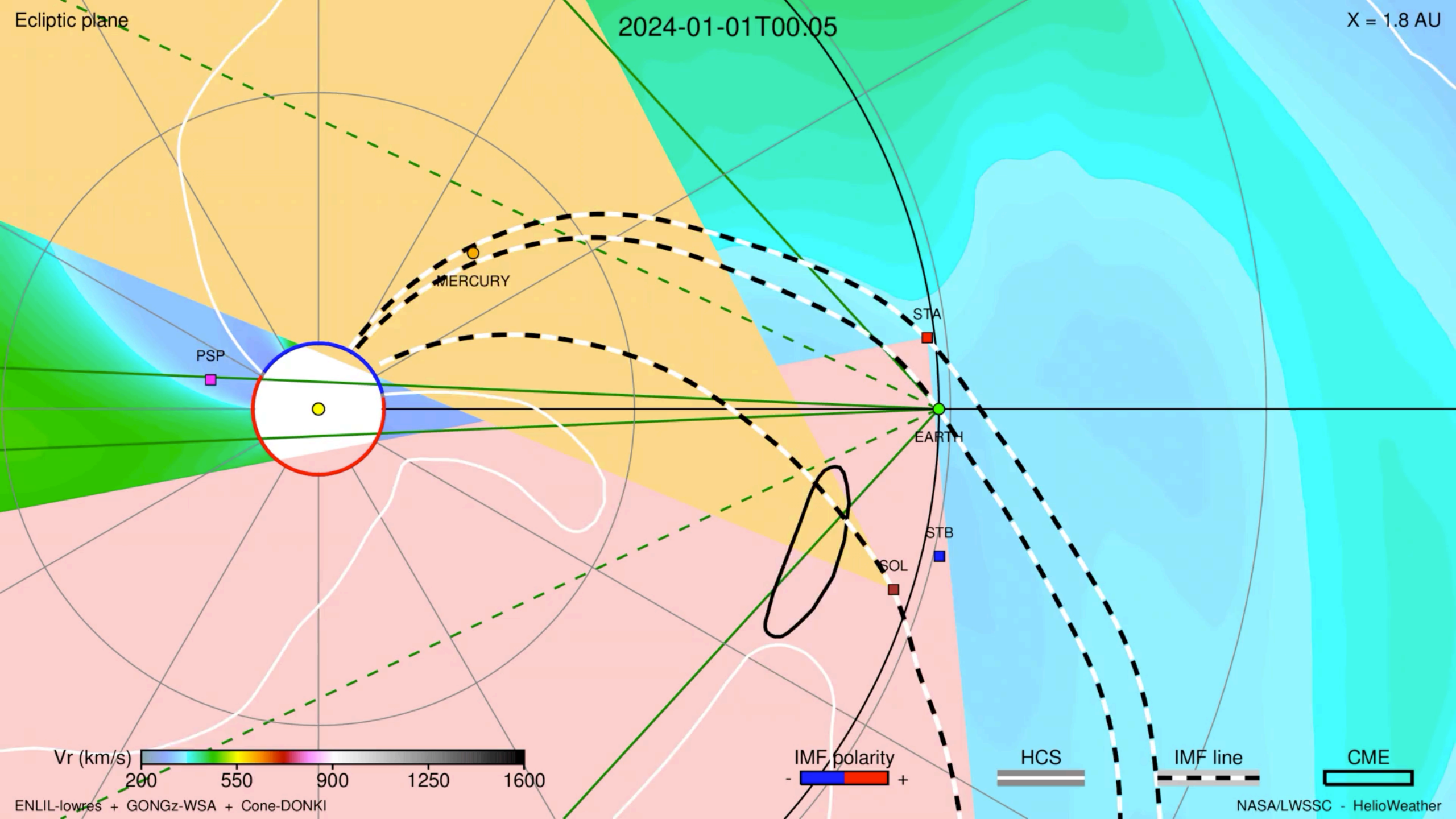
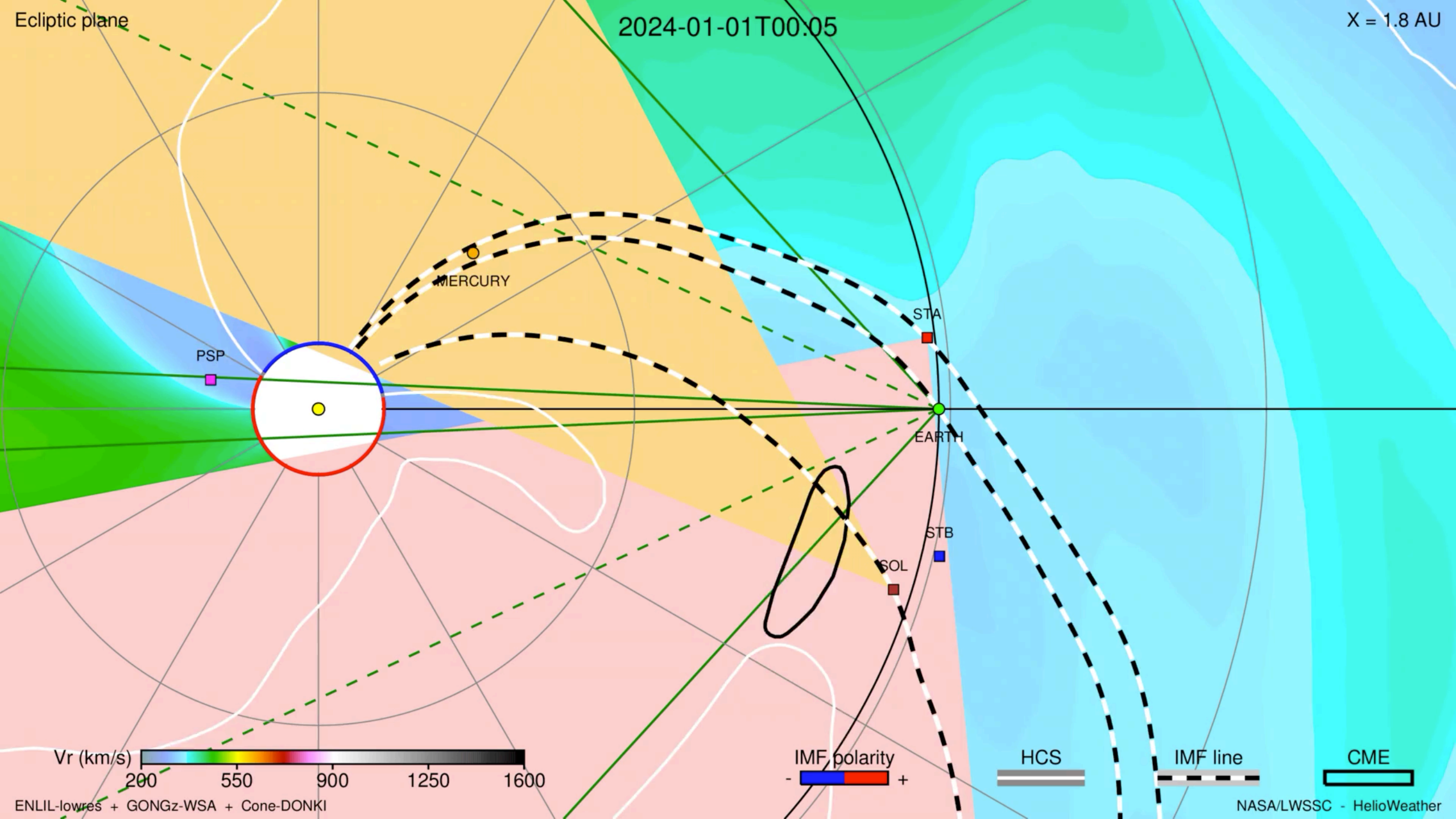
Top View



Side View



2012 Mar 5 09:07:02 UTC



ACTIVITIES AND CHAIN OF EVENTS

- **Monitor models and activity 8am-8pm daily (performed by students under supervision)**
- **Notifications are sent out to users when thresholds are exceeded**
- **10am video and in-person “tag-up” meetings each work day**
- **“International” tag-ups with international/external partners**
- **Weekly Space Weather Reports**

- Flare (M5 or above)
- CME (Depending on the speed notifications will be send as fast as possible first with measurements and then with the simulation)
- Solar Energetic Particle
- CME arrival (in-situ data at L1)
- Geomagnetic storm (indicated by Kp index)
- Radiation belt electron flux enhancement

CHALLENGES

- 1) Forecasting requires you to make assessments based only on what you know, not what you will know.
- 2) Some data are available immediately, some arrive later, some never arrive.
- 3) Some models and simulations are available quickly, and some take a while to run and produce results.
- 4) End users need different types of information. Some need it quickly, some need more detailed information and can receive it a little later.
- 5) For these reasons, we often iterate in our predictions, and provide updates.

CCMC COMMUNITY SCOREBOARDS


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



TRINITY
COLLEGE
DUBLIN



Royal Observatory
of Belgium



**Flare
Scoreboard**

Upload your Flare Predictions for
Full Disk
and/or Active Regions.

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



Met Office



**SEP
Scoreboard**

Under development
Help us plan and design.

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



Met Office



**CME
Scoreboard**

Submit your CME arrivable time
predictions and
compare with others.

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

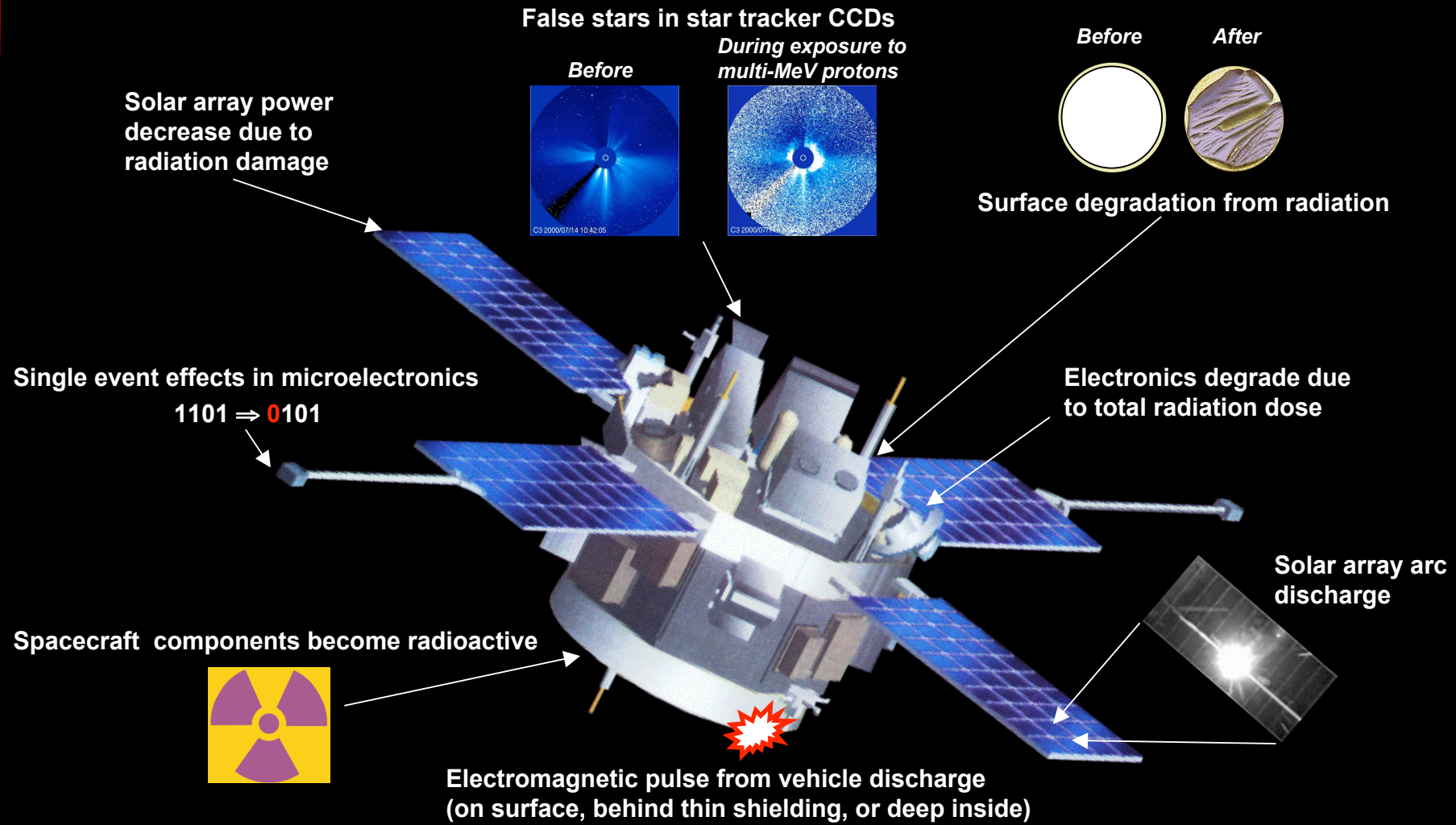
- Scoreboards collect forecast before event is observed
- Allow a consistent **real-time** comparison of various operational and research forecasts. Complementary to non-real time model assessments.



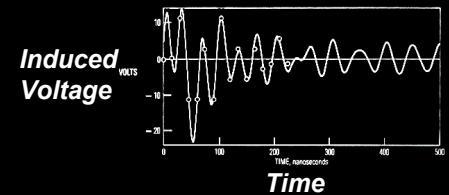
**IMF Bz
Scoreboard**

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

VISUAL REPRESENTATION OF SPACE ENVIRONMENT HAZARDS



Electromagnetic pulse from vehicle discharge
(on surface, behind thin shielding, or deep inside)



CCMC SPACE WEATHER FORECASTING

Anomaly Analysis Support for NASA Robotic Missions

- Anomaly Analysis are requested by NASA missions several times a month
- An assessment is prepared and sent to the mission team for their evaluation and decision.
- Sometimes face to face meetings are required when an evaluation board is conducted and the space weather environment is presented by our team.
- Critical decisions are made that take into account the space weather assessment.

- Some missions include:

MMS, ACE, STEREO, IBEX, Aqua, Aura, Terra, Landsat, VAP, GPM, Spitzer, DSCOVR, GOES, TDRSS, OSIRIS-Rex, SDO

We also work closely with the GSFC Space Asset Protection Program (SAPP) and we are part of the procedures for mission anomalies

The support has been very important for the development of new missions, like GOES series.

During Shutdown:

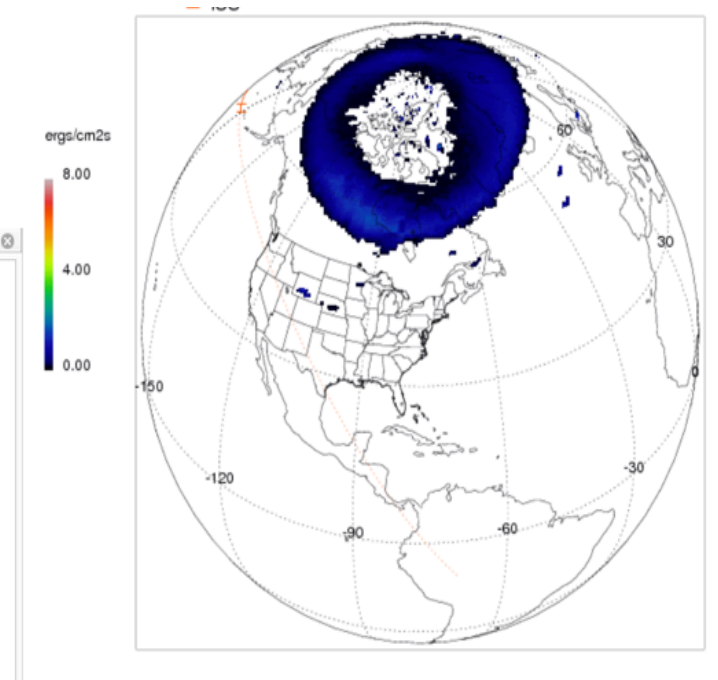
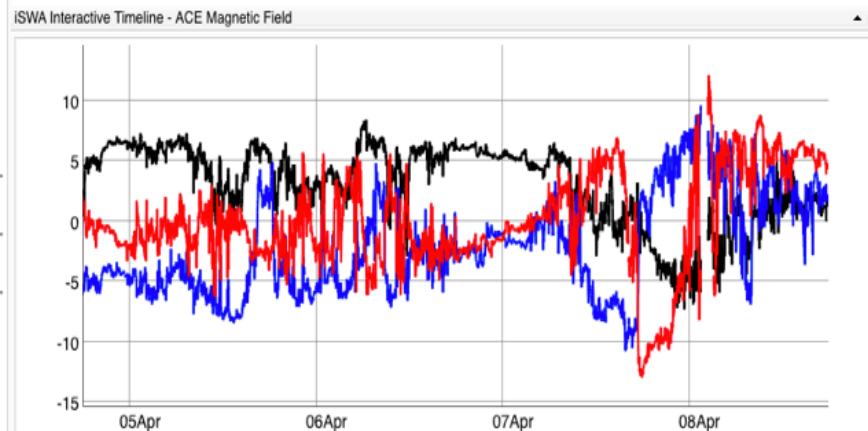
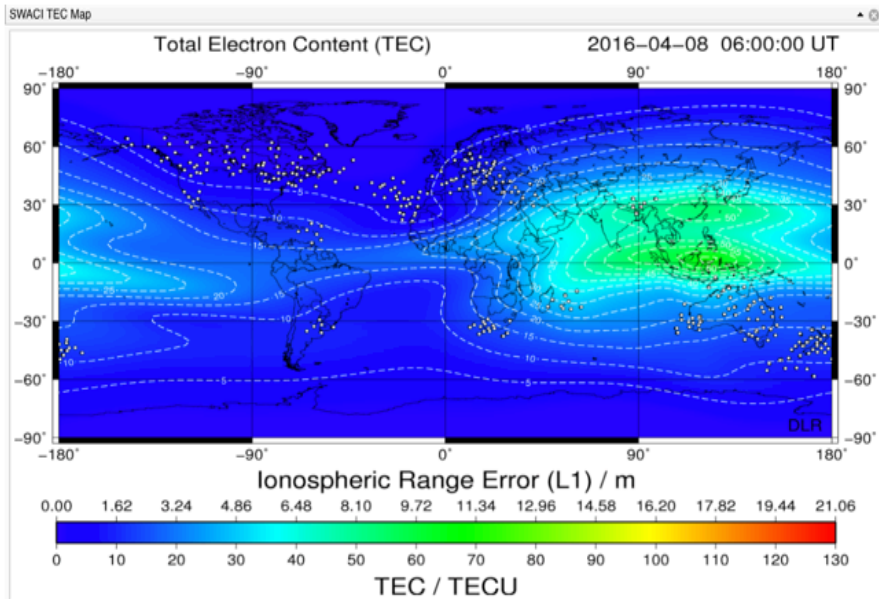
Space weather forecasting services were critical and excepted. A recently launched mission had an anomaly that needed to be evaluated for an orbit departure and spacecraft health and safety.

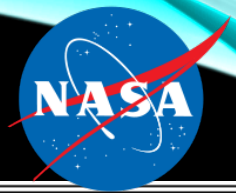
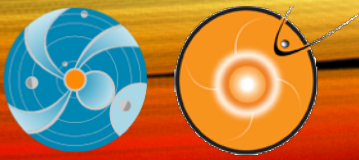
Anomaly Support Example

Please find below our assessment for the events on 2016-04-08:

Based on our preliminary analysis, space weather activity was low to moderate on 2016-04-08. There were no major solar flares or coronal mass ejections. The solar energetic particle environment at Earth was benign as GOES and SOHO proton fluxes were at background levels. However, the electron belt fluxes (>0.8 MeV channel) measured by GOES decreased below normal levels at the end of the day before (2016-04-07) due to a compression in the magnetosphere caused by an interplanetary shock that arrived at ACE around 2016-04-07T09:00Z. The interplanetary shock was believed to be associated with an arrival of a CME that originated in a filament eruption around 2016-04-04T14:40 UT close to solar disk center. This eruption was not visible in the coronagraphs and therefore was not measured, but it was noted in our logs. Geomagnetic activity was elevated to minor levels with $K_p \leq 5$ (ranges from 0-9, 9 being the strongest) due to this activity during the synoptic periods 2016-04-07T18:00Z to 2016-04-08T03:00Z.

The total electron content plot at 2016-04-08T06:00Z show slightly elevated levels at the anomaly location (see attached plot). I attached also the plot that describes the solar wind magnetic field at ACE (Bx (black), By (blue), Bz (red)) at the beginning of the day on 2016-04-08. Looking also at the Ovation Prime model, a precipitation model that separates different types of auroras, the auroral activity was very nominal during the 06UT time of the day. Auroral activity could be associated with scintillation and GPS error.





Geocentric missions	Missions near-Earth	Heliospheric missions	Sounding Rockets	International
<p><i>LEO:</i> , RHESSI, IRIS, ISS, CALIPSO, Terra, AURA, AQUA, TRMM, FASTSAT, and NASA's EOS</p> <p><i>GSO:</i> SDO</p> <p><i>LEO/Highly Elliptical:</i> Chandra</p> <p><i>Magnetospheric:</i> MMS, Van Allen Probes, THEMIS</p>	<p>ACE, SOHO, Wind, JWST</p>	<p>MESSENGER, STEREO, Spitzer Space Telescope, MAVEN, MSL, Dawn, Kepler, EPOXI, Juno, CASSINI, New Horizons, Voyager</p>	<p>Grand Challenge Sounding Rocket Campaign, STORM, VISIONS, VISIONS-2</p>	<p>SOTERIA, Venus</p>

CCMC provides vital science and space weather support to ongoing and future science missions in various capacities and during different phases:

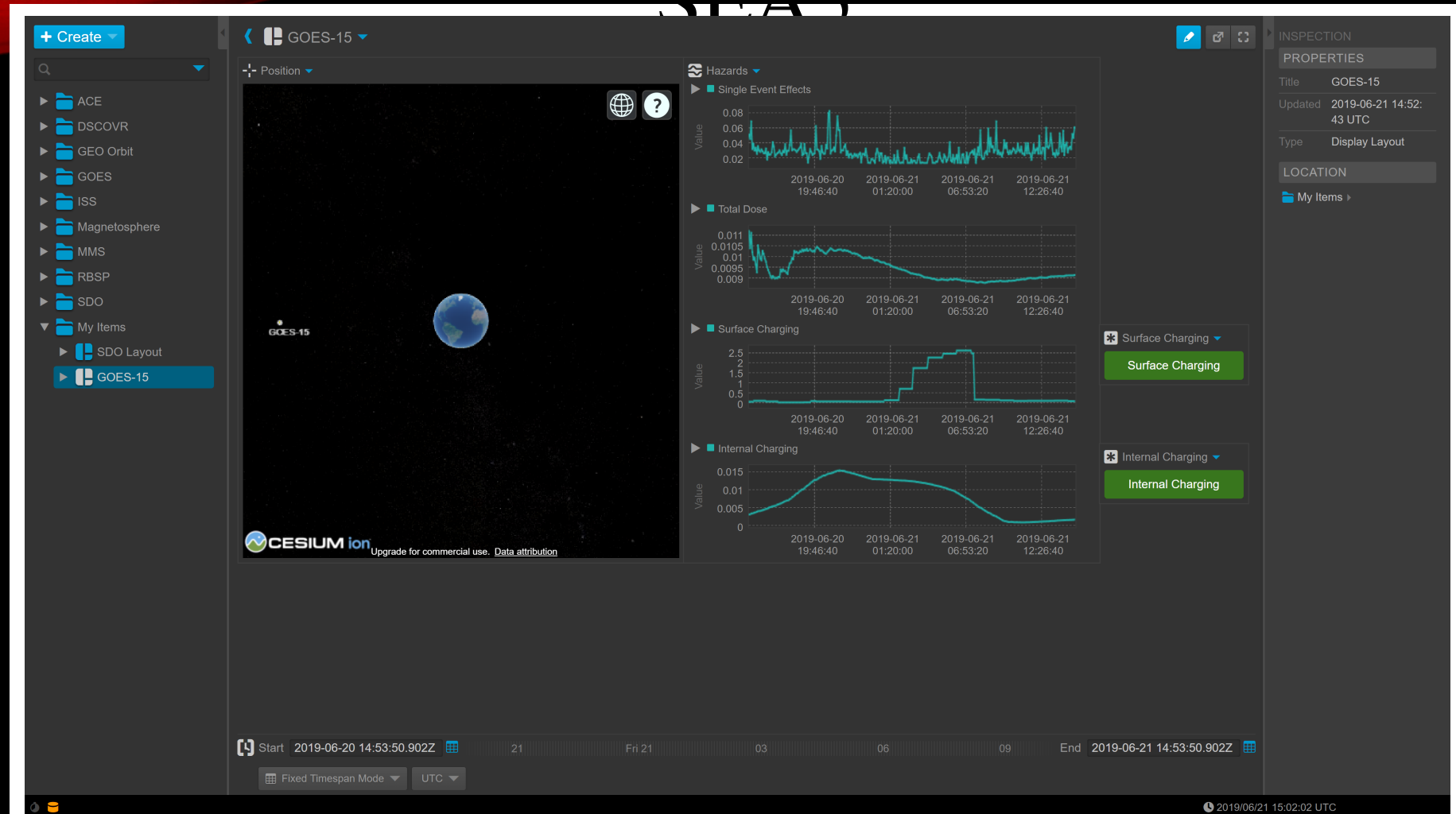
- mission planning/building
- operation/prime and extended science stages.

Support is provided through CCMC services:

- Runs on Request service
- Real-time runs and data viewable via webpages and iSWA
- DONKI, a searchable database of space weather events, simulations, and notifications
- Anomaly resolution

New Tools in Development

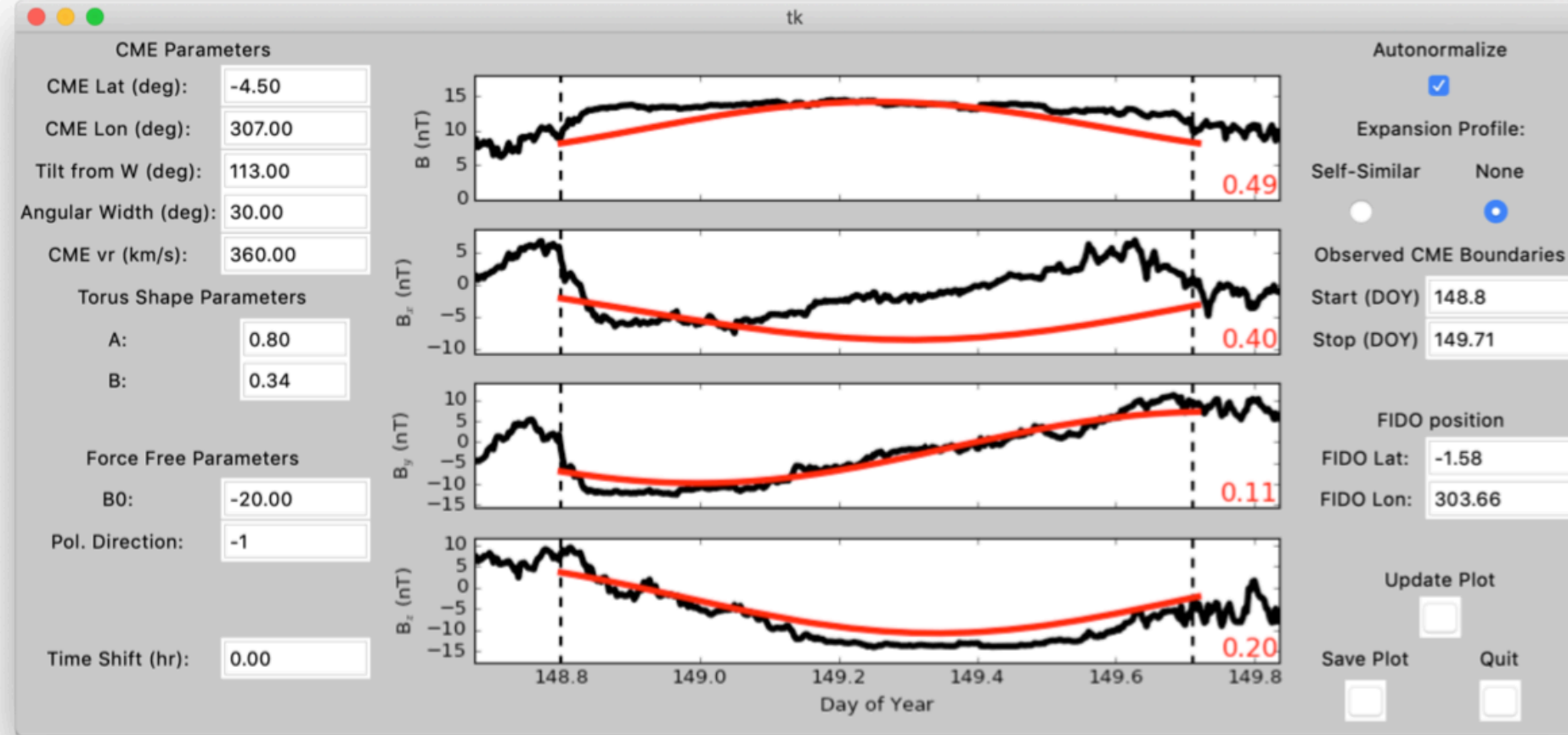
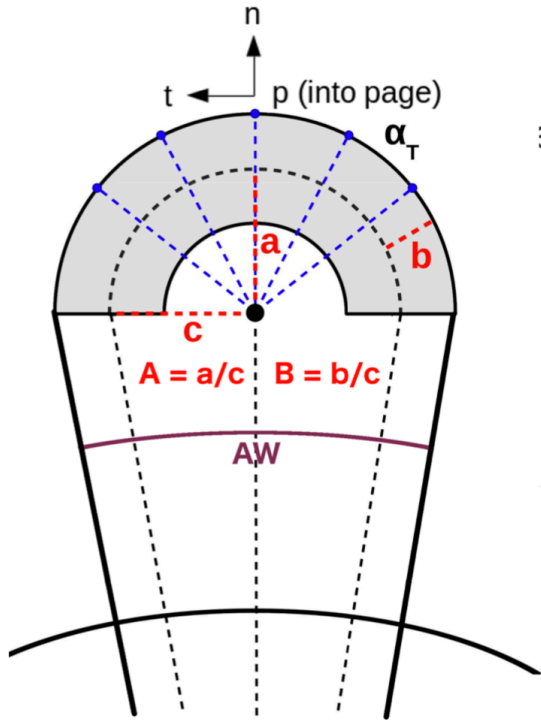
SEA5



- The Space Environment Automated Alerts & Anomaly Analysis Assistant (SEA5) system will provide past, present, and predicted space environment information for specific missions, orbits, and user-specified locations throughout the heliosphere and geospace.

ForeCAT In situ Data Observer (FIDO)

Torus Shape used to represent the CME flux rope



- **FIDO** is a tool that assumes a toroidal CME shape, propagates it past a synthetic spacecraft in three-dimensional space, and then applies a simple flux rope model to get the magnetic field as a function of time.
- Using observations from the solar wind monitors, FIDO compares the CME parameters predictions with the in-situ data and calculates scores (RMSE) for the specific CME moving in any location.
- This tool is being currently adapted to be used for real time analysis.

SUMMARY

- At CCMC we focus on providing critical space weather models and information for the scientific community.
- Our team provides accurate real-time experimental research forecasting of both large-scale and local space environments and their probable impacts for the current NASA missions.
- We perform experimental **research forecasts, notification, space weather analysis, and spacecraft anomaly resolution support**.
- Anomaly resolution assessments have been critical for the support of current missions and for the development of future ones.
- Since 2016, we have worked closely with the Space Asset Protection Program at NASA GSFC.
- We are also trying to develop or prototyping new capabilities.
- Results and lessons learned are communicated to the model developers and the wider space weather community