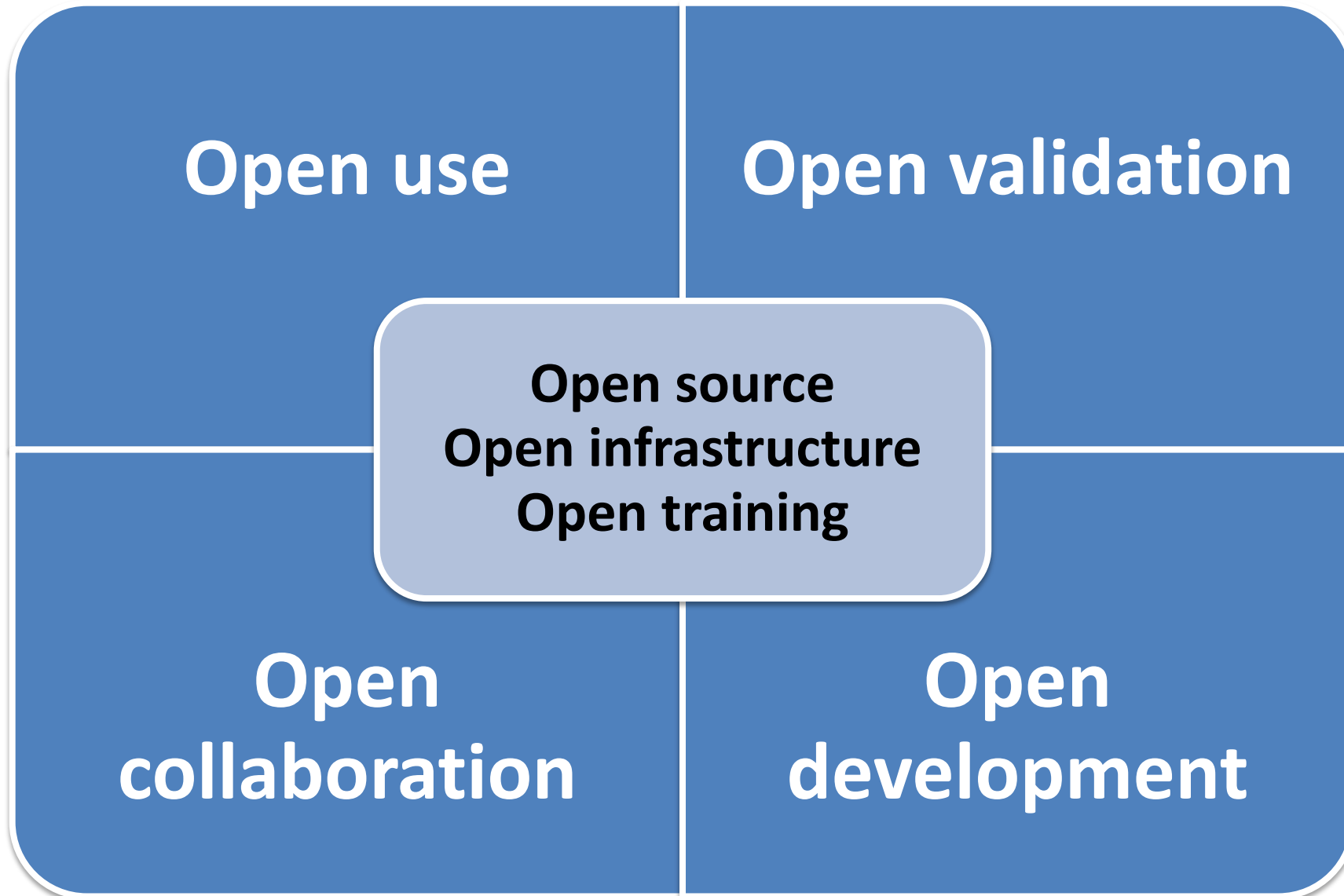


**Advancing Open Science at the  
Community Coordinated Modeling Center (CCMC)  
&  
International Space Weather Action Teams (ISWAT)**

***M. Kuznetsova, CCMC Team, ISWAT Moderators***

**October 18, 2024**

# Open Science in Modeling



# Open use of models

- ✓ CCMC is enabling open use of models for over 20 years
- ✓ Modelers are proposing implementation at CCMC
- ✓ Working with LWS Strategic Capabilities, NASA DRIVE Centers, SWx Centers of Excellence to enable community use of early outcomes
- ✓ Expert-guided simulation services
  - Simulation settings tailored for specific phenomena
  - Custom simulation settings
  - Configuration and input files are available for download
- ✓ Training/advising on how to use models
- ✓ Exploring remote execution (partnership with VSWMC)

# Open use of simulation results

- ✓ All simulation outputs are available for interactive on-line visualization and downloads
- ✓ **Kamodo** software based on Python
  - Online and offline. Core package in PyHC
  - Access, interpolation, dynamic visualization, satellite flythrough, reconstruction
  - Unit conversions, coordinate transformations
- ✓ **Visualization and analysis of runs produced outside of CCMC**
  - Focus on outputs from computationally/storage expensive runs
- ✓ Initiated implementation of post-processing, analysis and visualization software **developed by the community.**
- ✓ Post-processing on request
  - Custom derived quantities, Movies-on-Request
  - Distribution-Functions-on-Request for particle outputs (PIC codes)
- ✓ Link CCMC runs with **publications, phenomena, new findings**



# ISWA

## Interactive Space Weather Analysis

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

*A system for open space environment monitoring and analysis and collaborative system science*

ISWA

Browse

Search

Sync

Save  
Layout

Load  
Layout

Clear





Solar

Heliosphere

Magnetosphere

Ionosphere

Planetary

Radiation Effects

Events

Time Period Runs

ISEP

Mars

All

Retired

GOES



GOES SUVI Gallery



GOES Primary X-ray Flux



GOES Primary Proton Flux



GOES Primary Electron Flux

SDO



SDO - AIA 171



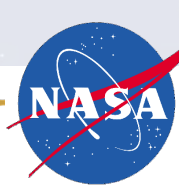
SDO - AIA 211



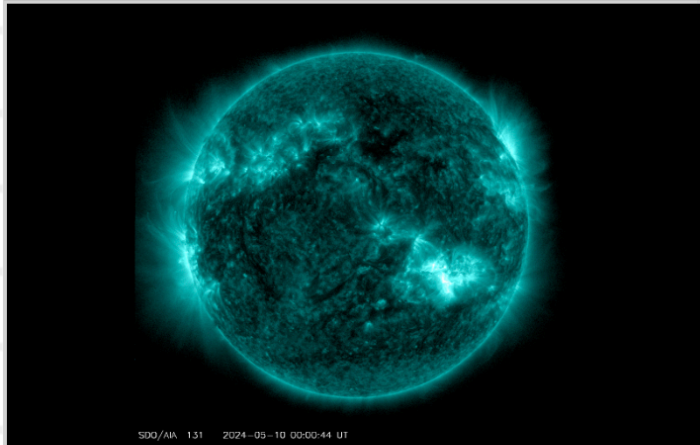
SDO - AIA 131



SDO - AIA 335



SDO - AIA 131 : 2024-05-10 00:00:44



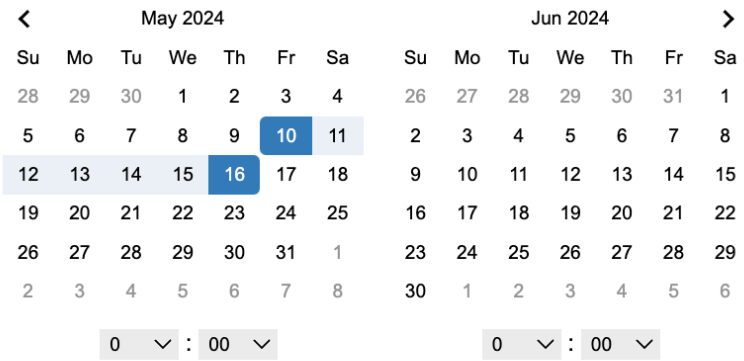
SDO/AIA\_131 2024-05-10 00:00:44 UT

2024-05-10 00:00:44

ISWA Sync

2024-05-10 00:00:00 → 2024-05-16 00:00:00 2024-05-10 00:00:00

- Last 1 hour
- Last 3 hours
- Last 6 hours
- Last 24 hours
- Last 7 Days
- Last 30 Days

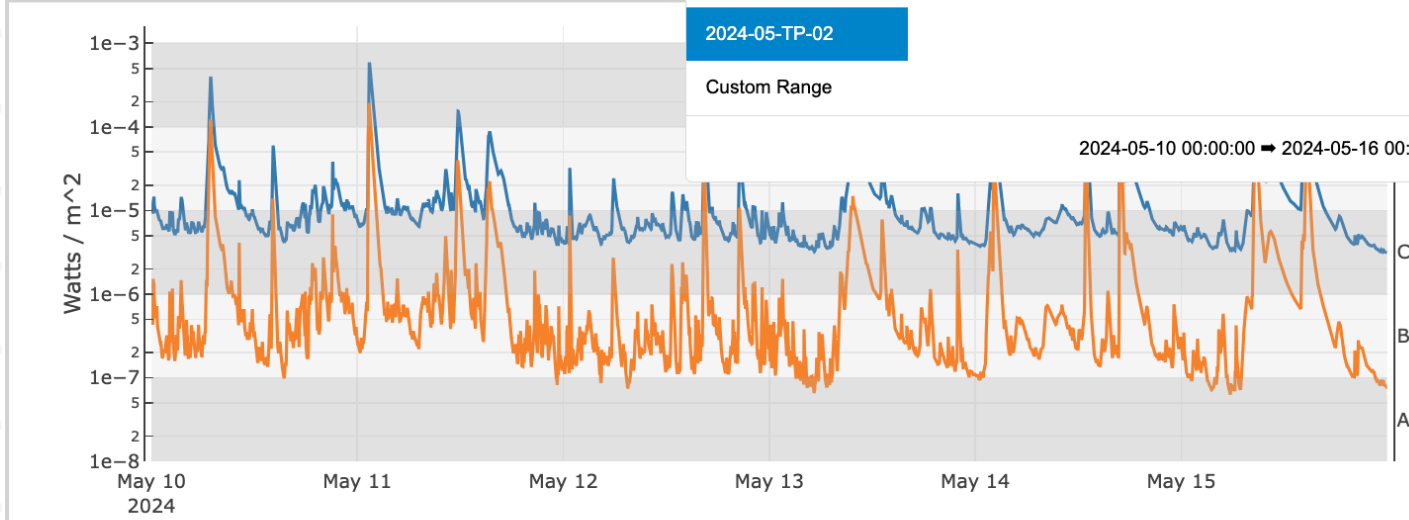


- 2023-03-TP-01
- 2023-04-TP-01
- 2023-11-TP-01
- 2024-05-TP-02**
- Custom Range

2024-05-10 00:00:00 → 2024-05-16 00:00:00

Cancel Apply

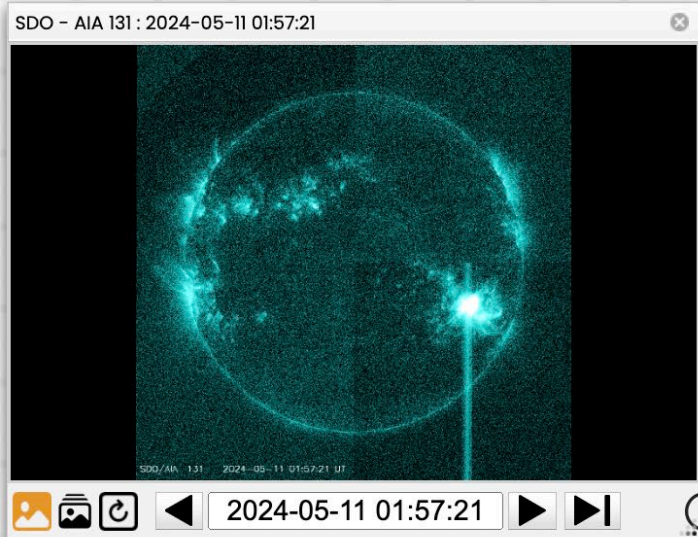
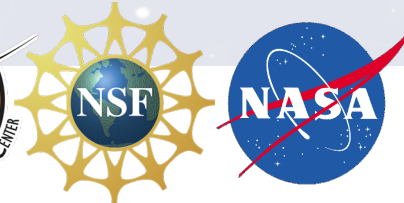
GOES Primary X-ray Flux



2024-05-10 - 2024-05-16

Settings



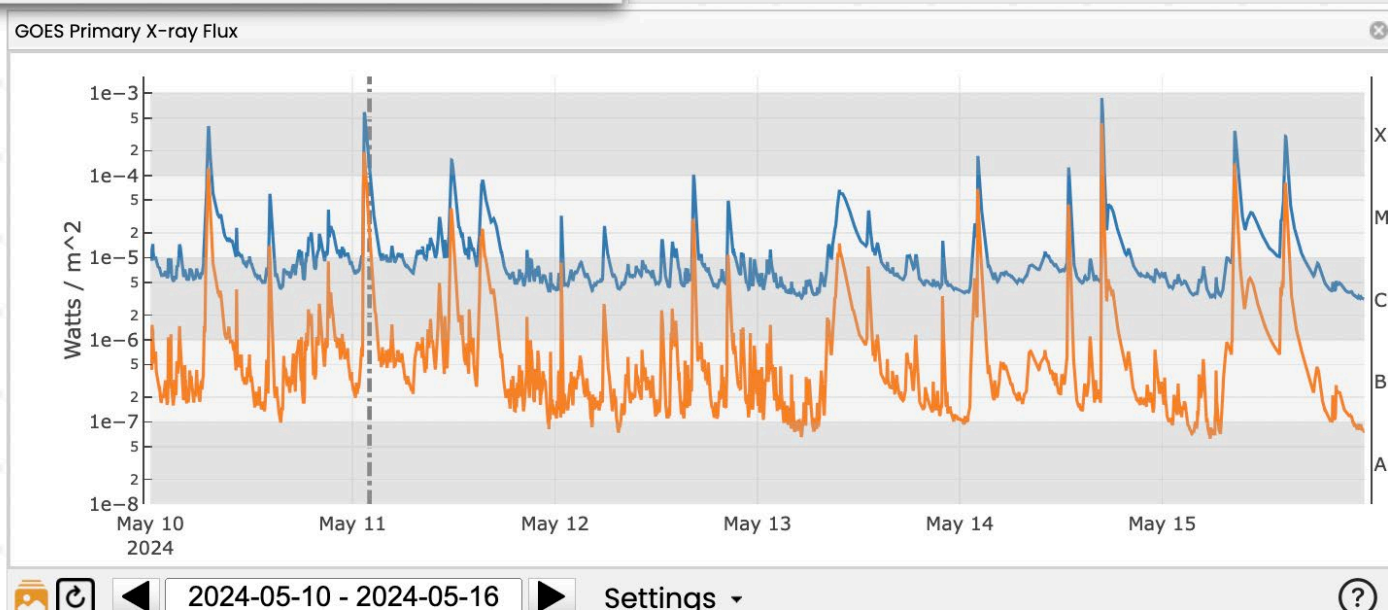


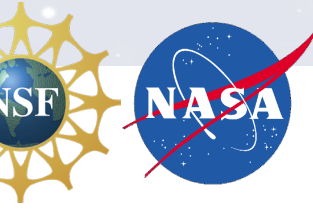
ISWA Sync

2024-05-10 00:00:00 → 2024-05-16 00:00:00 2024-05-11 02:00:00

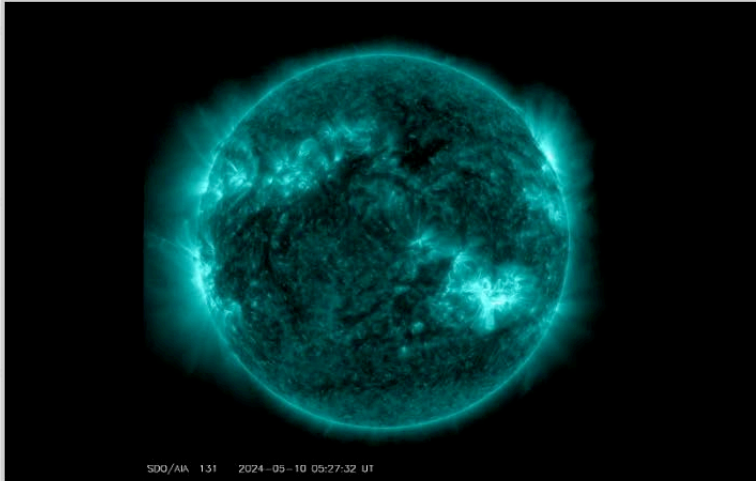
- SDO - AIA 131
- GOES Primary X-ray Flux

2hr steps 1x





SDO - AIA 131 : 2024-05-10 05:27:32



SDO/AIA 131 2024-05-10 05:27:32 UT



2024-05-10 05:27:32

ISWA Sync

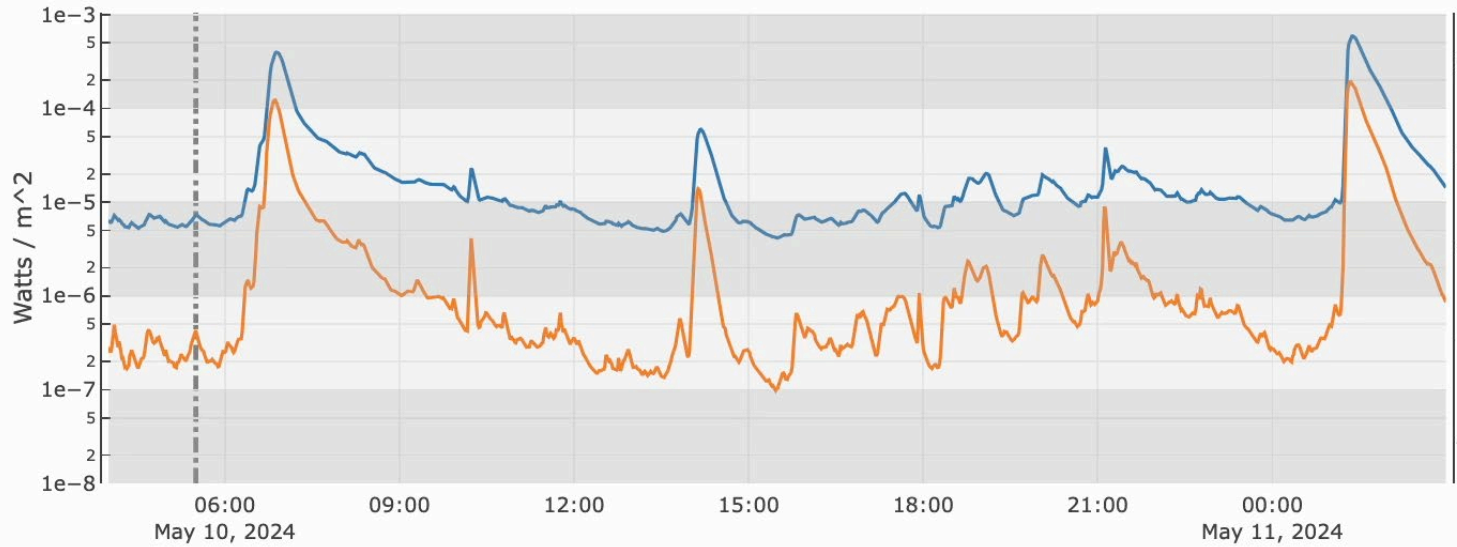
2024-05-10 04:00:00 → 2024-05-11 03:00:00 2024-05-10 05:30:00

SDO - AIA 131

GOES Primary X-ray Flux

30m steps 1x

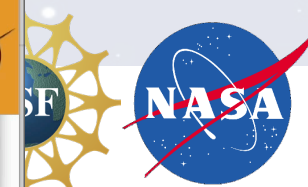
GOES Primary X-ray Flux



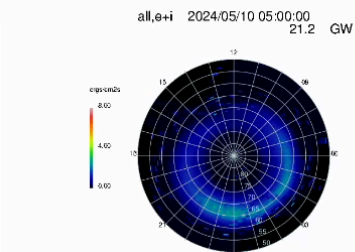
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Settings

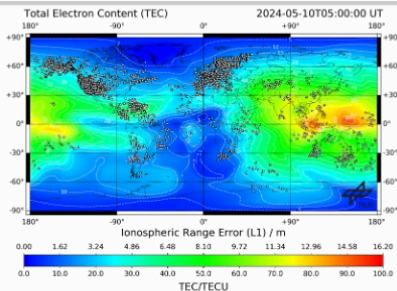




Magnetic Coordinates Electrons+Ion



IMPC TEC Map : 2024-05-10 05:00:00



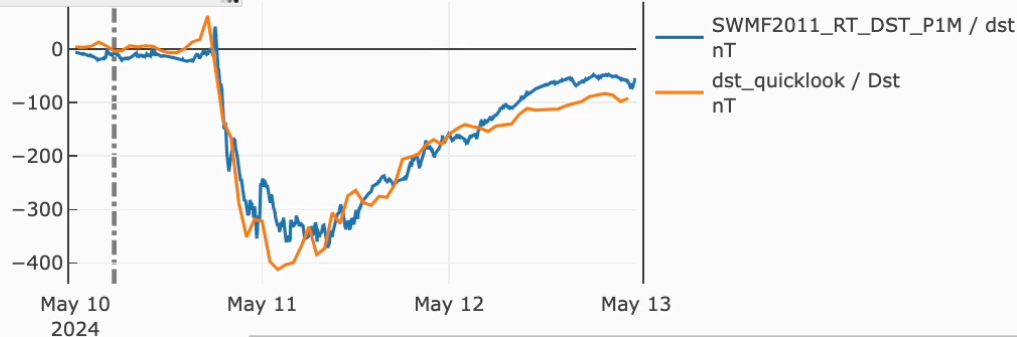
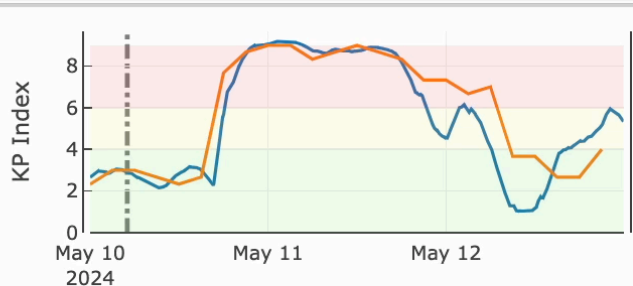
2024-05-10 00:00:00 → 2024-05-13 00:00:00 2024-05-10 05:00:00

Ovation Prime : Magnetic Coordinates / Electrons+Ion

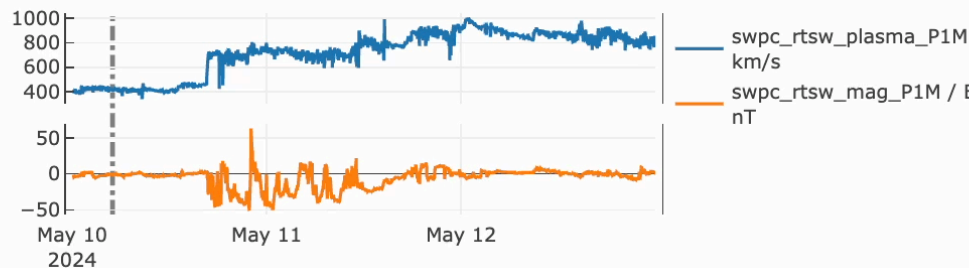
SWMF2011+RCM 3-Day Magnetopause Standoff Distance

1hr steps 1/2x

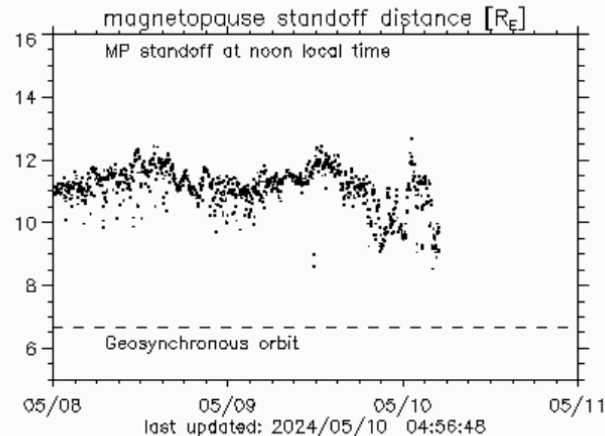
Observed Kp vs. Predicted Kp



Timeline Builder



SWMF2011+RCM 3-Day Magnetopause Standoff Distance : 2024-05-10 04:56:48



2024-05-10 - 2024-05-13

Add Parameter Parameters Sett

2024-05-10 04:56:48

# Open validation

- ✓ **Evaluations of model science quality**
  - How well is model output consistent with initial assumptions?
  - Is this feature real or a numerical artifact?
  - How well can models reproduce heliophysics phenomena?
  - Can similar models produce similar results (open reproducibility experiments)?
- ✓ **Demonstration of potential of new models to improve operational capabilities**
- ✓ Support community-wide model validation campaigns (SHINE, GEM, CEDAR, ISWAT)
- ✓ Geospace Storm World Modeling Challenge (part of HBY)
- ✓ **CAMEL**: open interactive online display system for model performance evaluations and tracking progress over-time
- ✓ Pre-Event Forecasting Methods **Scoreboards**



Comprehensive Assessment of Models and Events based on Library tools

Database (with API and GitHub access) of time series, derived from model output and observational data, for all validation studies..

## Thermosphere Neutral Density Campaign

- 2002-09-TP-03 Dst (min) = -181 CHA GRA GRB GOC SWA GFO ?
- 2003-11-TP-01 Dst (min) = -422 CHA GRA GRB GOC SWA GFO ?
- 2005-01-TP-02 Dst (min) = -93 CHA GRA GRB GOC SWA GFO ?
- 2005-01-TP-03 Dst (min.) = -66 CHA GRA GRB GOC SWA GFO ?
- 2005-05-TP-02 Dst (min.) = -247 CHA GRA GRB GOC SWA GFO ?
- 2005-05-TP-03 Dst (min) = -113 GRA GRB GOC SWA GFO ?
- 2005-06-TP-01 Dst (min) = -106 GRA GRB GOC SWA GFO ?
- 2005-07-TP-01 Dst (min.) = -92 CHA GRA GRB GOC SWA GFO ?
- 2005-08-TP-01 Dst (min) = -184 CHA GRA GRB GOC SWA GFO ?
- 2005-09-TP-01 Dst (min) = -80 CHA GRA GRB GOC SWA GFO ?
- 2005-10-TP-01 Dst (min.) = -50 CHA GRA GRB GOC SWA GFO ?
- 2006-12-TP-01 Dst (min) = -162 CHA GRA GRB GOC SWA GFO ?
- 2011-08-TP-01 Dst (min) = -115 GOC GRA GRB SWA GFO ?
- 2011-09-TP-01 Dst (min) = -118 GRA GRB GOC SWA GFO ?
- 2011-10-TP-01 Dst (min) = -147 GOC GRA GRB SWA GFO ?
- 2012-03-TP-01 Dst (min.) = -44 GOC GRA GRB SWA GFO ?
- 2012-04-TP-01 Dst (min) = -120 GOC GRA GRB SWA GFO ?
- 2012-09-TP-01 Dst (min) = -122 GOC GRA GRB SWA GFO ?
- 2012-11-TP-01 Dst (min) = -108 GOC GRA GRB SWA GFO ?
- 2013-03-TP-01 Dst (min.) = -132 GOC GRA GRB SWA GFO ?
- 2013-05-TP-01 Dst (min) = -124 GOC GRA GRB SWA GFO ?
- 2013-06-TP-01 Dst (min) = -102 GOC GRA GRB SWA GFO ?
- 2014-09-TP-01 Dst (min) = -88 GRA GRB GOC SWA GFO ?
- 2015-03-TP-01 Dst (min) = -234 GRA GRB GOC SWA GFO ?
- 2015-04-TP-02 Dst (min) = -88 GRA GRB GOC SWA GFO ?
- 2016-03-TP-01 Dst (min) = -99 GRA GRB GOC SWA GFO ?
- 2016-10-TP-01 Dst (min) = -110 GRA GRB GOC SWA GFO ?
- 2021-10-TP-01 Dst (min.) = -65 GFO ?
- 2021-11-TP-01 Dst (min.) = -105 GFO ?
- 2022-02-TP-01 Dst (min.) = -66 GFO ?

### Solutions to Score

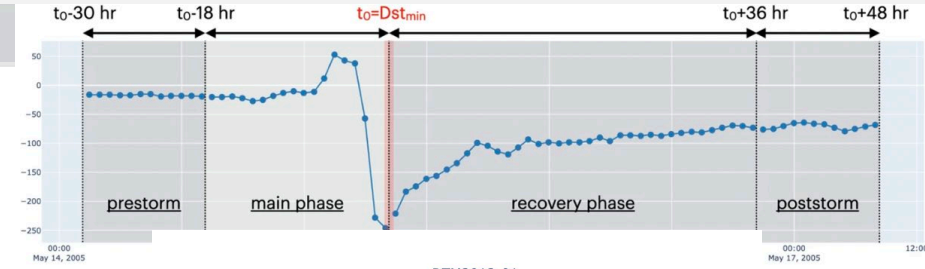
- CTIPe-01 ?
- DTM2013-01 ?
- DTM2020\_operational-01 ?
- JB2008-01 ?
- MSIS20-01 ?
- MSISE00-01 ?
- TIEGCM-Heelis-01 ?
- TIEGCM-Heelis-02 ?
- TIEGCM-Weimer-01 ?
- TIEGCM-Weimer-02 ?
- WACCMX-Heelis-01 ?
- WAMPIE-01 ?

### Observations

- CHA CHAMP ?
- GOC GOCE ?
- GRA GRACE\_A ?
- GRB GRACE\_B ?
- GFO GRACE\_FO ?
- SWA SWARM\_A ?

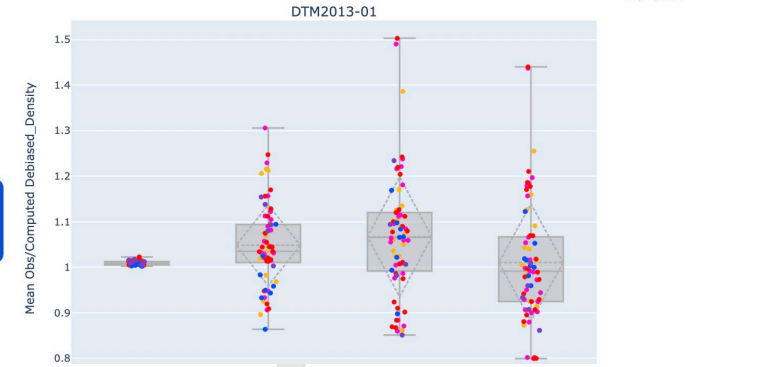
### Phases to Score ?

- prestorm phase
- main phase
- recovery phase
- poststorm phase



[CAMEL Validation Skill Scores Library Code on NASA GitHub →](#)

[Public CAMEL Data Git Repo →](#)



### Parameter to Score

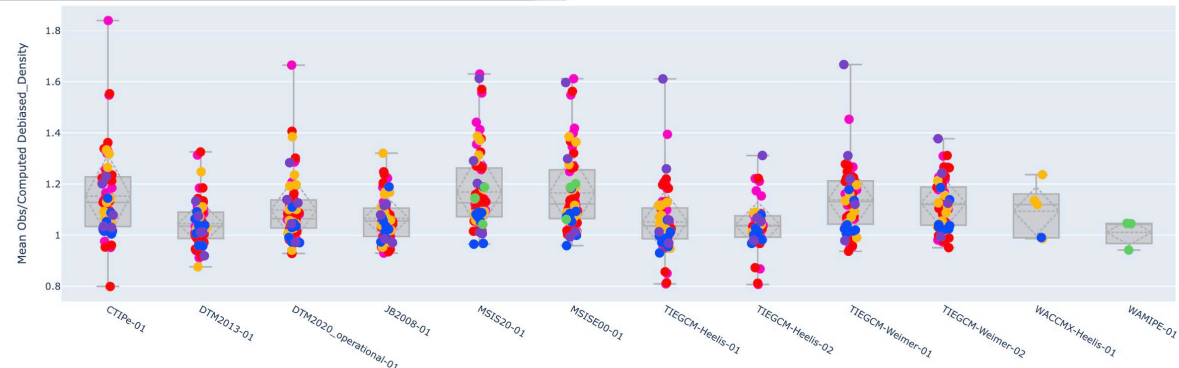
Normalized Density(g/cm<sup>3</sup>) x

### Skillscore Type

Standard Deviation Observed-To-Compute (O/C) De... x

### Skill Tables

[REFRESH SKILLS](#)



- GRACE\_A
- GRACE\_B
- CHAMP
- GOCE
- SWARM\_A
- GRACE\_FO

**Generate Skill Tables, Scorecards**

# CCMC Forecasting Methods Scoreboards



Flare  
Scoreboard



SEP  
Scoreboard



CME  
Scoreboard

- Scoreboards **collect and display** forecasts before the event is observed
- World-wide **ensemble** from research and operational models
- **Open participation** (forecasting technique registration in SPASE is required)
- Enables consistent **real-time** comparisons of various operational and research forecasts.
- **Demonstrates** operational potential of new capabilities
- Front ends are **designed** to address user needs. Many models **run locally** at CCMC.
- Plans: Mars Scoreboards, Geomagnetic Storm Scoreboard, Solar Wind Scoreboard, Neutral Density Scoreboards, continuous validation platforms, decision-making tools

IMPLEMENTATION PLAN OF THE NATIONAL SPACE WEATHER STRATEGY AND ACTION PLAN

2.5.7 Facilitate community-wide pre-event ensemble predictions. [NASA]



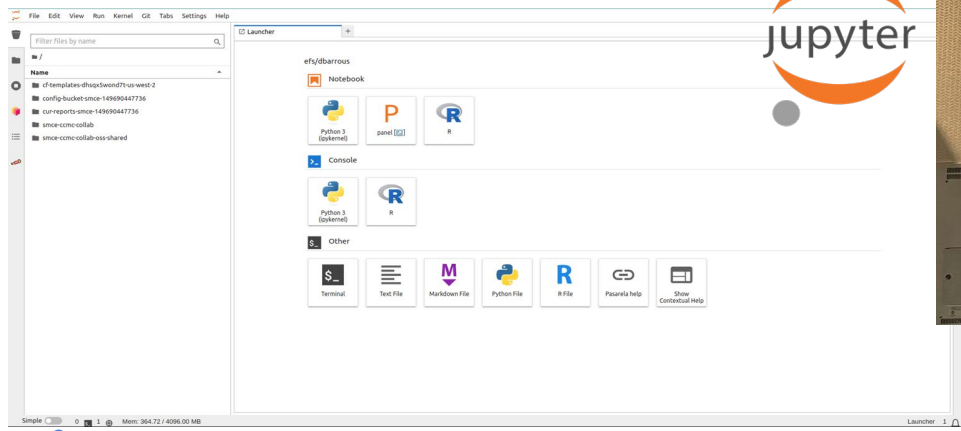
# Open development

- ✓ Distribution of source code: with **explicit approval** from developers
- ✓ **Links to public repositories** from CCMC model catalog
- ✓ CCMC-developed software are **NASA open source**
- ✓ Maintain **shared environments** on AWS cloud and NASA HECC for **collaborative on-boarding and improvements**
- ✓ Modelers are requesting CCMC to lead in introducing standards and guidance on **open science best practices**
- ✓ Ready to support **community modeling** to maximize return on an open source policy
- ✓ Working with developers on strategy for **preservation of valuable legacy codes**
- ✓ Created Open Science Studio (OSS) platform to support **hands-on training to compile and run models.**

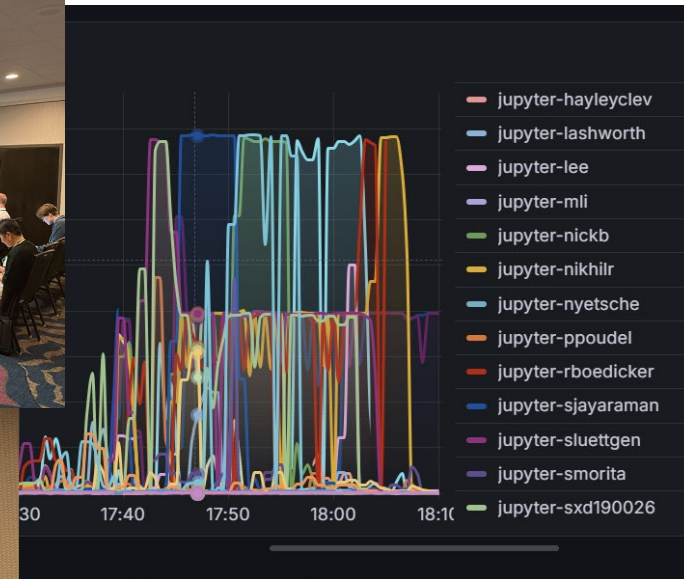
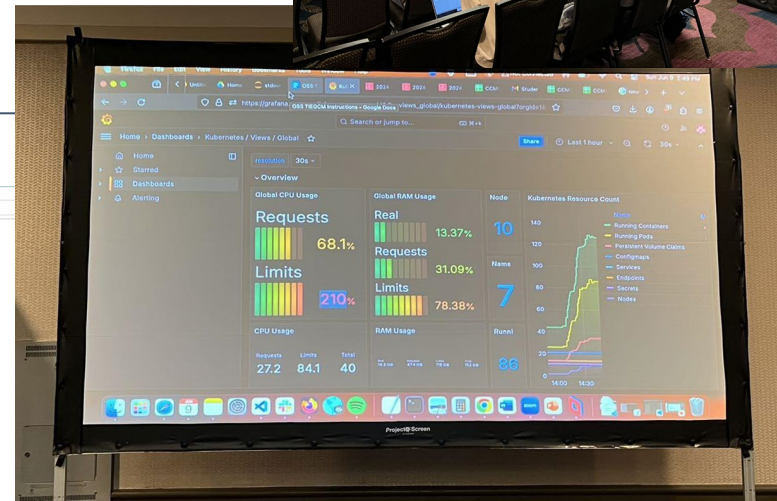
# Model demonstration with participants hands-on training session provided by CCMC

- Introduced at the CCMC/MAGE TIEGCM model demo at 2024 CEDAR Workshop Student Day
- Used Open Science Studio (OSS) platform to support 30+ students concurrently

 OSS by Navteca



 **kubernetes**  **KEYCLOAK**

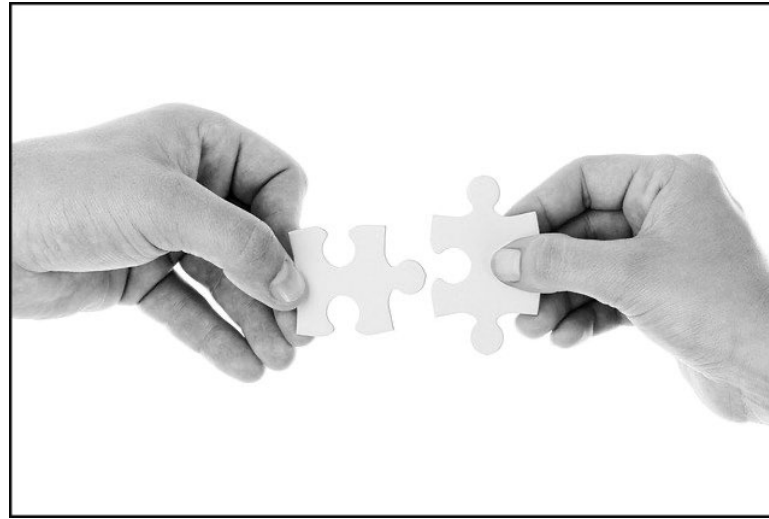


Also provided real-time IT resource monitoring for instructors to monitor students usage

Participants **gained practical experience** in compiling the model, building the input files, running the model and finally visualizing the output.



# Open Collaboration



Join forces with open mind and open heart

***TRUST***

***INFRASTRUCTURE***

***EXCITEMENT***



## CCMC Team, Modeling Community and Open Science

- Organized community workshop on open science in modeling (June, 2024)
- Initiated **Heliophysics Open Modeling Environment (HOME)** – bottom-up initiative

*HOME for numerical experiments*

*HOME for collaborative advancing open science in modeling*


*HOME for modeling community (models, modelers and users) and community modeling*

CCMC role:      **ENABLE**                      **SUPPORT**                      **FACILITATE**

# International Space Weather Action Teams

Platform for self-organized **open collaborations**

**COSPAR  
ISWAT**

<i>S: Space weather origins at the Sun</i>	<i>H: Heliosphere variability</i>	<i>G: Coupled geospace system</i>	<i>Impacts</i>
 <p><b>S1: Long-term solar variability</b></p> <p><b>S2: Ambient solar magnetic field, heating &amp; spectral irradiance</b></p> <p><b>S3: Solar eruptions</b></p>	<p><b>H1: Heliospheric magnetic field and solar wind</b></p> <p><b>H2: CME structure, evolution and propagation through heliosphere</b></p> <p><b>H3: Radiation environment in heliosphere</b></p> <p><b>H4: Space weather at other planets/planetary bodies</b></p>	<p><b>G1: Geomagnetic environment</b></p> <p><b>G2a: Atmosphere variability</b></p> <p><b>G2b: Ionosphere variability</b></p> <p><b>G3: Near-Earth radiation &amp; plasma environment</b></p>	<p><i>Climate</i></p> <p><i>Electric power systems/GICs</i></p> <p><i>Satellite/debris drag</i></p> <p><i>Navigation/Communications</i></p> <p><i>(Aero)space assets functions</i></p> <p><i>Human exploration</i></p>
<p><b>Overarching Activities:</b></p> <p><i>O1: Assessment</i>                      <i>O2: Information Architecture &amp; Data Utilization</i></p> <p><i>O3: Innovative Solutions</i>        <i>O4: Education &amp; Outreach</i></p>			

<https://iswat-cospar.org>

**Action Teams** (*building blocks of ISWAT*) are organised into **ISWAT Clusters** by domains, phenomena, impact, or overarching activity.

**Status:** **62** Action Teams, **15** Clusters, **580+** active members, **50+** countries, **400+** affiliations.

## Working Meetings:

2020 (Florida, USA)

2022 (Coimbra, Portugal)

Mini-ISWAT@ESWW2023

Mini-ISWAT@ESWW2024

**Feb 10 – 14, 2025 (Florida, USA)**

- ISWAT is an effort multiplier. Maximise return on investments by national/regional programs



# Community-Driven Space Weather Roadmap:

*Where are we now? Where are we going? Where we want to be?*

- Set of two Roadmap Special Issues in COSPAR '*Advances in Space Research*'
  - *ASR-SI-1 : Science Research and Applications* – 35 papers
  - *ASR-SI-2 : Achievements and Future Goals* ~ 25 papers accepted
- ISWAT initiative formed the backbone for the Roadmap with
  - a set of science papers for *ASR-SI-1* coordinated by Action Team Leads
  - a set of review papers coordinated by Cluster Moderators.
- **Transparency in writing process:** titles, abstracts, paper outlines were available for the community for comments/contributions at ISWAT website.
- Everyone has opportunity to participate in this peer reviewed endeavor by submitting papers to Roadmap Special Issues and contributing to review papers.
- The Roadmap is planned to be a periodically updated living document



# Planning for new community-wide endeavors

ISWAT

- Mini-ISWAT at European Space Weather Week 2024:
  - 03 November 2024, Coimbra, Portugal
    - Clusters/Teams to self-organize and book slots
    - Planning for the full ISWAT in 2025
- Full week ISWAT Working Meeting:
  - 10-14 February 2025, Cape Canaveral, Florida, USA
    - Planning for new community-wide endeavors
    - Building off of COSPAR/ISWAT Roadmap efforts

