Community Coordinated Assessment and Rapid Implementation of Space Weather Analysis and Forecasting Capabilities

M. Kuznetsova & CCMC Team
CCMC Pioneered the Path from Research 2 Operations
The CCMC as a Hub for Collaborative Advancing of Space Weather Predictive Capability System

Research to advance understanding

Data

Models

Ingestion Assessment Dissemination

Operations at NOAA, DoD

Prototyping Services for NASA’s Missions
Expanding Collection Of Models at CCMC: > 80

Corona Heliosphere Magnetosphere

Magnetosphere

Inner Magnetosphere

Ionosphere/The thermosphere

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

Corona  Heliosphere  Magnetosphere  Inner Magnetosphere  Ionosphere/The  

dots
CCMC Web-Based Signature Services

Runs-on-Request System
An interactive system to serve advanced models to the international research community

• Support advancing knowledge and understanding
• Maximize return on investment into model development

Integrated Space Weather Analysis System (iSWA)
A system for real-time space environment monitoring, event analysis, education and training.

• Real-Time & Historical Model + Observational Data
• Actionable Products. Web Services
• User Configurable, Interactive Displays
Non-Linear Force Free Model

- Designed to study energy and helicity build up in flaring active regions.
- Input SDO/HMI vector magnetograms
- Cartesian grid version available for use now
  – http://ccmc.gsfc.nasa.gov/requests/SH/NLFF
- Spherical & Global Grid versions – soon (June/July)

Modelers: T. Asfaw, T. Weigelmann

CCMC: P. Macneice
New approaches to time evolving global photospheric field

1 – Time interpolating WSA output based on hourly GONG synoptic magnetograms (Odstrcil)
2 – ADAPT (Arge and Henney)

WSA-Enlil 2.8f is installed and is offered for Runs-on-Requests. Simulations with time-dependent magnetograms are evaluated and available for special requests. Real-time implementation is coming soon.
A new SWMF/AWSoM-R coronal model incorporates semi-analytical Threaded-Field-Line model for the low solar corona (1 – 1.1 Rs)

- Speed up coronal simulations on factor of 100
- To initiate CME: magnetic flux rope superimposed on the background.

**EEGGL**  Eruption Event Generator (Gibson & Low)

Use synoptic magnetograms to define location and orientation of CME flux rope.

Modeler: I. Sokolov, U. of Michigan

CCMC: A. Taktakishvili, R. Mullinix
Towards coupled heliosphere and SEP models

SEPMOD → EPREM
EPREM → SWMF: FLAMPA
EPREM → SWMF: Kota SEP

WSA-ENLIL+Cone → SEPMOD
WSA-ENLIL+Cone → EPREM
WSA-ENLIL+Cone → CORHEL

CorHEL → SWMF: AWSoM-R

Modelers: N. Arge, D. Odstrcil, J. Luhmann, J. Linker, N. Schwadron, M. Gorby, I. Sokolov
Coupled SEP modeling at the CCMC
WSA-Enlil+SEPMOD

CCMC is facilitating first steps to couple WSA-ENLIL with SEPMOD (with model developers D. Odstrcil and J. Luhmann)

SEPMOD at STEREO B

STB Test of Aug 2010 multishock SEP model w/ESP

CCMC: P. MacNeice, M.L. Mays
Coupled SEP modeling at the CCMC
WSA+Enlil+EPREM

CCMC is facilitating first steps to couple WSA-ENLIL with EPREM
(with model developers D. Odstrcil, N. Schwadron and M. Gorby)

CCMC: P. MacNeice, M.L. Mays
Connecting Space Environment to Space Weather Impacts: Radiation Effects

- **NOVICE**
  - Radiation effect code for spacecraft and/or component in complex geometries

- **NAIRAS** (Nowcast of Atmospheric Ionizing Radiation System)
  - Models and assesses radiation exposure levels for aviation from GCRs and SEPs

- **CARI-7**
  - Calculates radiation dose from GCRs received by airline passengers/crews

- **Badhwar-O’Neill (BON) 2014 GCR model**
  - Latest Badhwar-O’Neill model of Galactic Cosmic Rays

Modelers: M. Xapsos, C. Martens, K. Copeland, P. O’Neill, S. Golge

CCMC: Y. Zheng
Assessment, Metrics & Validation

Testing predictive capability before the event onset

Forecasting Methods
ScoreBoards

Examples:
CME Arrival Prediction
Storm onsets
Flare Forecasts
SEP Forecasts

Event-based M&V to trace model improvement

[2003] 10/27 - 10/30
[2006] 12/13 - 12/16
[2010] 04/04 - 04/07
[2011] 08/05 - 08/07

A list of events.
High quality data.
A library of metrics.
Simulate the same set of events over and over…

Examples:
TEC, Neutral density,
Auroral boundaries,
Ground magnetic perturbations dB/dt

Sanity check Toolkit for real-time runs

Sensitivity analysis to external drivers and internal parameters

Performance evaluation for extreme driving

Correlate forecasts with impacts
Testing Predictive Capabilities Before Event Onset

- Collecting and displaying event forecasts from multiple models & different sources in a **Scoreboard**
- Generate experimental international community-wide ensemble forecasts.
- Demonstrate operational potential to users.

**CME Scoreboard**
Lead: **L. Mays**, CCMC

**Flare Scoreboard**
Leads: **S. Murray**, Met Office
**A. Devos, J. Adries**, ROB

**SEP Scoreboard (planning)**
Leads: **M. Dierckxsens**, BIRA
**M. Marsh**, Met Office
CME Arrival Prediction Scoreboard

- Initiated in 2013
- There are currently **19 registered methods** predicting CME arrival time, including entries from the CCMC, Met Office, NOAA/SWPC, KSWC, ROB/SIDC
- Total CMEs in ScoreBoard: **108**


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<table>
<thead>
<tr>
<th>Predicted Shock Arrival Time</th>
<th>Difference (hrs)</th>
<th>Confidence (%)</th>
<th>Submitted On</th>
<th>Lead Time (hrs)</th>
<th>Predicted Geomagnetic Storm Parameter(s)</th>
<th>Method</th>
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<tr>
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<td>-0.98</td>
<td>90.0</td>
<td>2015-06-21T02:48:00-CME-001</td>
<td>31.55</td>
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<td>Other (SIDC)</td>
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<td>---</td>
<td>2015-06-22T01:00Z</td>
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<td>WSA-ENLIL + Cone (Met Office)</td>
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<td>2015-06-22T03:25Z</td>
<td>14.57</td>
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<td>WSA-ENLIL + Cone (GSFC SWRC)</td>
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<td>Ensemble WSA-ENLIL + Cone (GSFC SWRC)</td>
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<td>---</td>
<td>2015-06-22T15:23Z</td>
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<td>Max Kp Range: --- - 7.0</td>
<td>WSA-ENLIL + Cone (NOAA/SWPC)</td>
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<td>2015-06-22T19:48Z</td>
<td>1.82</td>
<td>97.5</td>
<td>---</td>
<td>---</td>
<td>Max Kp Range: 5.5 - 7.8</td>
<td>Average of all Methods</td>
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</table>
Flare Scoreboard: Ensemble Solar Flare Forecasts


Activity initiated in Nov 2014

7 models, more are coming

Beta live display on iSWA
Assessment, Metrics & Validation are Challenging Research Tasks

Example of discouraging & misleading Skill Scores

Metric study: Ground magnetic field perturbations
Event: October 29th, 2003 06 00 UT - October 30th, 06 00 UT

Negative Prediction Efficiency (based on RMS): -0.2
(model performance is worse than “no perturbations” benchmark)

Metrics should reflect state-of-the-art and quantify useful information that can be derived from the model
Example of Skill Score selection to validate model ability to reproduce ground magnetic perturbations dB/dt
Examples of M&V Challenges: Biases in TEC Measurements

- Difference between GPS TEC data sets

- TEC – TEC_quiet

What is the best quiet time reference?

- TEC of one day prior to storm events
- Median for the 30 days prior to storms
Ionospheric foF2 Critical Frequency
at Millstone Hill
March 2013 Storm (doy 076)

red: foF2 – foF2_quiet (doy 075)

blue: foF2 – foF2_quiet
(30-day median)
Outlook

• CCMC is
  • a fast response unit to emerging space weather community needs.
  • a hub for collaborative advancing of space weather prediction capabilities
  • an asset and resource for addressing objectives identified in National Space Weather Action Plan
Supplementary material
Regional TEC over North American Sector
CTIPe driven by Enlil Cone Model Ensemble Forecasts

low lat (0° < lat < 25°)  middle lat (25° < lat < 50°)

IMF orientation uncertainty impact on regional TEC at different latitudes.

March, 2013

Modeler: T. Fuller-Rowell

CCMC: J-S. Shim
Regional TEC over North American Sector
Driven by Ensemble Enlil (Mean RT & Best Fit)

March, 2013

Modeler: T. Fuller-Rowell

CCMC: J-S. Shim
SRPM Irradiance Model

Status at CCMC

• Currently output EUV spectra between 1.8 and 200 nm with 1nm resolution
  – Most variable part of spectrum
• Posted at ISWA daily
  – iswa.gsfc.nasa.gov/iswa/iSWA.html
• Will extend to full spectrum in early 2016.
• Long term goals
  – Solar
    • ROR use – user supplied masks, customized resolution runs, archival runs etc
  – Stellar
    • Build ROR-like facility to generate irradiance spectra for use in modeling exoplanet atmospheres
    • Initially for solar like stars only
    • Later to support user modification to $\rho(r)$, $T(r)$ profiles of different feature types
Kameleon
Metadata, Standardization, Access, Interpolation

Goal: To facilitate access to space weather models hosted at the CCMC and enable scientific discovery.
Objectives:

• Address a need for a hub for the community to easily search and obtain simulations data for their own research
• Enable easy model-data comparisons
• Enable easy linkage between different CCMC databases (RoR, iSWA, DONKI, ScoreBoard)
• Enable community to build a wide range of tools and front-end applications utilizing simulation data from CCMC

Status:

• Database design based on SPASE and IMPEX
• Web interface allowing to enter model information
• Web service interface allowing applications to obtain model information (JSON format)