Community-wide space weather Scoreboards: Research assessment of real-time forecasting models and techniques

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

ESWW13 Thursday Nov17th, 15:00 - 16:30, Ridderzaal

Organizers:
M. Leila Mays (CUA/GSFC)
Mark Dierckxsens (BIRA-IASB)
Mike Marsh (UK Met Office)
Sophie Murray (TCD)
Jesse Andries (ROB)
Shaun Bloomfield (Northumbria University)
Jordan Guerra (TCD)
Masha Kuznetsova (GSFC)
Agenda

- **Introduction and general overview of agenda items** (Leila)
- **CME Scoreboard** (Leila Mays):
  - **Demo of CME Scoreboard**
  - **Initial CME scoreboard verification from the UK Met Office** (Suzy Bingham)
  - **Discussion of CME arrival time validation techniques** (Leila)
  - Open to the floor for further ideas
- **Flare Scoreboard** (Sophie Murray):
  - Brief introduction to the [flare scoreboard and demo](http://ccmc.gsfc.nasa.gov/challenges/scoreboards/esww13_wm.php) (Sophie)
  - Discussion regarding [mock-up of time-series display](http://ccmc.gsfc.nasa.gov/challenges/scoreboards/esww13_wm.php) (Leila)
  - Validation discussion (Sophie)
  - Open to the floor for further ideas (Sophie)
  - Mention of relevant items coming up in the Forecaster Forum (after coffee break)
- **SEP Scoreboard** (Mark Dierckxsens):
  - **General introduction**: *What is the scoreboard, how to register, how to submit forecast* (Mark)
  - XML Schema for submission of forecasts; quantities and observations to compare (Mark)
  - **Comparisons using historic SEP events** (Mark)
  - **Verification techniques: metrics, skill scores,...** (Mark)
  - **Linking flare & CME forecasts with SEP forecasts through scoreboard** (Leila)
Introduction to 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 CCMC Challenges.
- 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


- 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.
SEP Scoreboard


- Planning for the SEP Scoreboard has started (led by BIRA-IASB and the 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:
  - Continuous/Probabilistic
  - Solar Event Triggered
  - Non Near Real-Time

- 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 a set of historical events for a SEP Challenge” with different models, particularly those physics-based models in the third category that are not ready or relevant for real-time modeling.
CME Arrival Time Scoreboard

The CME scoreboard is a research-based forecasting methods validation activity which provides a central location for the community to:

- submit their forecast in real-time
- quickly view all forecasts at once in real-time
- compare forecasting methods when the event has arrived
- view the average of all forecasts for each event (ensemble).

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

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

Participation from the community:

- All prediction models and methods are welcome from the world-wide research community (currently 19 methods are registered)
- Users submit their predictions for ongoing CME events, listing their method assumptions and input parameters
- Researchers can then view all of the predictions, modeling details, and the ensemble average of all predicted arrival times submitted by participants
Community predictions for the 5 Nov 2016 CME

Please join! All prediction methods are welcome and all are encouraged to participate.

### CME: 2016-11-05T04:48:00-CME-001

**Actual Shock Arrival Time:** 2016-11-05T04:48:00Z

**Observed Geomagnetic Storm Parameters:**

- **CME Note:** Filament Eruption off the northern Hemisphere giving a very wide-angle partial halo. Another CME came off the farside and eastern limb at a similar time. Evident in SOHO and STEREO imagery after 05:0200UTC.

<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>
<th>Submitted By</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016-11-08T19:00Z (-12.0h, +12.0h)</td>
<td>-10.47</td>
<td>75.0</td>
<td>2016-11-06T11:10Z</td>
<td>66.30</td>
<td>Max Kp Range: 4.0 - 6.0</td>
<td>Other (SIDC)</td>
<td>Leila Mays (GSFC)</td>
</tr>
<tr>
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<td>-13.47</td>
<td>--</td>
<td>2016-11-05T17:52Z</td>
<td>83.60</td>
<td>--</td>
<td>WSA-ENLIL + Cone (GSFC SWRC)</td>
<td>Karin Muglach (GSFC)</td>
</tr>
<tr>
<td>2016-11-08T11:15Z</td>
<td>-18.22</td>
<td>57.5</td>
<td>--</td>
<td>--</td>
<td>Max Kp Range: 3.5 - 5.33333</td>
<td>Average of all Methods</td>
<td>Auto Generated (CCMC)</td>
</tr>
<tr>
<td>2016-11-08T10:00Z</td>
<td>-19.47</td>
<td>--</td>
<td>2016-11-06T00:30Z</td>
<td>76.97</td>
<td>Max Kp Range: -- - 5.0</td>
<td>WSA-ENLIL + Cone (NOAA/SWPC)</td>
<td>Barbara Thompson (GSFC)</td>
</tr>
<tr>
<td>2016-11-08T00:00Z (-9.0h, +6.0h)</td>
<td>-29.47</td>
<td>40.0</td>
<td>2016-11-06T01:00Z</td>
<td>76.47</td>
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<td>Met Office (Met Office)</td>
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</tbody>
</table>

### CME: 2016-11-05T04:48:00-CME-001

**Actual Shock Arrival Time:** 2016-11-09T05:28Z

**Observed Geomagnetic Storm Parameters:**

- **CME Note:** Filament Eruption off the northern Hemisphere giving a very wide-angle partial halo. Another CME came off the farside and eastern limb at a similar time. Evident in SOHO and STEREO imagery after 05:0200UTC.

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</table>

Community predictions for the January 7, 2014 CME (X1.2 flare):

15 submissions
Average of all submissions: 12 hours early, Kp geomagnetic index 6 to 7.6

Please join! All prediction methods are welcome and all are encouraged to participate. There are currently 19 registered models.

http://kauai.ccmc.gsfc.nasa.gov/CMEscoreboard
CME ScoreBoard

CME arrival time predictions from the research community:
The CME Scoreboard (developed at the Community Coordinated Modeling Center, CCMC) is a research-based forecasting methods validation activity which provides a central location for the community to:

- submit their forecast in real-time
- quickly view all forecasts at once in real-time
- compare forecasting methods when the event has arrived

Using this system:

- Anyone can view prediction tables
- Users can enter in your CME shock arrival time forecast after logging in:
  - Registered Users: Begin by finding your CME under the "Active CMEs" section, then click "Add Prediction" and select your forecasting "Method Type" from the list.
  - Power Users: If you do not see your CME listed under the "Active CMEs" section, click "Add CME" to get started (Click here to request power user privileges). To enter the actual CME shock arrival time, click "Edit CME" after you are done entering your prediction(s).
- Click here to see a list of registered methods. If you would like to register your prediction method, please send an email to M. Leila Mays or Yihua Zheng with your model/technique details.
- Click here for more detailed instructions.

http://kauai.ccmc.gsfc.nasa.gov/CMEscoreboard
Anyone can view predictions, please register to submit predictions.
Begin by clicking Add Prediction under the "Active CMEs" section and select your forecasting "Method Type" from the list. While logged in, if you do not see any CMEs listed under the "Active CMEs" section, click Add CME to get started.

Using this system:

- Anyone can view prediction tables
- Users can enter in your CME shock arrival time forecast after logging in:
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Active CMEs:

Note: If you can't find your CME below, please click Add CME to add your CME. To enter the actual CME shock arrival time, click "Edit CME" after you are done entering your prediction(s).

http://kauai.ccmc.gsfc.nasa.gov/CMEscoreboard
Prediction Form for CME (2014-01-01T00:00:00-CME-001)

Enter submission time in format (yyyy-MM-dd'T'HH:mm'Z' i.e. 2012-07-12T16:52Z):

Method Type (details):

Prediction notes: (Please include all initial conditions/parameters used in your prediction)

Enter predicted CME shock arrival time in format (yyyy-MM-dd'T'HH:mm'Z' i.e. 2012-07-12T16:52Z):

Positive Error Bar in hours (optional):
Negative Error Bar in hours (optional):
Kp Range Lower Limit (optional):
Kp Range Upper Limit (optional):
Dst min. in nT (optional):
Dst min. time in format (yyyy-MM-dd'T'HH:mm'Z' i.e. 2012-07-12T16:52Z) (optional):
CME Arrival Time Scoreboard

Suggested improvements coming soon:
• Automatic forecast submission via an XML file
• Mailing list that notifies users when a new CME has been added to the scoreboard
• Separate geomagnetic storm scoreboard that can link to CME scoreboard

Future plans:
• Showing data in table in plot form
• Automatic skill score calculations
• Quality factor for confidence in observed ICME associated shock arrival
• Quality factor for confidence in linking observed ICME arrival with CME in coronagraph
• Your ideas?

http://kauai.ccmc.gsfc.nasa.gov/CMEscoreboard
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Discussion on CME arrival time validation techniques
CME Arrival Time Error Validation Examples

See poster by A. Wold on Friday morning.
(b) Prediction error relative to CME transit time and input speed

![Graph showing prediction error relative to CME transit time and input speed. The graph indicates that the mean prediction error is approximately -0.08%.](image)
Assessment: Confidence (likelihood) in CME arrival

CME Arrival: Reliability Diagram of 52 Ensembles

- Example reliability diagram for CCMC/SWRC arrival time forecasts
- Underforecasting in the forecast bins between 40-80%
- Slightly overforecasting in the 80-100% forecast bins

Need to improve confidence in CME arrival forecast:
- Consider better way of translating CME “impact parameter” into probability that the CME will arrive which more accurately represents head-on vs. grazing impacts (and the ranges in between)
Likelihood of CME arrival forecast verification: Brier Score

Using the forecast probability about the likelihood that the CME will arrive submitted on the scoreboard.

A method defining the mean squared probability forecast errors is the Brier Score:

\[ BS = \frac{1}{N} \sum_{i=1}^{N} (p_i - o_i)^2 \]

\( N = \) number of events,
\( p_i = \) forecast probability of occurrence for event \( i \),
\( o_i = 1 \) if the event was observed to occur and 0 if it did not.

Ranges from 0 to 1, with 0 being a perfect forecast.

The Brier Skill Score (BSS) is the Brier score relative to climatology

Note: confidence intervals should be computed for verification scores
Simulated vs. Observed CME Parameters

The difference from different observation data can affect the results. For example, the difference of $V_{\text{max}}$ from OMNI and ACE is $>$200 km/s for 3 CMEs. The correlation for $N_{p\text{max}}$ is weaker if using ACE.

In several cases where the CME $V_{\text{max}}$ is overestimated, there are interactions of multiple CMEs.

Using the fixed parameters (a6b1), the $V_{\text{max}}$ and $N_{p\text{max}}$ are underestimated. They are overestimated in the case of self-adjusted parameters (ace3b).

Similar trends are found for the correlations of mean values of CME parameters. The mean temperature are overestimated in both settings.

From Lan Jian
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Display mock-ups
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 the Sun and will be dynamically paired with a graph of flare probability vs. time (coming soon).
## SEP Scoreboard

Display ideas

### Forecasts: 2016-11-03 00:00 + 24 hours

<table>
<thead>
<tr>
<th></th>
<th>E &gt; 5 MeV</th>
<th>E &gt; 10 MeV</th>
<th>E &gt; 60 MeV</th>
<th>E &gt; 100 MeV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model AAA</strong></td>
<td>12%</td>
<td>5%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt; 10 pfu</td>
<td>&gt; 5 pfu</td>
<td>&gt; 1 pfu</td>
<td></td>
</tr>
<tr>
<td><strong>Model BBB</strong></td>
<td>30%</td>
<td>20%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt; 10 pfu</td>
<td>&gt; 5 pfu</td>
<td>&gt; 1 pfu</td>
<td></td>
</tr>
<tr>
<td><strong>Model CCC</strong></td>
<td>100%</td>
<td>0%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt; 10 pfu</td>
<td>&gt; 5 pfu</td>
<td>&gt; 1 pfu</td>
<td></td>
</tr>
<tr>
<td><strong>Averages</strong></td>
<td>30%</td>
<td>82%</td>
<td>2.5%</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>&gt; 10 pfu</td>
<td>&gt; 5 pfu</td>
<td>&gt; 1 pfu</td>
<td></td>
</tr>
</tbody>
</table>

### All Clear Forecasts

<table>
<thead>
<tr>
<th>Model DDD</th>
<th>All Clear</th>
<th>All Clear</th>
<th>All Clear</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&gt; 10 pfu</td>
<td>&gt; 5 pfu</td>
<td>&gt; 1 pfu</td>
</tr>
</tbody>
</table>

### Proton Flux Profiles Forecasts

**Probability heat map at a single time**

**Predicted proton flux time-series**
### SEP Scoreboard

#### Display ideas

**Probability heat map at a single time**

**Probability time-series**

<table>
<thead>
<tr>
<th>Forecasts: 2016-11-06 00:00 + 24 hours</th>
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</thead>
<tbody>
<tr>
<td>E &gt; 5 MeV</td>
</tr>
<tr>
<td>Model AAA</td>
</tr>
<tr>
<td>Model BBB</td>
</tr>
<tr>
<td>Model CCC</td>
</tr>
</tbody>
</table>

Averages:
- 30% > 20 pfu
- 82% > 10 pfu
- 2.5% > 5 pfu
- 0% > 1 pfu

---

**SEP Probability Forecasts: 2016-11-03 00:00 + 24 hours vs issue time**

- Model AAA > 10 mEV
- Model AAA > 60 mEV
- Model AAA > 100 mEV
- Model BBB > 5 mEV
- Model BBB > 10 mEV
- Model CCC > 1 mEV
- Model CCC > 10 mEV
- Model CCC > 60 mEV
- Model DDD > 10 mEV
- Model DDD > 60 mEV
- Model DDD > 100 mEV

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

<table>
<thead>
<tr>
<th>Date/Time</th>
<th>Event Type</th>
<th>Location</th>
<th>NOAA Kp</th>
</tr>
</thead>
<tbody>
<tr>
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<td>FLR-001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2015-03-16T07:36:00</td>
<td>SEP-001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2015-03-17T04:05:00</td>
<td>IPS-001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2015-03-17T06:00</td>
<td>GST-001</td>
<td></td>
<td></td>
</tr>
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</table>

**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 flaring, bright post-flare arcade later in AR 2297

Submitted on 2015-03-15T14:17Z by Karin Mullach
Workshop announcement
Assessment of Space Weather Development: Understanding, Operational Readiness, Forecasting Skills.

When: April 3-7, 2017

Where: TBD (near KSC, Florida?)

What: Assess current capabilities based on Event-based World Challenges & ScoreBoards. Agree on metrics, metadata. Identify a path forward.

Hands-on working groups. Discussions. Deliverables.