CCMC/SWRC: Goals & Functions, Procedures, New Initiatives

Masha Kuznetsova and the CCMC/SWRC Team

SpxWx COW
March 28-29, 2012
Outline

- CCMC: overview
  - Evolution to current capabilities
- SWRC goals, functions & services
  - Research-based SWx prototyping
  - SWx services for NASA user
- Operational procedures
- Model validation
- New initiatives
…a multi-agency partnership to enable, support and perform the research and development for next generation of space science and space weather models

- Established in 2000
- Revolutionary step in space weather program evolution
- Changed the way how state-of-the-art space weather and space science models are utilized in research
- Paved the way for progress in space science modeling into space weather operations.
Community Coordinated Modeling Center

Models are one of the key elements of space weather forecasting.

Unique collection of state-of-the-art models

Facilitate Community Research

Support Research to Ops Transition

.. with world-wide community involvement
Runs-on-Request Service

http://ccmc.gsfc.nasa.gov

- Serves models to the international research community through web-based interactive Runs-on-Request system:
  - User-configurable input parameters and model settings.
  - Sophisticated on-line visualization and analysis tools.
  - Simulation archive
- Valuable and highly utilized resource:
  - 7000 total, ~1800 last year, ~50 average per week
  - Hundreds publications/presentations/reports
- Maximize return on investments into model development
- Models used and tested by the entire community (digest broad range of inputs).
- Automated operational system (since 2001).
Running for years:
- SWMF/Magnetosphere (since 2002)
- WSA-Enlil background solar wind
- WSA-Enlil cone model (CME prediction)
- Fok Ring Current & Radiation Belt
- AbbyNormal (HF signal loss)
+ statistical models (Dst, Kp, AL)

Recent additions/plans:
- CTIPe (global ionosphere) (2010)
- Ovation Prime (auroral boundaries) (2011)
- PBMOD (ion. scintillations) (2012)
- EMMREM (radiation exposure) (2012)
- TRIPL-DA (ion. assimilation) (in progress)
- DREAM (with Van Allen Probes feeds) (in progress)
Extract SW information from models
- Make complex models operationally useful.
- Ready to be used by forecasters.
- Products tailored for specific application/mission’s needs.
- Large number of tools from one model.
- Certain products combine outputs from several models + data.

Examples:
- CME arrival time
- Magnetopause position
- Ground magnetic perturbations, dB/dt (key to GICs)
Space Weather Tools & Displays
Geomagnetic activity indexes

Predicted Kp from ACE data

Estimated Kp from Enlil

Observed Kp

Dst, AL from WINDMI
Space Weather Tools & Displays
more examples

Auroral boundaries and polar cap absorption (polar routes)
Ionospheric TEC (GPS)
Neutral densities (atmospheric drag)

Joule heating integrated over polar cap

Electron densities at ISS (surface charging)
Innovative dissemination
One-stop shop for state-of-the-art

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

User-configurable web-based system for analyzing space environment. Includes the most comprehensive list of SW data products and modeling results.

> 300 products
Interactive timeline tool with pan, zoom, mouse-over, and quantity toggling functionality

Super Timelines

- Mouse over to view specific data values
- Zoom in feature
- Toggle on/off specific quantities
- Selectable time range 1 - 10 days
- User selectable resources & quantities
Android Front-End to iSWA
- History Mode
- Movie Mode
- >35k Downloads
- Available in Google Play Store

IOS Front-End to iSWA
- History Mode (coming soon)
- Movie Mode (coming soon)
- >70k Downloads
- Available in App Store
Evolution of R20 Transition

Prior to CCMC

Models accessed and used by developers only

CCMC RoR

Models used and validated by entire community (digest broad range of inputs)

CCMC RT

Models continuously running in real-time (robust, real-time data drivers). RT data flow monitoring and controlling systems

CCMC SW Displays

SW displays customized for specific applications/missions, ready to be used by forecasters (combine model output and data).

CCMC iSWA

Flexible collection & dissemination system of SW information. Tools for forecasters. World-wide access, Mobil apps.

CCMC/SWRC

Prototyping of research-based innovative SW analysis & forecasting. SWx services for NASA user.
is a solution to an **emerging need** for an innovative operational research facility with close proximity to state-of-the-art models & space science expertise for **rapid implementation** and **prototyping** of forefront SW analysis and forecasting systems, methods and procedures.
NASA GSFC Space Weather Research Center (SWRC) is a growing CCMC Branch with roots in its original Support R2O goal.

CCMC-SWRC – successful example of R2O & O2R.

CCMC (since 2000)

SWRC (since 2010)

Provide customized SpWx Services to NASA’s Robotic Missions

Prototype Innovative Research-Based SpWx Forecasting & Analysis

Facilitate Community Research

Support R2O Transition

Educate operators, students, general public
SWRC Prototyping Functions

- **Test-drive** innovative SW analysis and forecasting systems (including CCMC systems and LWS strategic capability deliverables) (R2O).
- Assess forecasting methods and procedures in real-time operations and build a **knowledge base** (O2R).
- Push frontiers of SW research and development (O2R).
- Lead **joint operations & innovative partnership** between space weather research, educational and operational institutions world-wide.
Monitor and analyze space environment (operator coverage currently 16 hours/day 7 days per week) using innovative tools and methods.

Send out timely space weather notifications and forecasts of adverse conditions throughout the solar system to NASA robotic mission operators & involved personnel.

Issue weekly space weather reports and event summaries.

Build database of space weather events.

Provide assistance in spacecraft anomaly resolution.
Users of SW products & decision makers need to know

- How good are model predictions? What is the level of confidence?
- What is current state-of-the-art? (periodic reports)
- What model to install next?
- How to trace model performance over time? Is it time for upgrade?

Evaluations need to be performed by independent agent
Physical parameter most useful for specific applications. (e.g., dB/dt – key for GICs)

Good quality observational data.

Algorithm for model-data comparison to produce one number (skill score) characterizing model performance. Examples of metrics formats: prediction efficiency, threshold-based metrics.

Model ranking depends on selected physical parameter and metrics format. User requirements are important.
Leadership in Community-Wide Model Validation Efforts

- Community-wide metrics studies (Modeling Challenges):
  - GEM (2008) - Magnetosphere
  - CEDAR (2009) - Ionosphere
  - SHINE (2011) – Solar
- Facilitate a dialog between research and operational communities to define physical parameters and metrics formats relevant to SWx applications.
- Address uncertainties and challenges in model-data comparisons.
- Physical parameters
  - Magnetic perturbations at ground stations and geosynch orbits
  - Dst Index, Joule Heating/Poynting Flux along DMSP, auroral boundaries.
  - Neutral densities at CHAMP, electron density parameters at CHAMP, ISRs, COSMIC.
  - TEC from ground-based GPS in eight 5° geographic longitude sectors
- Joint publications (> 10 participating models, 7 papers)
- On-going project: **Address the role of magnetosphere drivers on ionosphere metrics results.**
Automated Web-Based Validation System and Interactive Archive

- Time series data from a wide variety of models and quantities.
- Skill scores computed with plots.

Plot: CCMC

Figure: DST from observatory KYOTO and model runs
Campaign: GEM2008
Metric study: Dst
Event: December 14, 2006 12 00 UT - December 16, 00 00 UT

<table>
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<th>Variable: DST Observation file: DST_KYOTO_provisional_E2.txt</th>
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<tr>
<td>1_NARMAX</td>
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</tr>
<tr>
<td>1_RiceDst</td>
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<tr>
<td>1_RDST</td>
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PredEff: Prediction Efficiency metric
N_region: the number of samples in the selected time window
N_finite: the number of points that were used for comparison (i.e., those that were not NaN or infinite)
LogSpectDist: Log-Spectral Distance metric
nWin: the number of windows used for the spectral analysis (2-hour windows, offset by 30 minutes from the nearest
PredYield: is the ratio of the range of modeled values (max minus min) compared to the observation (max minus min)
CEDAR Challenge: Ne at 300 km from ISR

Millstone Hill (42.62 N, 288.51 E)
EISCAT Svalbard (78.09 N, 16.02 E)
EISCAT (69.58 N, 19.23 E)
Sondrestrom (66.99 N, 309.05 E)

Model ranking depends on latitude
Independent Geospace Model Validation

- Time derivative of magnetic perturbations dB/dt at ground stations. Key parameter for GICs.
- Threshold-based metrics (0.3, 0.7, 1.1, 1.5 nT/s)
- Skill score depends on combination of probability of detection (POD) and probability of false detection (POFD)
New Initiatives

- **Innovative Partnership** Between Space Weather Research, Operational & Educational Institutions World-Wide.

- CCMC/SWRC-Universities Space Weather Research, Education & Development Initiative (SW REDI).

- **On-line Tools for Forecasters**
  - CME analysis tool
  - One-click Enlil

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

- Space Weather Events Prediction Scoreboard.
CME analysis tool allows researchers and students to make and share measurements via a web browser.

One-Click Enlil coming soon (mid April for testing by AFWA)
Summer intern Jack LaSota (undergraduate at University of Alaska Fairbanks) re-wrote the CME analysis tool which allows researchers and students to make and share measurements via a web browser.
Database Of Notifications, Knowledge, Information (DONKI)

• One-stop on-line tool for SWRC forecasters. Connected to iSWA, e-mail and other information dissemination systems.

• Enables broader participation: students, world-wide partners, model and forecasting technique developers.

• Real-time building of catalog of SW events, forecaster-logs, predictions, notifications. Updated automatically and manually.

• Comprehensive database search functionality to support anomaly resolutions.

• Linkages, relationships, cause-and-effects between space weather activities.

• Forecasting methods scoreboard. Real-time validation.

Facilitate research and development!
### Currently Active Predictions

**Prediction Methods e.g.**
WSA/ENLIL Cone, H3DMHD, HAF, STOA, DBM (Drag-Based Model), HI J-map (Harmonic Mean), HI Solar storm watch (Harmonic Mean), Gopalswamy Empirical Shock Arrival model (ESA), ISPM (Interplanetary Shock Propagation Model), STE Lab IPS (Heliospheric Tomography of STEL IPS Data), Tappin-Howard, Ballistic projection

<table>
<thead>
<tr>
<th>Prediction</th>
<th>Method</th>
<th>Submitter</th>
<th>Submitted</th>
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<tr>
<td>2013-02-24 11:00</td>
<td>ENLIL</td>
<td>Leila Mays (NASA GSFC SWPC)</td>
<td>2013-02-22 12:05:00</td>
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<td>2013-02-24 4:00</td>
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<td>Tony Phillips (spaceweather.com)</td>
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Submit Your Prediction

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Submit Your Prediction
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**Actual Arrival Time:** 2013-02-24 8:30:00z

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### Standings

#### Submitter Standings

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#### Method Standings

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Q - Overall Quality  
PM - Predictions Made  
Wins - Best Predictions  
AS - Average Score  
AD - Average Difference  
AL - Average Lead Time
CCMC/SWRC-Universities
SW REDI Goals

• Promote space environment awareness as an important component of the new millennium core education.
• Facilitate establishment of SW programs at universities worldwide-wide.
• Involve undergraduate student workforce in support of CCMC/SWRC projects.
• Provide students with valuable skills and experience for any career path they choose
• Experimental research SW operations in innovative, collaborative and cost-effective ways.

• Joint daily SW tag-ups with remote participation world-wide.
  – Latest progress: weekly joint tag-ups with KMA and DTU (Technical University of Denmark) launched on Jan 15th, 2013.

• Information, data streams, tools sharing.

• Innovative experimental joint forecasting.
  – CCMC is developing on-line tools to support the activity.
  – Cost-effective way to sustain 24/7 operations.

• Support ILWS.

**Capability to release SW notifications in real-time to partners world-wide is a necessary element of the activity.**
Outlook

- CCMC pioneered the way from research models to innovative tools and systems for space weather operations.
- CCMC tools and services are continuously evolving in response to customer needs.
- Establishment of SWRC branch is a necessary step in R20 & O2R evolution
  - SWRC – in-house research-based RPC
  - NASA missions – in-house user
- CCMC holds biennial community workshops, SWRC holds annual NASA’s missions operators workshops for updates, feedback, guidance.
- Collaboration is a key to further progress.
Challenges

• SWRC continuity support.
• Growing demand for educational activities.
• Restrictions on real-time dissemination of research-based SW notifications.
• Restrictions on social media.
Opportunities for Collaboration

• New models for Runs-on-Request service are invited.
  - World-wide model exposure.
  - Feedback from broader community for further improvement.
• Joint research projects.
• Joint model validation projects. Good quality data are in demand.
• Real-time data streams and model output sharing.
• Joint space weather tag-ups.
• Joint operations.
• Educational projects. Personnel training.
CCMC/SWRC Opportunities for Students

- **Research** projects using CCMC/SWRC capabilities.
  - Runs on Request
  - Student Research Contests
  - Research Internships
- **Software** development projects.
- **Media** and science writing projects.
- Basic space weather **education** + hands-on **practicum**.
- Space weather operations summer and year-around **internships**.
- Mentoring/teaching experience for advanced interns.
Real time data feed to iSWA:

Jicamarca Radio Observatory (Koki Chau):
- Electron Density Profile (over Jicamarca)
- more data in the near future
  (e.g., magnetometer data, ExB drifts)

PBMOD model outputs (low and middle latitudes)
- Electron Density Profile (over Jicamarca)
- TEC maps
- maps for the strength of the intensity scintillation index, S4
CCMC-ISRs Collaboration

- ISR data along a longitudinal chain (e.g., from Greenland to Peru)
- We are in the process of setting up data streams from PFISR (Mike Nicolls)
  - Ne, Te, Ti, ion line-of-sight velocity, and etc.
- Real time data and the data also from coordinated campaigns
CCMC-AMNH-LiU Collaboration:
Real-time Space Weather to Museums
Address the role of magnetosphere drivers on metrics results.