The iNtegrated Space Weather Analysis System

M. Maddox
and the CCMC, SWRC, & ISWA Team

587 / Science Data Processing Branch
674 / Space Weather Laboratory

http://iswa.gsfc.nasa.gov
“A US multi-agency partnership to enable, support and perform the research and development for next generation space science and space weather models.”
CCMC Goals

Facilitate Community Research

Address National Space Weather Needs

NASA, DoD and NOAA

...through partnering with the international community
What the CCMC provides:

- Model Coupling in collaboration with model owners
- Scientific Validation of Models
- Metrics implementations
- Model Runs on Request
- Data Format Standardization
- Advanced Visualization
- Real-Time Products
- Support for Space Weather Center at GSFC
  - Issue Alerts, Warnings, & Anomaly Reports
  - SWx Support - develop tailored space weather analysis tools in support of NASA missions, Operations, and Forecasters
Space Weather Models at the CCMC

http://ccmc.gsfc.nasa.gov/models/
Computational Resources

- Dedicated Beowulf Computing Clusters for parallel codes
- Dedicated workstations for
  - Runs-on-request processing
  - serial codes
  - development environments (staff & guests)
  - visualization, movies-on-requests
  - web, wiki, svn, cvs, ftp, JIRA servers
  - lab computers
- Direct Attached Storage & Storage Area Network implementations – Active/Online
- Dedicated Network and Storage Fabrics
• Dedicated Infrastructure
  • 19 Rack Footprint
  • 5 Beowulf Clusters
  • 27 Enterprise Class Workstations
  • 1100 CPU Cores
  • .5 Petabyte of Storage
  • dedicated network
  • web, ftp, wiki, cvs, svn, file servers

• Multi-Building Setup for High Availability and Failover
Data Management & Dissemination

- CCMC RoR Database and Data Archive
  - All simulation results are online
- Data Trees for Model Input and Output
  - RoR input
  - RT input
  - RT output
- iSWA Database, Data Archive, and Web Services
  - Information Retrieval & Data Sorter Robot Modules
  - Data Streaming Service/API
  - Cygnet Streaming Service/API
  - Incoming Data Staging Areas
- FTP Drop Box and Download Area
- Kameleon Data Format Standardization Software Suite
Model Simulation Runs-On-Request

http://ccmc.gsfc.nasa.gov

CCMC Center at NASA

- Super Computing Clusters (1100 CPU’s)
- Dedicated Workstations
- 427 Terra-Bytes of Data Storage
- Online Analysis Tools

Requests

Results

- 25+ Available Models (covering from the Sun to Earth)
- User Configurable Input Parameters
- Data Downloads
- Simulation Archive
- Searchable Database
- Online Visualization Tools
- Downloadable Analysis Software
- Automated Movie Generation Tools
Runs-On-Request vs. Real-Time Processing

CCMC Center
- Super Computing Clusters (1100 CPU’s)
- Dedicated Workstations
- 427 Terra-Bytes of Data Storage
- AUTOMATED RT PROCESSES

SWRC Center
- Space Weather Research Center
- iSWA: solar, heliosphere, magnetosphere, ionosphere, planetary

Requests
Results

http://ccmc.gsfc.nasa.gov
http://swrc.gsfc.nasa.gov
Objectives: provide the latest space weather information to NASA’s robotic mission operators, as well as DoD partners.

**Primary Objective:** Provide the latest space weather information to NASA’s robotic mission operators.

since March 2010
NASA GSFC Space Weather Research Center

Community Coordinated Modeling Center (CCMC)

Space Weather Research Center

Partnering

Protecting NASA’s Missions

iSWA System

Tools for Citizen Scientists

NASA, Other, Data Streams

Space Weather Related Research

Partnering

Education & Training
**iSWA Project Overview**

**OCE Technical Excellence Initiative Project**
- Partnership between NASA HQ OCE, SWL, CCMC, & AETD
- Address technical challenges in acquiring space weather environment information
- Began March 2008
- Version 1.0 deployed November 2009

**Fundamental Challenges To Be Addressed**
- Existing space weather resources are diverse and scattered
- Data accessibility
- Accurate real time now-casting & forecasting of the space environment
- Historical space weather impact analysis

**Initial Requirements Gathering**
- GSFC SSMO, JSFC SRAG

**Refined Requirements**
- Space Weather Workshops for NASA Robotic Missions
1. Acquire, ingest, and produce NASA relevant space weather information
2. Utilize both observational and simulation/model data
3. Produce and provide real-time data streams
4. Categorize and archive data for historical impact analysis
5. Provide customizable and highly configurable displays
6. Disseminate through the most widely deployed and accessible interface – the web
iSWA Project Team

David Berrios (587)
- Cygnet development
- Servlet development
- Performance tuning

Michael Hesse (670)
- HSD Division Chief
- iSWA Co-PI
- iSWA Visionary Leader

Peyush Jain (587)
- JS Framework trade study
- Servlet development
- Interactive Timeline infrastructure and tools

Marlo Maddox (587)
- Project Lead/iSWA Co-PI
- System Architect
- Data model, database design
- Back-End development

Richard Mullinix (587)
- Front-End development
- User Interface
- Servlet development
- JS Framework & Ajax

Lutz Rastaetter (674)
- Real-Time Modeling
- Scientific Visualization
- Cygnet development
iSWA System collects data from a large and evolving list of sources. Data is sorted, characterized, and processed into ‘mission decision supporting’ products in response to individual user queries. iSWA generates and provides a user-configurable display panel that can be accessed from a standard web browser. The end user can then customize their display to focus on specific products of interest.

Highly diverse and distributed space weather data consisting of the latest observational data along with the most advanced space weather model simulation output.
Data Management Challenges

• Ingesting data streams from a variety of sources with varying:
  • Transfer Methods (push and pull)
  • Levels of availability
  • Access Protocols (http, ftp, scp, mv)
  • Naming Conventions
  • Update Intervals (efficient polling for new data)
  • Date & Time Stamp Formats i.e.
    [2011-01-01_212500] or [2011-1-1_212500] or [20100101_212500] or [2011_001_212500] or [2010_Jan_01_212500] or [latest] or...

• Sorting, Archiving, and Management
  • Persistent storage (file system or database)
  • Cataloging, How to keep track of what is where
  • Scalability, Additional storage

• Changes (urls, names, formats, extensions, etc.)
Distributed Space Weather Resources  
CCMC Space Weather Model Resources

Resource Registry  
Data Registry  
Data/Tool Registry  
Product Registry  
Cygnet Registry

Information Retrieval Robot  
Data Sorter  
Tool Service  
Widget Agent

Configurable Web-Based Dissemination Service

iSWA

Internet

IRR  
• Routinely ingest and receive external data streams.

DS  
• Data is registered in database, time-tagged, sorted, and archived in a data tree.

TS  
• New data products are created using raw data and combinations of existing data.

WA  
• Data products are registered and packaged for display in iSWA system.

CWDS  
• iSWA System Interface provides a highly configurable control panel to present operators with only the products and tools of interest.

• 370 Unique Data Feeds, 27 Million Files Registered and Archived, 275 Consumable Display Products currently managed in iSWA Cygnet Catalog
Cygnet Gallery
Floating/Resizable Cygnets
Date/Time Selection
Share/Bookmark Layout
Mobile Apps (iOS, Android)
Additional “Views”

JavaScript / Dojo

Gallery Data
Cygnet Data
Additional Web Services

Servlets

iSWA Back End

BACK END
FRONT END

R. Mullinx, D. Berrios
iSWA Design Highlights

**BACK END**

- Comprehensive data model that drives the system
  - Minimizes need for actual code modifications
  - Allows rapid additions and modifications to data feeds and display products
- Every granule of data is registered, cataloged, and archived
  - Access data products for any available time period
  - Generate new tools and functionality using multiple existing data products

**FRONT END**

- Consistent Interface with uniquely identifiable product icons
- Customizable layout
  - automatically saved on browser exit
  - can be bookmarked and shared
- Auto updating products and tools
- Individual and global date search functionality for historical impact analysis
- Detailed descriptions for data products
Interactive Products

Interactive CME alert tool with chronological record of SWx Center issued CME time of arrival predictions.

Interactive timeline tool with pan, zoom, mouse-over, and quantity toggling functionality.
Monitor Magnetic Connectivity and Proximity to Active Regions

- Monitor active regions and their proximity to magnetically connected foot-point locations of the earth
- View future projections of active regions and foot-point locations
- Date selection tool for historical analysis
- Select different EIT wavelengths
- Monitor in real-time
Monitor CME propagation in real-time or for historical events

- Monitor in real-time
- Date selection tool for historical analysis
- Left/Right controls for single steps within time window

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
High Availability Architecture

- IP failover
- Load Balancing proxy/virtual proxy front end servers
- Database Replication
- Data Tree Replication/Mirroring
- Multi-site backups systems (multi-building in our case)
- Redundant Storage Fabrics
- Software-Monitoring Software (health, performance)
- Network Failover with Dual Homing (not allowed per gsfc security)
High School and College Interns

Young Scientists

Educating the public (e.g., teachers) about space weather
Teachers’ Visit (Summer 2012)

Arranged by NASA IV&V Educator Resource Center
High school teachers from West Virginia

Y. Zheng
Impressed with their progress
Space weather excites them
  ✓ Real time
  ✓ Creative experimental research forecasts
  ✓ Help NASA robotic missions
  ✓ Responsibilities
Jack LaSota
Web-based CME Analysis Tool

Justin Boblitt
Android iSWA App

CME Tool Link  Sample Analysis Link  iTunes Link  Android Link
### Usage/Growth

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>iSWA Version <strong>1.0</strong></td>
<td>iSWA Version <strong>1.9.8</strong></td>
</tr>
<tr>
<td><strong>171</strong> Data Feeds</td>
<td><strong>370</strong> Data Feeds</td>
</tr>
<tr>
<td><strong>6</strong> Million Data Files</td>
<td><strong>27</strong> Million Data Files</td>
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<tr>
<td><strong>135</strong> SWx Products/Cygnets</td>
<td><strong>275</strong> SWx Products/Cygnets</td>
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<tr>
<td>0 twitter followers <strong>@NASAiSWA</strong></td>
<td>132 twitter followers <strong>@NASAiSWA</strong></td>
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### Present / In-Progress Users

<table>
<thead>
<tr>
<th>NASA GSFC (SSMO)</th>
<th>Heliophysics Summer School</th>
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<tbody>
<tr>
<td>NASA MSFC (ISS)</td>
<td>CISM Summer School</td>
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<tr>
<td>NASA JSC (SRAG)</td>
<td>CCMC Research &amp; Event Studies</td>
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<tr>
<td>NASA LRC (CALIPSO)</td>
<td>Space Science Programs (CUA, Michigan, GMU, Embry-Riddle, UCLA, ITU, AFIT, BU)</td>
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<tr>
<td>AI Solutions/GSFC Conjunction Assessment Risk Analysis Team</td>
<td>Korea Astronomy and Space Science Institute (KASI)</td>
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<tr>
<td>UK Met Office</td>
<td>Department Of Homeland Security</td>
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<tr>
<td>Air Force Weather Agency</td>
<td>Federal Aviation Administration</td>
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<tr>
<td>Air Force Institute Of Technology</td>
<td>Power Grid Community (NERC, EPRI)</td>
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<tr>
<td>Electric Power Research Institute</td>
<td>NASA TDRSS</td>
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<tr>
<td>Belgium Institute Of Technology</td>
<td>Japan Aerospace Exploration Agency</td>
</tr>
<tr>
<td>Space Research Institute, Russia IKI RAN</td>
<td>American Museum Of Natural History</td>
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<tr>
<td>Korea Meteorological Administration</td>
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<tr>
<td>Space Environment Technologies</td>
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Potential Users

• Any agency, entity, or individual with space weather requirements and/or interests
• Extended educational use (training, K-12, higher education)
• Extended research use (case studies, correlation studies, historical events, general space weather research)

iSWA software can be applied to any agency, group, or project with general data ingestion, storage, management, display, & dissemination needs….

• “instant ground system” for other NASA projects
• turn-key software system for commercial and/or educational data management and dissemination
• customizable interface for existing data archives and sets
iSWA Impact

NASA

• iSWA provides a new capability to quickly assess past, present, and expected space weather effects.
  • Mission operators have a resource to assist in both anomaly resolution as well as potential space weather impacts.
• iSWA has helped enable the Space Weather Laboratory to establish a new Space Weather Center service providing alerts, anomaly reports, and weekly space weather summaries based on iSWA tools and products.

External Agencies

• Air Force Space Weather Agency can monitor the iSWA system 24x7 for CME eruptions and notify the CCMC as soon as an event is detected. A notification triggers a CME Cone Model calculation at CCMC that estimates the CME arrival time, duration, and expected impact on earth.
• iSWA has enabled numerous collaborations with data, model, and product developers/providers who want their tools to be available in iSWA.

Science, Education, and Public Outreach

• Researchers, universities, and “citizen scientists” have access to a comprehensive suite of real-time and historical space environment data products.
**New Products, Services, & Business**

- Integral tool for **NASA Space Weather Center**
- iSWA is integral component of several new proposals and activities. One currently underway between GSFC and SRAG at JSC.
- Interoperable interfaces allow external entities to tap into iswa data streams.
- Two mobile **NASA Space Weather** applications for IOS and Android Devices—both powered by iSWA

> 40K IOS downloads
> 17K Android downloads
Summary / Future

SWL, CCMC, & Space Weather Center aim to advance space weather specification and forecasting capabilities…

• Increased computing capacity
• Increased storage capacity
• Ingest state-of-the-art space weather models
• Update existing space weather model suite
• Continue to advance model output metadata standards
• Improve visualization techniques
• Improve real-time and forecasting capabilities
• Generate custom tools and services
• Improve general public knowledge and access to space weather
Specific Examples...
Jan 23 flare (M8.7)/CME (v=2210km/s)
The Jan 23 and Jan 27 flare/CME pairs were associated with the same active region 1402. Both events created significantly enhanced ion radiation (SEP flux levels).

Several polar flights were rerouted due to the radiation.
CME impact at Earth (a minor geomagnetic storm only)

CME arrival

Max KP Level: Minor

Kp=5 /minor geomagnetic storm
An iSWA layout for the 23 Jan 2012 event


Provide a dynamic view of the event with some key products

The Jan 23 event produced a very strong radiation storm
- slightly less than that of the March 7 2012 event

Peak flux (Jan 23): 6310 pfu at Jan 24 15:30 UT
Peak flux (Mar 7): 6530 pfu at Mar 8: 11:15 UT

Active Region 1429 activities during March 2012

Earthside Major Events

Backside major events
END