National Aeronautics and Space Administration

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

HSD

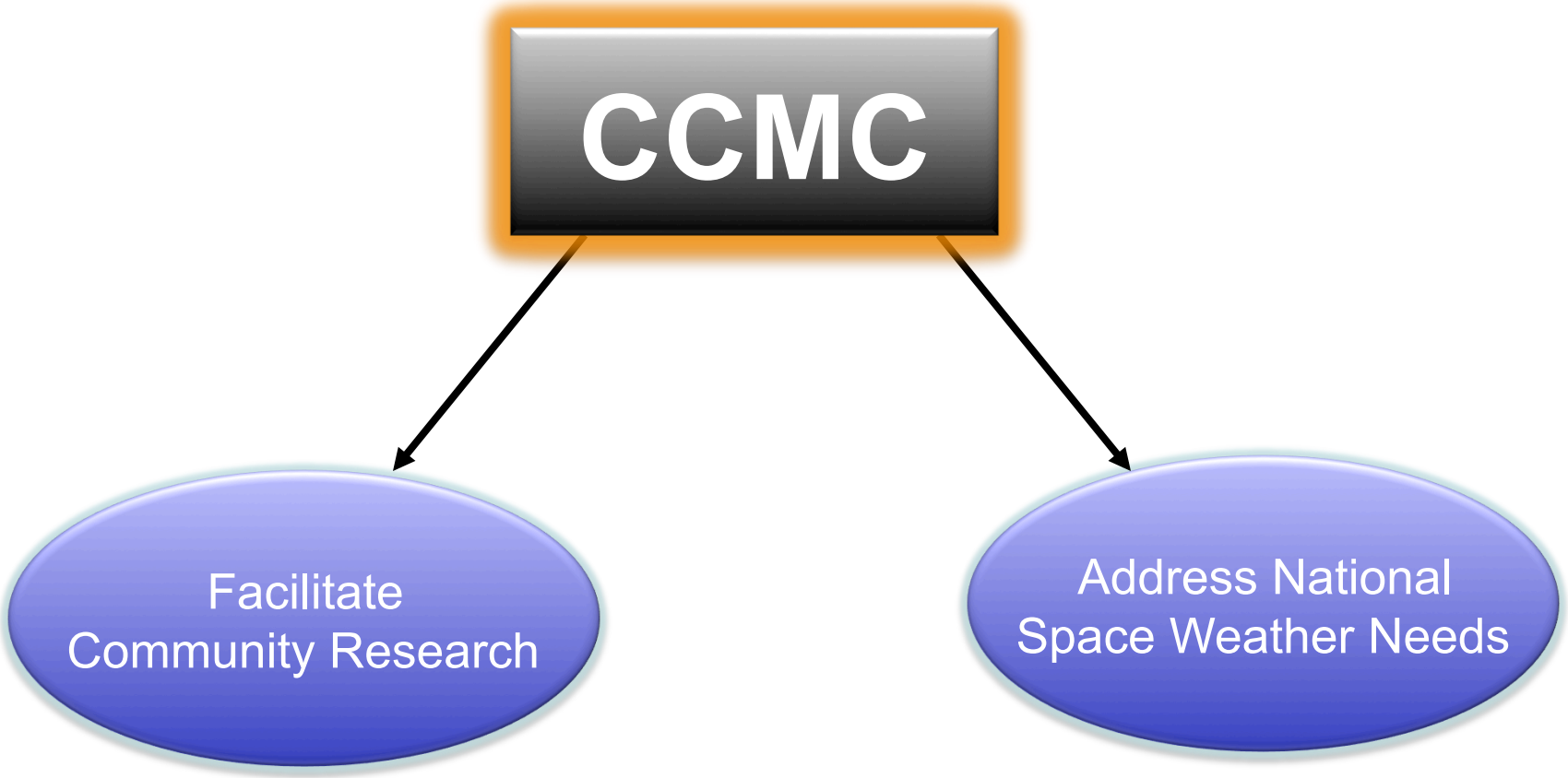
SED Software Engineering Division

Space Weather LAB

About The CCMC

"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

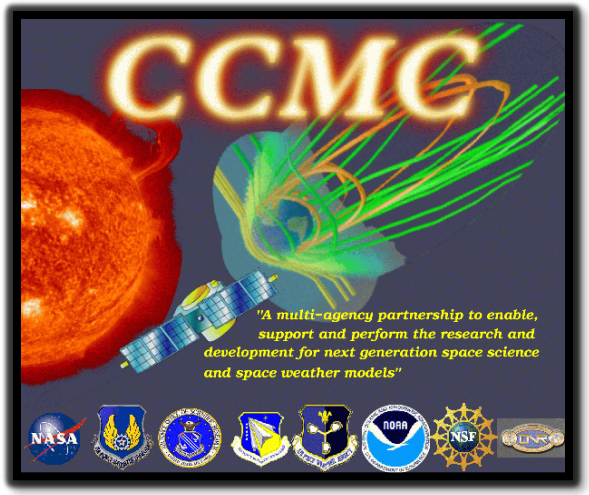


NASA, DoD and NOAA

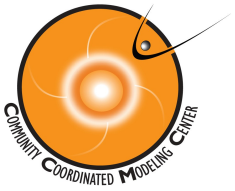
..through partnering with the international community

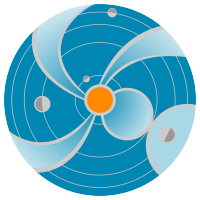
CCMC Products & Services

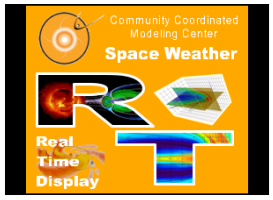
What the CCMC provides:

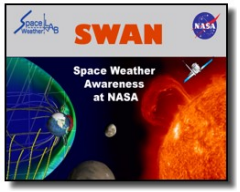


- Model Coupling in collaboration with model owners
- Scientific Validation of Models
- Metrics implementations
- Model Runs on Request
- Data Format Standardization
- Advanced Visualization
- Real-Time Products
- Support for Space Weather Center at GSFC
  - Issue Alerts, Warnings, & Anomaly Reports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

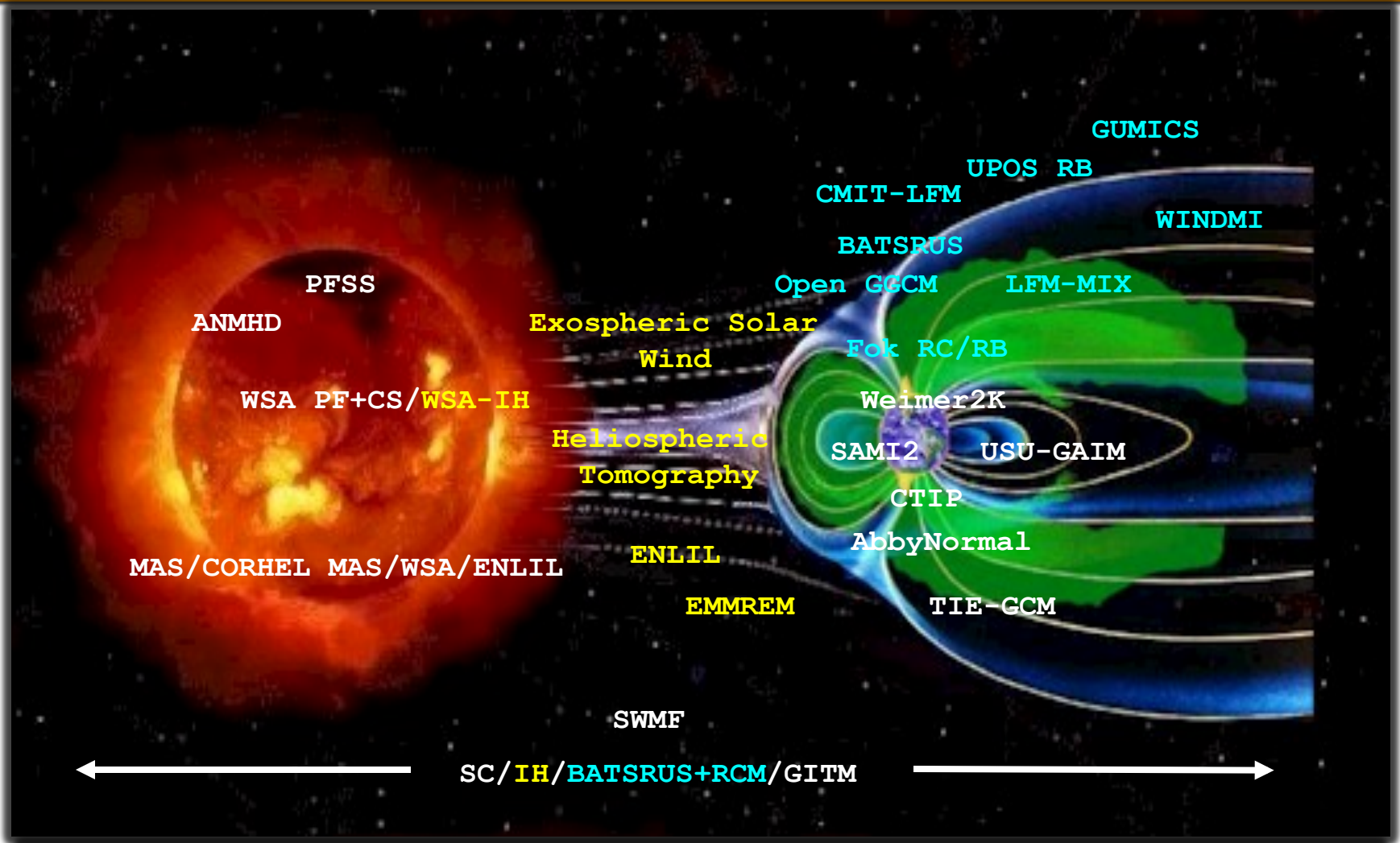








Space Weather Models at the CCMC



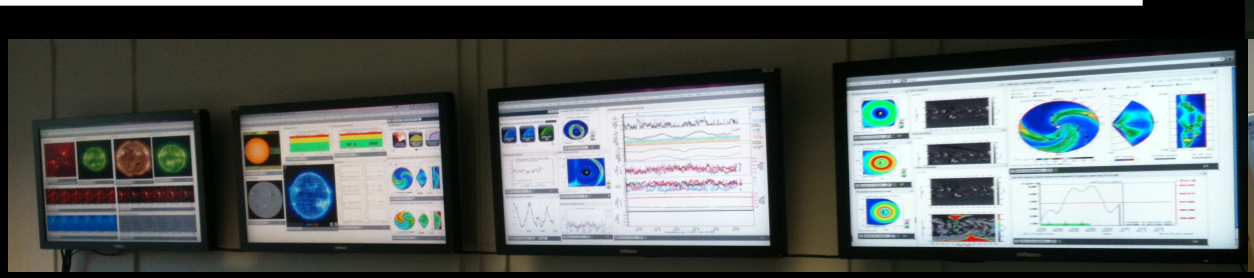
http://ccmc.gsfc.nasa.gov/models/

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

Computational Resources

- 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

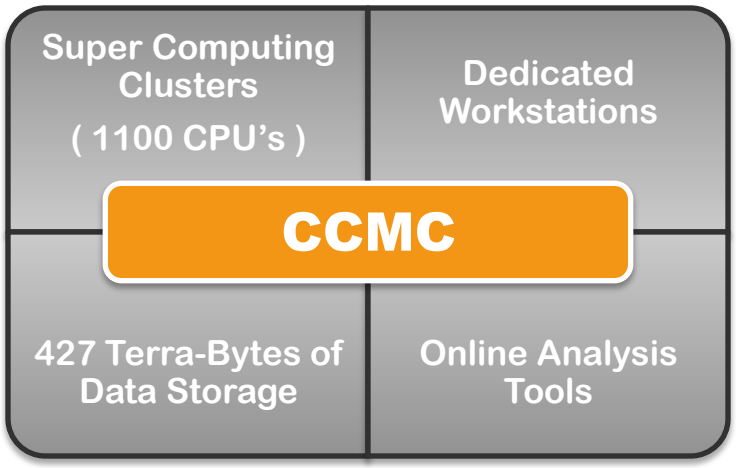
Model Simulation Runs-On-Request

http://ccmc.gsfc.nasa.gov

Requests

Results

CCMC Center at NASA



- 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

CCMC

427 Terra-Bytes of Data Storage

AUTOMATED RT PROCESSES

Requests

Results

http://ccmc.gsfc.nasa.gov

SWRC Center

iSWA

solar

heliosphere

magnetosphere

ionosphere

planetary

Space Weather Research Center

http://swrc.gsfc.nasa.gov

NASA GSFC Space Weather Research Center

Primary Objective:

Provide the latest space weather information to NASA's robotic mission operators.

since March 2010

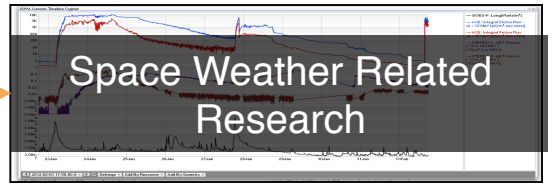
NASA GSFC Space Weather Research Center

Community Coordinated Modeling Center (CCMC)

Space Weather Research Center

Partnering

Johnson Space Center
NOAA
AIR FORCE WEATHER AGENCY
ASTRA
EPRI
NiCT
esa
Met Office
KASI
JAXA
KMA
Meteorological Administration



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

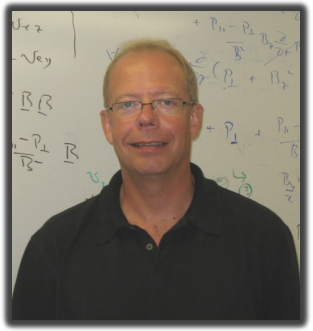
iSWA Solution & Deliverables

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

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



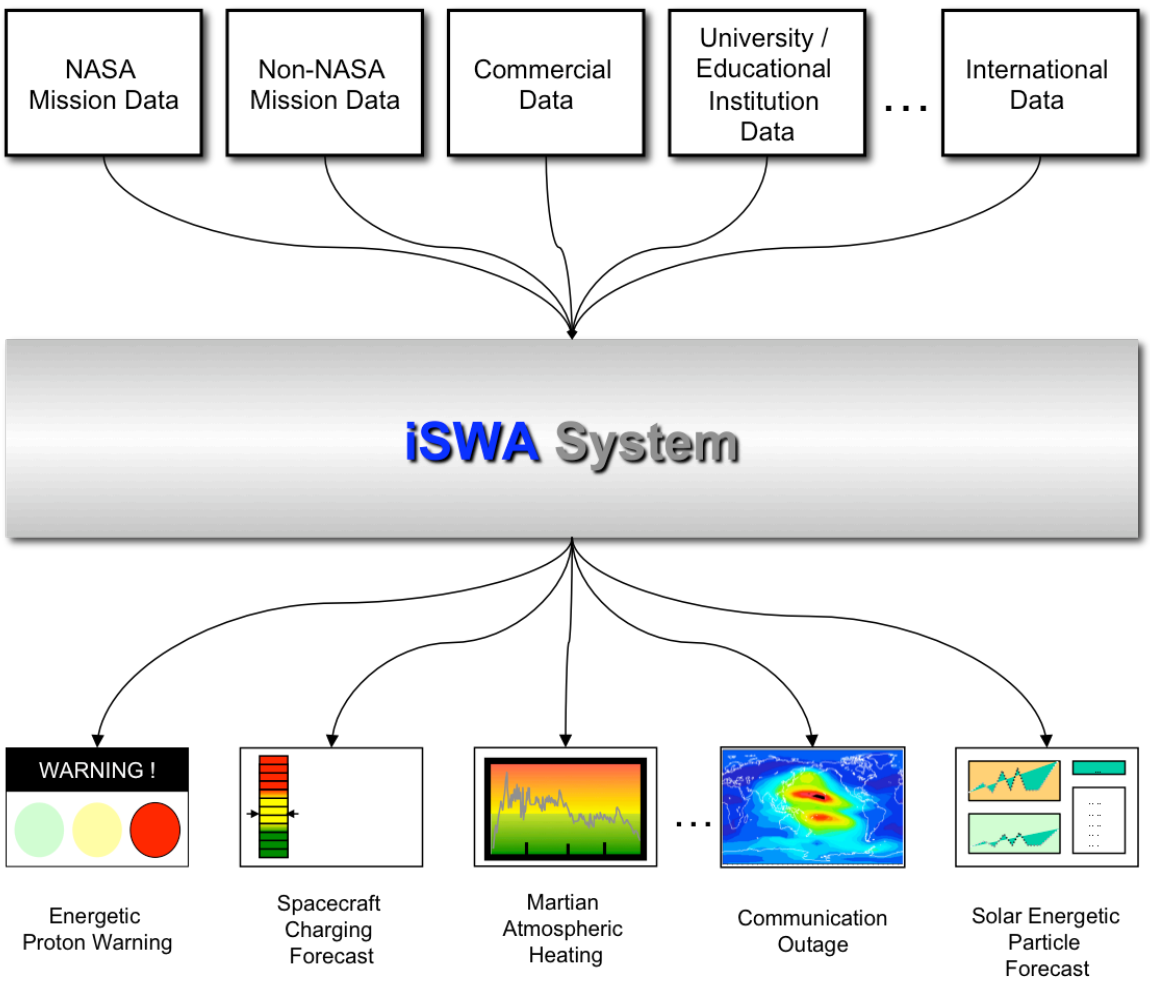
Michael Hesse (670)
- HSD Division Chief
- iSWA Co-PI
- iSWA Visionary Leader

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

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

Lutz Rastaetter (674)
- Real-Time Modeling
- Scientific Visualization
- Cygnet development

iNTEGRATED SPACE WEATHER ANALYSIS SYSTEM



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

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.

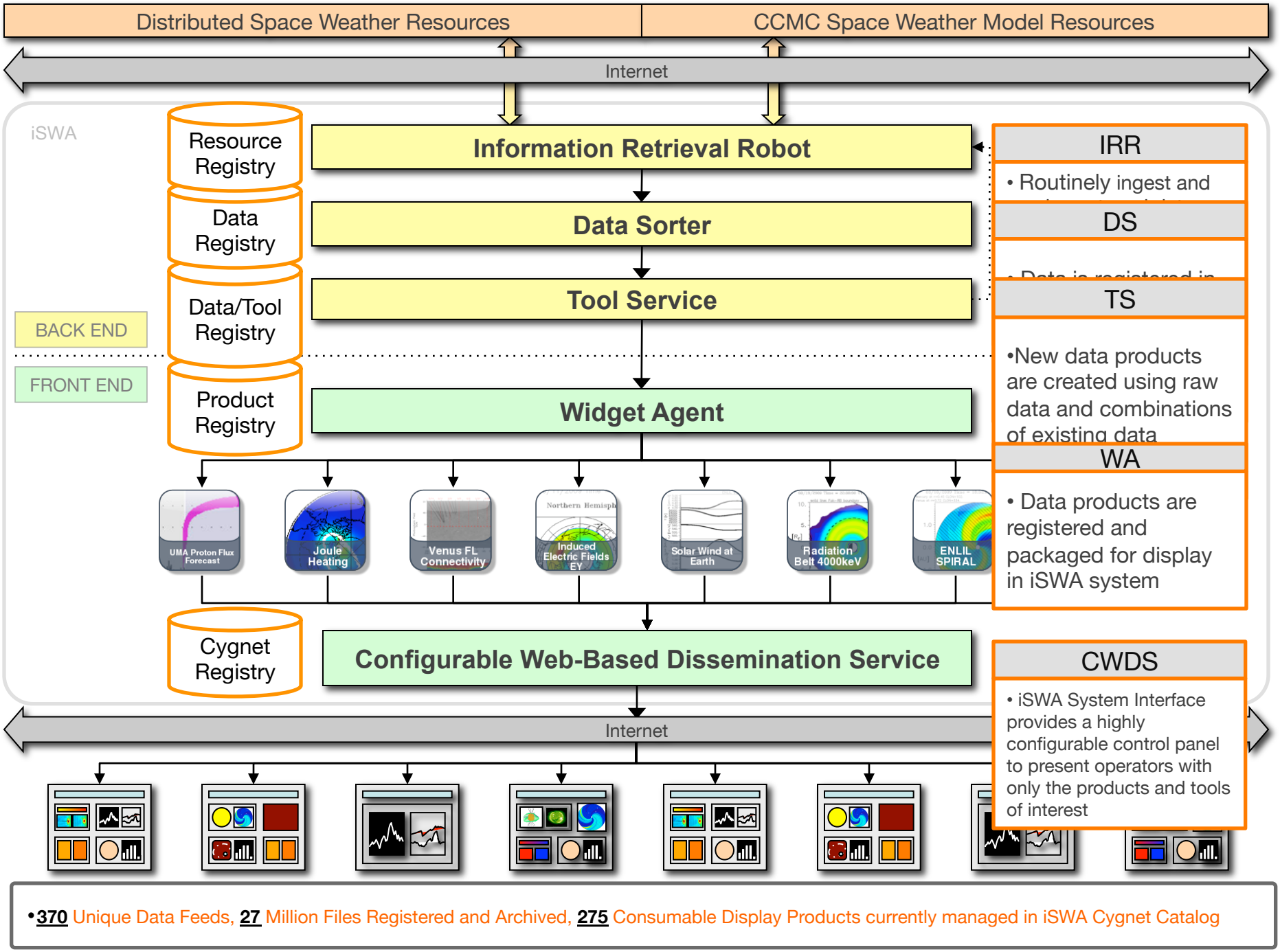
iSWA generates and provides a user-configurable display panel that can be accessed from a standard web browser. The end user can then customize their display to focus on specific products of interest.

iNTEGRATED SPACE WEATHER ANALYSIS SYSTEM

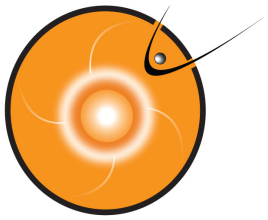
Data Management Challenges

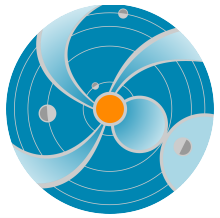
- Ingesting data streams from a variety of sources with varying:
  - Transfer Methods (push and pull)
  - Levels of availability
  - Access Protocols (http, ftp, scp, mv)
  - Naming Conventions
  - Update Intervals (efficient polling for new data)
  - Date & Time Stamp Formats i.e.

  [`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
Internet
iSWA
Resource Registry
Data Registry
Data/Tool Registry
Product Registry
Information Retrieval Robot
Data Sorter
Tool Service
Widget Agent
BACK END
FRONT END
UMA Proton Flux Forecast
Joule Heating
Venus FL Connectivity
Induced Electric Fields EY
Solar Wind at Earth
Radiation Belt 4000keV
ENLIL SPIRAL
Cygnet Registry
Configurable Web-Based Dissemination Service
Internet
IRR
• Routinely ingest and
DS
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

Widget Agent & Configurable Web based Dissemination Service





FRONT END

BACK END

Cygnet Gallery

Floating/Resizable Cygnets

Date/Time Selection

Share/Bookmark Layout

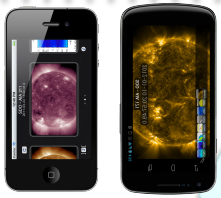
Mobile Apps (iOS, Android)

Additional “Views”

JavaScript / Dojo

Gallery Data

Cygnet Data



Additional Web Services

Servlets

iSWA Back End

R. Mullinix, D. Berrios

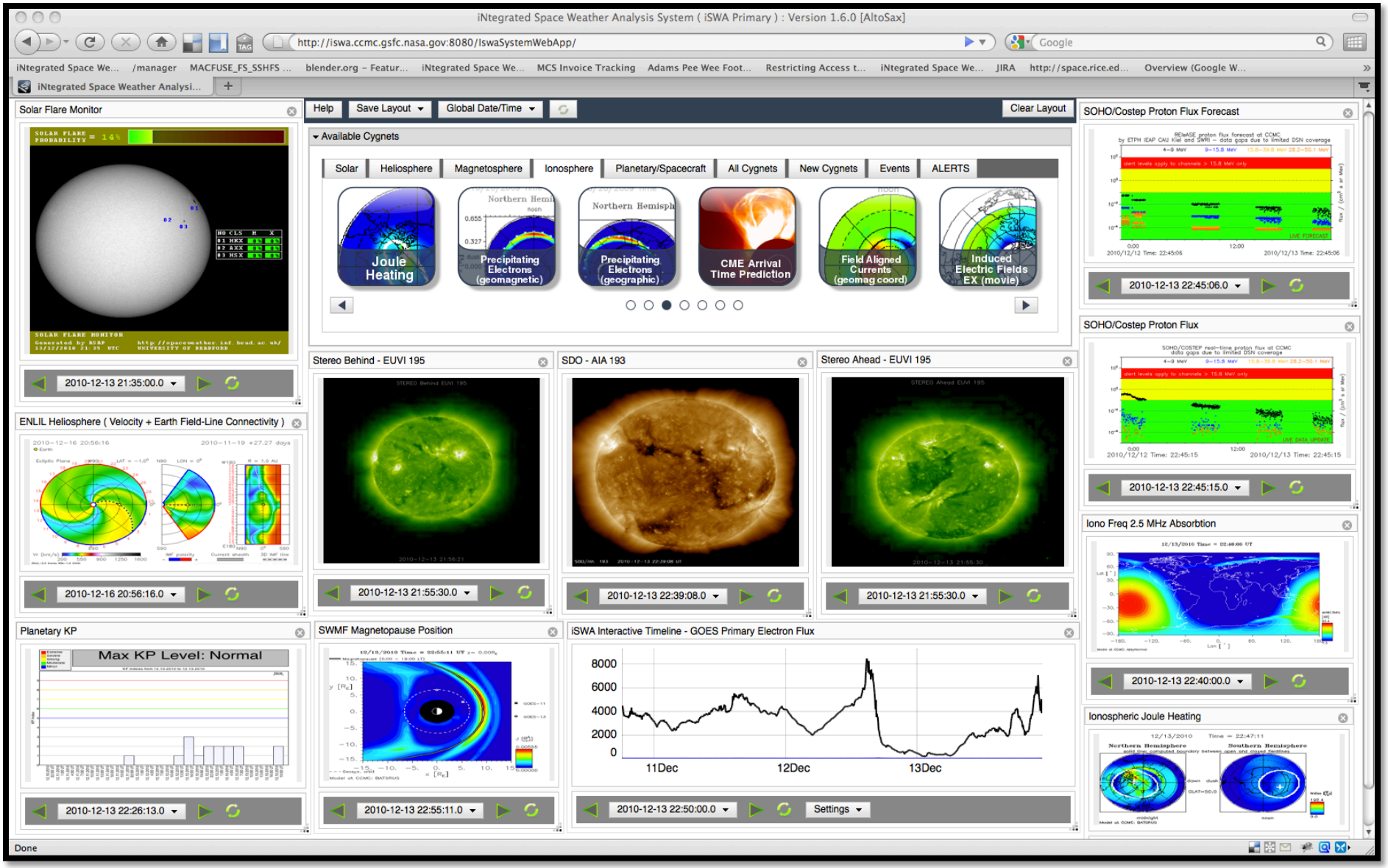
iSWA Design Highlights

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**~~



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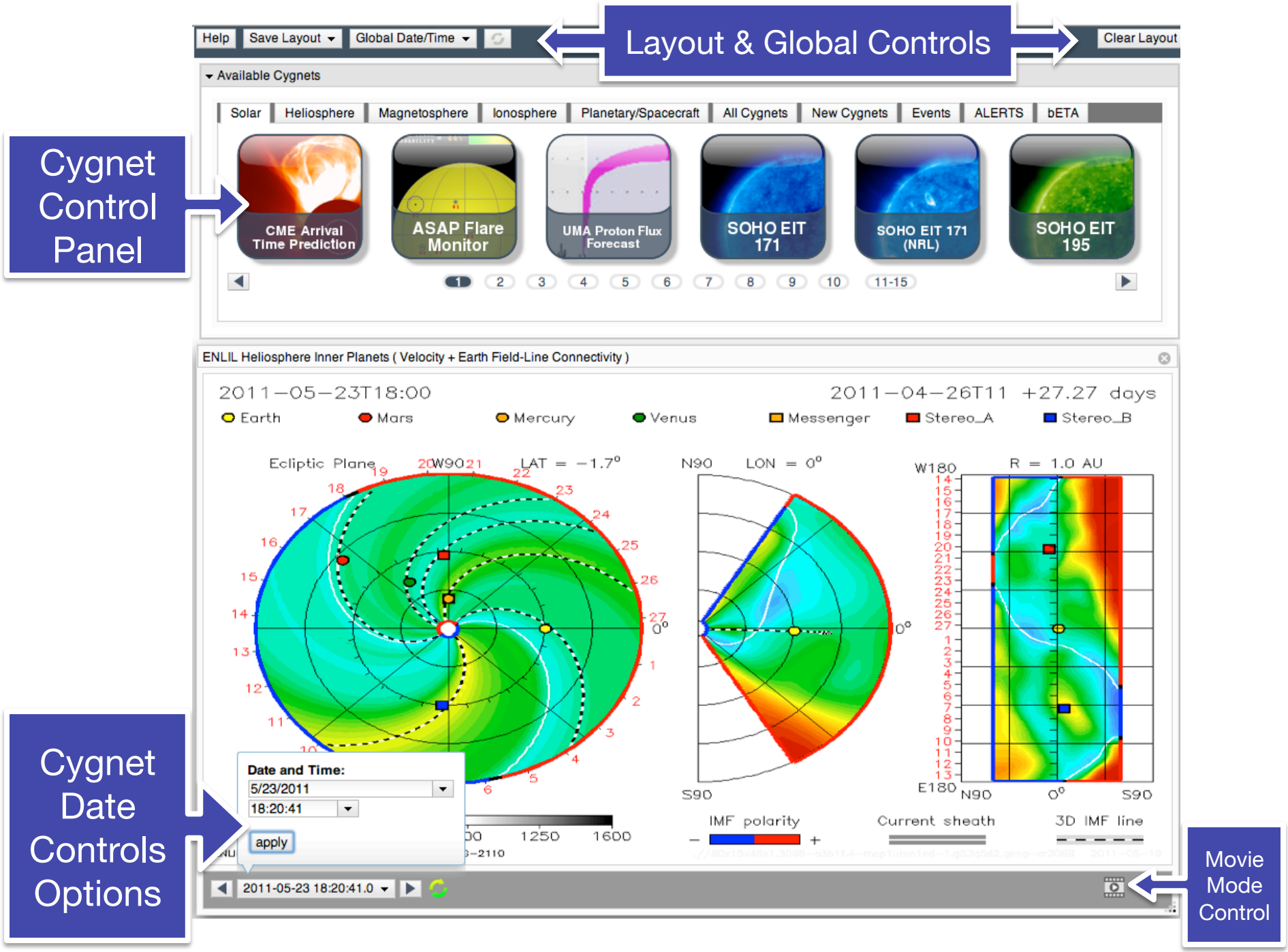
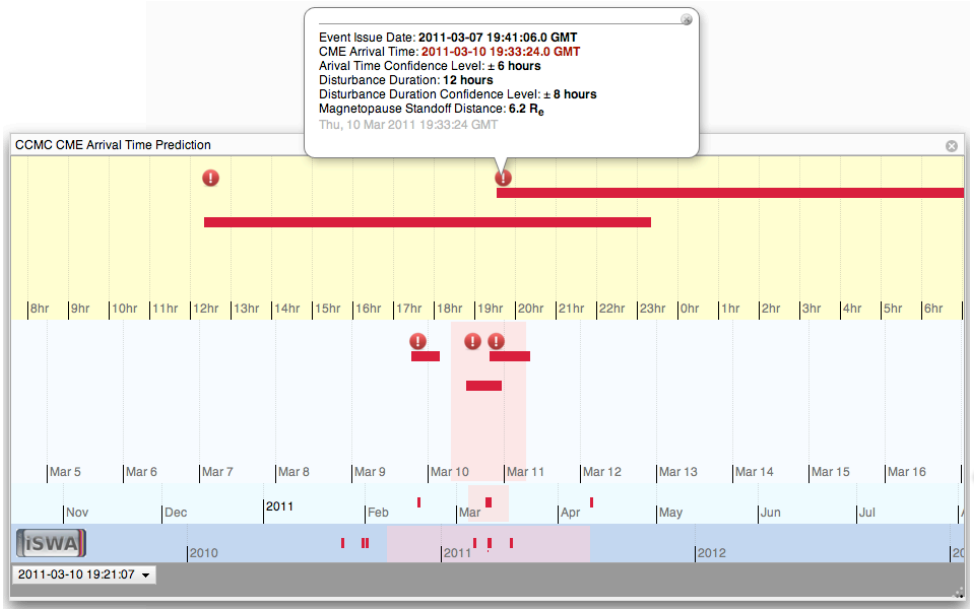
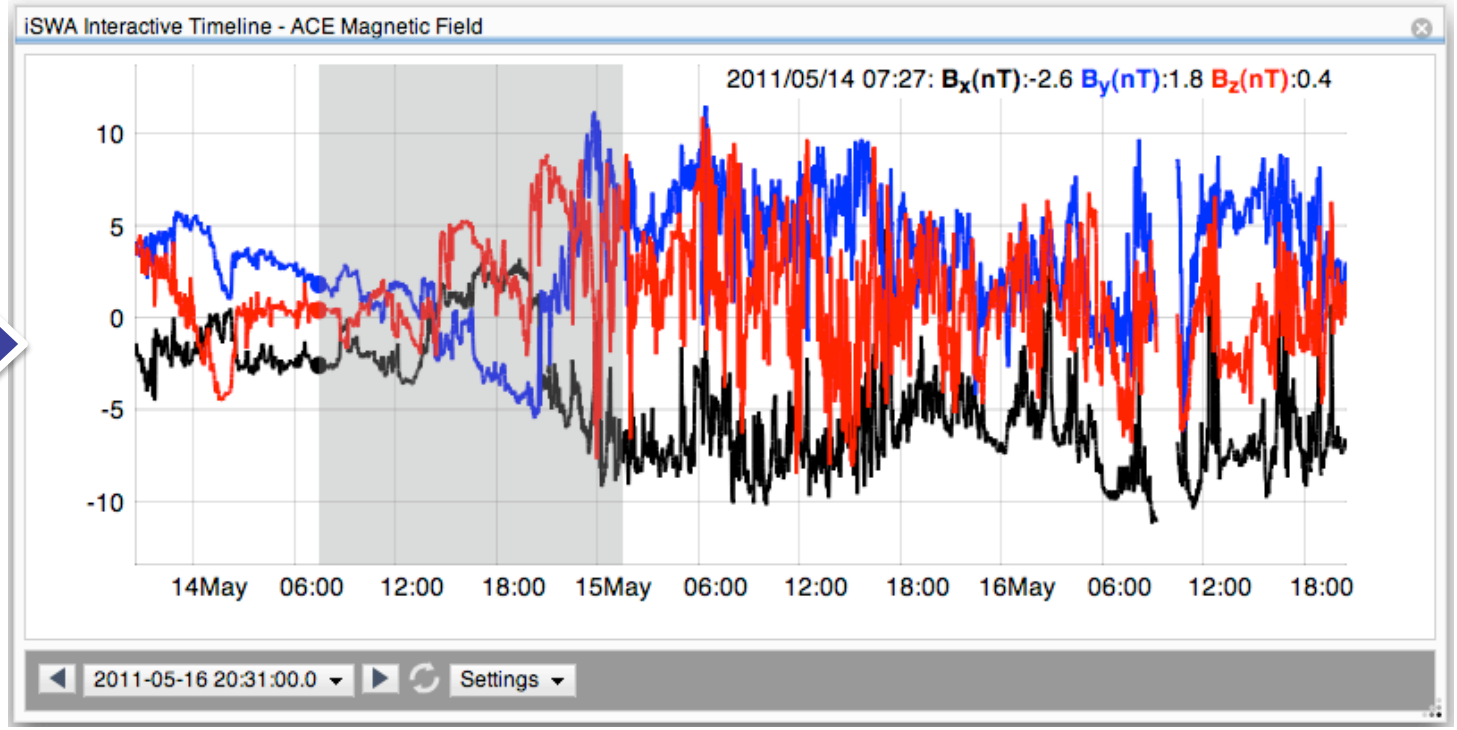

Layout & Global Controls
Cygnet Control Panel
Cygnet Date Controls Options
Movie Mode Control
Help
Save Layout
Global Date/Time
Clear Layout
Available Cygnets
Solar
Heliosphere
Magnetosphere
Ionosphere
Planetary/Spacecraft
All Cygnets
New Cygnets
Events
ALERTS
bETA
CME Arrival Time Prediction
ASAP Flare Monitor
UMA Proton Flux Forecast
SOHO EIT 171
SOHO EIT 171 (NRL)
SOHO EIT 195
1 2 3 4 5 6 7 8 9 10 11-15
ENLIL Heliosphere Inner Planets (Velocity + Earth Field-Line Connectivity)
2011-05-23T18:00
2011-04-26T11 +27.27 days
Earth
Mars
Mercury
Venus
Messenger
Stereo_A
Stereo_B
Ecliptic Plane
LAT = −1.7°
N90
LON = 0°
W180
R = 1.0 AU
S90
E180
IMF polarity
Current sheath
3D IMF line
Date and Time:
5/23/2011
18:20:41
apply
2011-05-23 18:20:41.0

Interactive Products



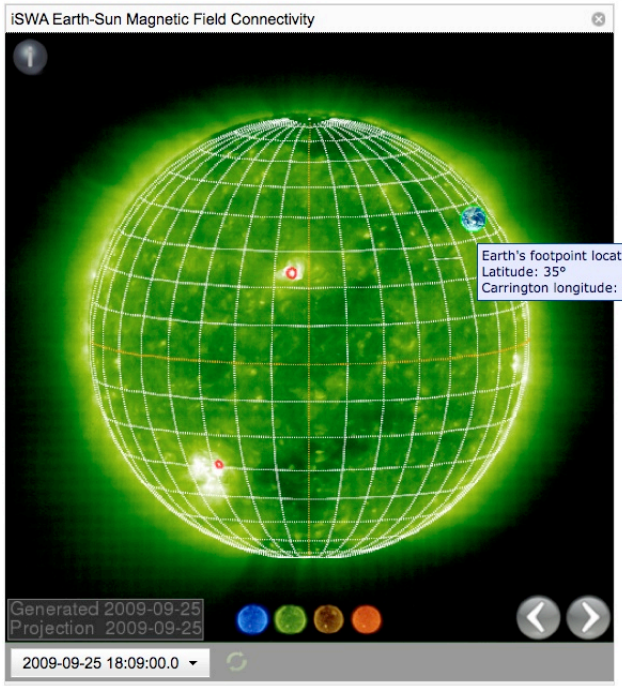
Interactive CME alert tool with chronological record of SWx Center issued CME time of arrival predictions

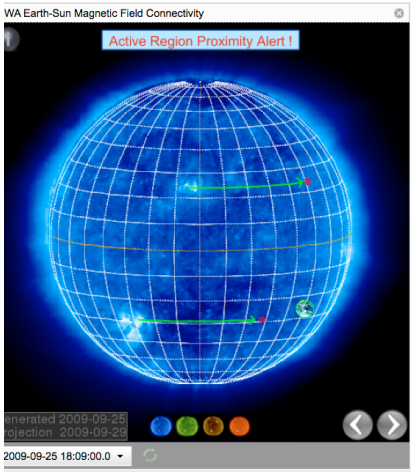
Interactive timeline tool with pan, zoom, mouse-over, and quantity toggling functionality

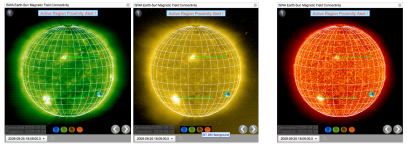


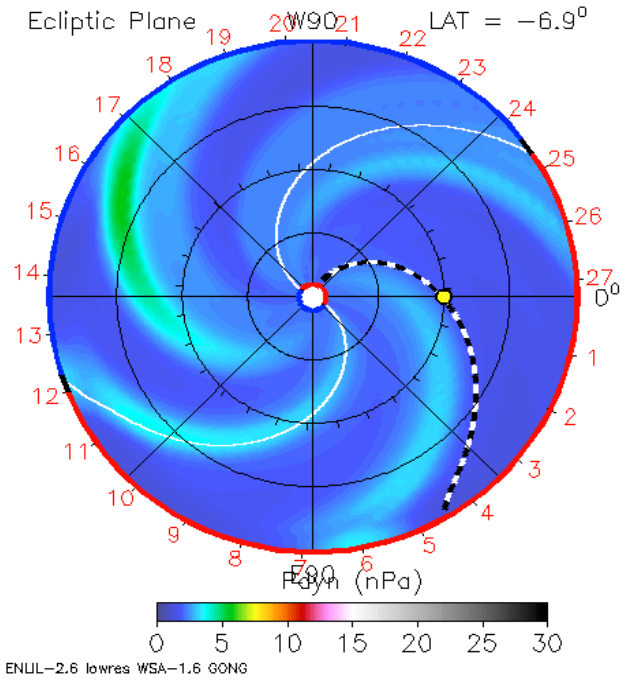
Sample iSWA Products/ Cygnets

Monitor Magnetic Connectivity and Proximity to Active Regions



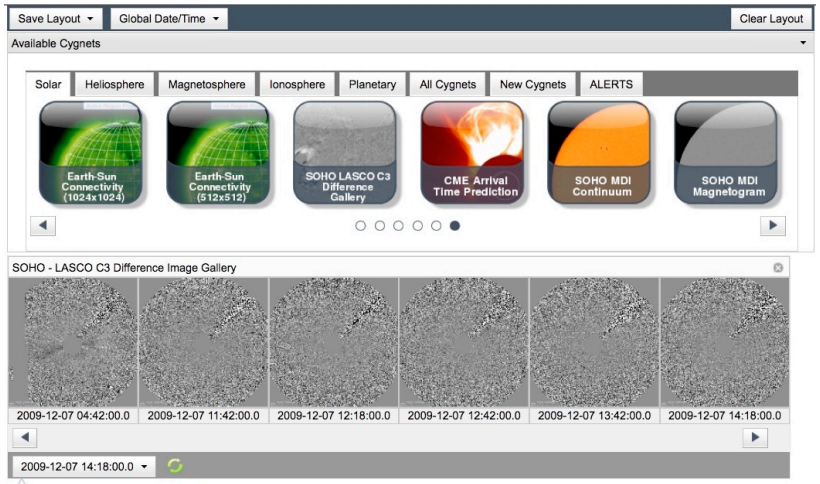


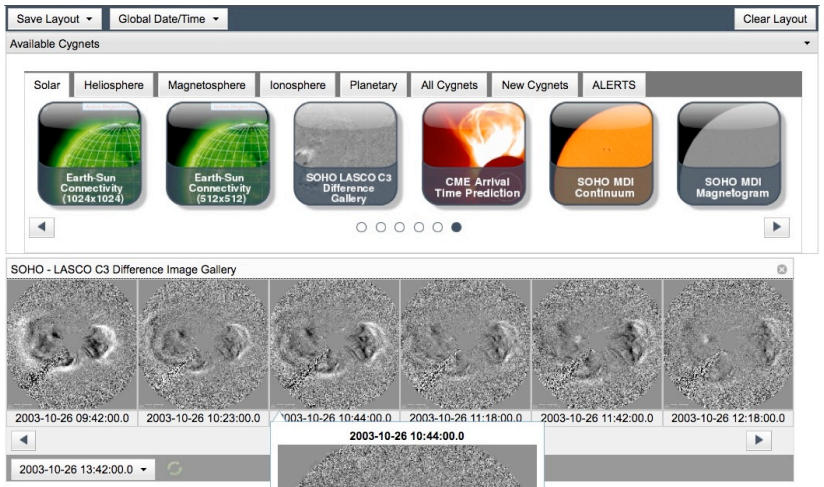


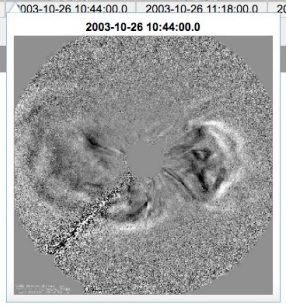


- Monitor active regions and their proximity to magnetically connected foot-point locations of the earth
- View future projections of active regions and foot-point locations
- Date selection tool for historical analysis
- Select different EIT wavelengths
- Monitor in real-time

Monitor CME propagation in real-time or for historical events



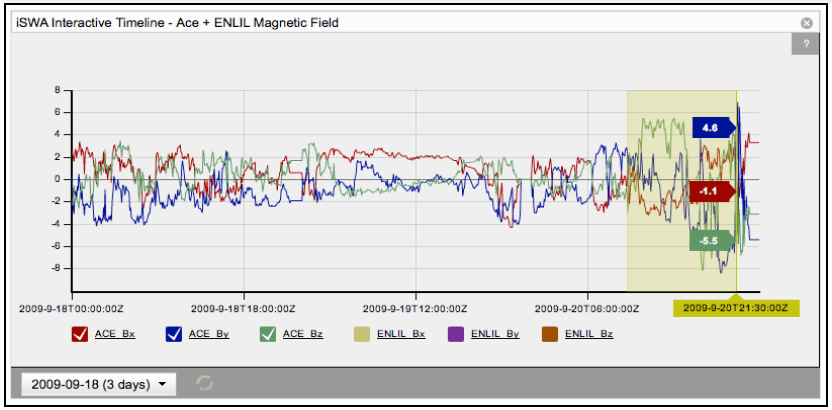




- Monitor in real-time
- Date selection tool for historical analysis
- Left/Right controls for single steps within time window

.Zoom 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

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)

Education

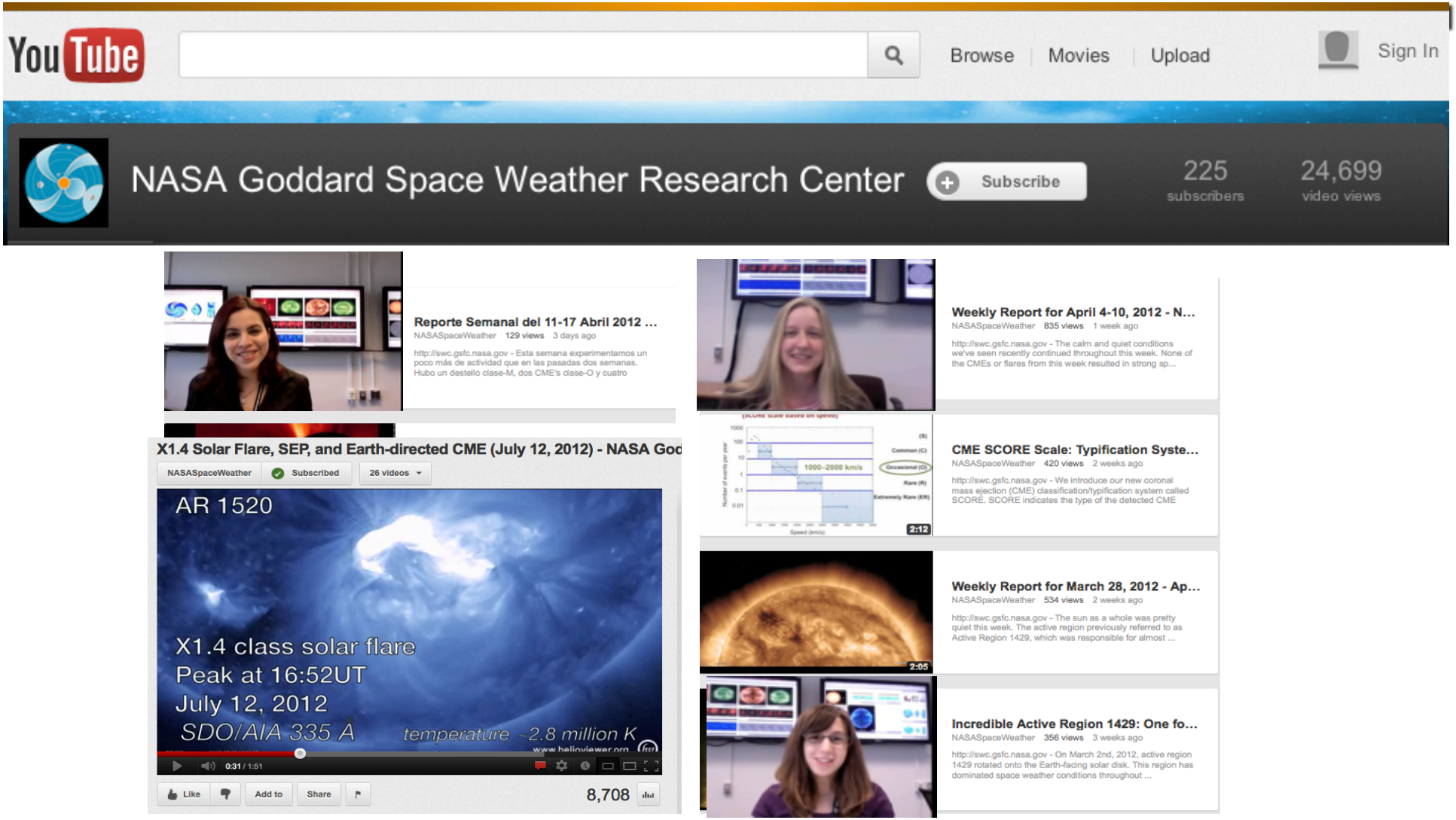
- ✓High School and College Interns
- ✓Young Scientists
- ✓Educating the public (e.g., teachers) about space weather

Teachers' Visit (Summer 2012)

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

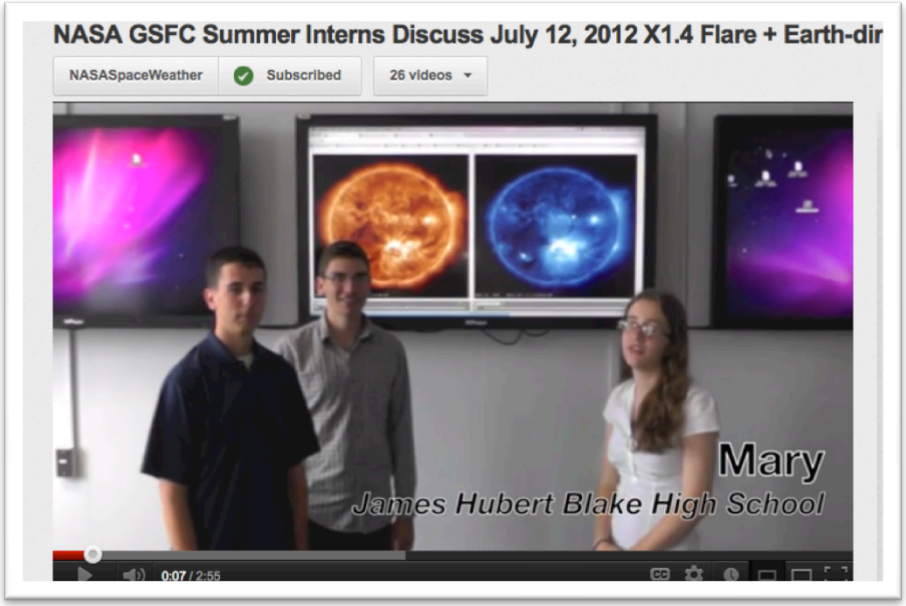
Y. Zheng

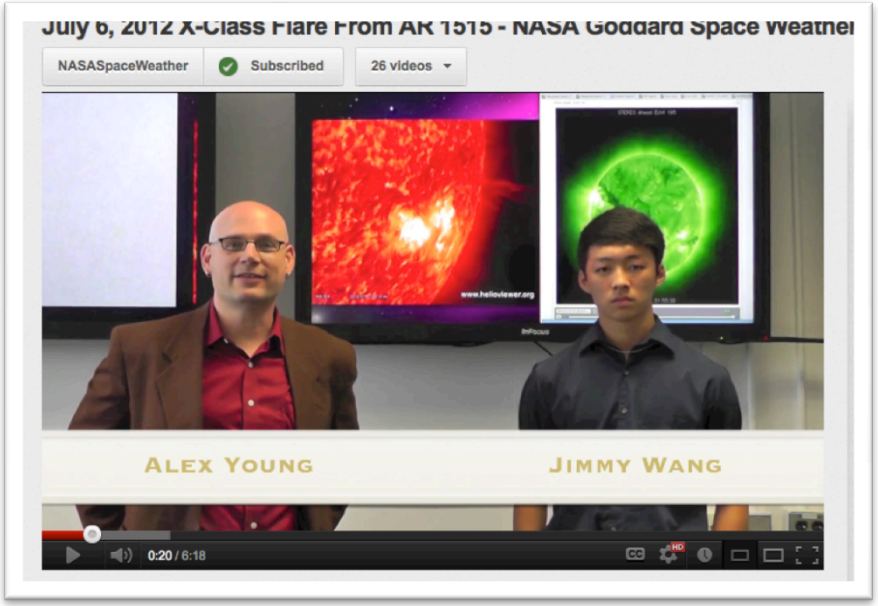
Training Young Scientists and Educating the Public



C. Black, D. Berrios, L. Mays, J. Collado-Vega, R. Evans

Summer Interns Learning Space Weather Science





- Impressed with their progress
- Space weather excites them
  - ✓ Real time
  - ✓ Creative experimental research forecasts
  - ✓ Help NASA robotic missions
  - ✓ Responsibilities

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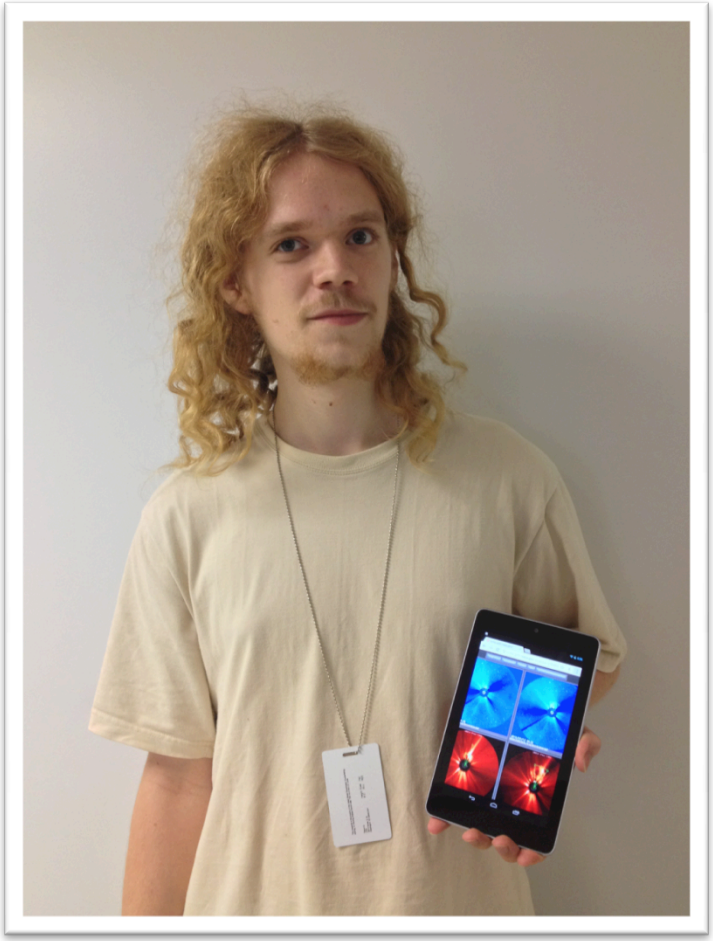
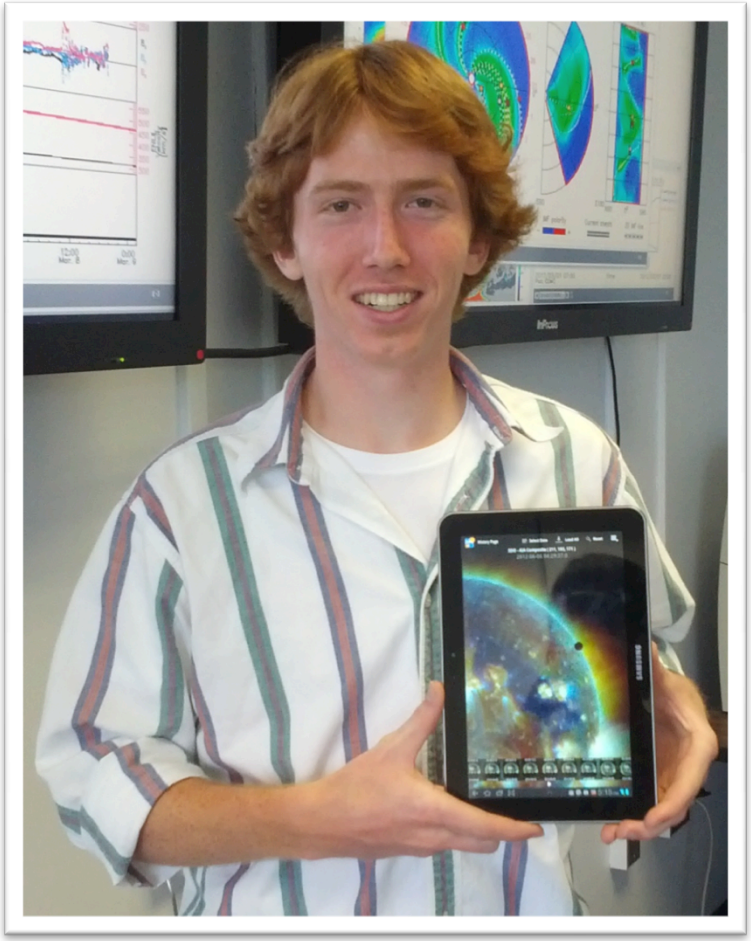
Undergraduate Computer Science Interns
SW Research Analysis Tool Development

Jack LaSota
Web-based CME Analysis Tool



Justin Boblitt
Android iSWA App



CME Tool Link Sample Analysis Link iTunes Link Android Link

Usage/Growth

January 2010 [TRL 6]	January 2012 [TRL 7/8]
iSWA Version **1.0**	iSWA Version **1.9.8**
171 Data Feeds	**370** Data Feeds
6 Million Data Files	**27** Million Data Files
135 SWx Products/Cygnets	**275** SWx Products/Cygnets
3K Visits (2008, 2009)	**170K** Visits (2010, 2011)
728 NASA Visits (2008,2009)	**10K** NASA Visits (2010, 2011)
671 Unique Visitors (2008, 2009)	**70K** Unique Visitors (2010, 2011)
0 twitter followers @NASAiSWA	**132** twitter followers @NASAiSWA

Present /In-Progress Users

- NASA GSFC (SSMO)
- NASA MSFC (ISS)
- NASA JSC (SRAG)
- NASA LRC (CALIPSO)
- AI Solutions/GSFC Conjunction Assessment Risk Analysis Team
- UK Met Office
- Air Force Weather Agency
- Air Force Institute Of Technology
- Electric Power Research Institute
- Belgium Institute Of Technology
- Space Research Institute, Russia IKI RAN
- Korea Meteorological Administration
- Space Environment Technologies

- Heliophysics Summer School
- CISM Summer School
- CCMC Research & Event Studies
- Space Science Programs (CUA, Michigan, GMU, Embry-Riddle, UCLA, ITU, AFIT, BU)
- Korea Astronomy and Space Science Institute (KASI)
- Department Of Homeland Security
- Federal Aviation Administration
- Power Grid Community (NERC, EPRI)
- NASA TDRSS
- Japan Aerospace Exploration Agency
- American Museum Of Natural History

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.

iSWA Impact

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

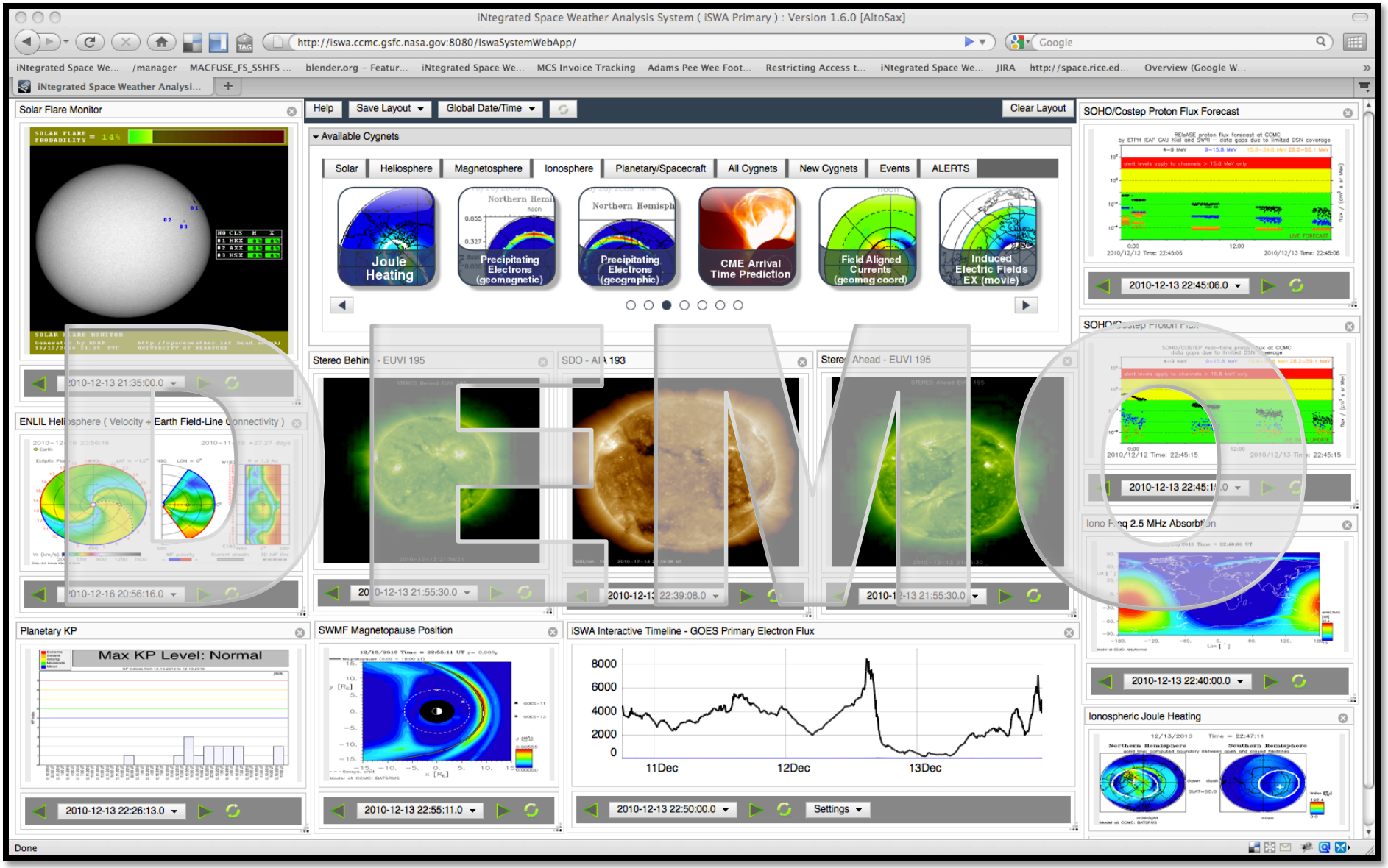
> 40K IOS downloads

> 17K Android downloads

Summary / Future

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

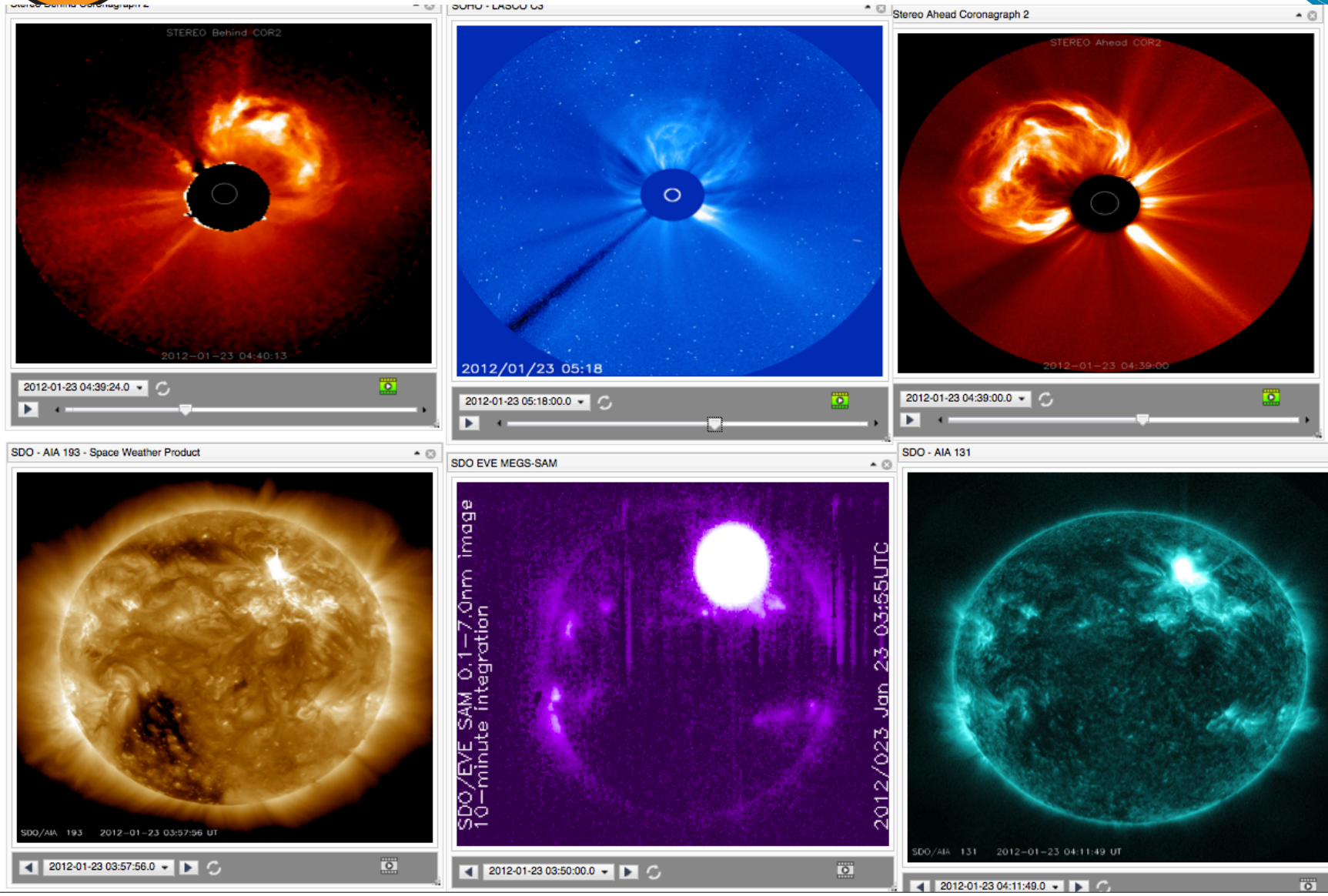
- Increased computing capacity
- Increased storage capacity
- Ingest state-of-the-art space weather models
- Update existing space weather model suite
- Continue to advance model output metadata standards
- Improve visualization techniques
- Improve real-time and forecasting capabilities
- Generate custom tools and services
- Improve general public knowledge and access to space weather



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

Specific Examples…

Jan 23 flare (M8.7)/CME (v=2210km/s)

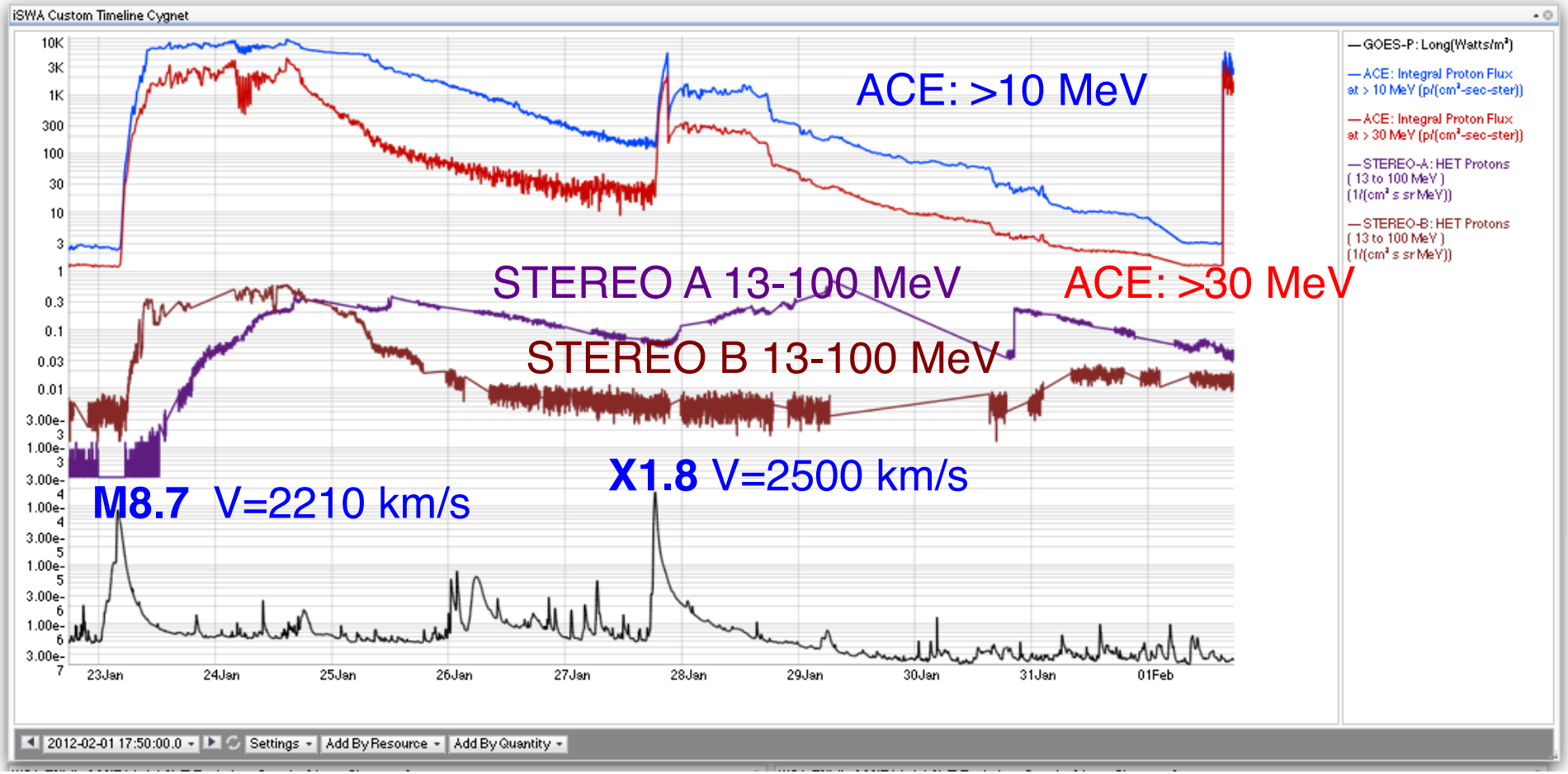


CME

Flare

SEP: proton radiation (flare and CME)

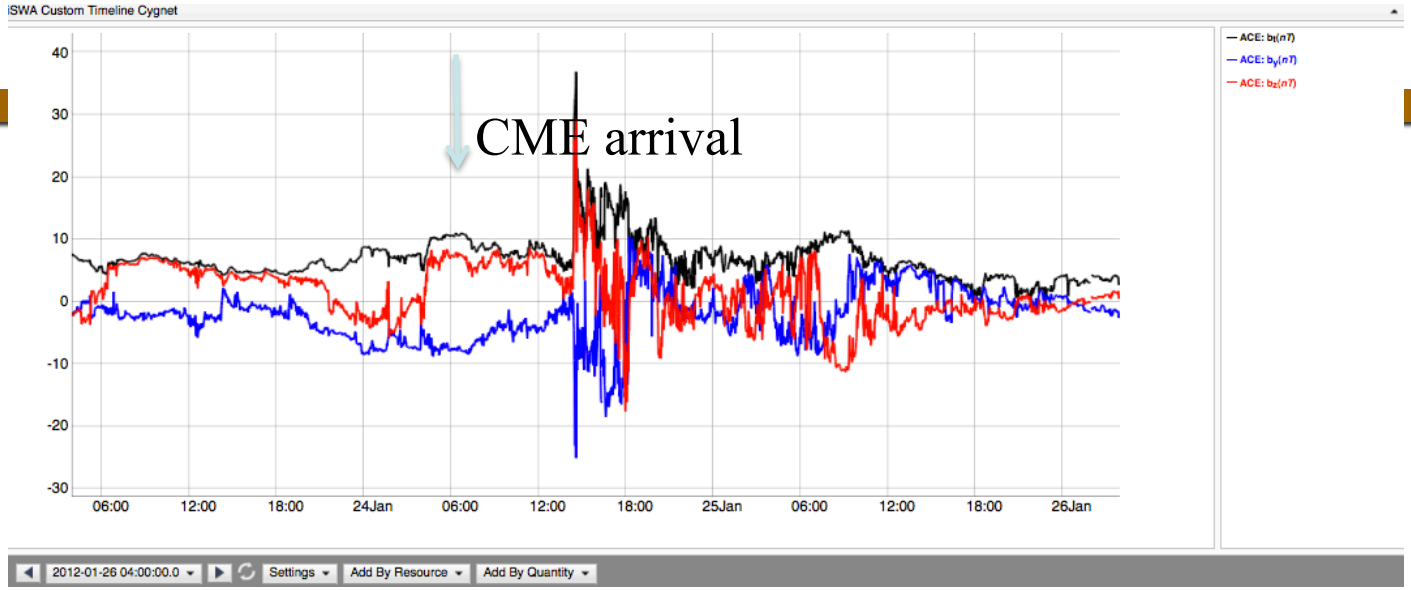
iSWA SuperTimeline

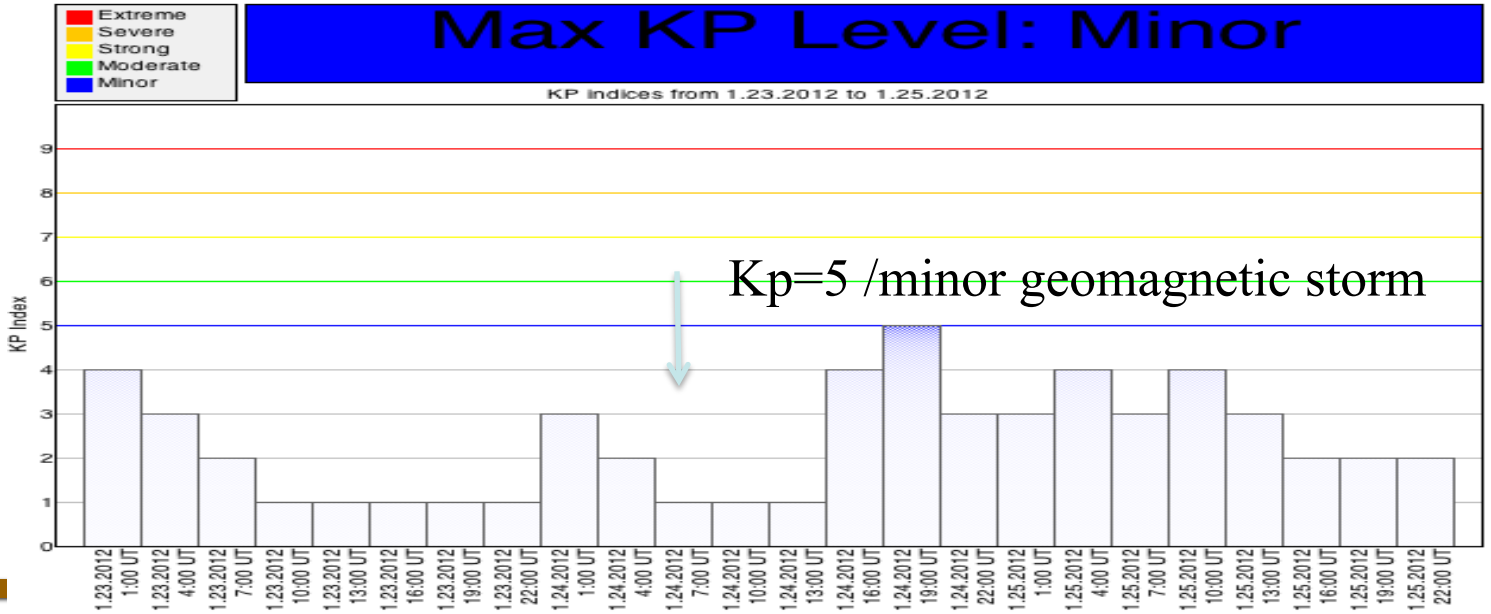


The Jan 23 and Jan 27 flare/CME pairs were associated with the same active region 1402. Both events created significantly enhanced ion radiation (SEP flux levels).

Several polar flights were rerouted due to the radiation

CME impact at Earth (a minor geomagnetic storm only)





An iSWA layout for the 23 Jan 2012 event

http://bit.ly/Jan23_27_2012_layout

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