

NOAA SWPC Needs (Transition to Operations)

H.J. Singer

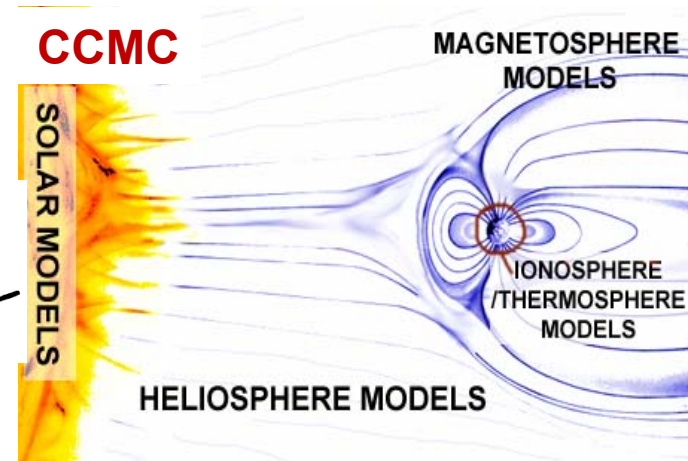
NOAA Space Weather Prediction Center

CCMC Workshop, Key Largo, Florida, January 19, 2012

- **Some History and Motivation**
- **Model Transition to Operations: WSA-Enlil and Geospace**
- **High Priority Customer Needs**
- **Future**
- **Acknowledgments: Biesecker, Millward, Pizzo, Murtagh**



Using Models to Support Customers



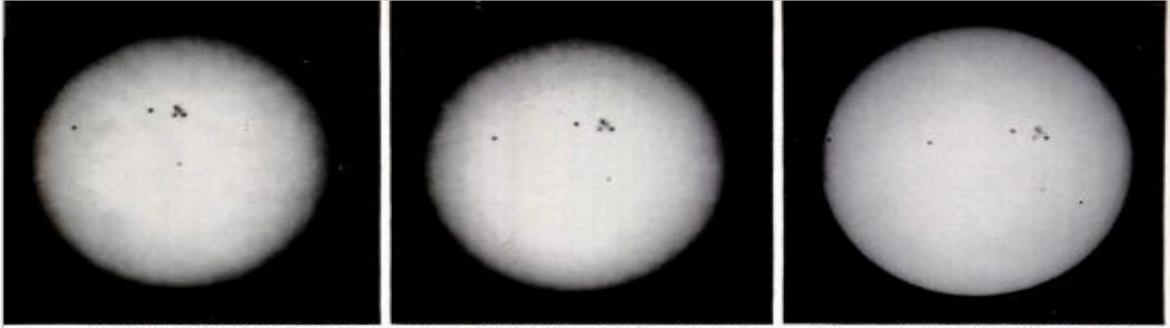
Modeling the Solar-Terrestrial System

Space Weather: Societal and Economic Impact

- March 25, 1940
- Large Geomagnetic Storm
- Western Union set up emergency circuits to re-route messages as regular lines went dead
- Telegraph lines went haywire

Community Developed
Models Are in Use Today at
SWPC to Warn of such
Occurrences

Life Magazine, vol 8, no 15,
page 38, April 8, 1940.




SUNSPOTS GREW TO THIS SIZE BY MARCH 25 **MARCH 26. SPOTS MOVE SLOWLY ACROSS THE SUN'S FACE** **MARCH 27. BIGGEST GROUP IS 32,000 MILES ACROSS**

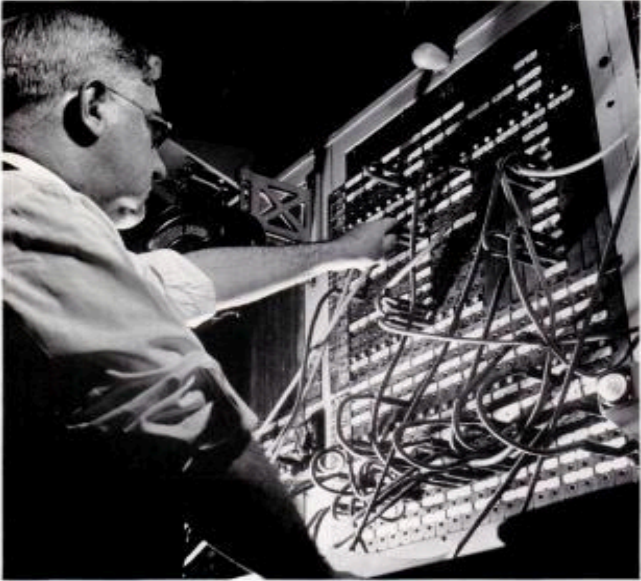
SPOTS ON THE FACE OF THE SUN MESS UP EARTH'S COMMUNICATIONS

Just week the earth's magnetic field had a bad attack of spring fever. Well-behaved landlines of A. T. and T. turned taciturn. The ionosphere, the super-stratospheric layer of the earth's atmosphere, which radio companies use for a cushion to bounce their signals like billiard balls across the ocean, suddenly went porous. Wirephotos showed black streaks and teletype machines went to work on their own to click off alphabetic rhapsodies like the one below.

Moving across the face of the sun could be seen the villains of the piece—a series of sunspots, volcanic whirlwinds of gas which so upset the earth's magnetic field that forces as high as 700 volts were induced in power and communications lines. Counting up at the end of the week, the world found a debit that no one cared to estimate in disrupted communications and fused wires. On the credit side were several spectacular displays of northern lights.



MAP OF U. S. AREAS WHERE "EARTH CURRENTS" WERE STRONGEST



WESTERN UNION SET UP EMERGENCY CIRCUITS TO RE-ROUTE MESSAGES AS REGULAR LINES WENT DEAD

AT THE HEIGHT OF THE MAGNETIC STORM, TELETYPE AND OTHER AUTOMATIC TELEGRAPH MACHINES WENT HAYWIRE, PRINTED OUT MESSAGES LIKE THIS ON THEIR OWN HOOD

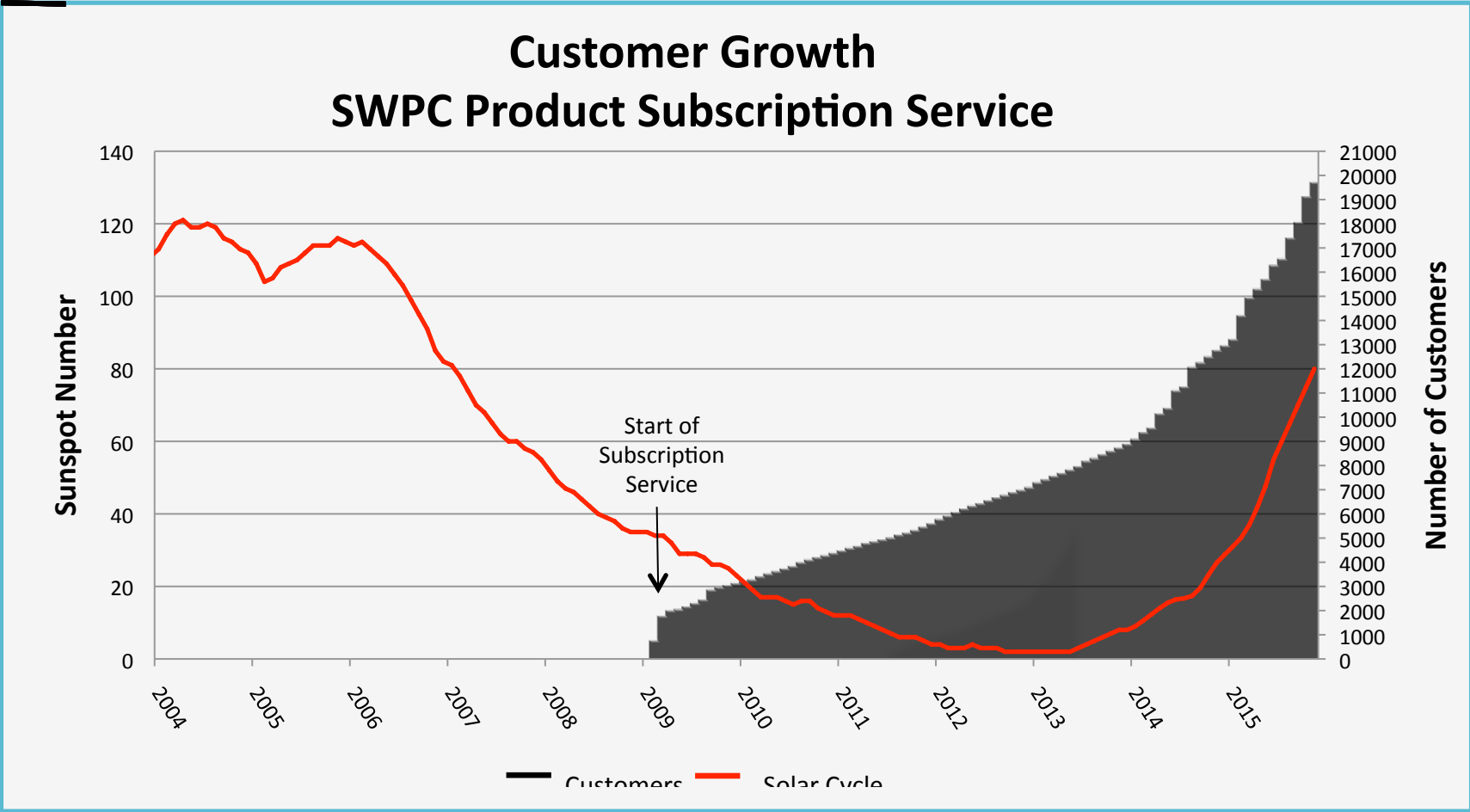
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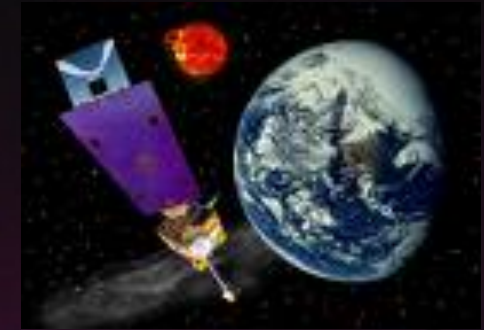
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SWPC Customer Growth is Accelerating



Geomagnetic Storm Impacts

Impacts from geomagnetic storms are wide-ranging with potentially significant consequences.



Satellite Operations

Loss of mission, reduction in capability



Human Spaceflight

Increased radiation risk



Aircraft Operations

Polar Flights, WAAS, NextGen,
Airline Communication



GPS

Precision Agriculture,
Surveying, Drilling, Military

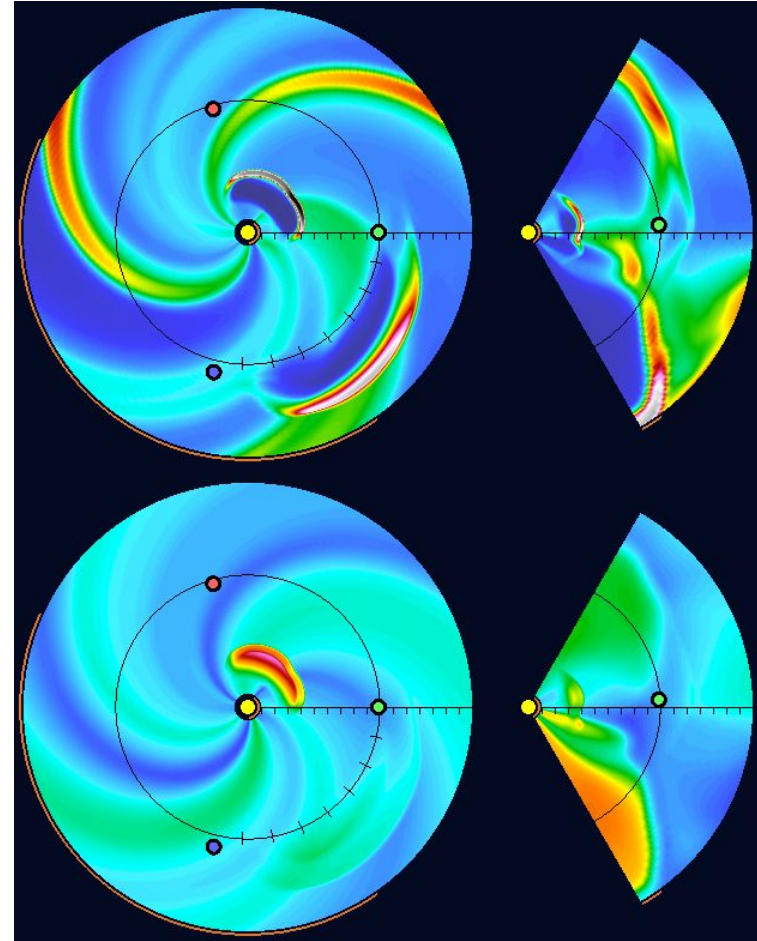


Power Grid Operations

Grid failure, Grid capacity, Component Failure,
GPS Timing

WSA-Enlil Improves Geomagnetic Storm Prediction

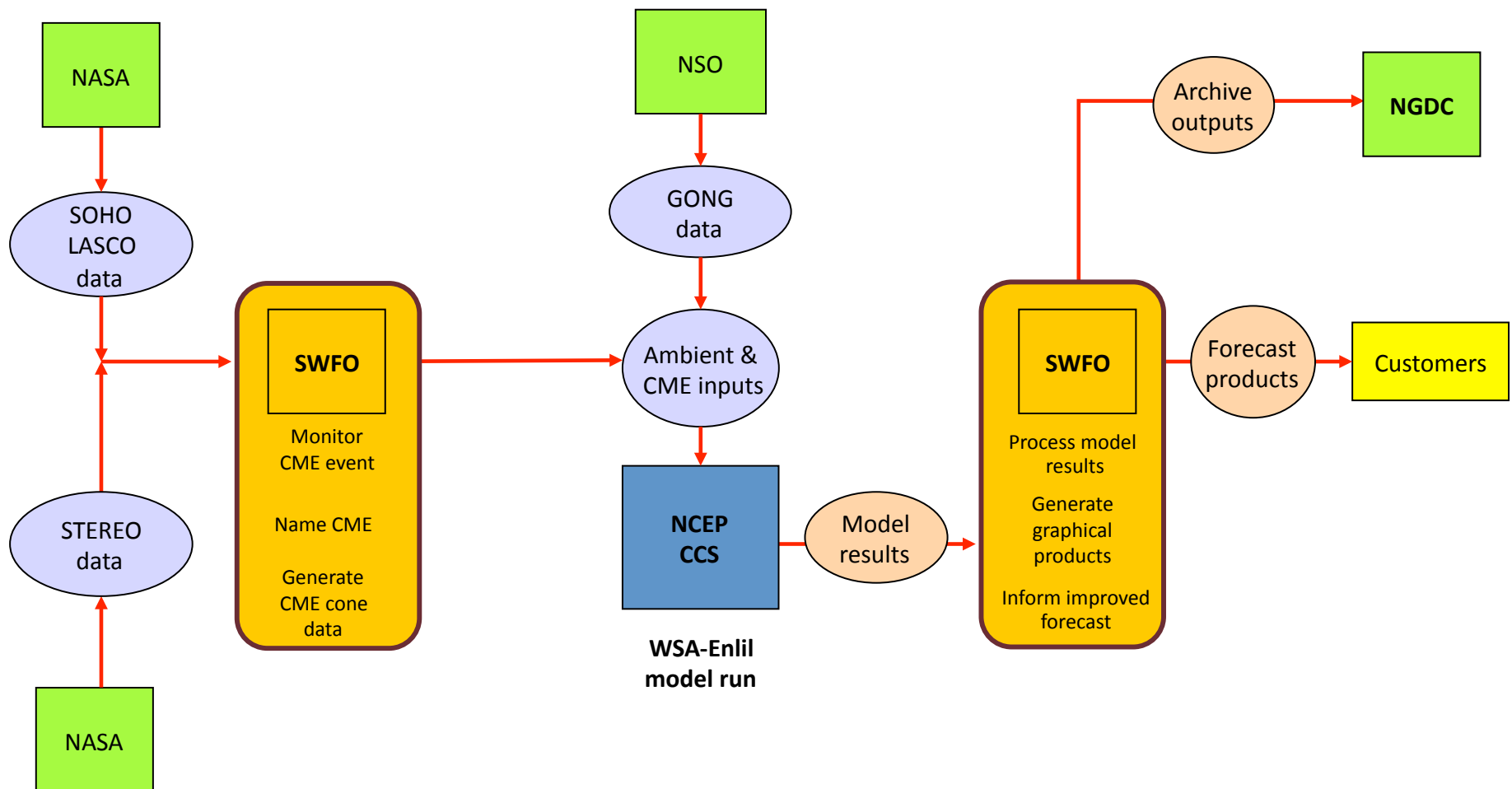
- Provides perspective on co-rotating structures 1-27 days in advance, **CME's 1-4 days**
- Reduces error in geomagnetic storm onset time **from ± 12 hrs to ± 6 hrs**
- Expected to result in improvements to SWPC GPRA



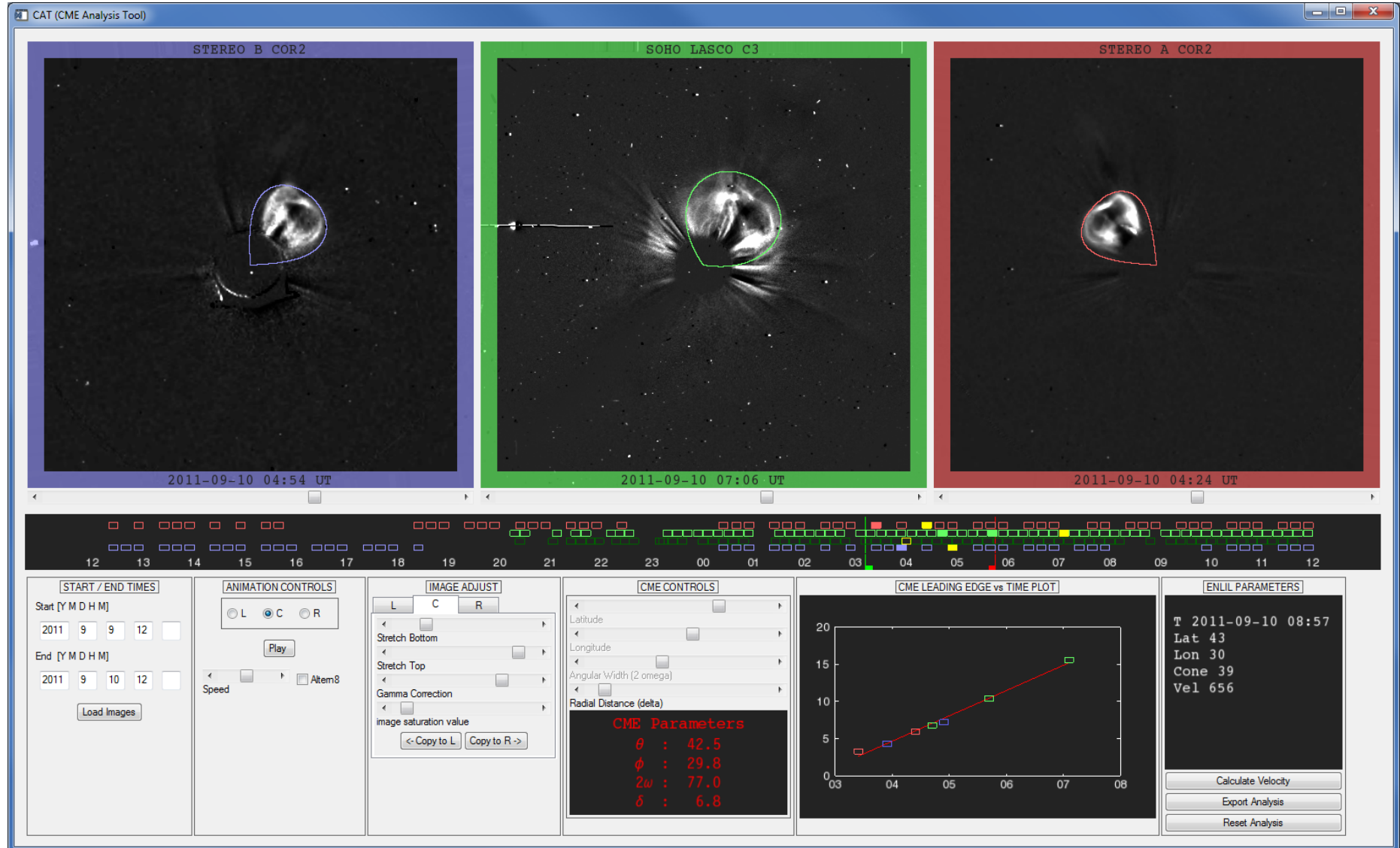
Partnerships

- **NOAA / NWS / NCEP / EMC & NCO (computing) / NGDC (archive)**
- **DoD / AFWA**
- **DoD / AFRL (Nick Arge, WSA model developer)**
- **DoD / NRL (Cone development, STEREO) & ONR (WSA support)**
- **George Mason University & University of Colorado/CIRES**
(Dusan Odstrcil, Enlil model developer)
- **NASA / ESA (SOHO / LASCO / STEREO)**
- **NASA / CCMC (Cone model development)**
- **NSF / CISM / NCAR / LASP**
- **NSF / NSO (GONG)**
- **Basic research community**

WSA-Enlil CONOPS



CAT (CME Analysis Tool)



▪3D rendering of 'lemniscate' (tear drop) onto images from STEREO and LASCO

Tool not yet transitioned to operations as there is significant development still in progress. Meanwhile, the WSA-Enlil team can use the tool as needed.

The Results

EVENT START	Shock at ACE	WSA/ENLIL NOAA	DIFF
02/13/2011 01:44	02/18/2011 00:49	02/17/2011 15:00	9:49
03/08/2011 20:14	03/10/2011 06:10	03/10/2011 08:00	1:50
06/02/2011 07:57	06/04/2011 19:58	06/04/2011 08:00	11:58
06/21/2011 03:25	06/23/2011 02:26	06/23/2011 12:00	9:34
08/02/2011 06:19	08/05/2011 17:22	08/05/2011 17:00	0:22
09/06/2011 00:00	09/09/2011 11:49	09/09/2011 17:00	5:11
09/14/2011 02:00	09/17/2011 02:56	09/16/2011 21:00	5:56
09/24/2011 10:00	09/26/2011 11:53	09/26/2011 16:00	4:07
10/01/2011 00:00	10/05/2011 06:47	10/05/2011 16:00	9:13
10/26/2011 10:00	10/30/2011 08:55	10/30/2011 10:00	1:05
11/09/2011 13:54	11/12/2011 05:30	11/12/2011 02:00	3:30
11/26/2011 08:00	11/28/2011 21:15	11/29/2011 12:00	14:45
AVERAGE ERROR			6:26
RMS ERROR			7:48

‘Average error’ is calculated as ‘average absolute error’, which was used by CCMC in *Taktakishvili et al. 2010.*

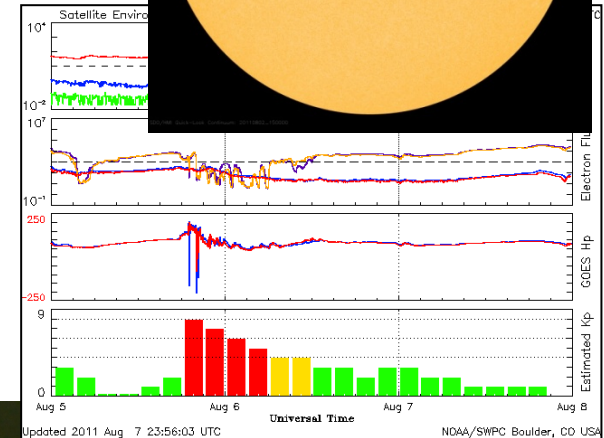
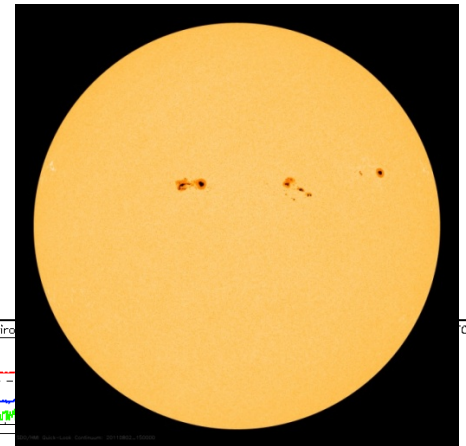
‘RMS error’ is the community preferred measure.

The ‘community’ accepted error during Solar Cycle 23 is ± 12 to ± 15 hours

Aug 2011

Three radio blackouts reaching the R2 (Moderate) levels, all with Earth-directed coronal mass ejections on August 2nd, 3rd, and 4th.

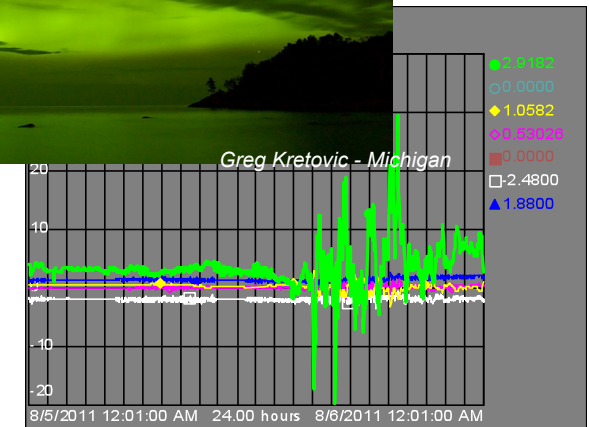
“Storming levels are expected to attain G3 (Strong)”



SWPC performance reviewed at NERC (North American Electric Reliability Corp.) in Atlanta.

NERC, FERC, DOE, NASA, USGS, and multiple industry types in attendance

“SWPC forecasts were spot-on” - PJM



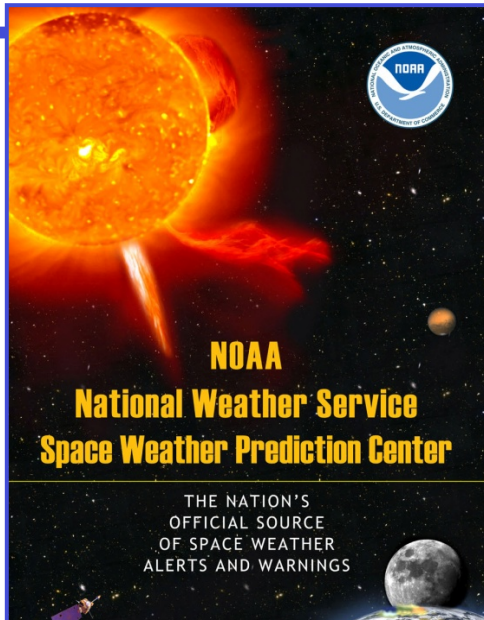
Excellent job by SWPC Operations and supporting staff

Future Plans

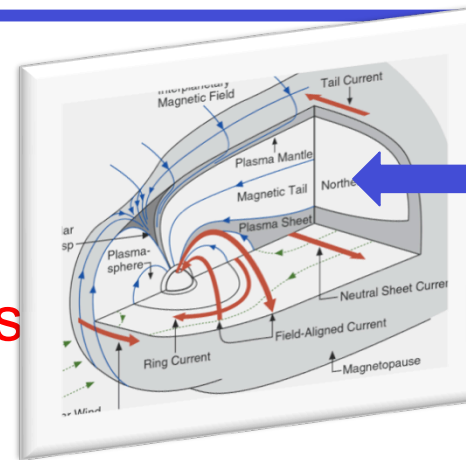
- **For FY12**
 - Tool development continuing
 - Forecaster Training
 - **Modify WSA-Enlil to enable continuous updating mode**
 - Should provide better estimate of evolving background flow
 - Will 'fix' inconsistencies that result when more than 1 CME
 - Should eliminate 10 simulation days of ENLIL startup, cutting CCS runtime to ~45 minutes
 - V&V and enhanced performance tracking
- **Beyond FY12**
 - Improved inputs
 - especially as regards CME parameterization
 - Improved products
 - 3D rendering, estimates of storm strength and duration, Bz
 - Ensembles
 - Enabled through improved CCS runtime and results of V&V



Geospace Model Transition to Operations

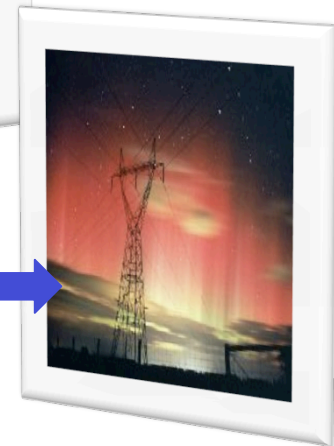


- Metrics
- Selection Considerations
- Plans



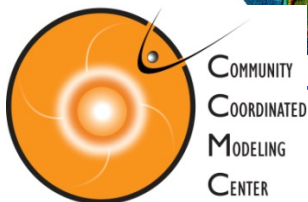
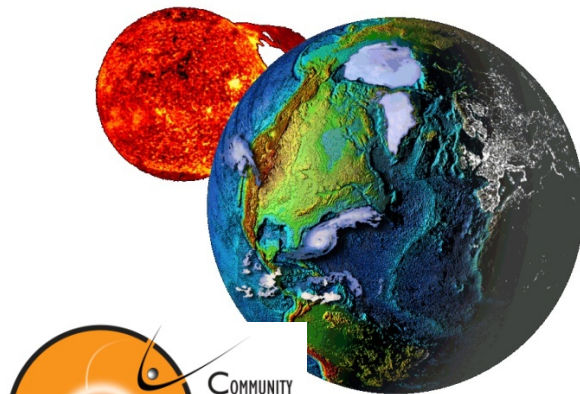
Geospace
Models

Protecting
Power Grids
(and other services)



Howard Singer and Terry Onsager
NOAA Space Weather Prediction Center
Masha Kuznetsova, Antti Pulkkinen, Lutz Rastaetter
NASA Community Coordinated Modeling Center

Safeguarding Our Nation's Advanced Technologies



High-level government response...

Coordinating on ways forward to develop and implement mitigation strategies to safeguard critical infrastructure from the impacts of severe space weather.

- **The Shield Act (H.R. 668) (Feb 2011)**

To amend the Federal Power Act to protect the electric infrastructure geomagnetic storm (and EMP)

- **Meeting at White House with National Security Staff and OSTP (18 Feb)**

- **Op Ed in NY Times on space weather by Holdren and Beddington (10 Mar)**

- **Electric Infrastructure Security Summit (EISS) in Washington D.C. (11 Apr)**



The New York Times
The Opinion Pages

WORLD U.S. N.Y. / REGION BUSINESS TECHNOLOGY

I.H.T. OP-ED CONTRIBUTOR
Celestial Storm Warnings
By JOHN P. HOLDREN and JOHN BEDDINGTON
Published: March 10, 2011

Weather is often in the headlines. But largely unnoticed last month was the weather that forced airlines flying the polar route between the United States and Asia to detour south over Alaska. This unusual routing was a response to a “space weather” event — an enormous ejection of charged gas from the Sun capable of scrambling terrestrial electronic instruments.

John P. Holdren is the science and technology adviser to President Barack Obama. John Beddington is the chief scientific adviser to Prime Minister David Cameron.



The New York Times
Opinion

WORLD U.S. N.Y. / REGION BUSINESS TECHNOLOGY SCIENCE HEALTH

EDITORIALS COLUMNISTS CONTRIBUTORS LETTERS

OP-ED CONTRIBUTOR
The Sun Also Surprises
By LAWRENCE E. JOSEPH
Published: August 15, 2010

Los Angeles

DESPITE warnings that New Orleans was unprepared for a severe hit by a hurricane, America was blindsided by Hurricane Katrina, a once-in-a-lifetime storm that made headlines years ago this month. We were similarly unready for another potential natural disaster: storms, bursts of gas on the surface that release tremendous energy pulses.



Geospace Model Project Goals



- **Goal:** Evaluation of Geospace prediction models to determine which model or models should begin transition to operations process beginning about Q4 2012.
- **Focus:** Models that can predict regional geomagnetic activity
- **Process:** CCMC leads evaluation; Build on GEM Storm Challenge; Establish partnerships; Select metrics; Conduct evaluation, Model(s) selection
- **Community Discussions:** GEM, AGU, and CCMC Meetings; Geomagnetic activity products documents circulated, Geospace Model Validation Workshop...



Models at CCMC Participating in Geospace Evaluation



MHD Models:

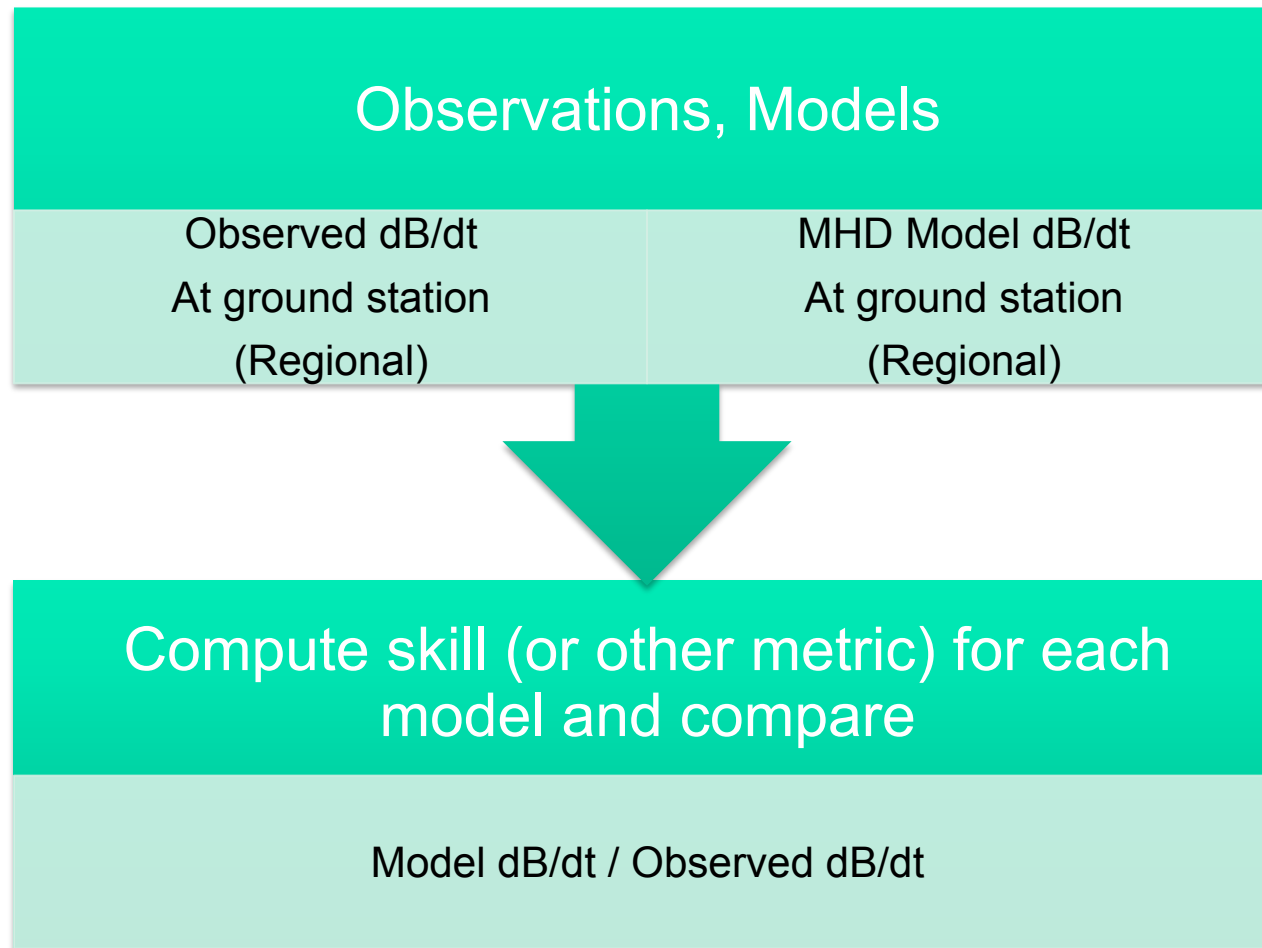
- Space Weather Modeling Framework (SWMF) - U. of Michigan (delivered to CCMC)
- The Open Geospace General Circulation Model (Open GGCM) - University of New Hampshire (delivered to CCMC)
- Coupled Magnetosphere-Ionosphere-Thermosphere (CMIT) - BU CISM, Dartmouth, NCAR (delivered to CCMC)
- Grand Unified Magnetosphere-Ionosphere Coupling Simulation (GUMICS) - Finnish Meteorological Institute (recently parallelized, not ready for full evaluation for selection process)

Empirical Models:

- Weimer Empirical Model, Va. Tech (delivered to CCMC/may update)
- Weigel Empirical Model, George Mason (delivered to CCMC)

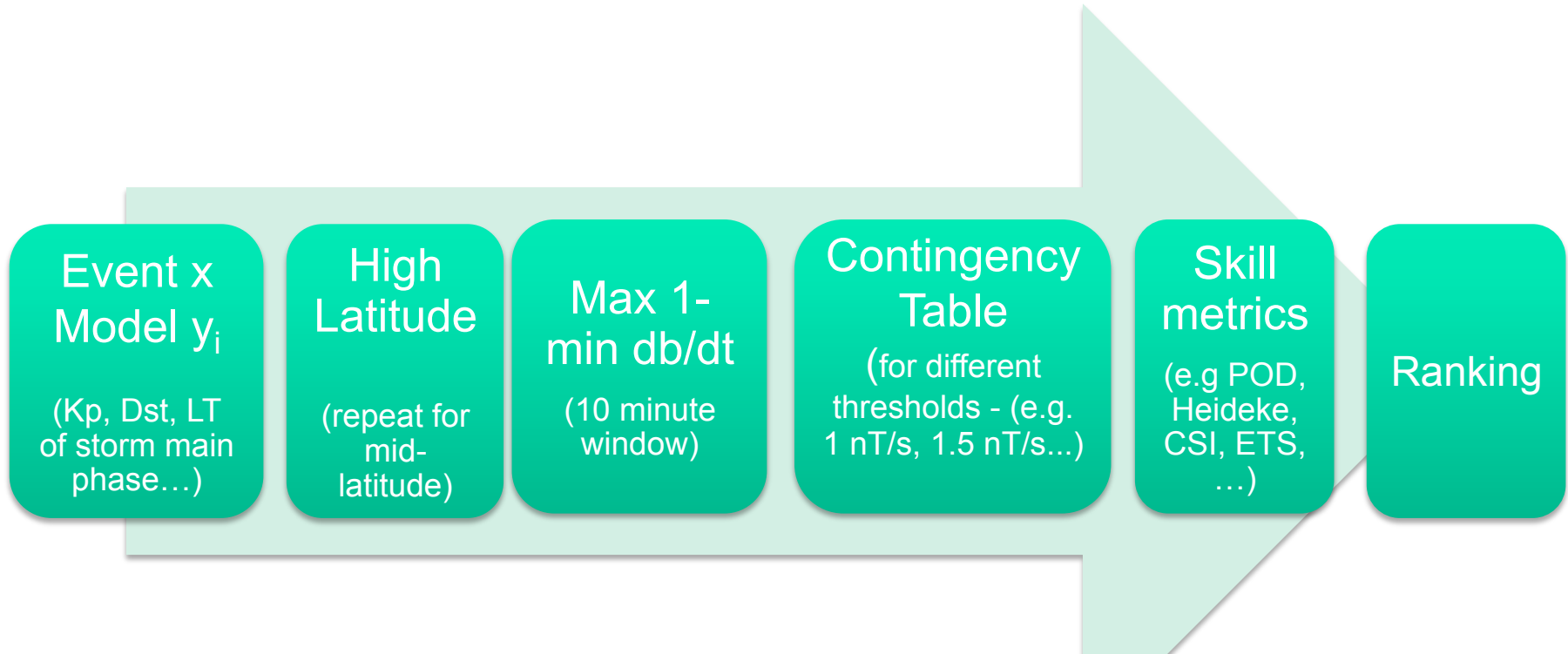


Regional dB/dt Prediction

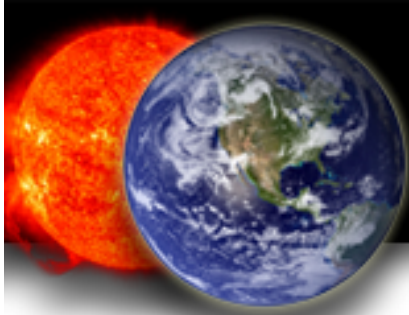




dB/dt Evaluation

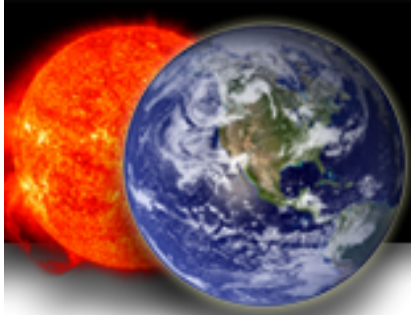


Contingency Table	Event Observed	
	Yes	No
Event Forecast	Yes H (hit)	No F (false alarm)
	No M (misses)	N (correct rejections)



Geospace Model Recommendation Process

- Models will be evaluated on four criteria:
 - Strategic Importance
 - Operational Significance
 - Implementation Readiness
 - Cost to Operate, Maintain, and Improve
- Evaluation team will consist of internal and external participants
- Modelers to review and comment on draft Recommendation Report prior to delivery to SWPC Director
- The final Recommendation Document will be made public
- Selection will be made by SWPC Director



Possible Findings/Recommendations

- One (and only one) MHD model has sufficient value to justify transition and operation costs – Recommend transition
- Multiple MHD models have sufficient value – Recommend one model based on highest long-term value and lowest cost
- No MHD model has sufficient value, but near-term improvements could be made – Recommend SWPC support for additional development and testing
- One or both empirical models have sufficient value – Recommend either or both for transition
- No model has sufficient value – Recommend no SWPC action



Geospace Model Transition: Recent Activities and Current Schedule

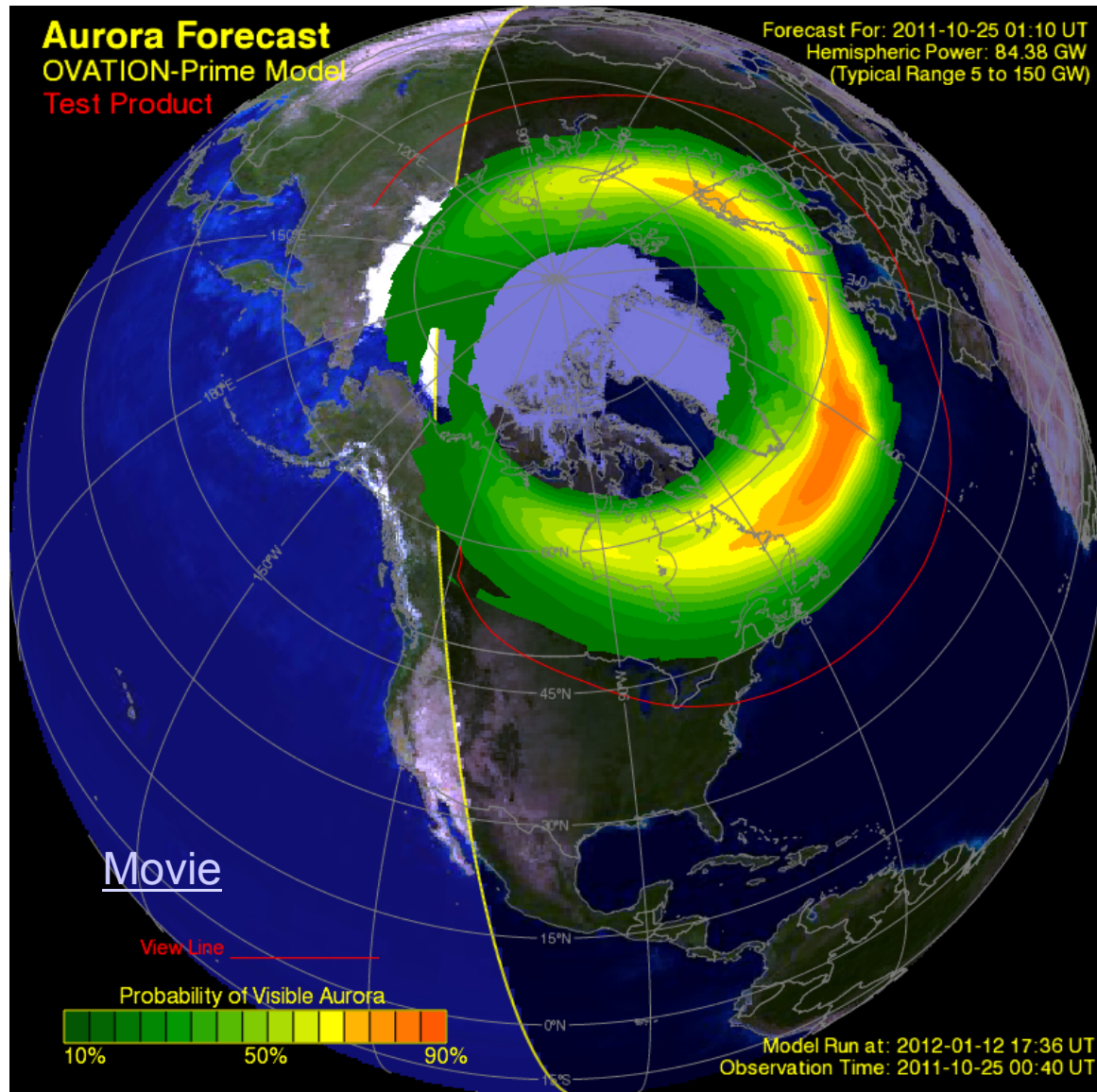


(draft under discussion with CCMC)

- 4/25/11: Geospace modeler meeting focused on evaluation metrics, selection process and initiate discussion to understand resource requirements
- May-June 2011: Spatial, temporal, and window sensitivity testing at CCMC to refine and iterate on metrics, event selection, verification measures
- June 26 – July 1 2011: GEM-CEDAR Workshop including Modeling Challenges and discussions with modelers on sensitivity tests and schedule
- July – Nov 2011 : Empirical model tests, gathering data for additional events, tool to integrate currents, comparisons of db/dt calculated by CCMC and modelers (SWMF and GGCM)
- Dec: Presentations and discussions with modelers at Metrics and Validation Session at Geospace Modeling Workshop (day before AGU meeting)
- Jan 2012: Runs and post processing
- Feb – March 2012: Analysis and Report Writing
- April-May 2012: SWPC circulate draft report for comments
- June 2012 - : Model Selection at SWPC

New Test Product Example

Newell Auroral Model



Highest Priority Needs for SpWx Operations 1.

(An evolving list with some topics for improvement)

1. Improved forecasts of Geomagnetic storms

- 1. Requires better CME specification and parameterization.**
- 2. Requires better specification of the background solar wind.**
- 3. Requires improved modeling of heliospheric magnetic fields and fields within CMEs (B_z).**

2. Forecasts of geomagnetic activity, including spatially resolved variations in electromagnetic fields and Geomagnetic Induced Currents (GICs)

- 1. Requires magnetospheric models driven by solar wind observations.**
- 2. Requires improvements to magnetosphere-ionosphere coupling and the generation of electromagnetic fields on the ground.**

3. Prediction of ionospheric scintillations and gradients in the Total Electron Content (TEC) of the ionosphere.

- 1. Requires modeling of all ionospheric drivers including solar EUV, geomagnetic storms, and waves/tides from the troposphere.**
- 2. Requires better understanding of the small-scale physics of ionospheric scintillation.**

Highest Priority Needs for SpWx Operations 2.

(An evolving list with some topics for improvement)

4. Forecasts of the location and intensity of the Aurora

1. Requires research on coupling WSA-Enlil output to the OVATION Prime model and significant improvement in predicting Bz and other field components

5. Forecasts of the magnitude and timing of solar flares

1. Flares are the precursor to all large space weather storms

2. Flare forecast would provide predictions of HF radio blackouts

6. Forecasts of Solar Energetic Particle events and Radiation Storms

1. Research required to insert energetic particles and electromagnetic shock physics into heliospheric models such as WSA-Enlil

7. Forecasts of the geospace energetic particle radiation environment

1. Requires understanding of sources and losses of energetic particles

Transfer of Models to Operations: Some Key Lessons Learned

- **Demonstrating customer benefit – whether a new product or showing improvement of an existing product**
- **Model validation is essential to demonstrate readiness for transition and user metrics need to be established (as well as the scientific metrics).**
- **Evaluating Cost/Benefit**
- **Importance of iterative development between SWPC (forecasters, scientists, managers, IT..) and model developers—bringing together partners with different expertise and perspectives to find solutions and develop products**
- **Focus on limited set of model products at any one time**
- **Model transition needs to involve and support model developers**

Future

- Evaluate where there is match between customer needs and research models available at CCMC and in the scientific community
- Invest in those models where there is a significant customer benefit

Research to Operations – Operations to Research

- On-going activity supporting NOAA SWPC is also extremely beneficial to CCMC Runs-on-Request users [models have been updated]
- NASA/GSFC Space Weather Desk supporting NASA Robotic Missions
- GEM Community

-- M.

Kuznetsova