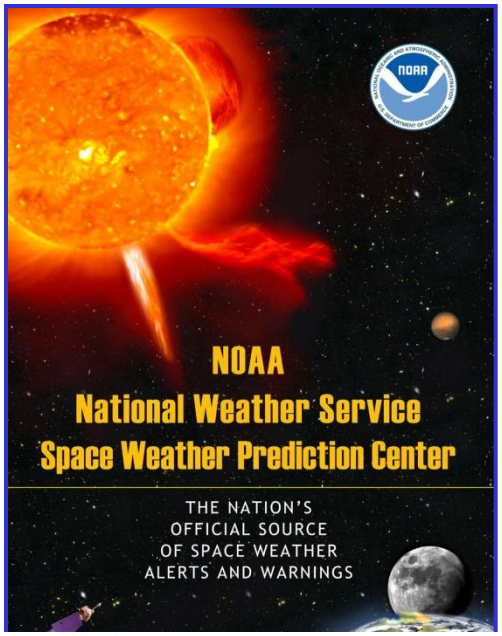
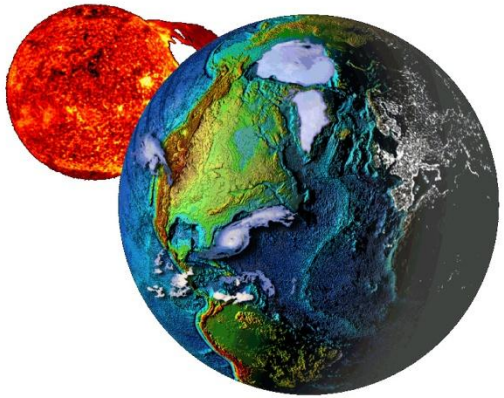
Assessing Geospace Models for Use in Space Weather Operations





Outline:

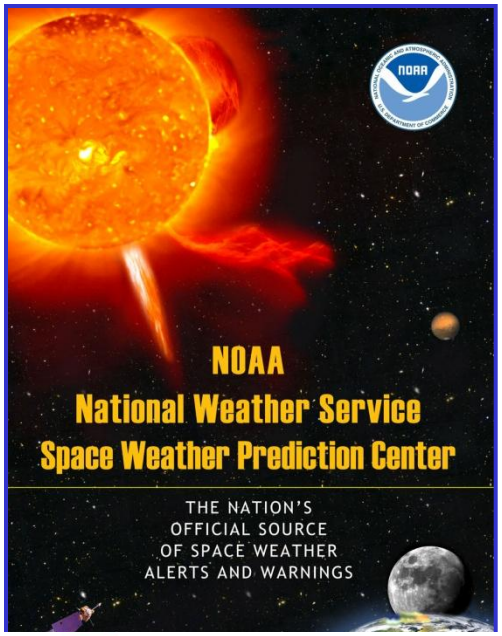
- Customer Needs (selected examples)
- Geospace Model Project and Partners
- Events, Evaluation, New Results
- Selection Process and Next Steps
- Conclusions

Acknowledgments: Balch, Doggett, Onsager, NASA CCMC (Kuznetsova, Pulkkinen, Rastaetter), Geospace Modelers

Howard J Singer- NOAA Space Weather Prediction Center
Space Weather Workshop, Boulder CO, April 27, 2012

Safeguarding Our Nation's Advanced Technologies

Assessing Geospace Models for Use in Space Weather Operations



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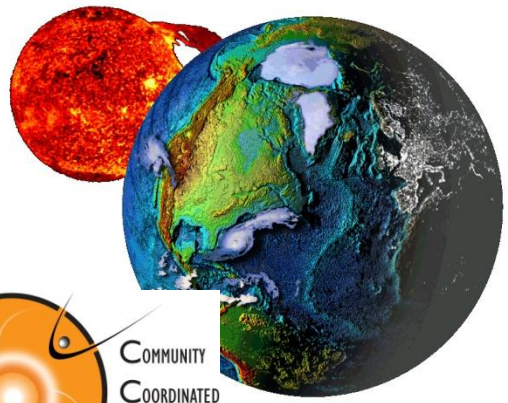


NASA CCMC (Kuznetsova, Pulkkinen, Rastaetter) and Geospace Modelers

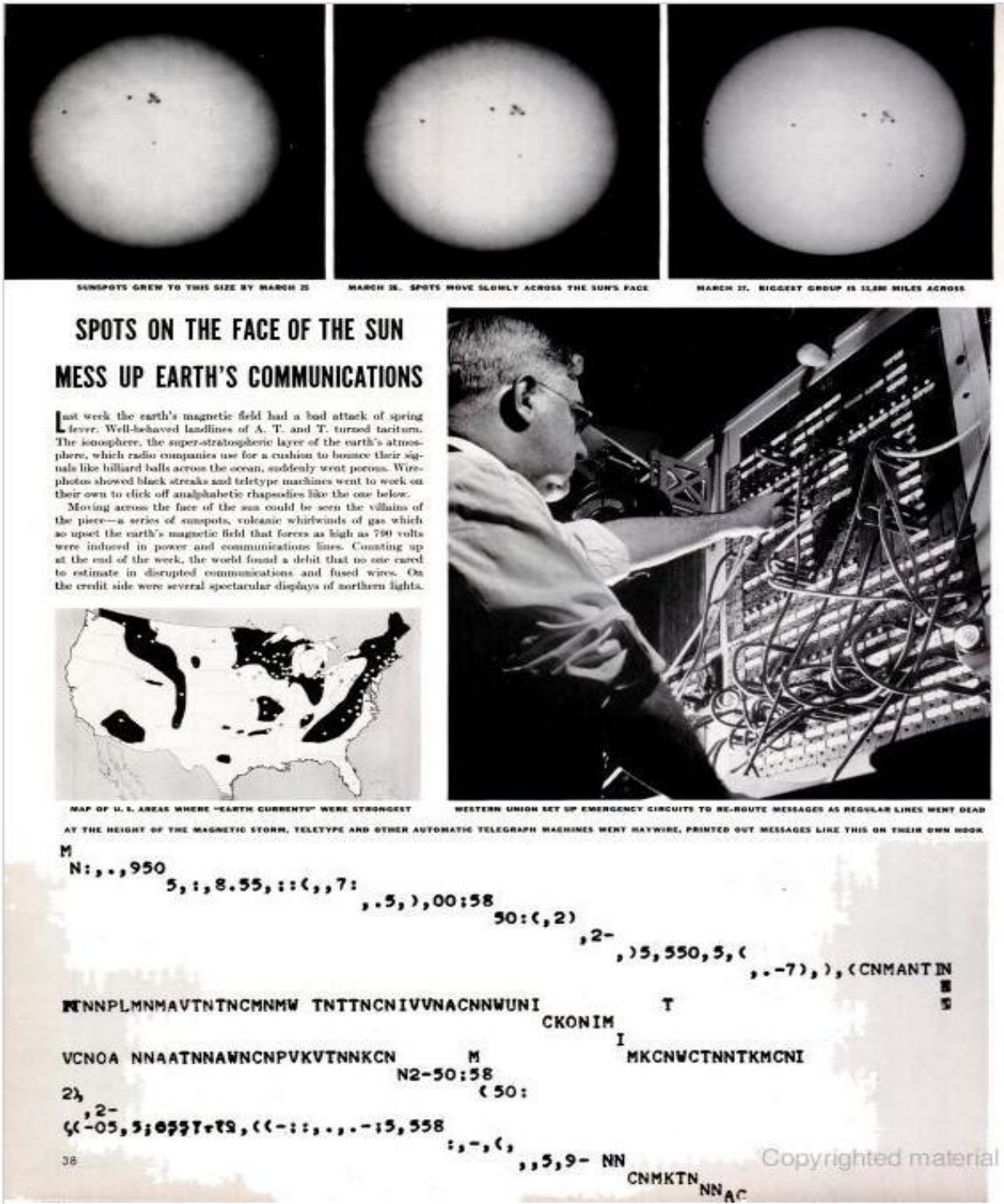
Space Weather Workshop, Boulder CO, April 27, 2012

COMMUNITY COORDINATED MODELING CENTER

Safeguarding Our Nation's Advanced Technologies

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.
- Geospace models in operations will help to protect similar, but modern, vital services



SUNSPOTS GREW TO THIS SIZE BY MARCH 25 MARCH 26. SPOTS MOVE SLOWLY ACROSS THE SUN'S FACE MARCH 27. BIGGEST GROUP IS 11,500 MILES ACROSS

SPOTS ON THE FACE OF THE SUN

MESS UP EARTH'S COMMUNICATIONS

Last 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 analphabetic 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 HOOK

38

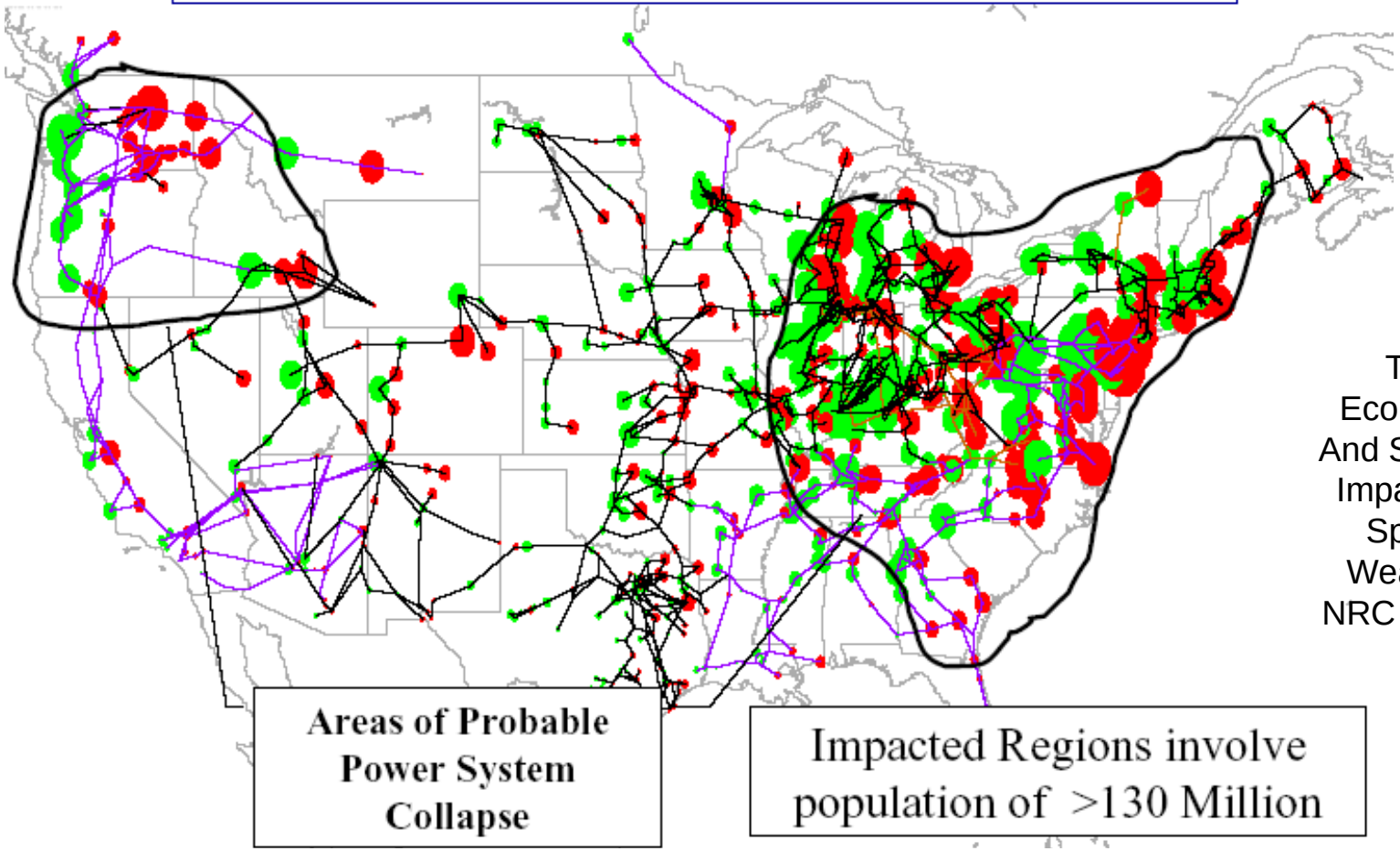
Copyrighted material

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

Regional Power Grid Disruptions

Severe Electrojet Disturbance Scenario

Power System Disturbance and Outage Scenario of Unprecedented Scale



The Economic And Societal Impacts of Space Weather, NRC Report

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)*

- **Effects of Geomagnetic Disturbances on the Bulk Power System** *(NERC, 2012)*


The New York Times
The Opinion Pages

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

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

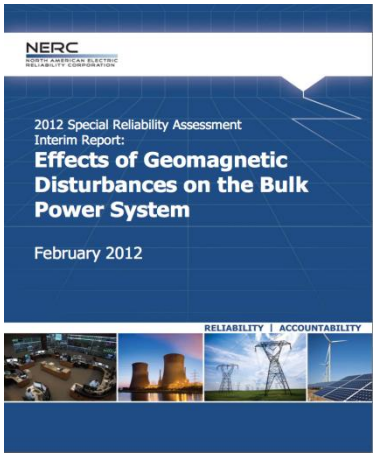
OP-ED CONTRIBUTOR

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 landfall five years ago this month. We are similarly unready for another potential natural disaster: solar storms, bursts of gas on the sun's surface that release tremendous energy pulses.


NERC

2012 Special Reliability Assessment
Interim Report:
Effects of Geomagnetic Disturbances on the Bulk Power System

February 2012

RELIABILITY | ACCOUNTABILITY

Prediction is our Goal

Given the severe economic and societal impacts that can result from intense geomagnetic activity, our goal is to evaluate, select and transition to operations geospace model(s) with predictive capability.

Relevant to this goal is a quote and corollary used by Oxford mathematician David Orrell:

“ A good hockey player plays where the puck is. A great hockey player plays where the puck is going to be. –Wayne Gretzky

In our case, we want to know what future geomagnetic activity is going to be, and where it is going to occur, so that like the hockey player we are ready to respond.

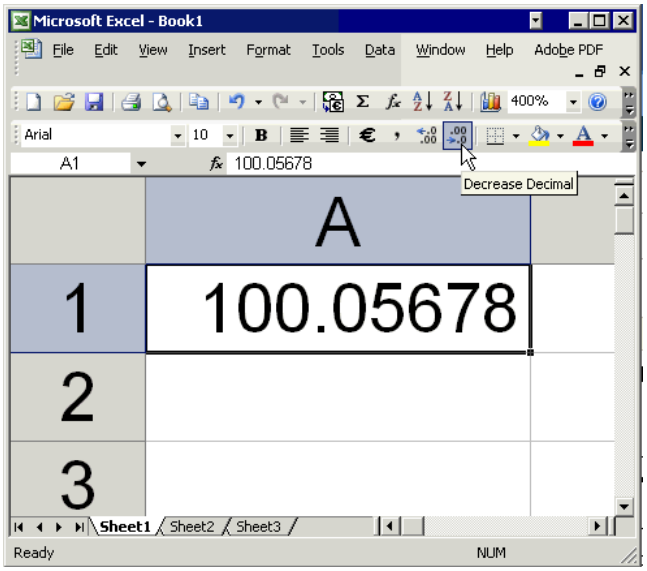
Corollary: It doesn’t work if everyone follows Gretzky’s advice. At least one player has to play the puck, or the puck would be put down and everyone would move away.

And, speaking of prediction

Our work will be done with a high degree of precision, because we want emulate the economists:

"Economists give their predictions to a digit after the decimal point to show that they have a sense of humor."

– Unknown



Geospace Model Project Goals

- Goal: Evaluation of Geospace prediction models to determine which model or models should begin transition to operations process in 2012.
- Focus: Models that can predict regional geomagnetic activity
- Process: CCMC leads evaluation; Build on GEM Storm Challenge; Establish partnerships; Select metrics; Conduct evaluation
- Community Discussions: GEM, AGU, CCMC Meetings, Space Weather Workshop; Geomagnetic activity products documents circulated, Geospace Model Validation Workshops…

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
  (parallel version not ready for full evaluation, but showing progress)
- Empirical Models
- Weimer Empirical Model, Va. Tech (delivered to CCMC)
- Weigel Empirical Model, George Mason (delivered to CCMC)

Challenge Setup: Events

Table 1. Geospace storm events studied in the Challenge. The last two columns give the minimum Dst index and the maximum Kp index of the event, respectively.

Event #	Date and time	min(Dst)	max(Kp)
1	October 29, 2003 06:00 UT - October 30, 06:00 UT	-353 nT	9
2	December 14, 2006 12:00 UT - December 16, 00:00 UT	-139 nT	8
3	August 31, 2001 00:00 UT - September 1, 00:00 UT	-40 nT	4
4	August 31, 2005 10:00 UT - September 1, 12:00 UT	-131 nT	7

Pulkkinen et al. 2010

Additional events

5. April 5, 2010 00 UT - April 6, 2010 00 UT -73 nT 8-
(Galaxy 15 Event)

6. August 5, 2011 09 UT – August 6 2011 09 UT -113 nT 8-

Challenge setup: stations

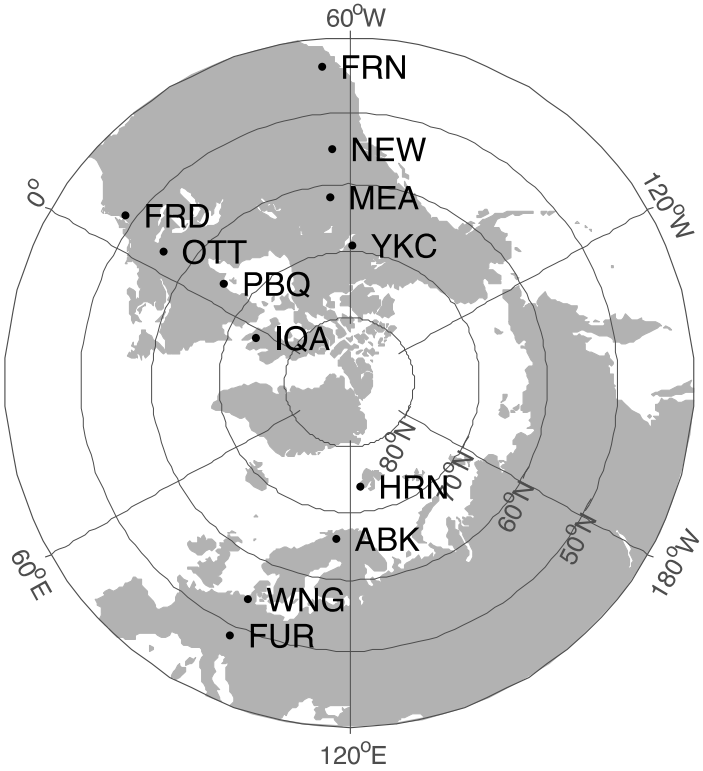


Figure 2. The locations and the station codes of the geomagnetic observatories used in the study. Geomagnetic dipole coordinates are used.

Note: For recent events: needed to substitute station SNK for PBQ. PBQ was discontinued. Separated by about 2 deg geographic

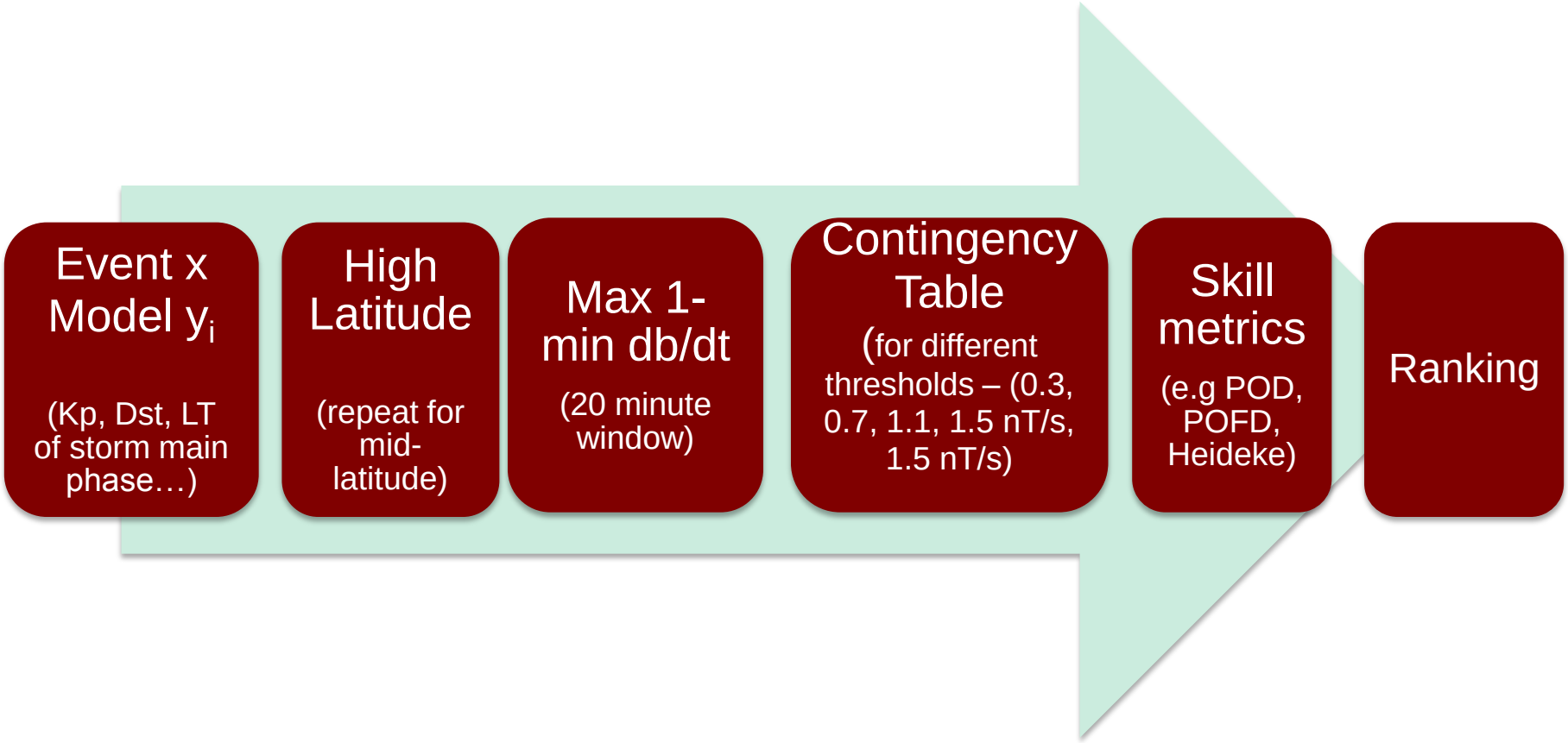
Pulkkinen et al. 2010

Regional dB/dt Prediction

Challenge

- How well can MHD and empirical models predict a regional (high and mid- geomagnetic latitudes in three distributed latitudinal chains) dB/dt (max disturbance exceeding specific thresholds) compared to the ground observed value over specified time interval (20 min)?
- Currently Available: No product

dB/dt Evaluation Metrics Selection



Contingency Tables:

Probability of Detection (POD), Probability of False Detection (POFD), and Heidke Skill Score

Event Forecast	Event Observed		
	Yes	No	Marginal Total
Yes	A (Hit)	B (False Alarm)	A + B
No	C (Miss)	D (Correct Negative)	C + D
Marginal Total	A + C	B + D	A+B+C+D = N

Probability of Detection: fraction of observed events forecast correctly. POD = A/(A+C). Ranges from (0,1) bad to good.

Probability of False Detection: fraction of no events, incorrectly forecast as yes events. POFD = (B)/(B+D) Ranges from (0,1) good to bad.

Heidke Skill Score: fraction of correct forecasts after eliminating forecasts that would be correct by random HSS = 2(AD-CB)/((A+C)(C+D)+(A+B)(B+D)) where 0 no skill, 1 perfect.

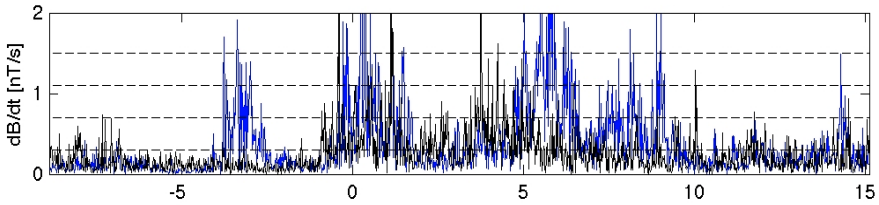
In part from: Lopez et al., Space Weather Journal, 2007.

Preliminary db/dt Results

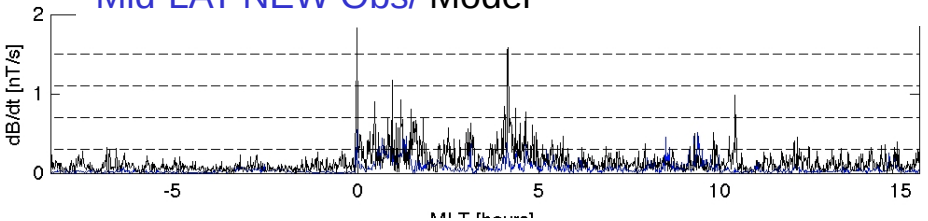
Event X / Model Y

High Latitude and Mid-Latitude Chains

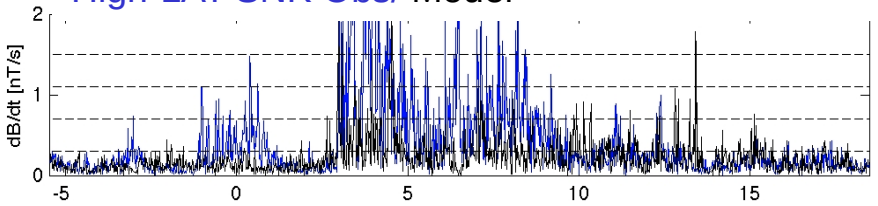
High-LAT YKC Obs/ Model



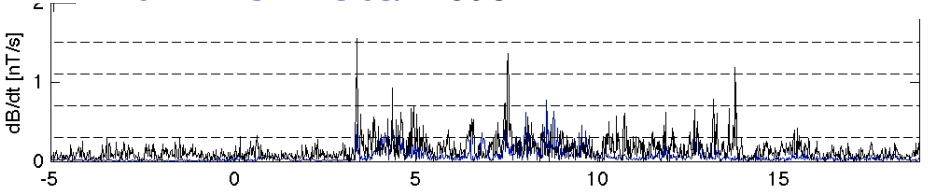
Mid-LAT NEW Obs/ Model



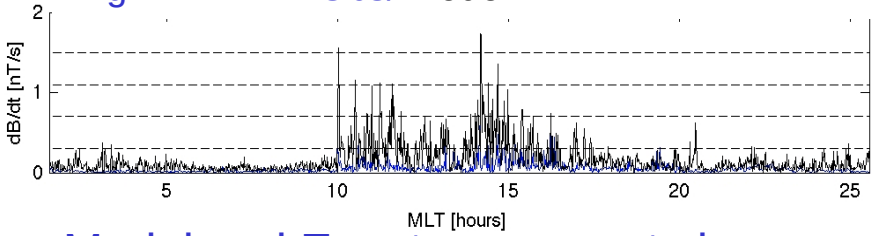
High-LAT SNK Obs/ Model



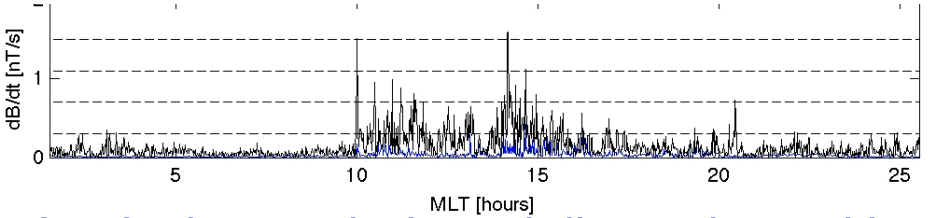
Mid-LAT OTT Obs/ Model



High-LAT ABK Obs/ Model



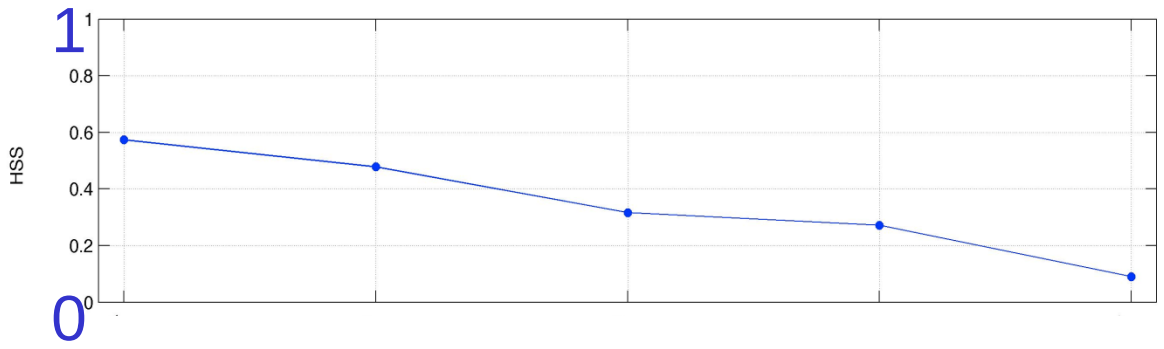
Mid-LAT WNG Obs/ Model



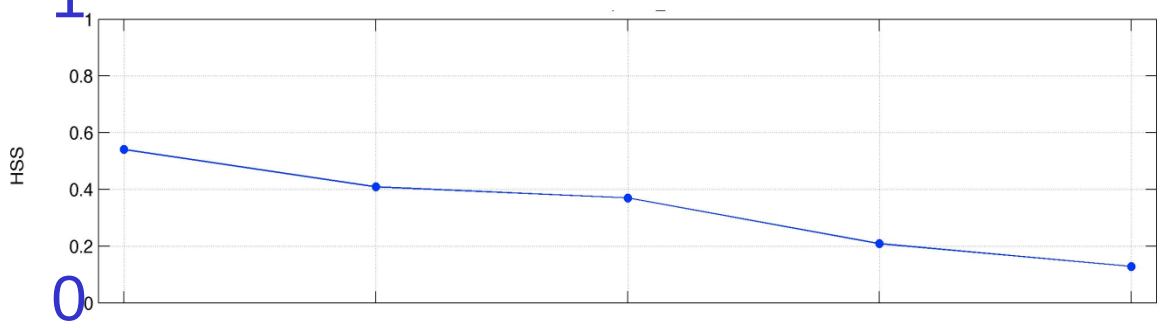
- Model and Event names not shown until after further analysis and discussions with modelers
- Generally the models capture the major enhancements at both high and mid-latitudes, although differences in magnitudes; remember these are predictions
- This model underestimates and misses some of the disturbances
- Similar results for other events; encouraging results that models provide value

Heidke Skill Score
Ranked for all model/data comparisons over all Events

Mid Latitude 0.3 nT/s Threshold



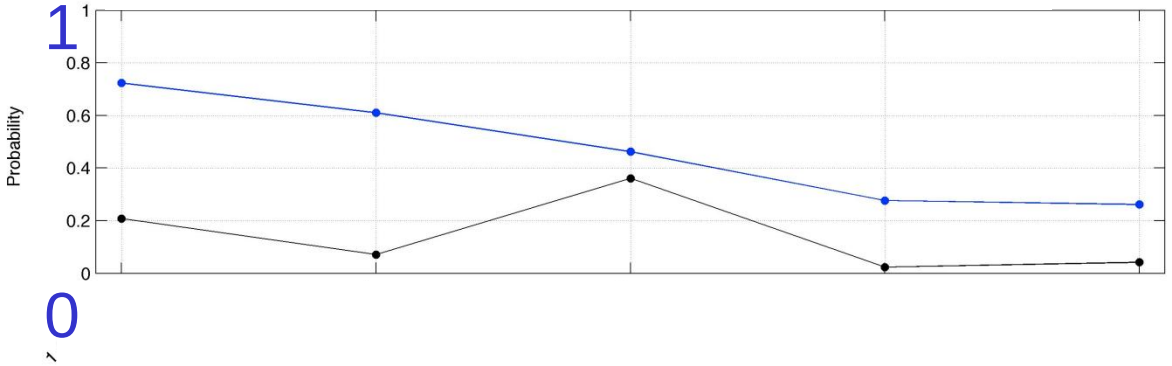
High Latitude 0.3 nT/s Threshold



- Each point represents a different model
- Scores show better than what would be expected by chance
- Similar results for larger thresholds, but typically at lower skill.

Probability of Detection and False Detection Ranked for all model/data comparisons over all Events

Mid Latitude 0.3 nT/s Threshold



High Latitude 0.3 nT/s Threshold

- Each point represents a different model
- Similar results for larger thresholds, but typically at lower skill.
- POD: 1 is good
- POFD: 0 is good

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

Recent Accomplishments

- Sensitivity analysis for time window and station spatial separation completed
- New model versions installed and operating at CCMC
  - O2R: this evaluation has encourage modelers to provide improved models that are now available to the science community
- Two new events selected and data gathered
- All model runs completed
- Metrics finalized
- Method for computing ground magnetic perturbations developed at CCMC and verified through comparison to Michigan model
- Code for computing K's made available to CCMC

Next Steps

- Analysis of db/dt results
- Model runs made available for modeler examination
- Evaluate need for runs with different thresholds, scalings, time windows, etc.
- Meet with modelers at GEM to discuss results, obtain feedback, develop plans for journal articles reporting results, discuss SWPC selection process
- CCMC prepares report on db/dt results and delivers to SWPC by early September (after review by modelers)
- SWPC selection based on CCMC reports and other criteria previously mentioned such as operational significance, costs to maintain, operate etc.

Next Steps

- **Compare model K values with observations and current Wing Kp**
  - **Wing Kp needs to be run on all events**
  - **More data needs to be collected to calculate observed K's**
  - **Analysis tools need to be implemented**
  - **Post-processing for all events, analyze, share, and interpret**
  - **Results present during GEM meeting in association with Fall 2012 AGU**
  - **Report to SWPC**

Conclusions

- In response to a recognized national need to provide improved regional geomagnetic activity services; NOAA's SWPC, in partnership with the NASA CCMC and modelers, is evaluating geospace models for transition to operations
- The effort builds on a foundation of work performed by the research community, supported by many agencies, and through model challenges in the NSF GEM program
- Challenges in this work include the preparation of robust models; recognizing the need for, and carrying out, model sensitivity studies; developing tools to evaluate the models; and the selection of operational, rather than research metrics
- Initial results look promising, with models showing positive skill
- The initial selection process will be completed in 2012
- This is only a beginning…