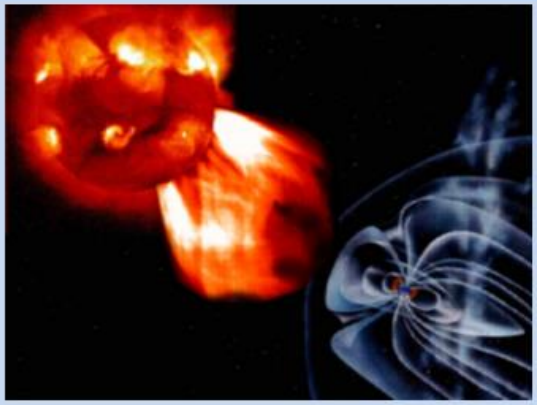
Geospace Models for Transition to Operations: Assessment Results and Next Steps



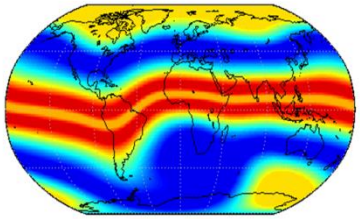
Solar Influences on Geospace Predicted with Geospace Models using Solar Wind Input

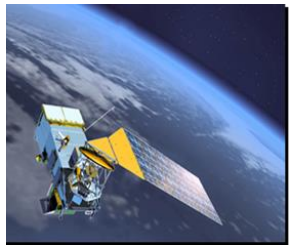
Current Focus: Regional Geomagnetic Activity (dB/dt and K index)

Electric Utilities

Future Possible Applications include:

- **Airlines – Polar Cap Boundary**
- **Communications – Ionosphere**
- **Satellites - Energetic Particles**





Howard J. Singer
Space Weather Prediction Center
Space Weather Workshop
Boulder, CO April 19, 2013

Acknowledgments: CCMC (Kuznetsova, Rastaetter, Pulkkinen, Glocer), Modelers, Balch, Onsager, Millward, Murtagh, Doggett

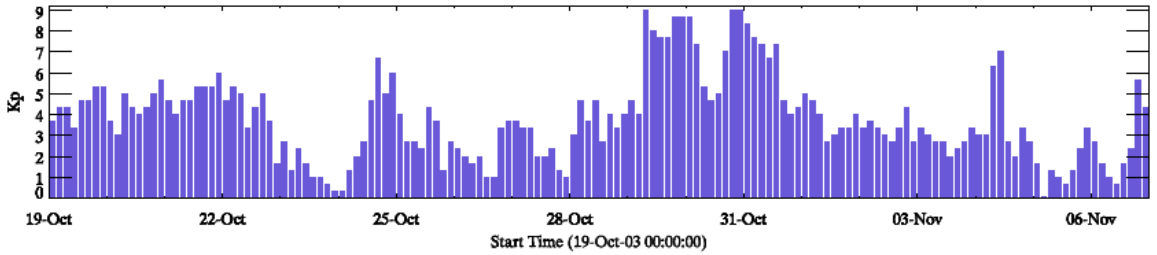
Electric Power Impacts – October, 2003

Sweden:
- Power outage
- Transformer heating in nuclear plant

United States:
- Power reduced at nuclear facilities to mitigate impacts

South Africa:
- 14 transformers damaged
- $60 million impact
- Basic commerce and security impaired

Why Regional Forecasts? Halloween Storms Example




Service Assessment
Intense Space Weather Storms
October 19 – November 07, 2003

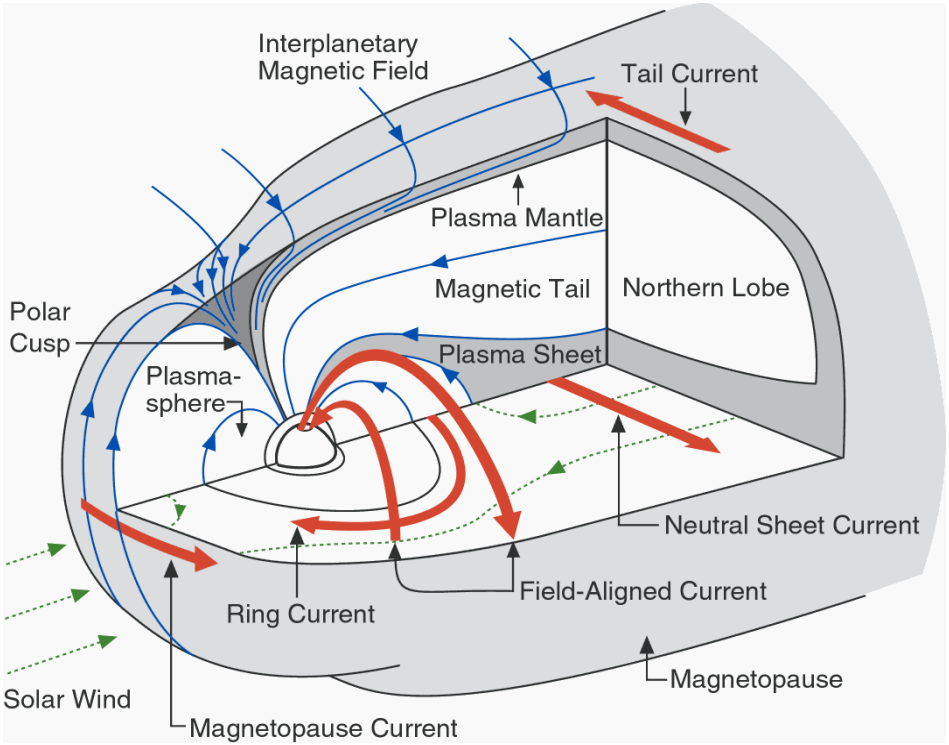
U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service
Silver Spring, Maryland

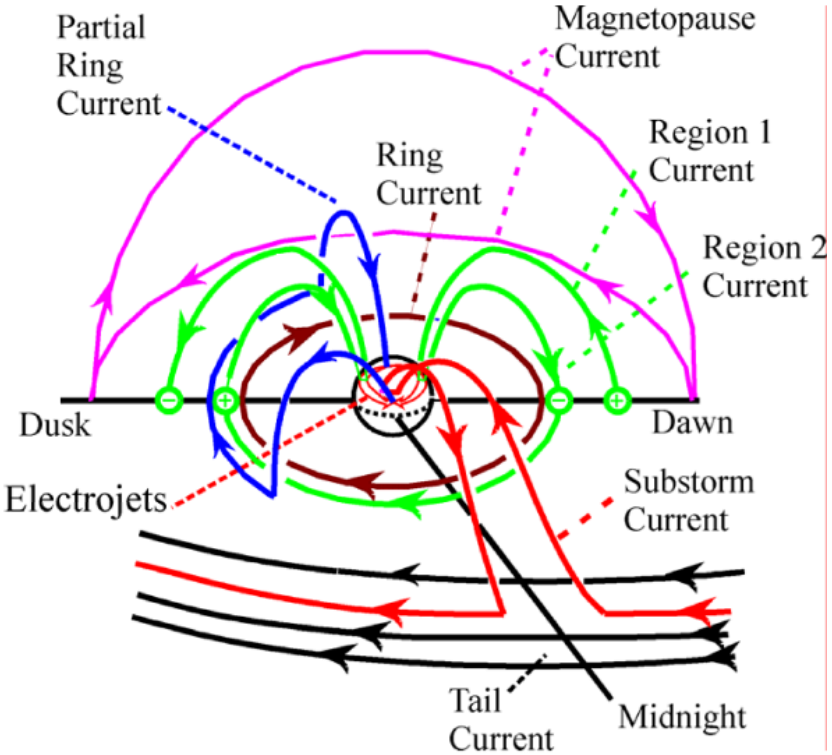
Long intervals of high Kp, yet…effects regional

- GIC impacts were **more significant in Northern Europe** where heating in a nuclear plant transformer was reported and a power system failure occurred on 30 October in Malmo, Sweden
- A representative from the North American Electric Reliability Corporation (NERC) commented: “Although the bulk electric system was not significantly affected by the solar activity, **some systems** reported higher than normal GIC’s that resulted in fluctuations in the output of **some generating units**, while the output of other units was reduced in response to the K-index forecast.” Responses to warnings included reducing system load, disconnecting system components, and postponing maintenance.

South Africa
Transformer overheating
15 Transformers damaged

Science Background
SOLAR WIND – INDUCED ELECTRIC CURRENTS FLOWING IN THE MAGNETOSPHERE



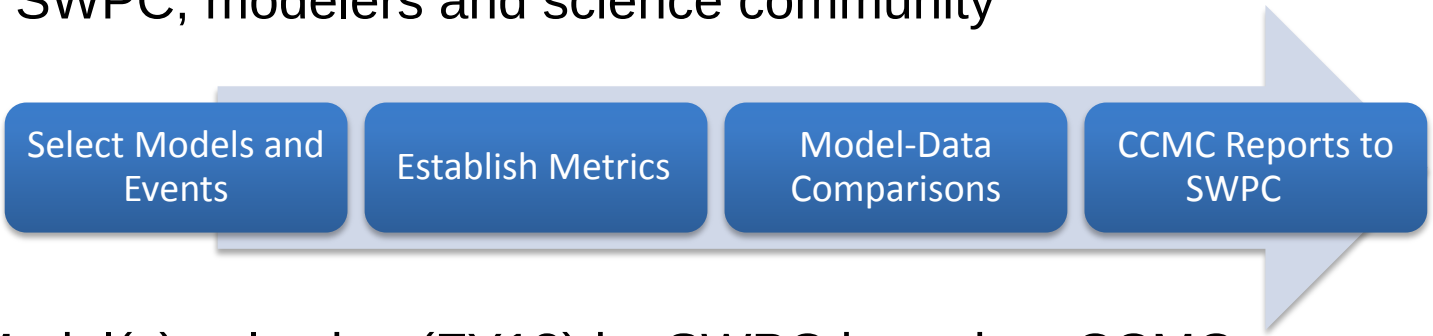


Credit: Kivelson and Russell, Introduction to Space Physics

Time varying currents in the magnetosphere and ionosphere, predicted by Geospace models, produce observed magnetic disturbances, including those on the ground (dB/dt and local K indices). Together with local geology, conductivities, and grid specific design, these magnetic disturbances can be used to calculate electric fields and geomagnetically induced currents (GICs).

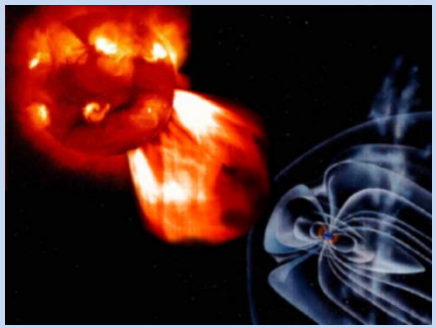
Geospace Models: Transition to Operations

- Goal: Evaluate Geospace models (MHD and empirical) to determine which model(s) are ready for transition to operations
- Focus: Regional K and dB/dt (important to electric utilities)
- Partnership: Evaluation at NASA/Goddard CCMC working with SWPC, modelers and science community



Model(s) selection (FY13) by SWPC based on CCMC reports, internal and external advice, and following considerations:

- Strategic Importance
- Operational Significance
- Implementation Readiness
- Cost to Operate, Maintain, and Improve



Solar Influences on Geospace Predicted with Geospace Models using Solar Wind Input

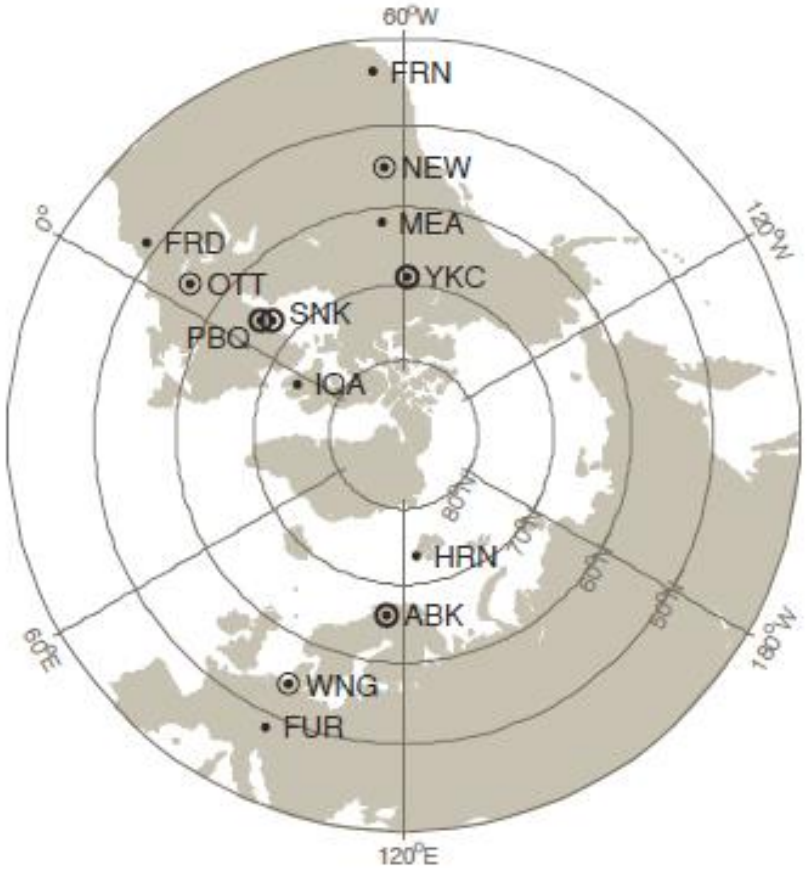
Models at CCMC Participating in Geospace Evaluation

- MHD Models:
- Space Weather Modeling Framework (SWMF) - U. of Michigan
- The Open Geospace General Circulation Model (Open GGCM) - University of New Hampshire
- Coupled Magnetosphere-Ionosphere-Thermosphere (CMIT) - BU CISM, Dartmouth, NCAR
- Grand Unified Magnetosphere-Ionosphere Coupling Simulation (GUMICS) - Finnish Meteorological Institute
  (not ready for initial evaluation, but showing significant progress)
- Empirical Models
- Weimer Empirical Model, Va. Tech
- Weigel Empirical Model, George Mason

Ground Magnetic Observatories used for Model Validation of Six Storms

Six Storm Events

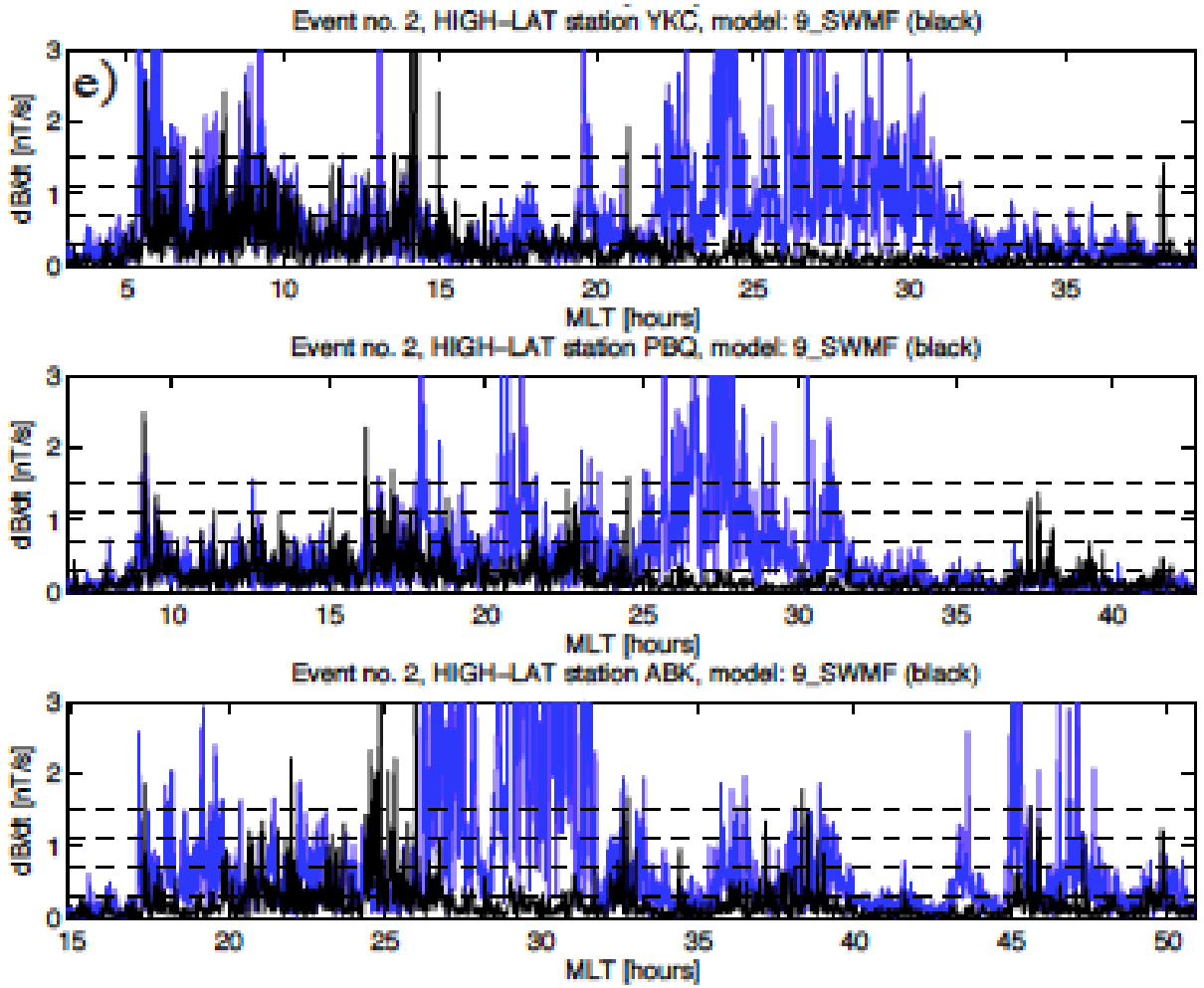
- Oct 29-30, 2003
- Dec 14-16, 2006
- Aug 31- Sep 1, 2001
- Aug 31 – Sep 1, 2005
- Apr 5-6, 2010
- Aug 5-6, 2011

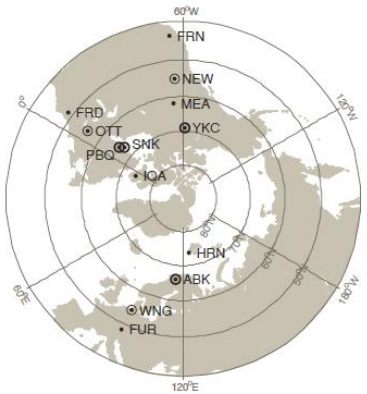


Three high-latitude auroral zone stations and
Three mid-latitude sub-auroral stations

Example of dB/dt Model-Data Comparisons At Three High-Latitude Stations

Pulkkinen et al.: Geospace Model Transition, Space Weather Journal, submitted, 2012.





Dec 14, 2006 12 UT
Dec 16, 2006 00 UT

Black – Model
Blue - Observation

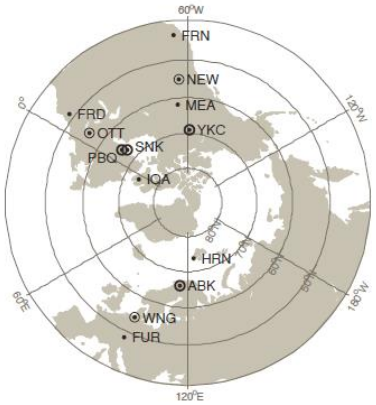
Example of Model-Data Comparisons

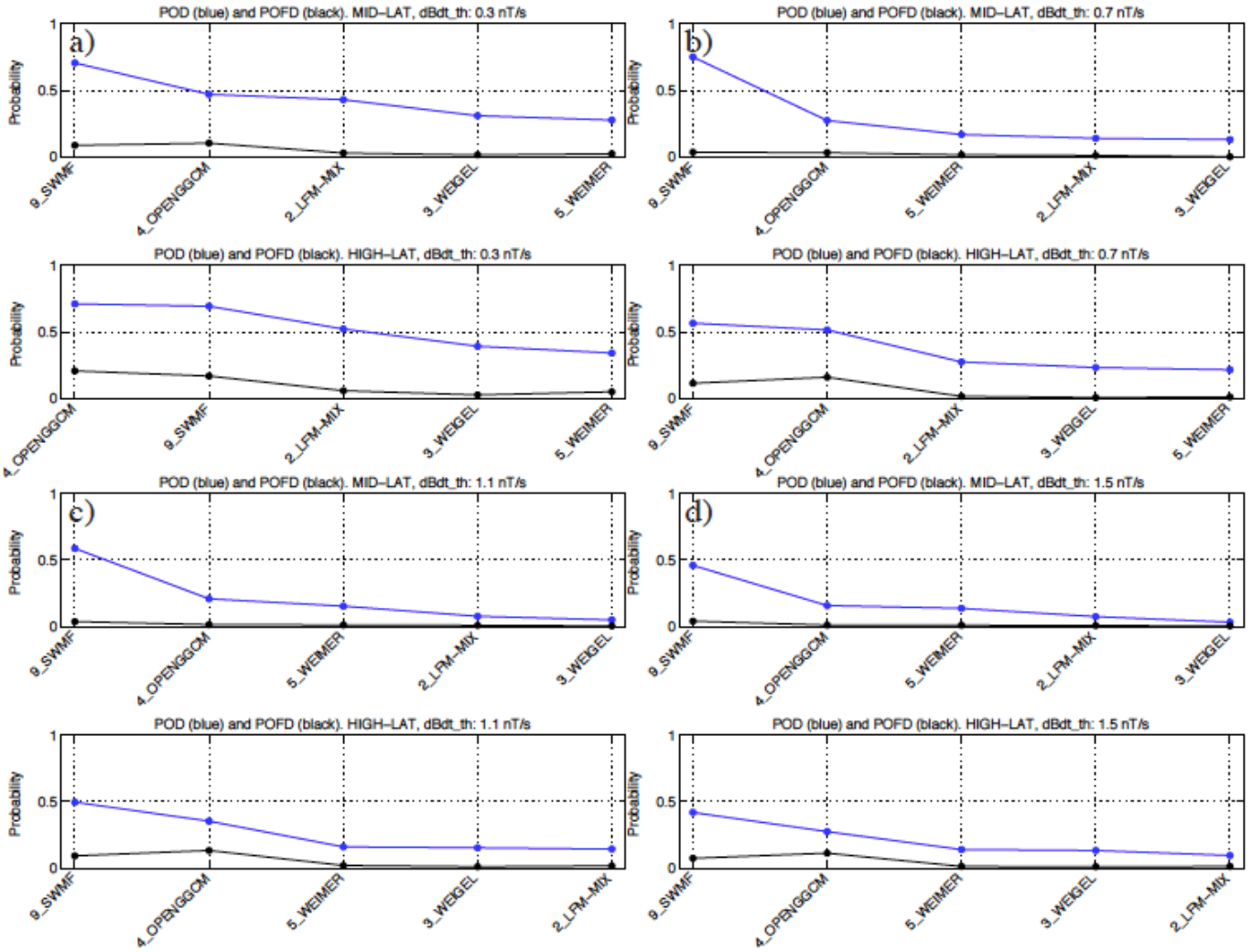
POD and POFD for different dB/dt Thesholds integrated over high and mid-latitude stations

Pulkkinen et al.: Geospace Model Transition, Space Weather Journal, submitted, 2012.

Blue - POD

Black – POFD

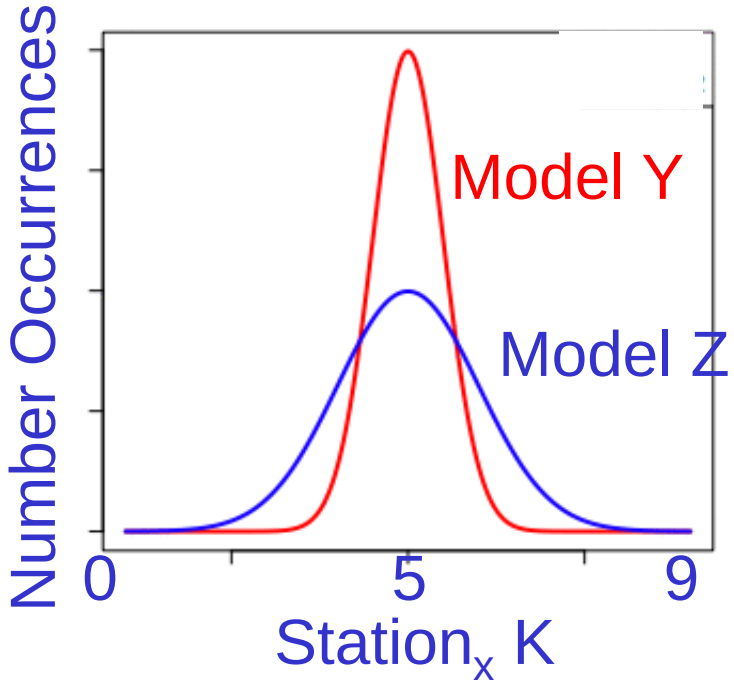




Regional K
Distribution Metric Prescription

These results can be used by forecasters to give guidance that if model Y gives a K of 5, then there is a certain probability that station X will observe a specific K

Model Results in K = 5
All events, station X



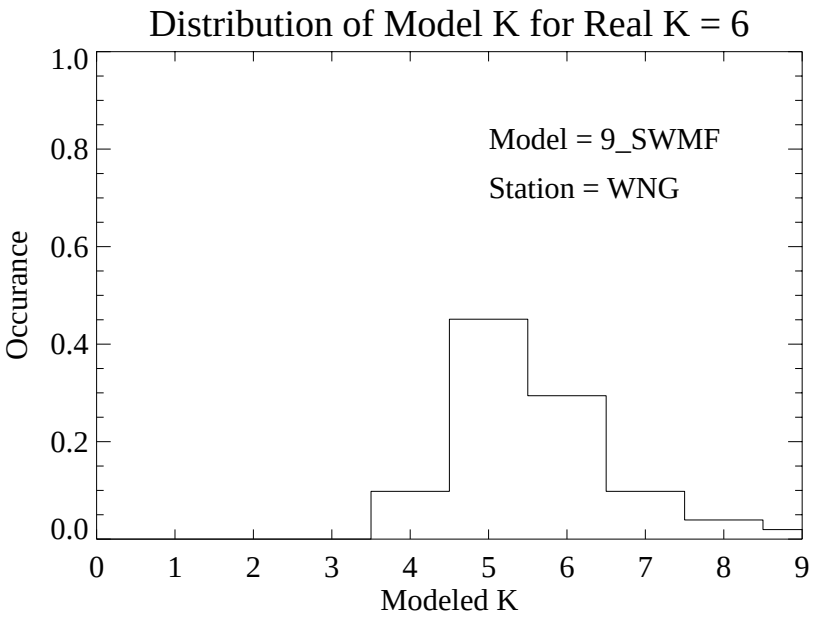
Note: The opposite procedure could also be done by choosing an observed K value for a specific station and determining the distribution of model K values

Examples of Preliminary Results for Regional K

K Threshold = 6

6 Models

Heidke skill score	Critical Success Index	POD	POFD
0.66	0.60	0.68	0.06
0.66	0.59	0.61	0.02
0.33	0.38	0.60	0.25
0.48	0.42	0.45	0.03
0.58	0.50	0.51	0.01
0.53	0.45	0.47	0.01



A. Glocer

Definitions:

Heidke Skill Score = 2(H*N-M*F)/[(H+M)*(M+N)+(H+F)*(F+N)]

Critical Success Index (Threat Score) = H/(H+M+F)

Probability Of Detection (POD) = H/(H+M)

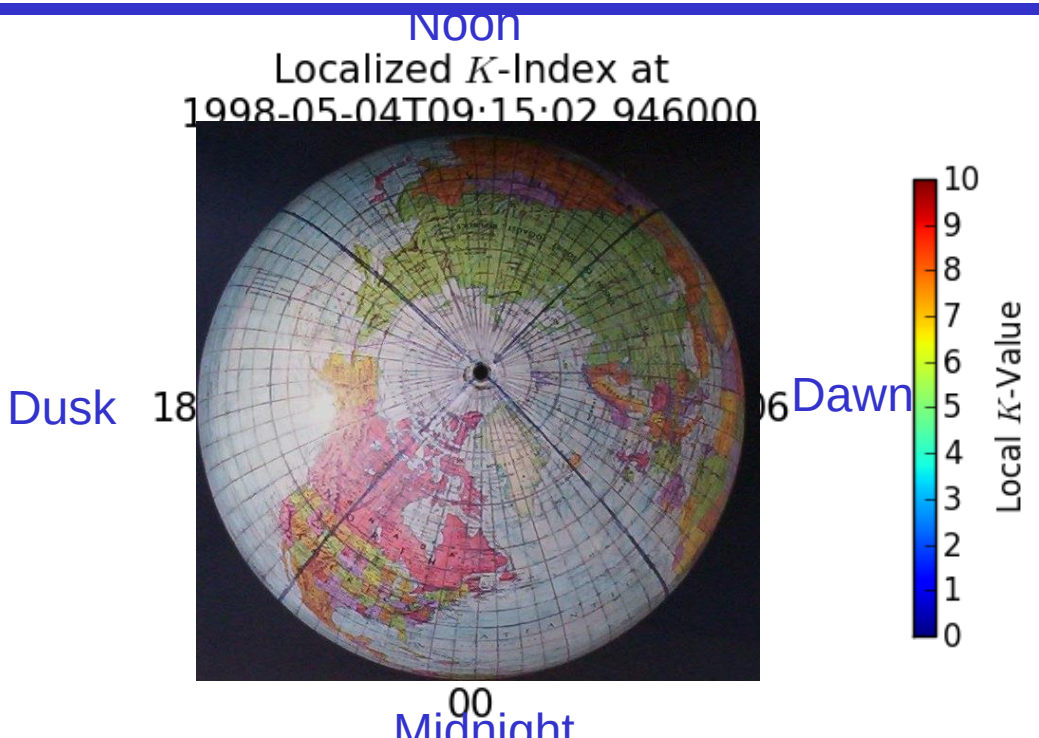
(perfect=1, no skill=0)

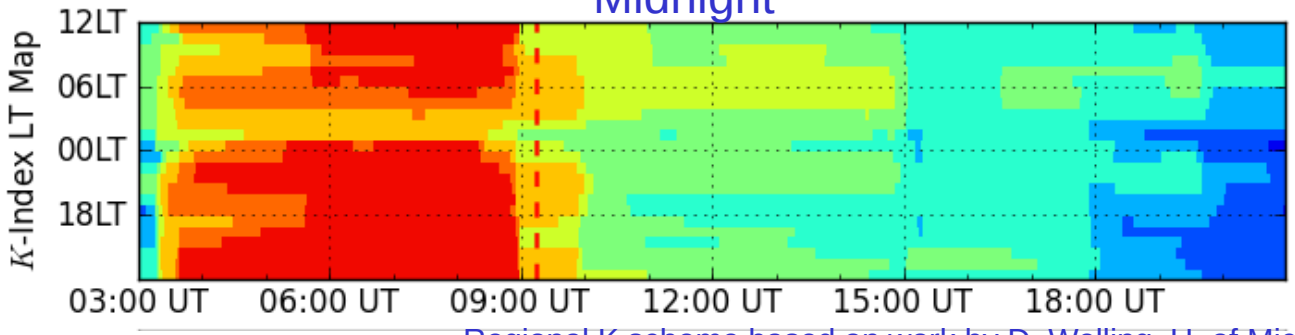
Probability Of False Detection (POFD) = F/(F+N)

(perfect=0)

Future Displays

Some initial ideas





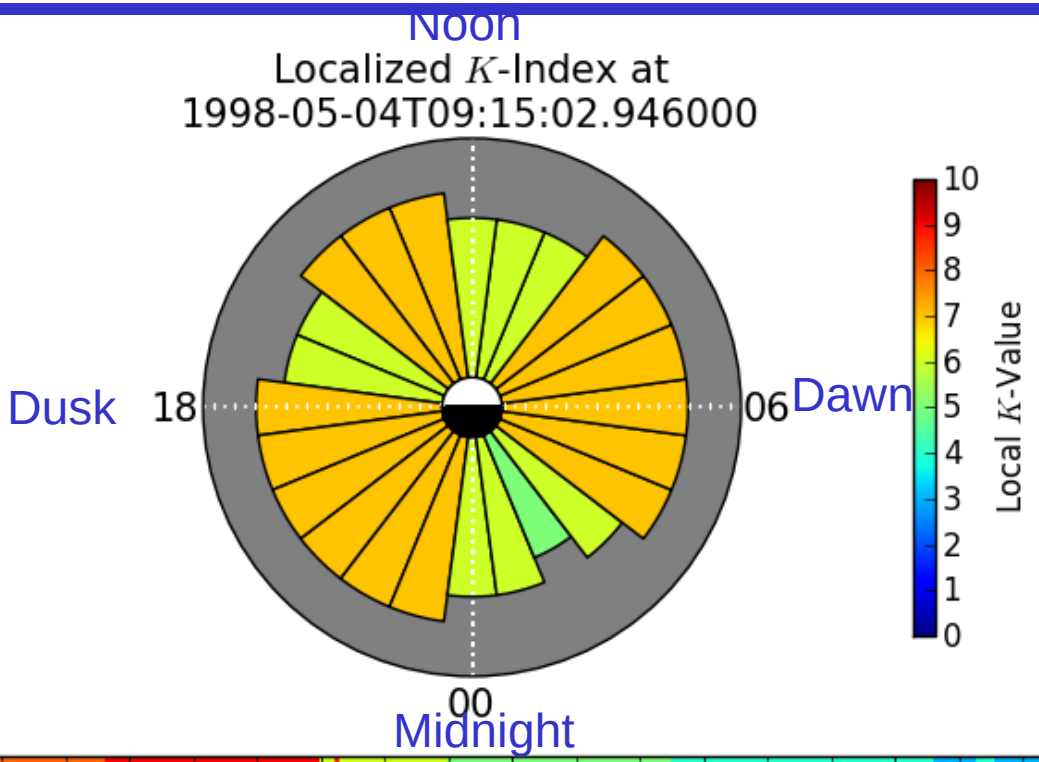
Without regional K, each vertical strip would be one Kp level (one color)

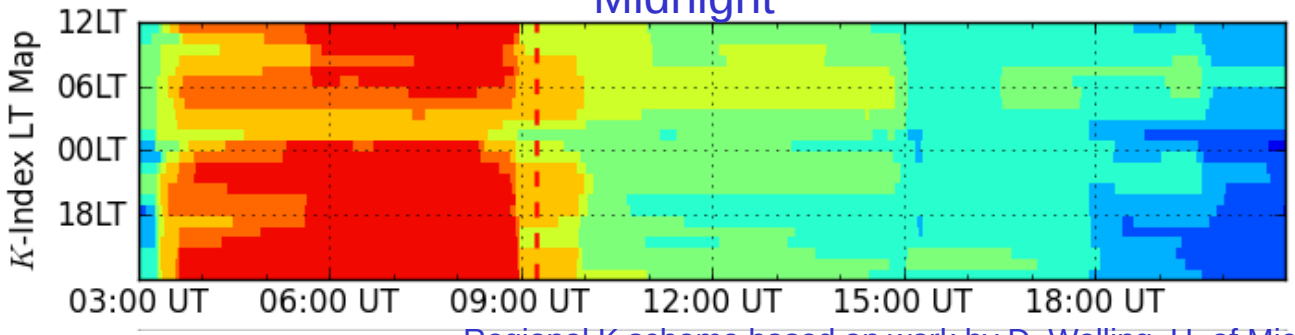
Regional K scheme based on work by D. Welling, U. of Michigan

Map from: http://www.genekeyes.com/WATERMAN-REVIEW/C-K-globe-5-degrees.jpg

Future Displays

Some initial ideas





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Geospace Models: Transition to Operations
Recent Accomplishments and Next Steps

- Dec 2012: CCMC delivers draft report on dB/dt to SWPC; CCMC led publication submitted to Space Weather Journal
- Dec 2012 - Jan 2013: SWPC reviews dB/dt report and assess ancillary model results; iterate with CCMC if additional information needed in report
- Dec 2, 2012: AGU/GEM Mtg, CCMC reports on initial results from Regional K, discussions with modelers on publications and assessment
- Jan-Apr 2013: complete work on Regional K, iterate with modelers, prepare publications and report
- Jan-Apr 2013: SWPC discussions with modelers about implementation activities; e.g. working arrangements with modeler, intellectual property rights, explore open source code (NWS paradigm), ability to make changes to accommodate operational implementation, sharing models with operational partners; model conops and maintenance requirement…
- May 2013: SWPC review regional K report and iterate as needed with CCMC
- Jun – Sep 2013: SWPC utilize reports, our own review of the data (model results), additional discussions with modelers, consult with partners, and make selection.

Conclusions

- Space weather customers will benefit from improved regional geomagnetic activity predictions of dB/dt and K
- Auroral and ionosphere products are an additional potential outcomes
- SWPC values the continuing support and expertise provided by modelers, CCMC and other partners
- Additional future efforts needed for sensitivity analyses such as how model results depend on: Spatial and temporal scales, model grid size, etc.
- Model evaluation has been extremely beneficial to science community by accelerating availability of new model versions at CCMC and will help to identify what is needed to improve models
- Evaluation results need careful interpretation:
  - Different models may do better on different events
  - Although one model be best for chosen parameters (db/dt and K) for the specific metrics (POD, POFD, etc.), different models may do better for other parameters (e.g. substorm onset, polar cap potential, etc.) and for other metrics (timing, RMS, etc.). Therefore, the model selected, may only be "best" at this time, for SWPC's specific evaluation factors
- A model(s) selection will be made in FY13.