Measuring the Performance of Scientific Models

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Need for Metrics

- Create objective measure of current capabilities both for scientific and operational needs.
- Measure the improvement of model capabilities over time.
- Provide an objective comparison between models with comparable output.

  Metrics which lead to scores near unity now are useless!

Elements of a Metric

- An output parameter from a model.
  - An example is currents in the ionosphere can be used to calculate ground magnetic perturbations.
- A satellite or ground-based measurement that can be used for comparison.
  - An example is ground magnetometer data.
- A quantifiable norm that assesses the difference between the parameter from the model and the measurement.

Possible Metrics

- Ground magnetic perturbations using data from ground magnetometer chains.
- Particle fluxes at geosynchronous orbits using Los Alamos National Laboratory satellite data.
- Other metrics that may be suggested by the space weather operational or research community.

Community Coordinated Modeling Center (CCMC)

- Multi-agency partnership established to help bridge the gap between the space weather research community and operational agencies of National Oceanographic and Atmospheric Administration and the United States Department of Defense.
- Provides validation of models through both science-based testing and metrics evaluations by an independent evaluator.
- Serves the space weather research community by providing access to models through runs-on-request web site.

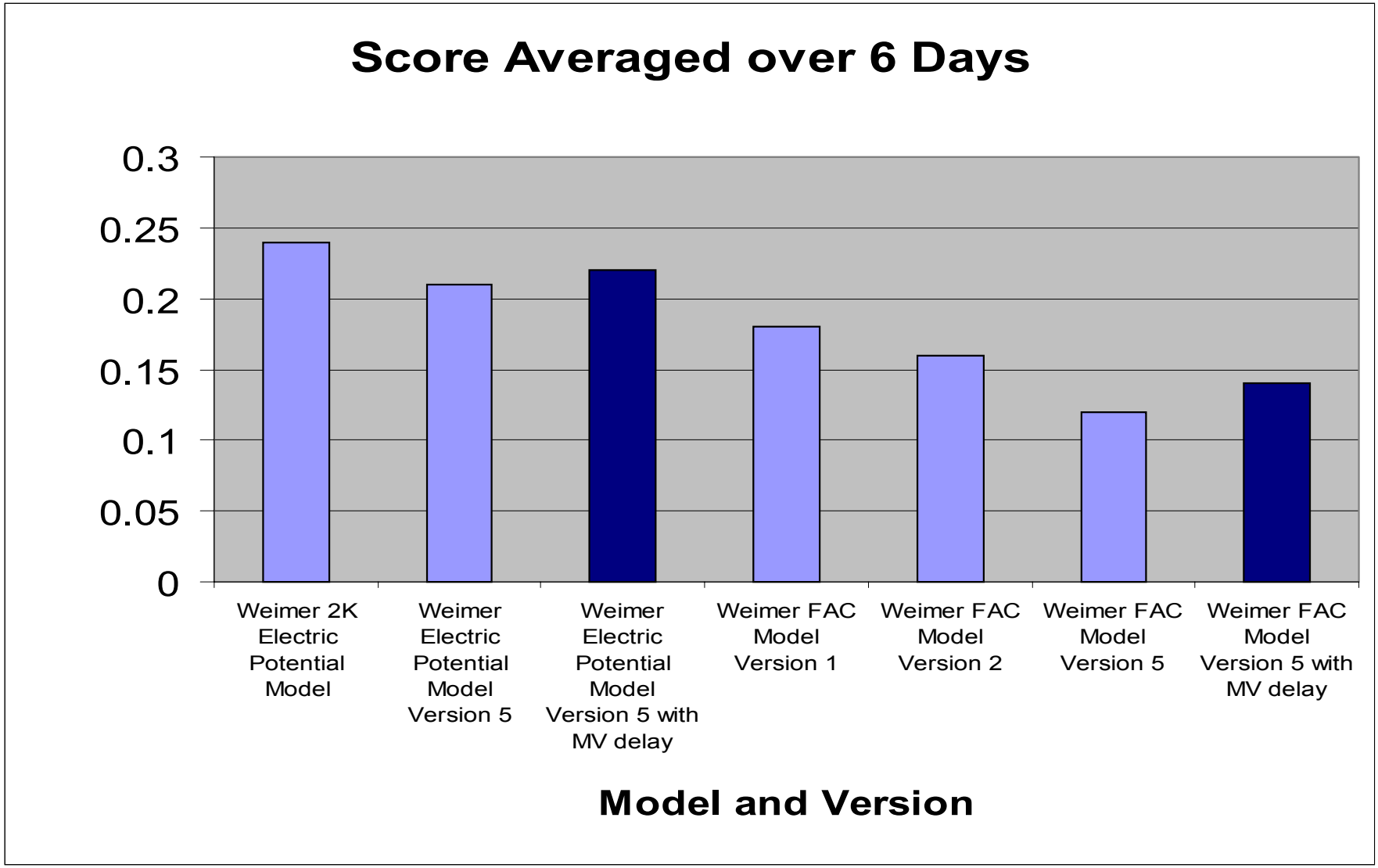
Ground Magnetic Perturbations

- Data
  - 10 stations in the Greenland chain using the H component of the data.
- Models
  - Weimer electric potential model (2 different versions).
  - Weimer field-aligned current model (3 different versions).
- Skill score
  - An individual model is scored $D_i = \Sigma |\Delta H_{model} - \Delta H_{data}| / npts$.
  - A skill score is computed for each ground station by

$$M_i = 1 - D_i / D_s$$

where D_s is for the standard model. In this case, the standard model is $\Delta H_{standard} \equiv 0$.

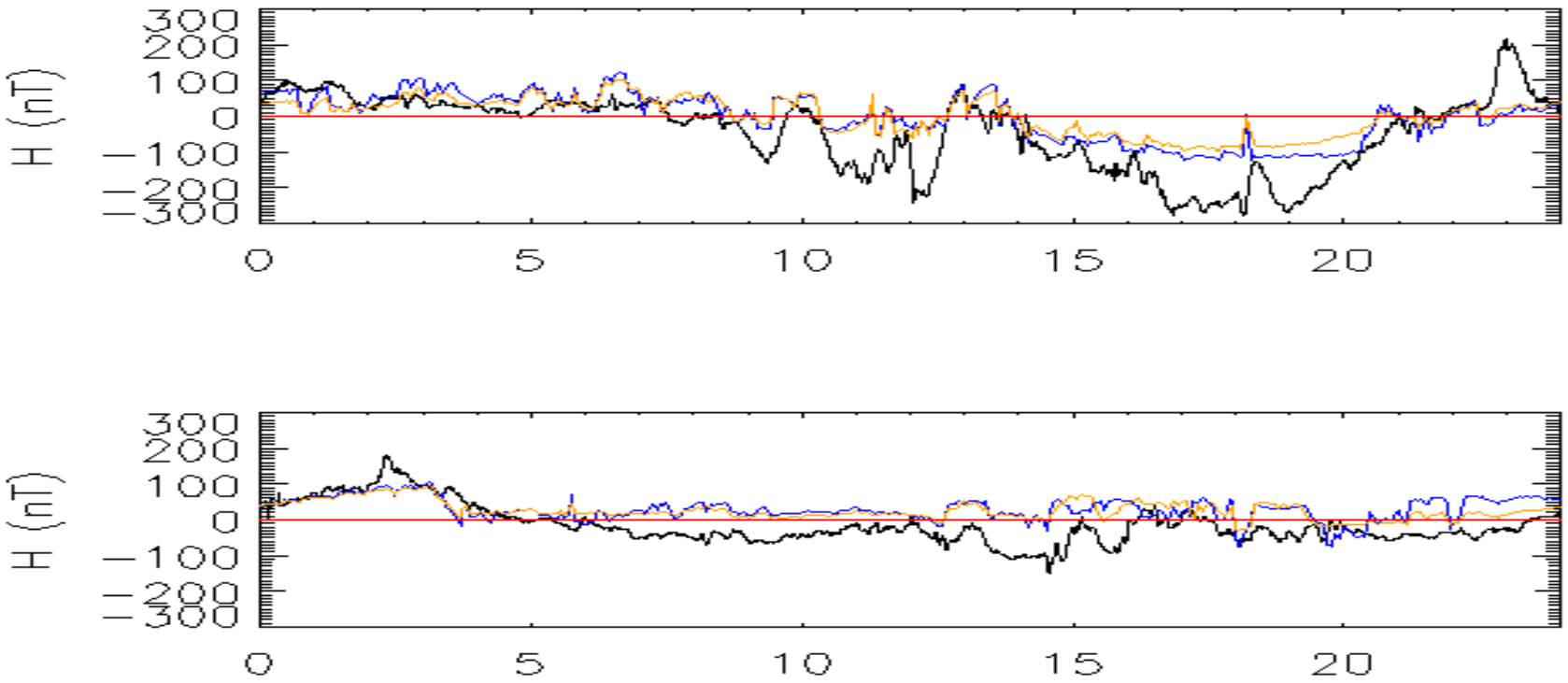
Results for Weimer Models (averaged over 10 stations) for H component.



Parameter Tests

- Different time delays for the ACE data were used. The skill scores were not very sensitive to the time delays.
- Different Hall conductivities were used for the electric potential model. The skill scores were better for Hall conductivities of 5 and 7.5 mhos. For later versions, the scores are more sensitive to different conductivities.

Comparison of Model Results to Data



Black: Data from ground magnetometers

Orange: Model results from Weimer 2k Electric Potential Model

Blue: Model results from Weimer Electric Potential Model Version 5

Magnetometer data was provided by the Danish Meteorological Institute (Dr. Jurgen Watermann, Project Scientist)

Proton Fluxes

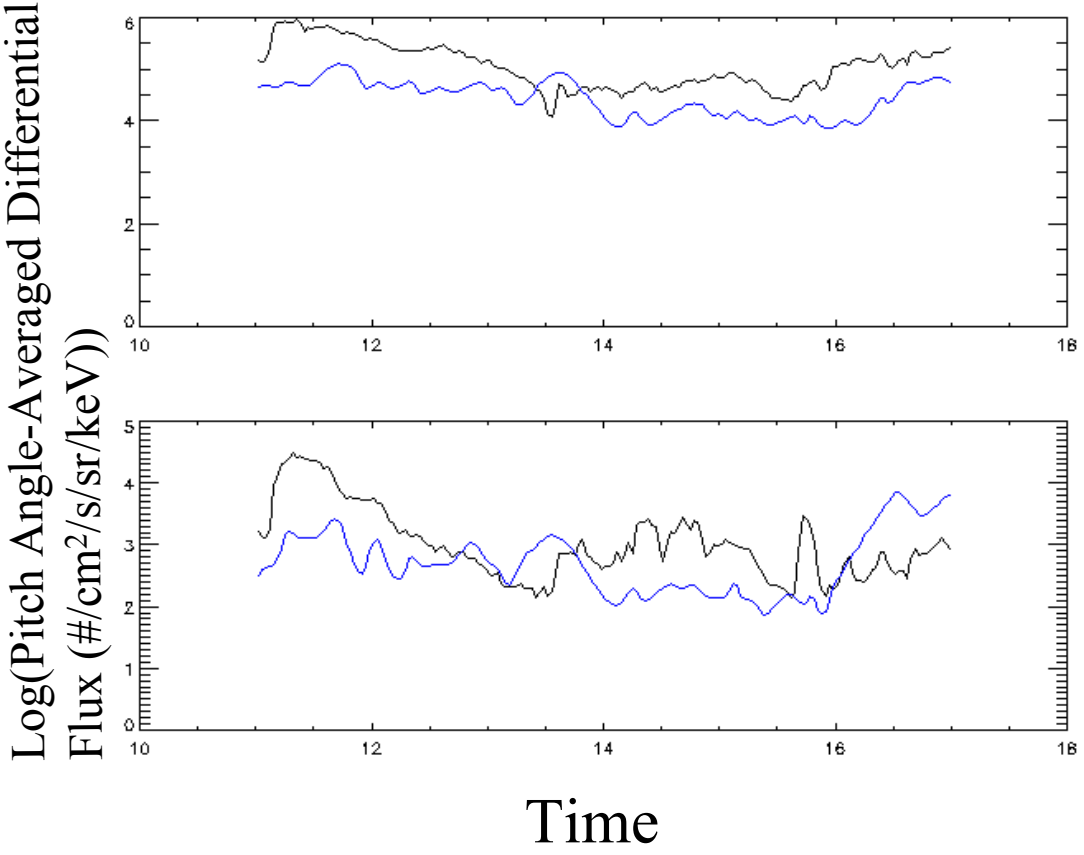
- Data
  - Proton fluxes from LANL geosynchronous satellites
- Model
  - Fok ring current model coupled to MHD models
- Root Mean Square Error Skill Score
  - Calculate root mean square error (RMSE)

    $RMSE = sqrt(\sum(predicted - observed)^2/npts)$
  - Calculate standard deviation of observations

    $STD = sqrt(\sum(observed - mean)^2/npts)$
  - RMSE skill score

    Skill score = 1- RMSE/STD
- Cross Correlation

Sample of Ring Current Metric



RMSE Skill Score	Cross Correlation
0.07	.59
-0.01	0.07

Black is LANL data. Blue is the model results.

Geosynchronous proton flux data was provided by the Energetic Particle team at Los Alamos National Laboratory, Richard Belian (PI).

Summary

- The ground magnetic perturbations is a first attempt at creation and application of a standard and repeatable metric.
- Blind test (no fine tuning)!
- Fine tuning of metrics is required in collaboration with the operational agencies and researchers.
- First steps, more to come.