Using Metrics to Measure the Performance of Scientific Models

Kristi A. Keller, Michael Hesse, Lutz Rastatter, Therese Moretto

NASA Goddard Space Flight Center

Daniel Weimer

Mission Research Corporation

Abstract

- Metrics are one tool for measuring the progress of scientific models in space weather prediction. A scientific metric as defined by the National Space Weather Program has three elements: 1). An output parameter from the model such as currents in the ionosphere, 2.) A satellite or ground-based measurement that can be used for comparison, and 3) A quantifiable parameter that can measure the difference between the model parameter and the measurement. We will use ionospheric currents from models to compute the magnetic perturbations on the ground. We will compare the computed magnetic perturbations with the measured values in the Greenland magnetometer chain. We will compare model results with data for both quiet and storm days. We will present results from the metric study.

Need for Metrics

- Create objective measure of current capabilities both for scientific and operational needs
- Measure the improvement of 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. In this case, we calculate currents in the ionosphere.
- A satellite or ground-based measurement that can be used for comparison. In this case, we use ground magnetometer data.
- A quantifiable norm that assesses the difference between the parameter from the model and the measurement.

Models

- Weimer 2K model (Weimer, 2001a) for the ionospheric electric potential using solar wind input parameters. (SEC request)
- Empirical model of ionospheric currents based on solar wind input parameters developed by Weimer (2001b).

Method: I. Solar Wind Data Preparation

- Inspired by Electrojet challenge (T. Onsager)
- Level 2 data from ACE were used.
- The time interval was 4 minutes.
- Added time delay from ACE to the ionosphere
  - (xpos(ACE)-10 R_E)/v_x + 14 min
- Other time delays were used for comparison purposes.

ACE magnetic field data were provided by the ACE/MAG team: **Bartol Research Institute** Norman F. Ness, Jacques L'Heureux, Charles W. Smith, **Goddard Space Flight Center** Len Burlaga, Mario Acuña.

ACE plasma data were provided by the ACE/SWEPAM team (Dave J. McComas P.I).

Method: II. Calculation of magnetic perturbations

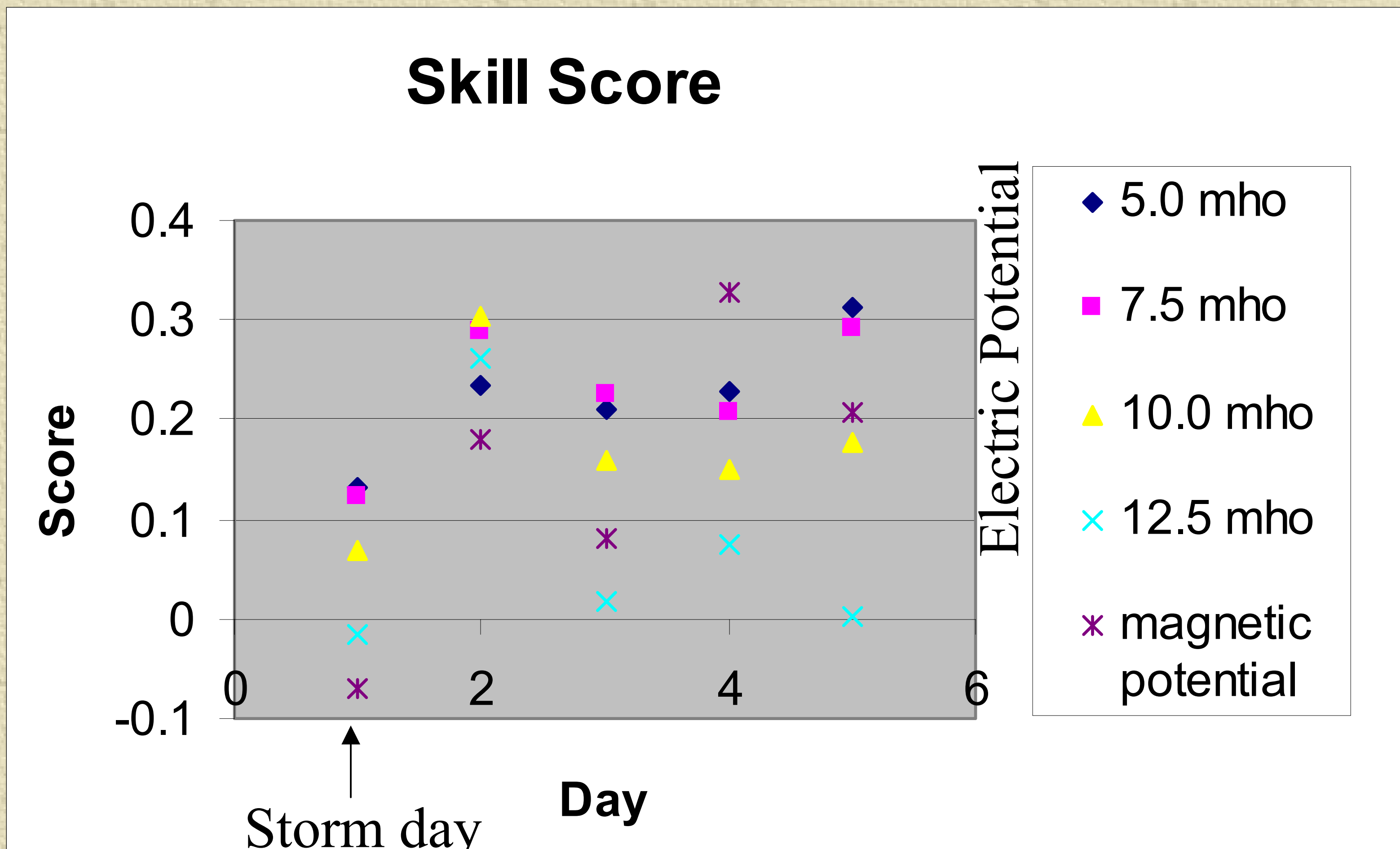
- Electric or magnetic Euler potentials are used to calculate a Hall current.
- Fukushima's theorem [Fukushima, 1976] states that for constant conductivity that the field-aligned currents and Pedersen currents will cancel in the Biot-Savart calculation of ground magnetic perturbations.
- Biot-Savart integration of Hall currents to calculate the perturbation on the ground.

Method: III. Metric Calculation

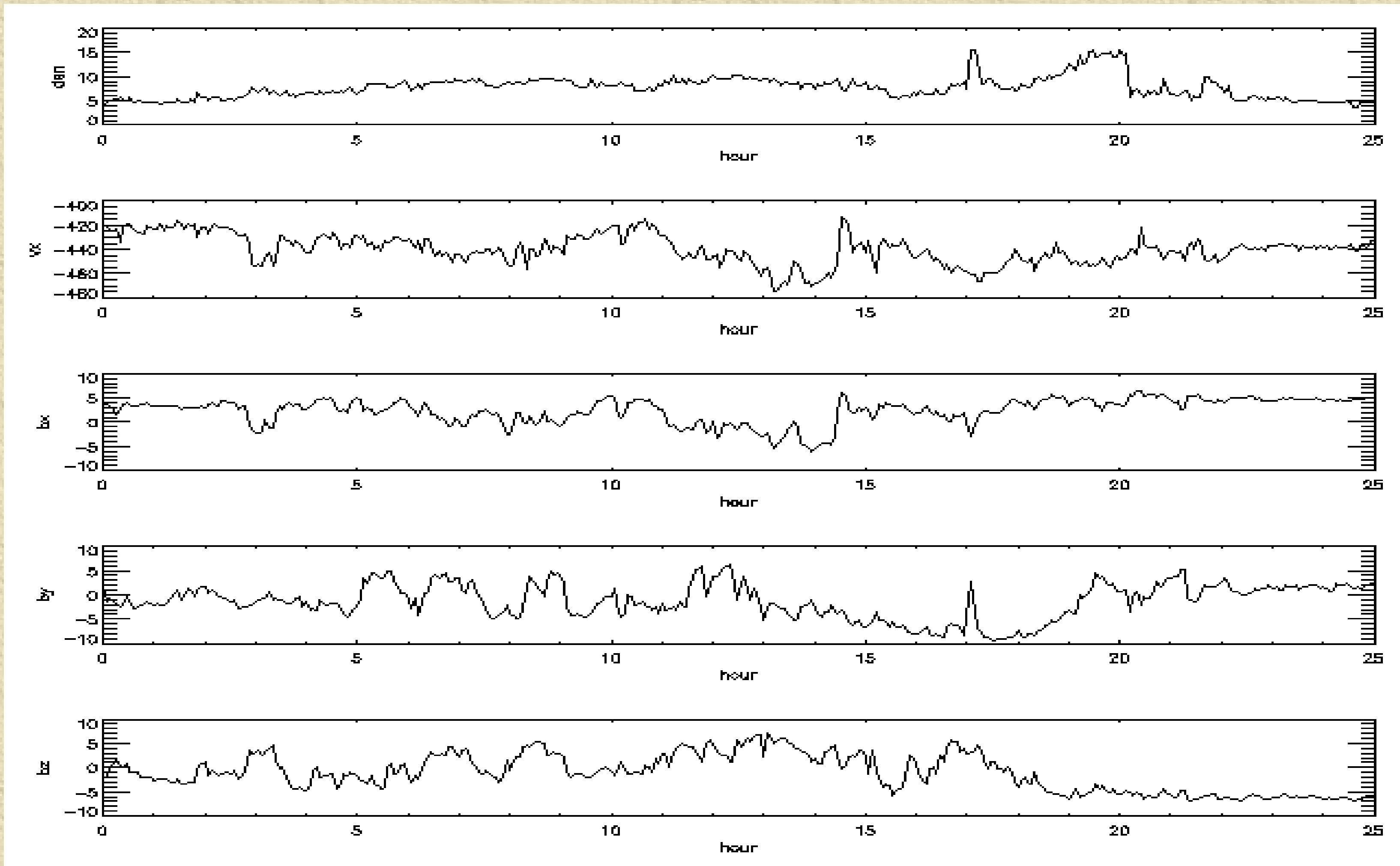
- The Greenland data cadence is 20 seconds. The model data are interpolated to this time period.
- An individual model is scored $D_i = \Sigma|\Delta H_{model} - \Delta H_{data}|$ for each time point of the data.
- A skill score is determined by $M_i = 1 - D_i / D_s$ where D_s is for the standard model. In this case, the standard model is $\Delta H_{standard} \equiv 0$.

Greenland data were supplied by the Danish Meteorological Institute.

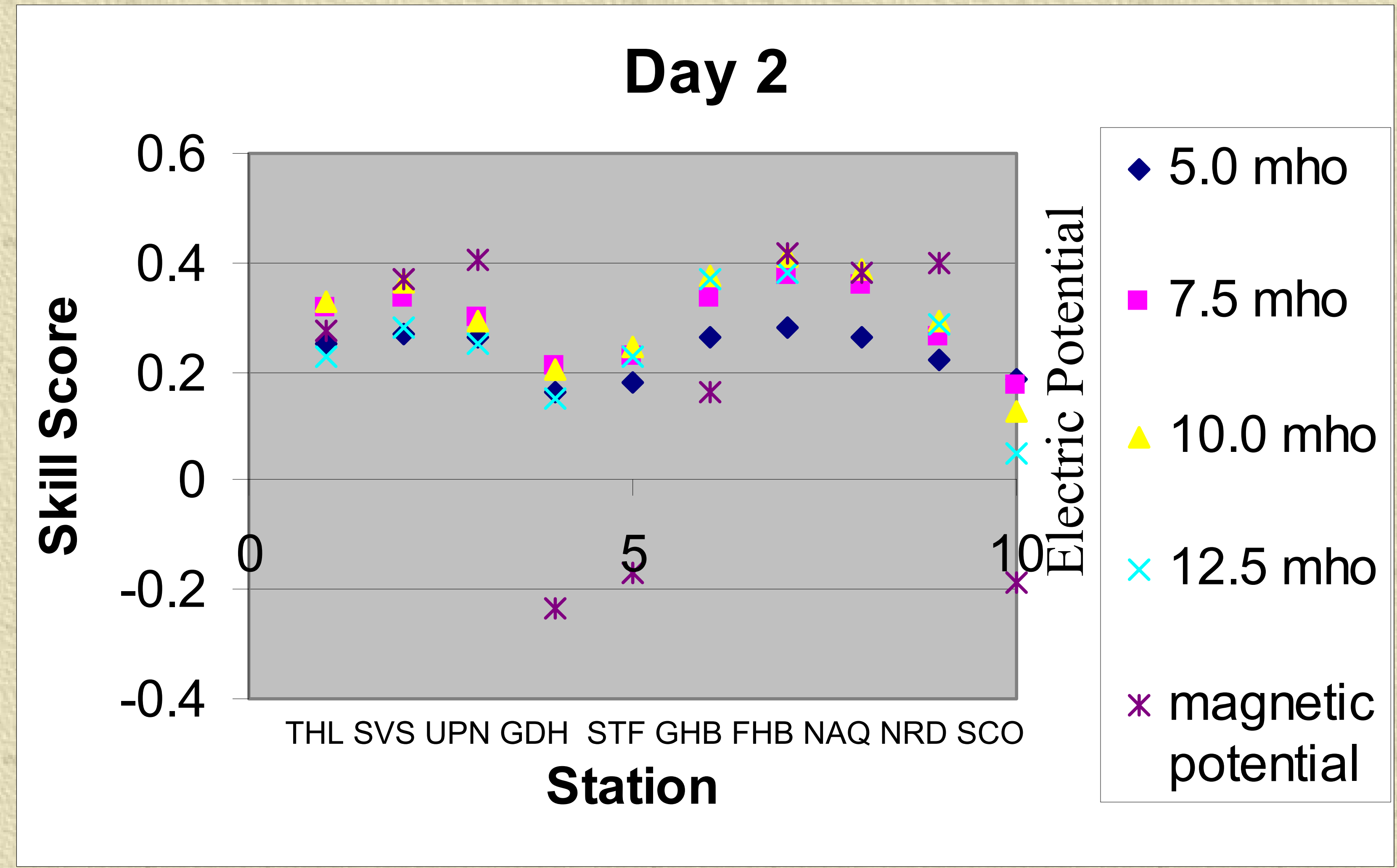
Results for Models (averaged over 10 stations) for H component.



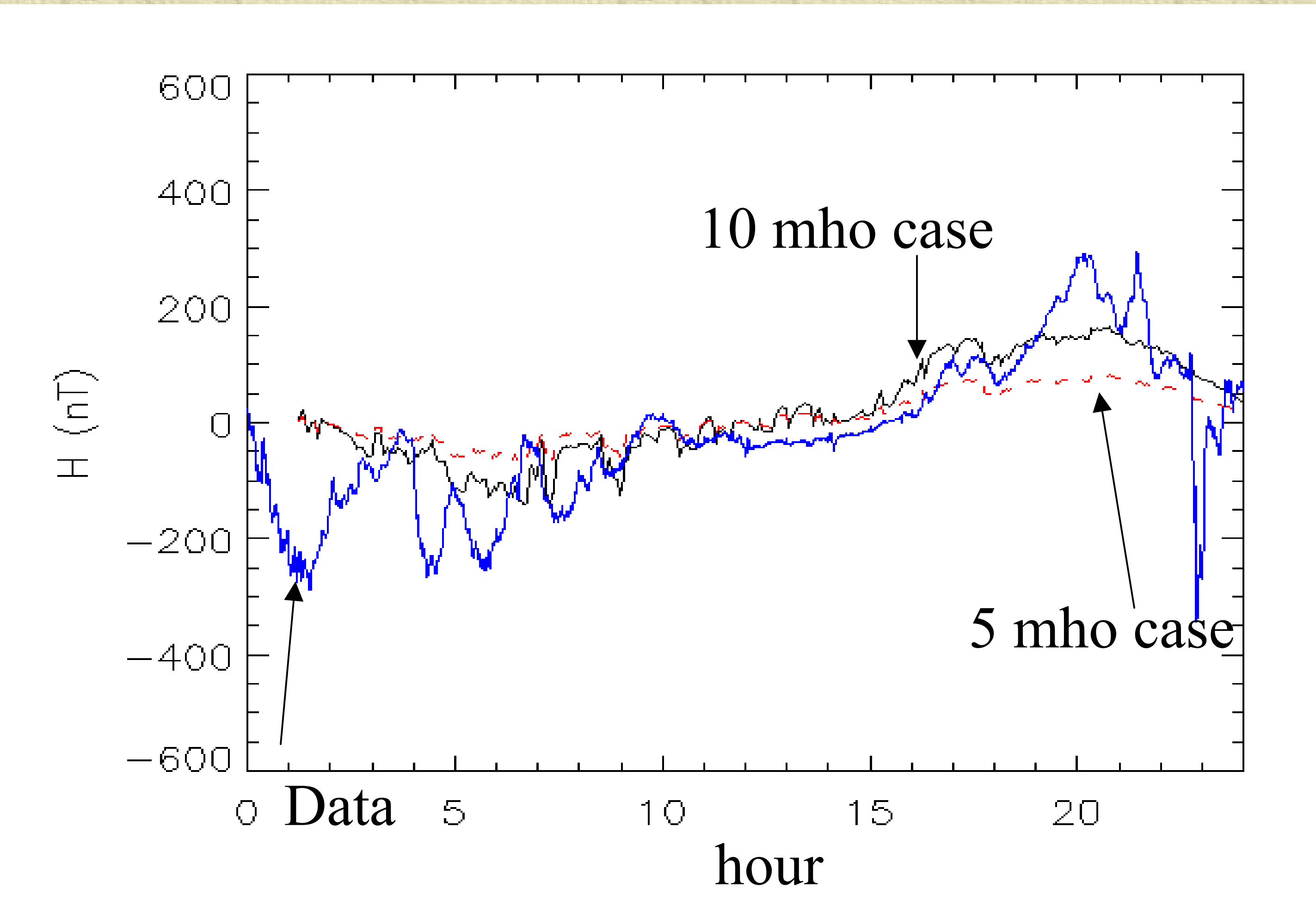
Solar Wind Data for Day 2



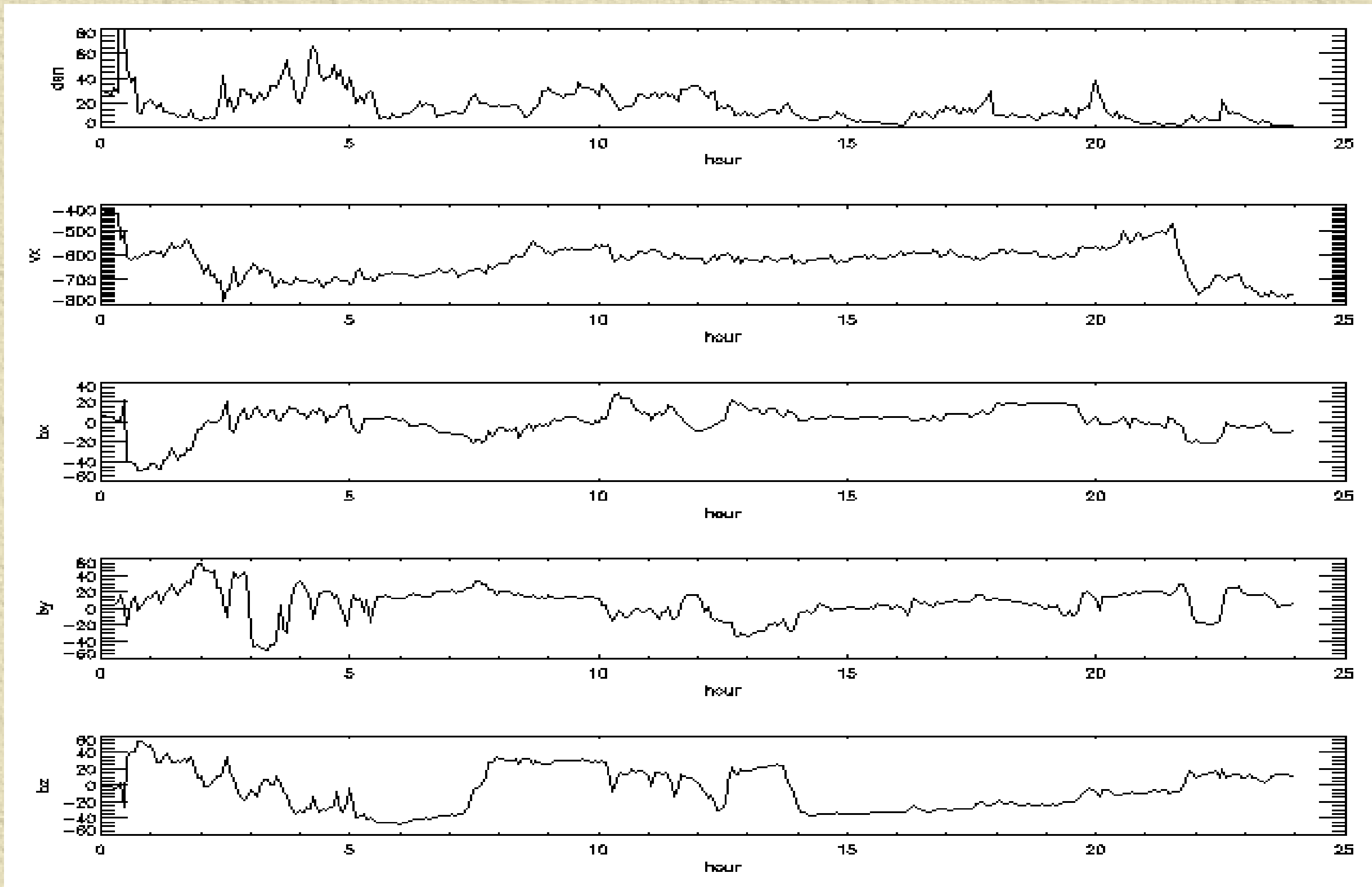
Scores at Stations for Day 2



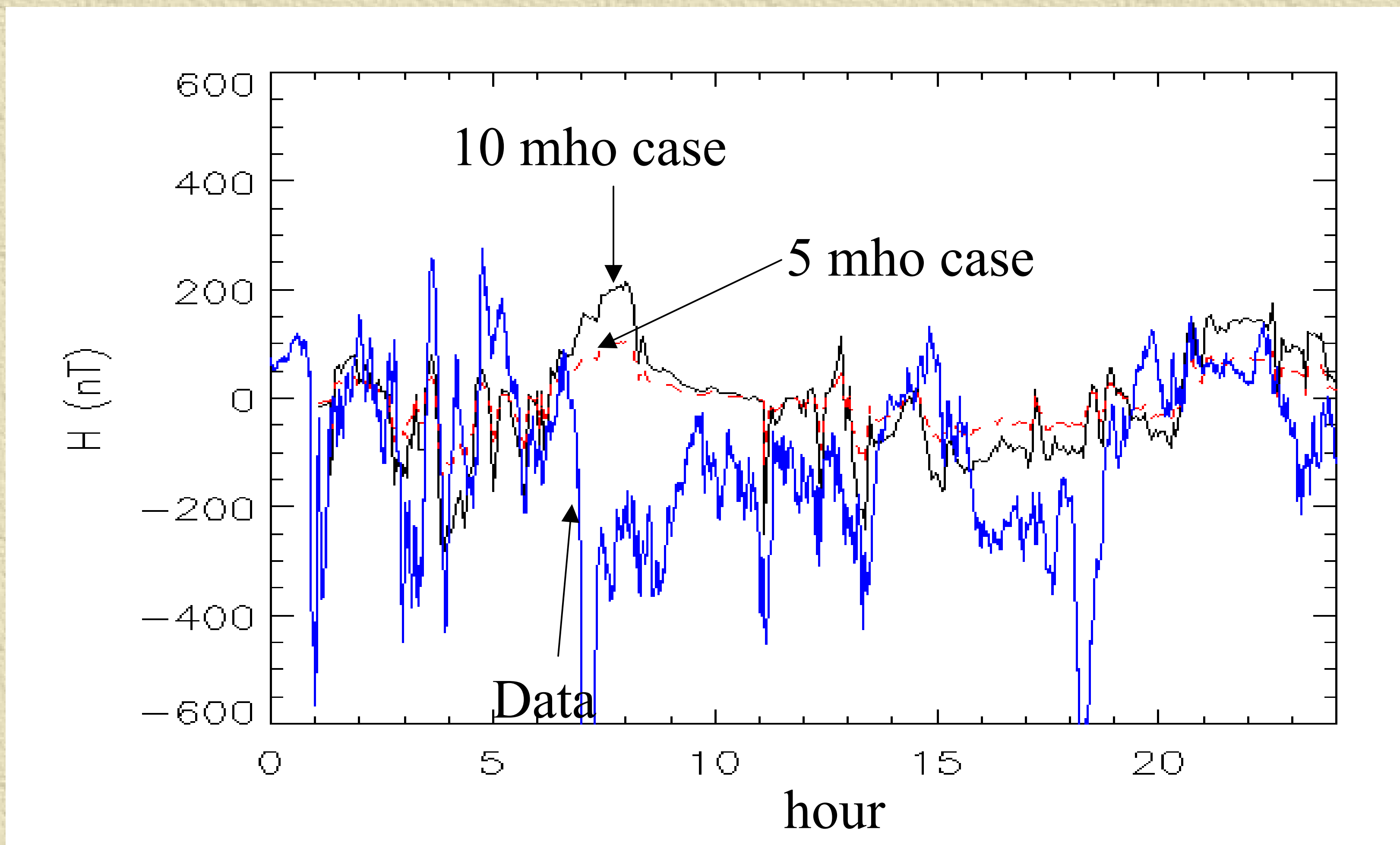
Comparison at FHB for Day 2



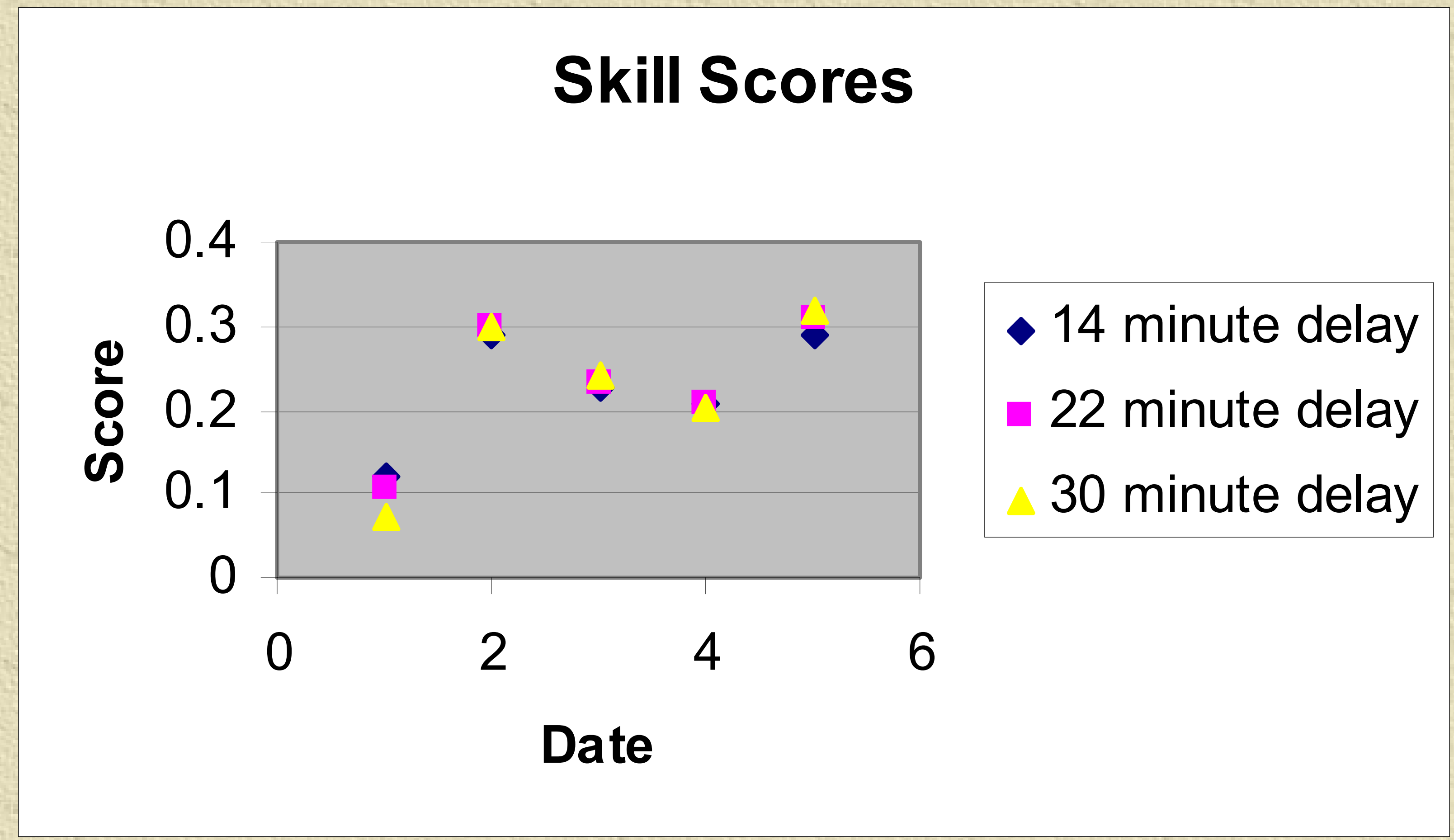
Solar Wind Data for Storm Day



Comparison at FHB



Differences in Time Delay



Summary

- 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.
- Interacting with Daniel Weimer to improve model.
- First step, more to come.

References

- Fukushima, N., Generalized theorem for no ground magnetic effect of vertical currents connected with Pedersen currents in the uniform conducting ionosphere, *Rep. Ionos. Space Res. Jpn., 22*, 219, 1969.
- Weimer, D. R., An improved model of ionospheric electric potentials including substorm perturbations and applications to GEM November 24, 1996 event, *J. Geophys. Res., 106*, 407, 2001a.
- Weimer, D. R., Maps of ionospheric field-aligned currents as a function of the interplanetary magnetic field derived from Dynamics Explorer 2 data, *J. Geophys. Res., 106*, 12,889, 2001b.