GEM Challenge: ground magnetic field perturbations

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Acknowledgements: A. Ridley, CCMC staff, GEM community.

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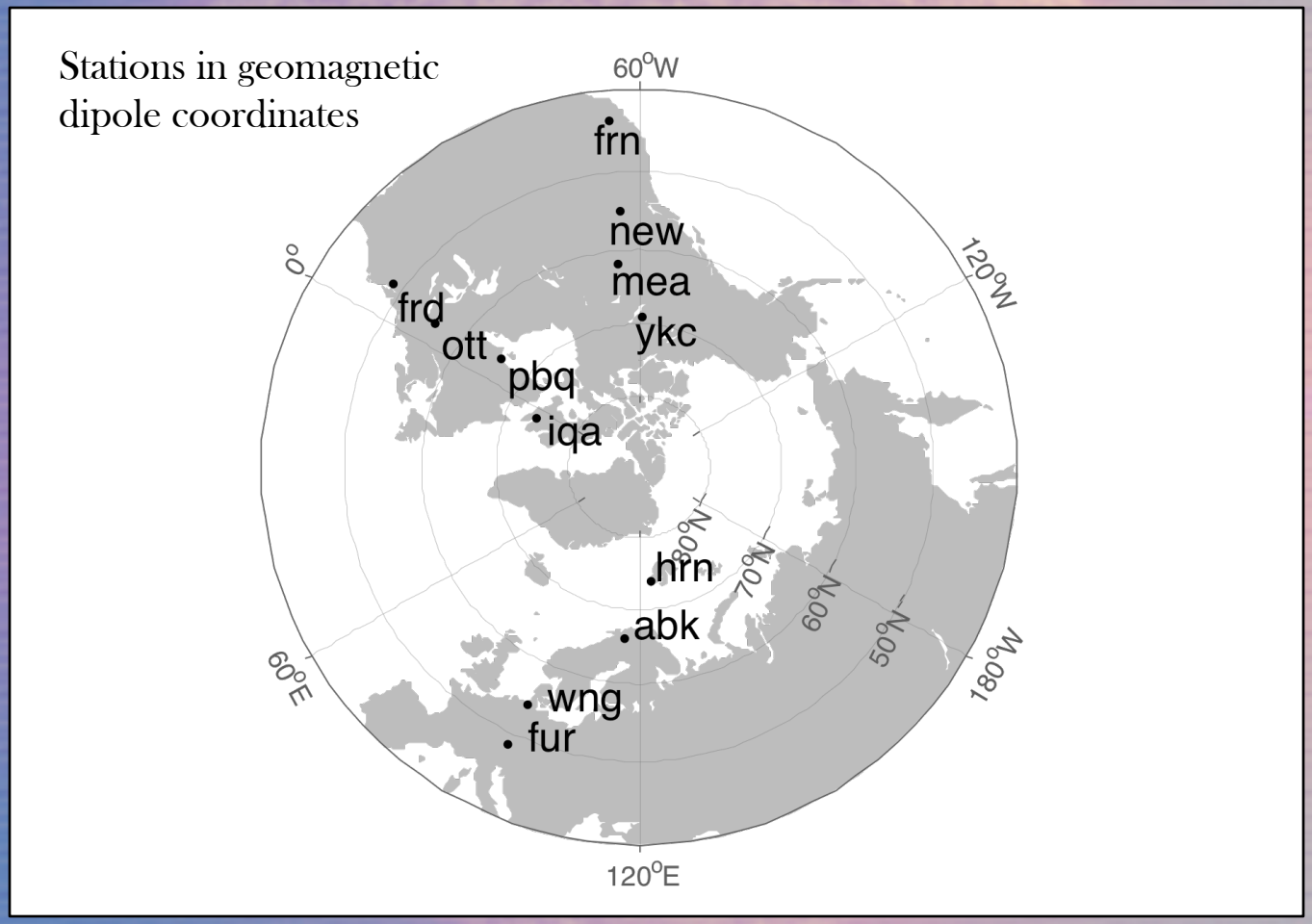
Data preparation

- Selected storm events:
  1. October 29, 2003 06:00 UT - October 30, 06:00 UT.
  2. December 14, 2006 12:00 UT - December 16, 00:00 UT.
  3. August 31, 2001 00:00 UT - September 1, 00:00 UT.
  4. August 31, 2005 10:00 UT - September 1, 12:00 UT.
- For this particular analysis, 12 ground magnetometer stations were selected based on the spatiotemporal coverage.

Data preparation



Data preparation

- One-minute geomagnetic field data downloaded via INTERMAGNET.
- Visually detected baseline removed to obtain the disturbance field.
- Small data gaps no longer than few minutes patched via linear interpolation.

Methods of analysis

- Visual inspection of magnetic field time series by using the CCMC's Metrics Tool.
- Mean (over 2 hour windows and different stations) power spectra generated for both observed and modeled field fluctuations.

Methods of analysis

- "Metrics" analysis (or metrics study)
  - The term *metric* not used in a strict mathematical sense but to refer to more general functions mapping two elements of a set into a single real number.
  - The computed number quantifies the model performance in terms of "distance" from the perfect performance.
  - Different metrics measure different aspects of the model performance.
  - Two metrics selected for the analysis.

Methods of analysis

- Prediction efficiency:

$$PE(x_{obs}, x_{mod}) = 1 - \frac{\left\langle (x_{obs} - x_{mod})^2 \right\rangle_t}{\sigma_{obs}^2}$$

Perfect model, *PE=1*

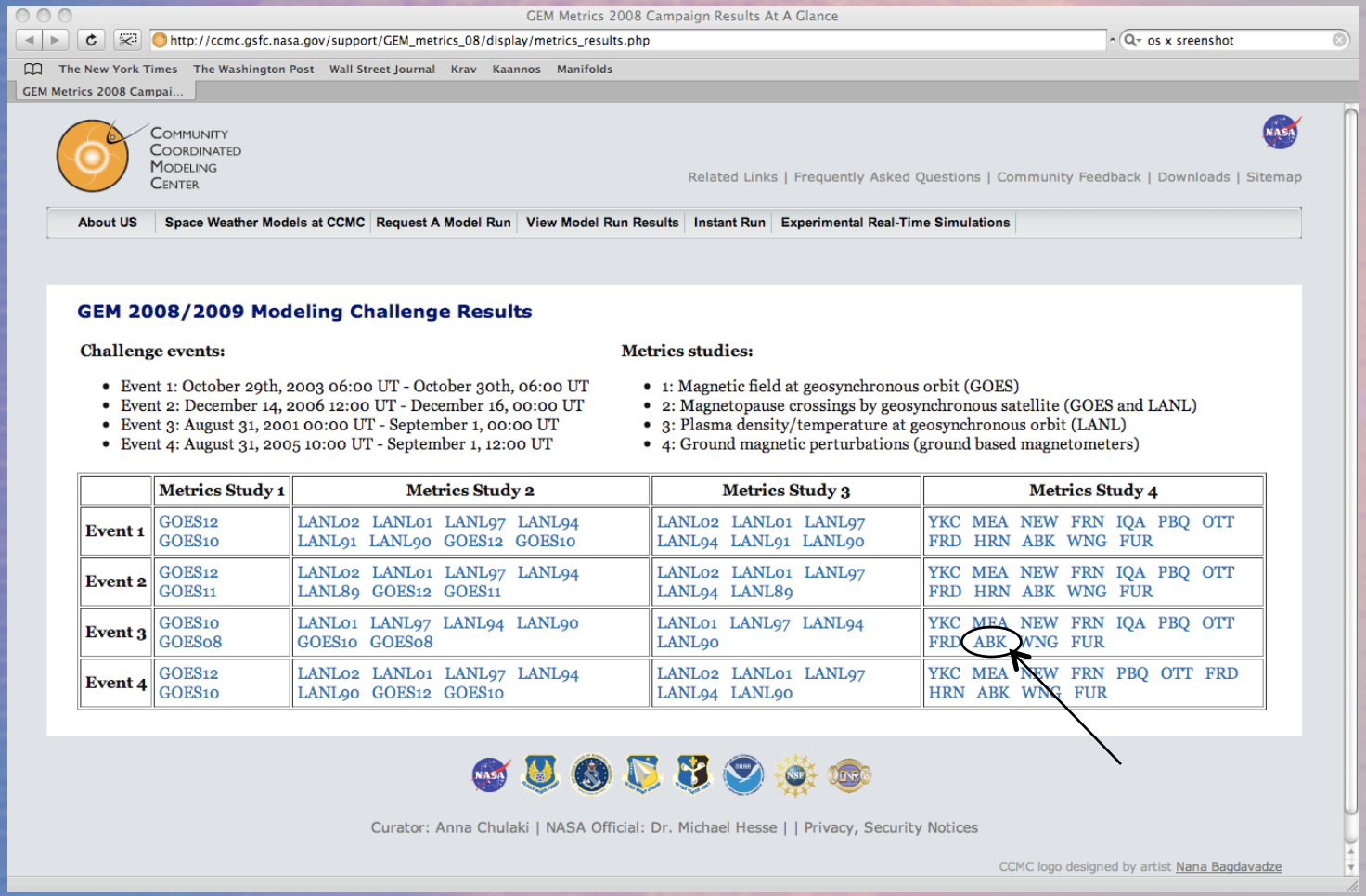
- Log-spectral distance (GIC-related derivation)

$$M_s(\tilde{\mathbf{x}}_{obs}, \tilde{\mathbf{x}}_{mod}) = \sqrt{\sum_{\omega} \left(\log \frac{|\tilde{x}_1|_{obs} + |\tilde{x}_2|_{obs}}{|\tilde{x}_1|_{mod} + |\tilde{x}_2|_{mod}} \right)^2}$$

Perfect model, $M_s=0$

Model setting description	Identifier
CMIT 2.0, currents from TIEGCM	1_CMIT
LFM	1_LFM
Weimer (2005, JGR), 4-min. output interpolated to 1 min.	1_WEIMER
OpenGGCM v3.1, number of cells: 3 million	1_OPENGGCM
OpenGGCM v3.1, number of cells: 6.5 million	2_OPENGGCM
BATS-R-US v7.73, number of cells: 2 million	1_SWMF
BATS-R-US v7.73, number of cells: 700000	2_SWMF
BATS-R-US v8.01 coupled to RCM, number of cells: 2 million	3_SWMF
BATS-R-US v8.01, number of cells: 3 million	4_SWMF
BATS-R-US v8.01 coupled to RCM, number of cells: 3 million	5_SWMF
BATS-R-US v20090403 coupled to RCM, number of cells 900000	6_SWMF

Magnetic field time series via Metrics Tool



	Metrics Study 1	Metrics Study 2	Metrics Study 3	Metrics Study 4
Event 1	GOES12 GOES10	LANL02 LANL01 LANL97 LANL94 LANL91 LANL90 GOES12 GOES10	LANL02 LANL01 LANL97 LANL94 LANL91 LANL90	YKC MEA NEW FRN IQA PBQ OTT FRD HRN ABK WNG FUR
Event 2	GOES12 GOES11	LANL02 LANL01 LANL97 LANL94 LANL89 GOES12 GOES11	LANL02 LANL01 LANL97 LANL94 LANL89	YKC MEA NEW FRN IQA PBQ OTT FRD HRN ABK WNG FUR
Event 3	GOES10 GOES08	LANL01 LANL97 LANL94 LANL90 GOES10 GOES08	LANL01 LANL97 LANL94 LANL90	YKC MEA NEW FRN IQA PBQ OTT FRD ABK WNG FUR
Event 4	GOES12 GOES10	LANL02 LANL01 LANL97 LANL94 LANL90 GOES12 GOES10	LANL02 LANL01 LANL97 LANL94 LANL90	YKC MEA NEW FRN PBQ OTT FRD HRN ABK WNG FUR

Magnetic field time series via Metrics Tool

Plot Options:

Image magnification 2.0

Line thickness 3

Character thickness 3 (all annotations)

☐ **Lock plot range:**

Min.: -1 Max.: 1

Select model settings

- ☐ 1_SWMF: BATSRUS 7.73, 2M cells, CCMC
- ☐ 2_SWMF: BATSRUS 7.73, 700k cells (real-time setup), CCMC
- ☐ 3_SWMF: BATSRUS 8.01 with RCM, 2M cells, CCMC
- ☐ 4_SWMF: BATSRUS 8.01, 3 M cells, CCMC
- ☐ 5_SWMF: BATSRUS 8.01 with RCM, 3M cells, CCMC
- ☑ 6_SWMF: SWMF V.20090403, BATSRUS+RCM2, 900k cells, RT on 64 procs., A. Ridley
- ☑ 1_OPENGGCM: OpenGGCM 3.1, 3 M cells
- ☐ 1_LFM: LFM, Michael_Wiltberger (13/11/2008,15/05/2009)
- ☐ 1_CMIT: CMIT 2.0, George_Millward (28/05/2009, 04/06/2009)
- ☑ 1_WEIMER: Weimer 2005, Daniel_Weimer (12/05/2009)

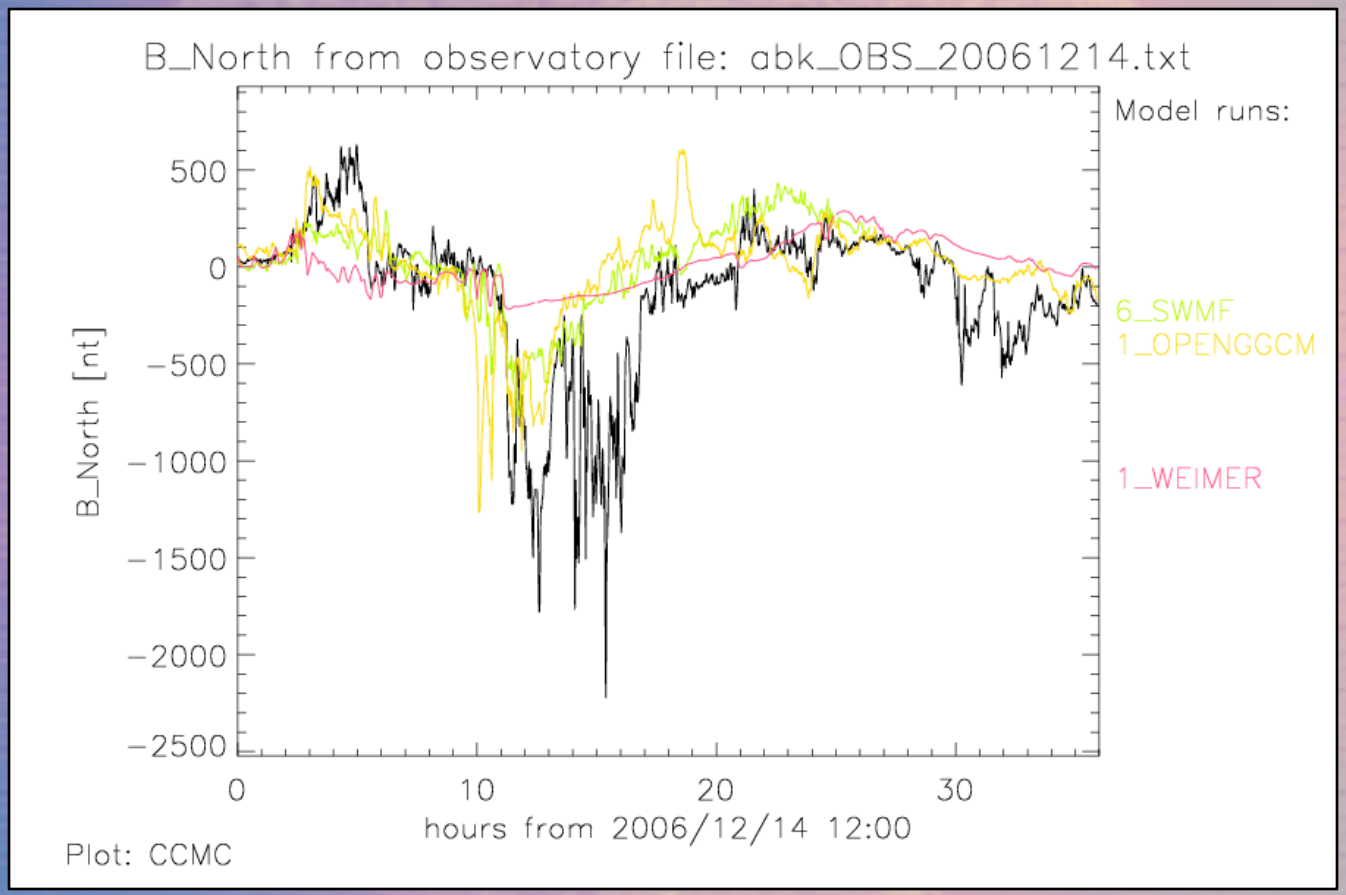
Reset Form *Reset Form* will reset changes to the defaults specified by the previous run of this script.

Update Plot *Update Plot* will update (generate) the plot with the chosen time and plot parameters above.

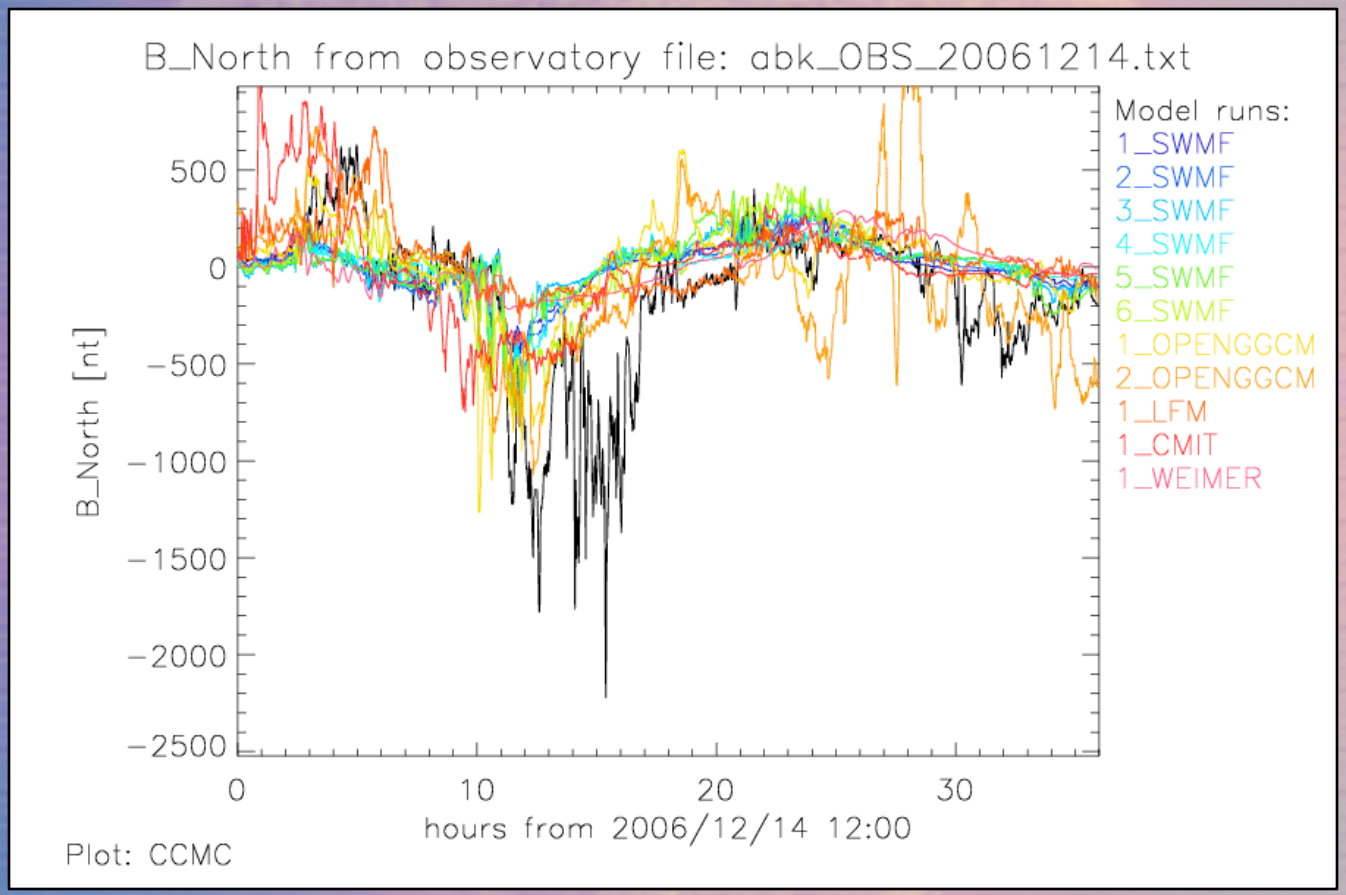
Runs-on-Request: Contact CCMC Staff

Visualization: Dr. Lutz Rastätter

Magnetic field time series via Metrics Tool



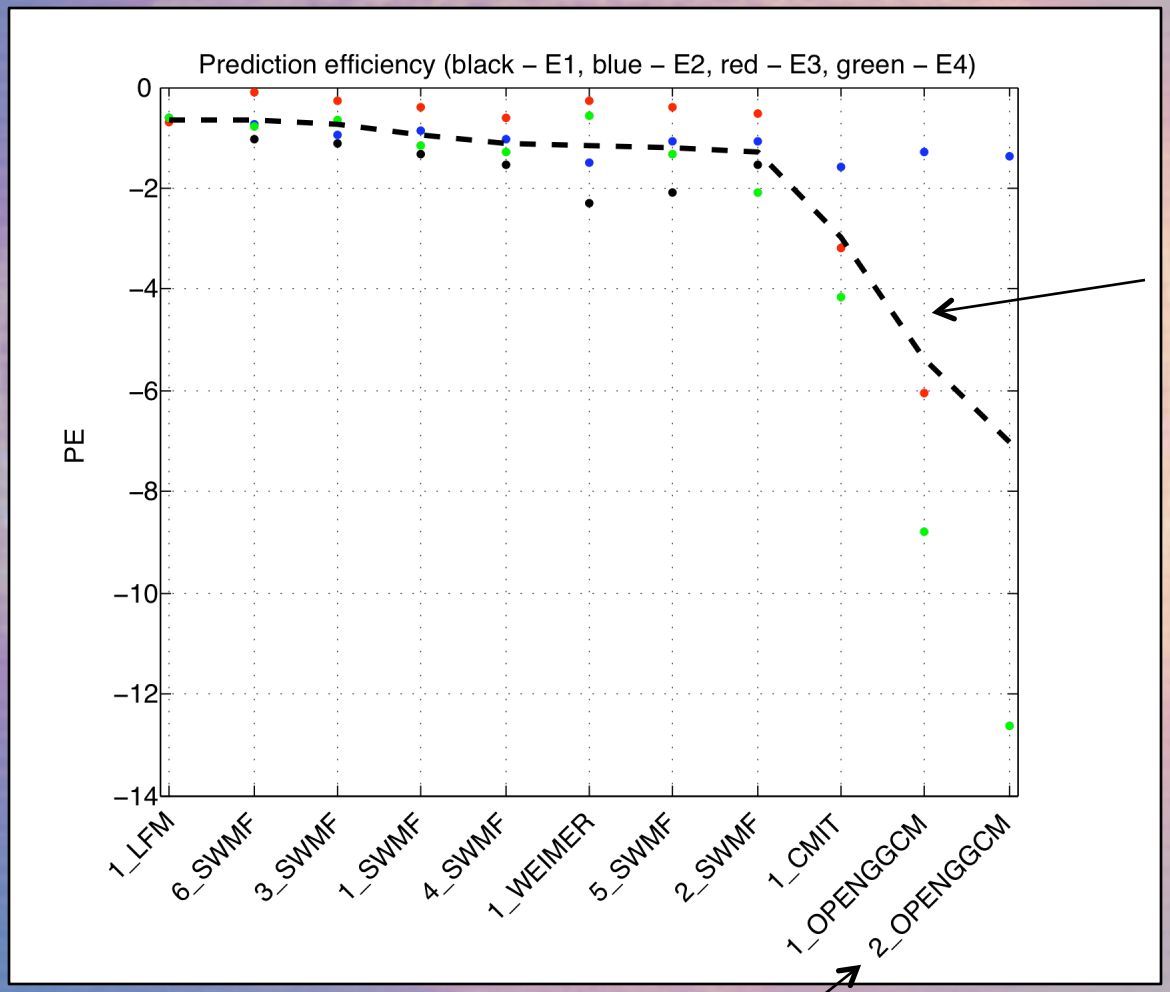
Magnetic field time series via Metrics Tool



Metrics results

- Report mean prediction efficiency for each event. Mean taken over all stations and both horizontal components.
- Report log-spectral distance computed by using the mean spectral power. Mean taken over all stations.

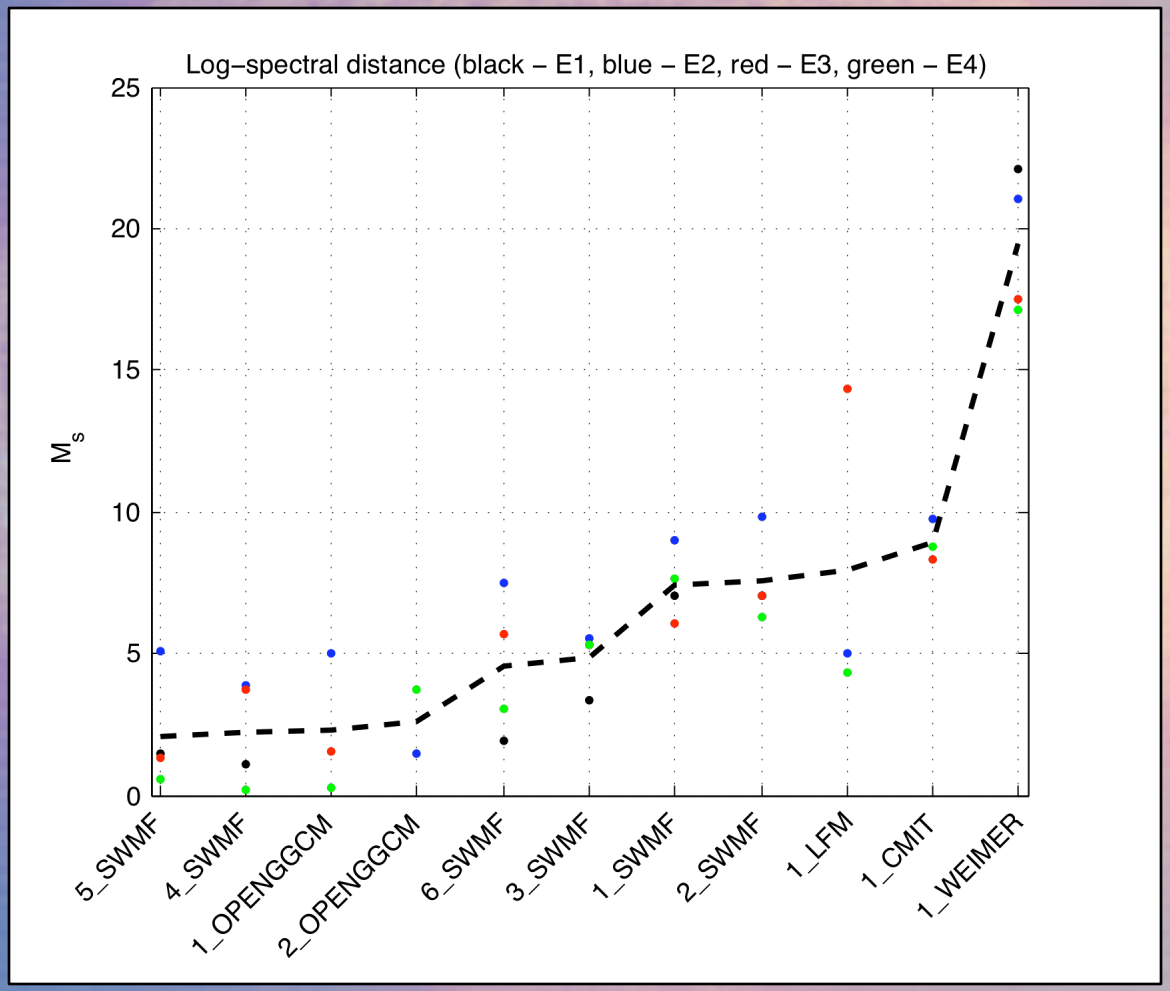
Metrics results



Mean over events

Model setting identifier

Metrics results



Summary

- Observed and modeled data for 12 magnetometer stations analyzed for four storm events.
- 11 model settings analyzed.
- Visual analysis and later metrics analyses can be carried out via CCMC's Metrics Tool.
- Overall rank determined by means of average prediction efficiencies and log-spectral distances.
- Different metrics provide quite different ranking.
- Additional checks and physics-based analyses to be carried out.