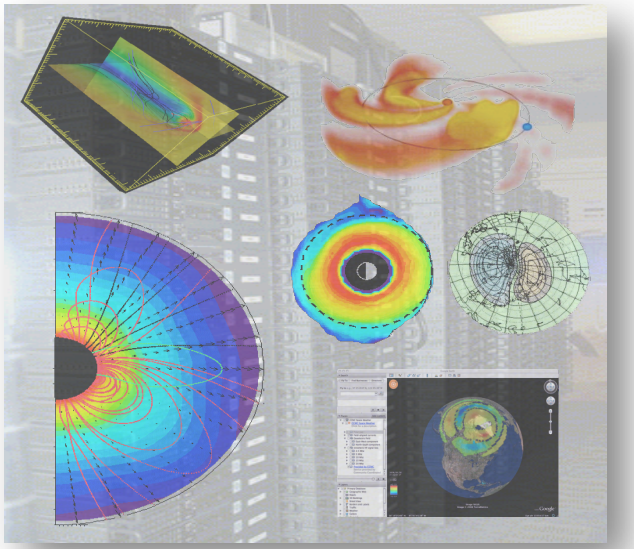
Community Coordinated Modeling Center

From GEM metrics studies to operational geospace model selection



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Background

- GEM community recognized need for a community-wide model validation effort: GEM 2008-2009 Challenge, which was supported by CCMC via GEM Metrics and Validation Focus Group.
- Similar activities supported by CCMC ongoing at CEDAR and SHINE programs.
- Goal to address both scientific and operational aspects of the model performance.

GEM 2008-2009 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

GEM 2008-2009 Challenge setup: ground stations

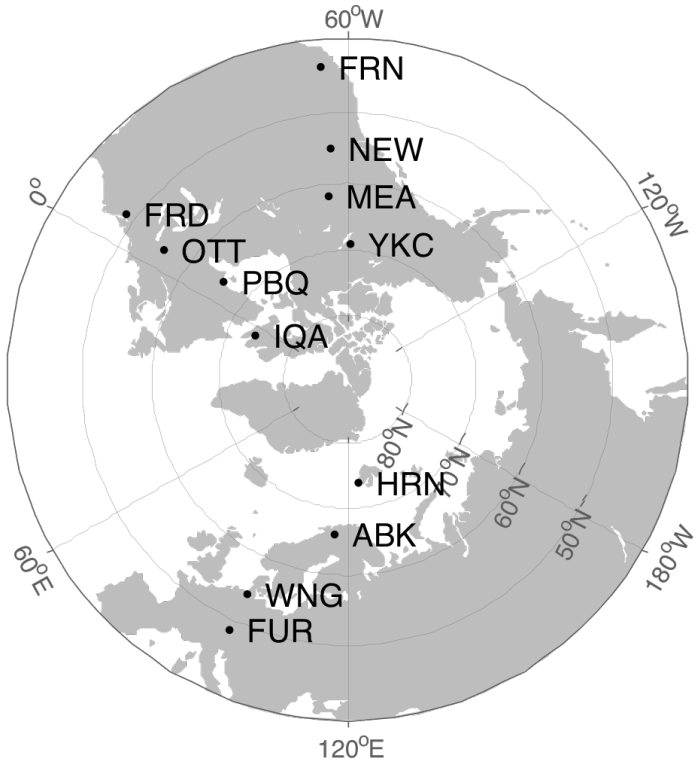


Figure 2. The locations and the station codes of the geomagnetic observatories used in the study. Geomagnetic dipole coordinates are used.

Metrics 1/4: prediction efficiency

$$PE = 1 - \frac{< (x_{obs} - x_{mod})^2 >_i}{\sigma_{obs}^2}$$

- Perfect model prediction: *PE* = 1.

Metrics 2/4: log-spectral distance

$$m_s(\omega) = \log\left[\frac{|\tilde{B}_x|_{obs} + |\tilde{B}_y|_{obs}}{|\tilde{B}_x|_{mod} + |\tilde{B}_y|_{mod}}\right]$$

$$M_s = \sqrt{\frac{1}{N}\sum_{\omega} m_s^2}$$

- Perfect model prediction: $M_s = 0$.

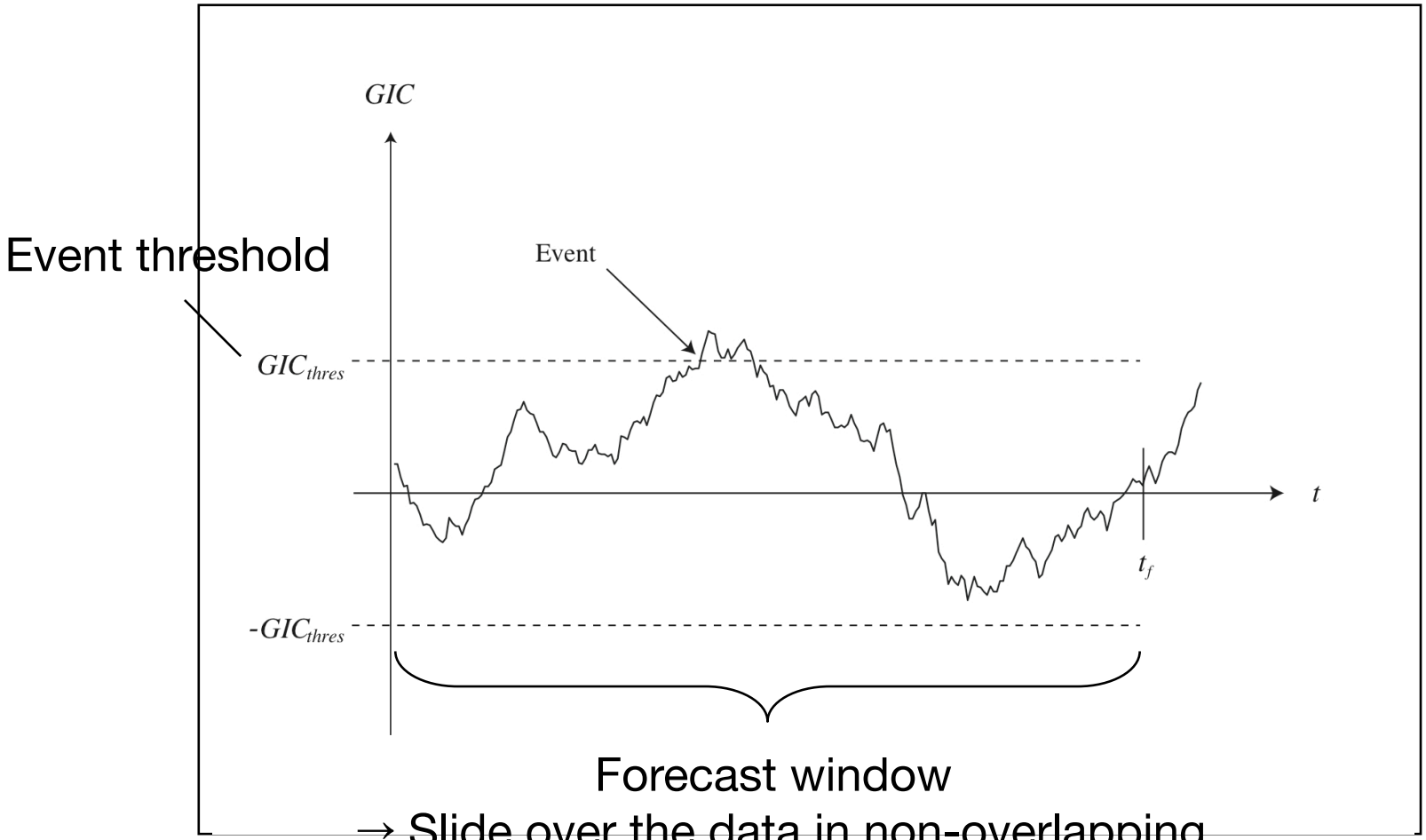
Metrics 3/4: utility metric (forecast ratio)

$$U_f = BN_H - CN_{\overline{H}}$$

$$R_f = N_H / N_{\overline{H}}$$

- Perfect model prediction: R_f = Inf.
- 45 min. forecast window used.
- Compute R_f for both $|\mathbf{B}_h| = \sqrt{B_x^2 + B_y^2}$ and $|d\mathbf{B}_h/dt|$

Metrics 3/4: utility metric (forecast ratio)



→ Slide over the data in non-overlapping segments and record "events"

Metrics 4/4: ratio of maximum amplitudes

$$R_{max} = \frac{\max(|x_{mod}|_i)}{\max(|x_{obs}|_i)}$$

- Perfect model prediction: R_{max} = 1.
- Compute R_{max} for both $|\mathbf{B}_h| = \sqrt{B_x^2 + B_y^2}$ and $|d\mathbf{B}_h/dt|$

In addition, model ENSEMBLE

Model submissions

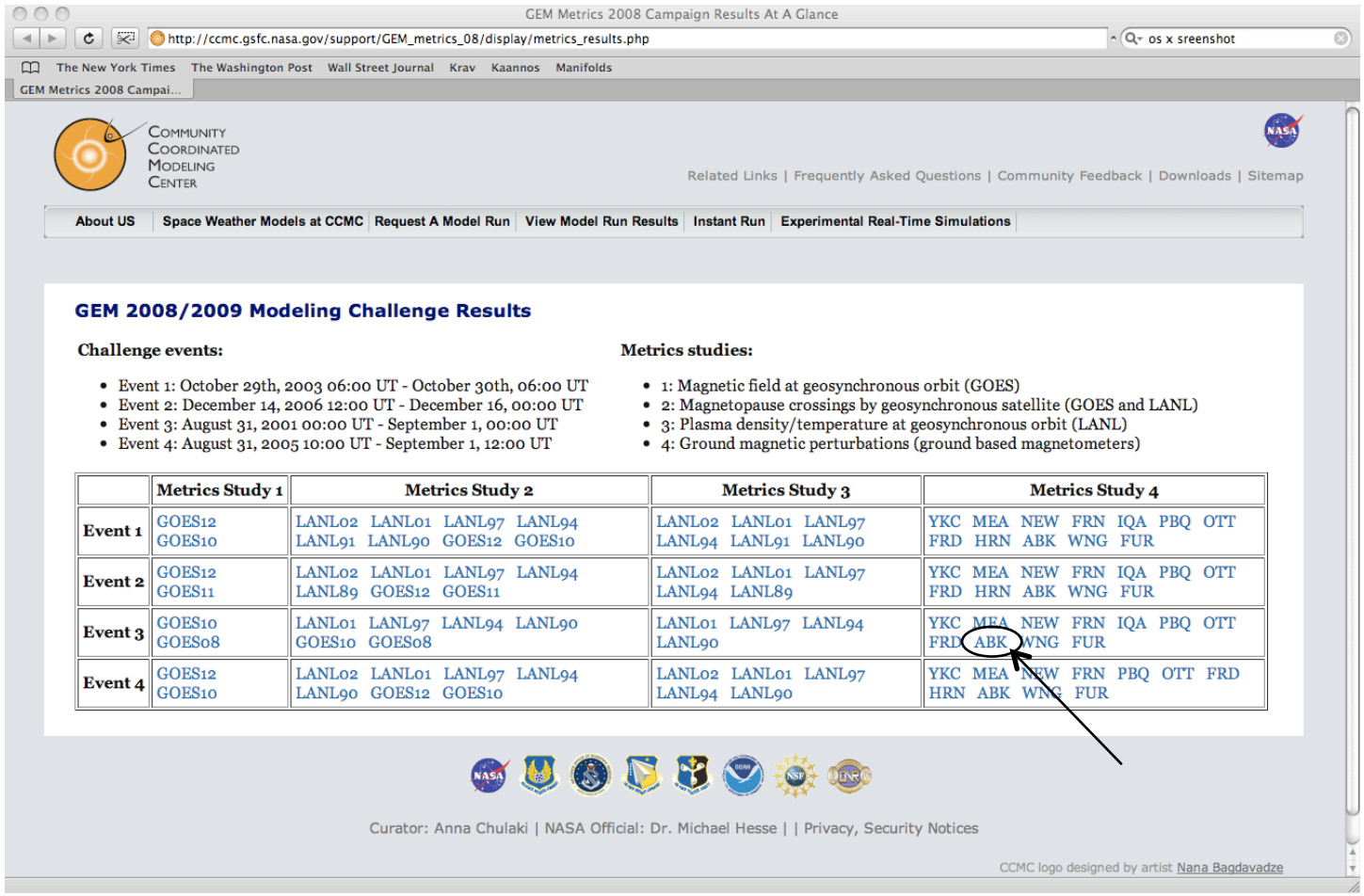
Table 3. Model Submissions Analyzed in the Challenge[a]

Identifier	Model	Grid (Number of Cells, Min. Res.)
1_CMIT	CMIT 2.0, LFM coupled to TIEGCM	40,000, 0.5 R_e
1_LFM	LFM	160,000, 0.3 R_e
1_OPENGGCM	OpenGGCM v3.1 coupled to CTIM	3 million, 0.3 R_e
2_OPENGGCM	OpenGGCM v3.1 coupled to CTIM	6.5 million, 0.25 R_e
1_SWMF	SWMF v7.73, BATS-R-US	2 million, 0.25 R_e
2_SWMF	SWMF v7.73, BATS-R-US	700,000, 0.25 R_e
3_SWMF	SWMF v8.01 BATS-R-US coupled to RCM	2 million, 0.25 R_e
4_SWMF	SWMF v8.01, BATS-R-US	3 million, 0.125 R_e
5_SWMF	SWMF v8.01, BATS-R-US coupled to RCM	3 million, 0.125 R_e
6_SWMF	SWMF v20090403, BATS-R-US coupled to RCM	900,000, 0.25 R_e
1_WEIMER	*Weimer* [2005]	4 min output interpolated into 1 min
2_WEIMER	New empirical model by D. Weimer	4 min output interpolated into 1 min
1_WEIGEL	*Weigel et al.* [2003]	30 min output

[a]Each model is assigned a unique model identifier given in the first column. The table indicates the model version, and if applicable, the number of cells and the minimum spatial resolution used in the global MHD part of the model. Note that different model setups are referred as different "models."

Models run both by CCMC and developers. All submissions placed into a common database.

GEM 2008-2009 Challenge Metrics Interface



GEM 2008-2009 Challenge Metrics Interface

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)

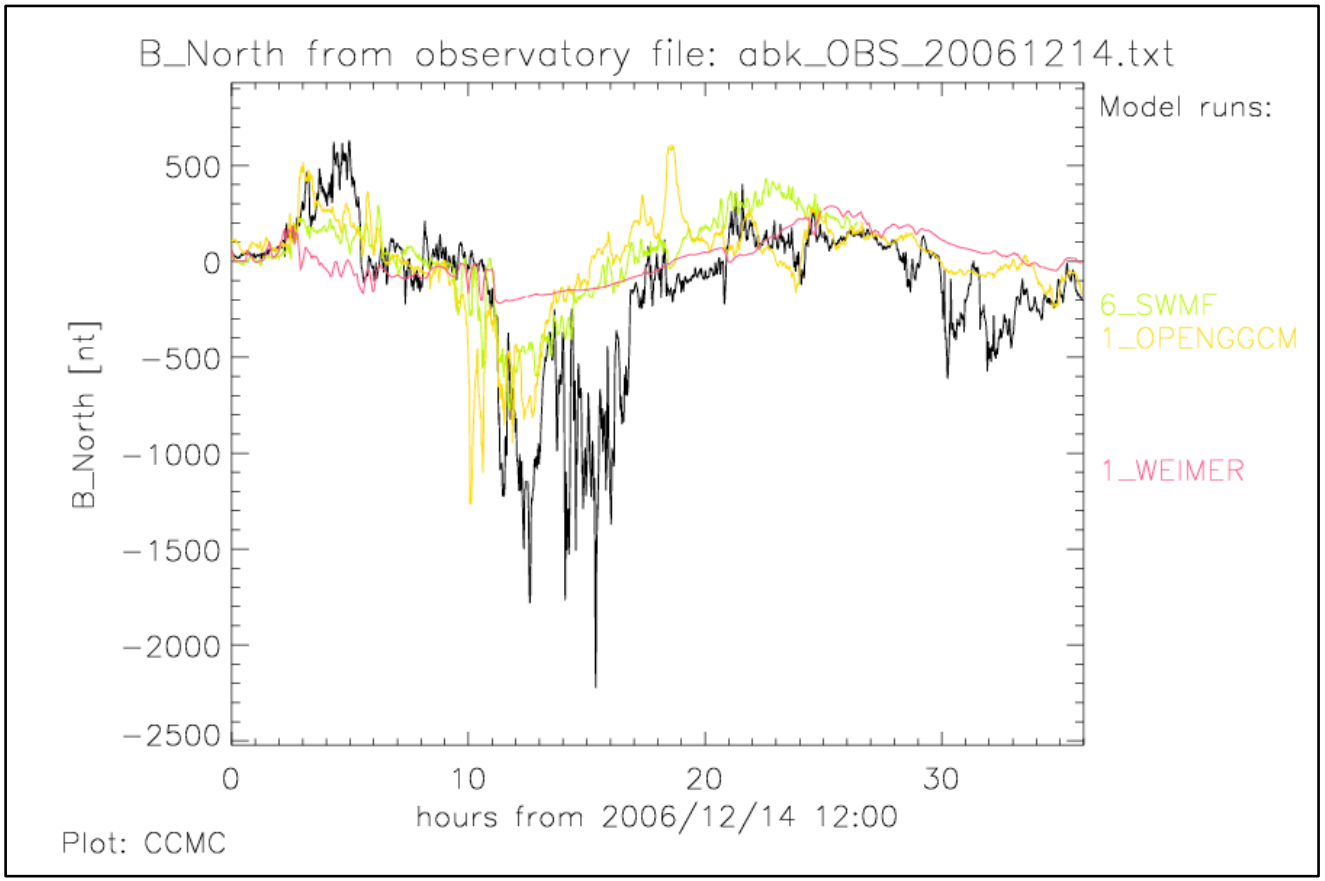
Reset Form *Reset Form* will reset changes to the defaults specified by the previous run of this script.

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

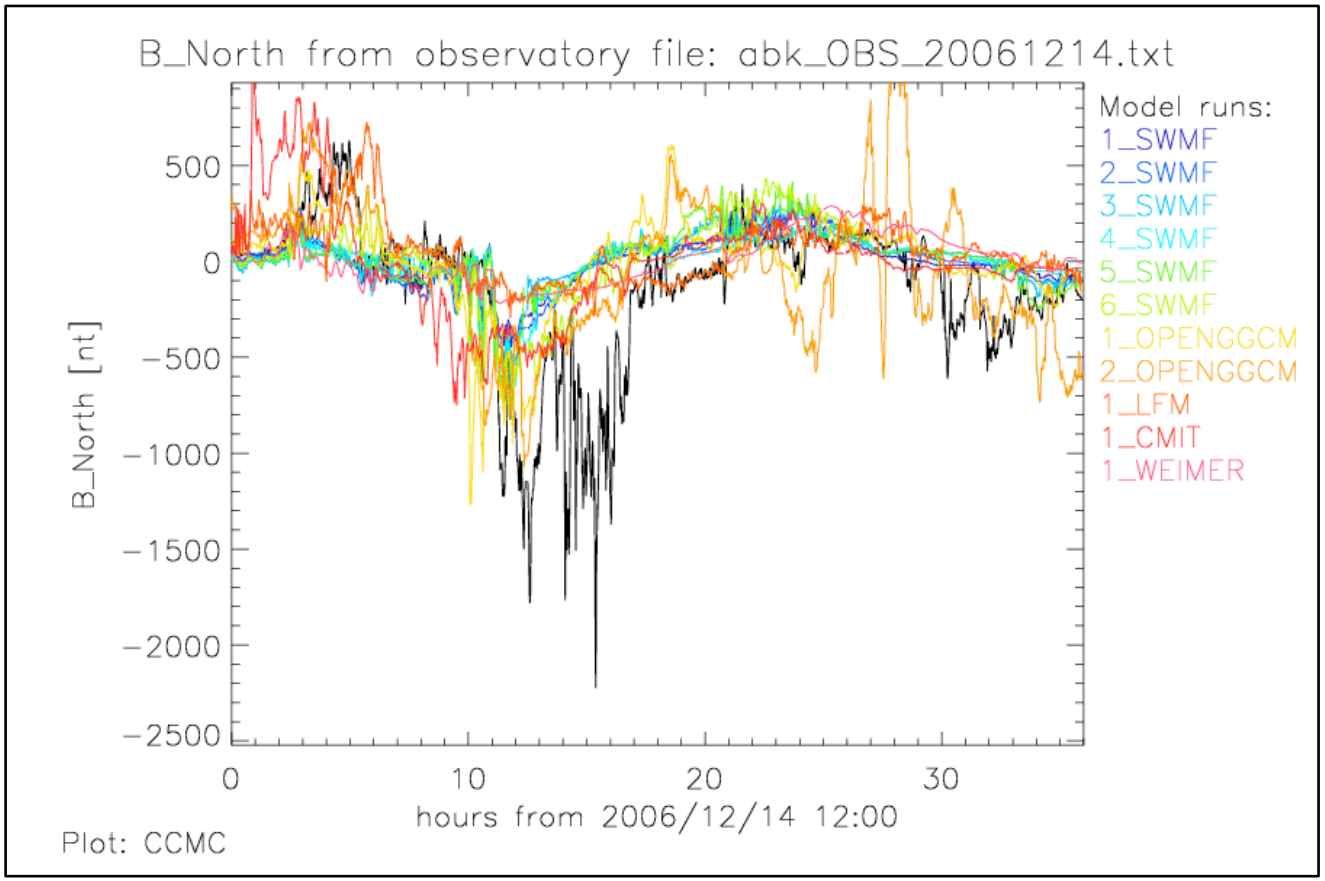
Runs-on-Request: Contact CCMC Staff

Visualization: Dr. Lutz Rastätter

GEM 2008-2009 Challenge Metrics Interface



GEM 2008-2009 Challenge Metrics Interface



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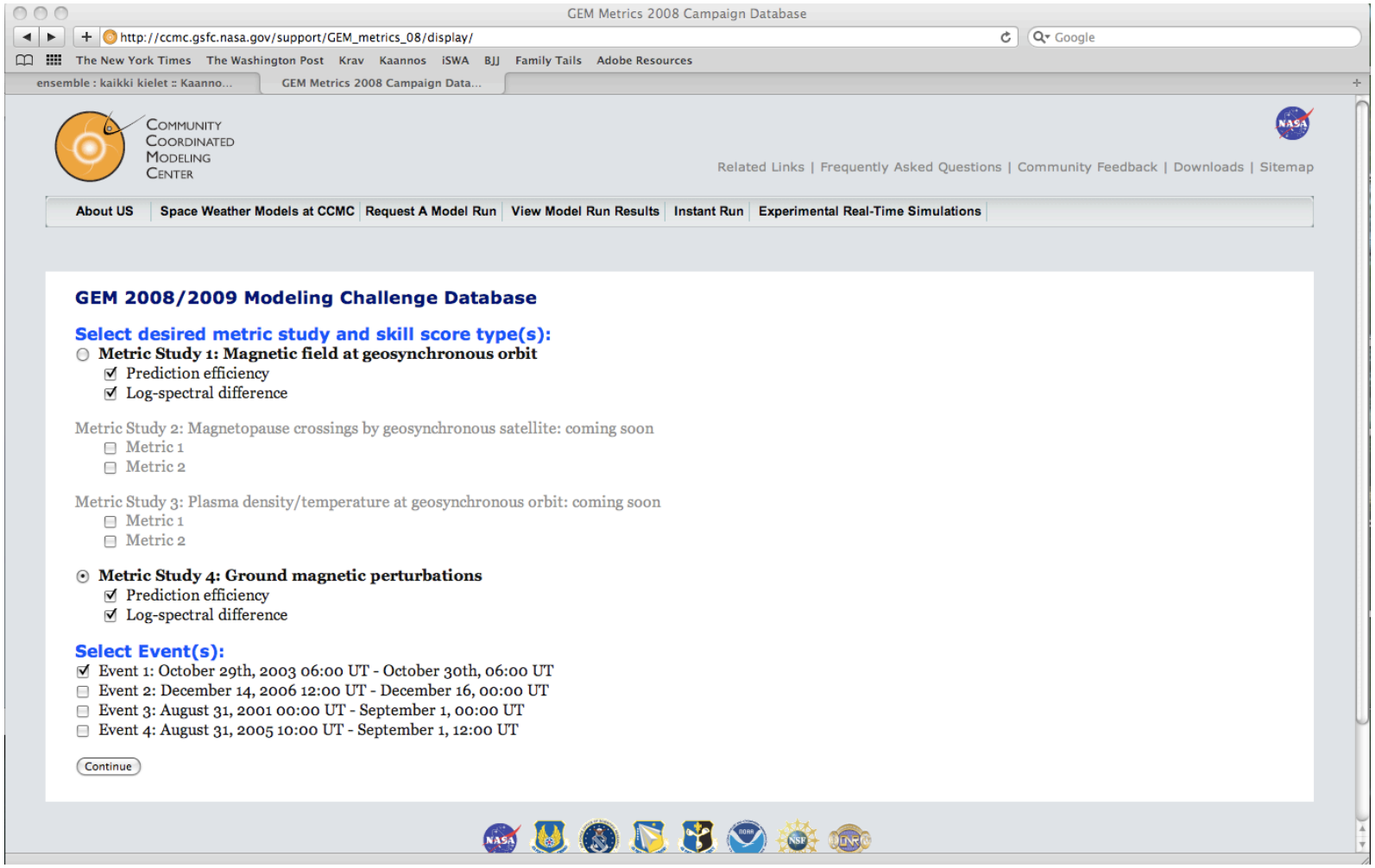
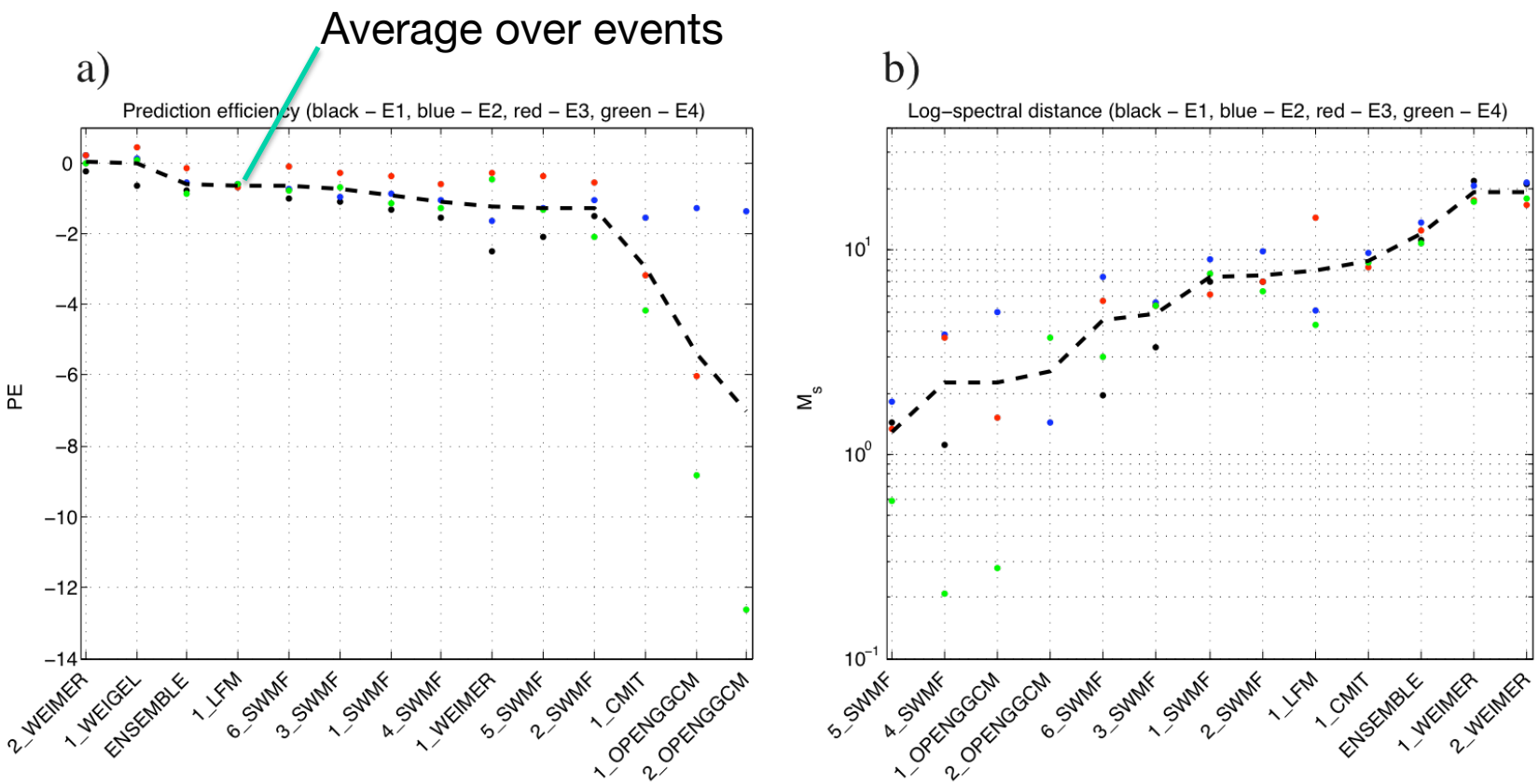


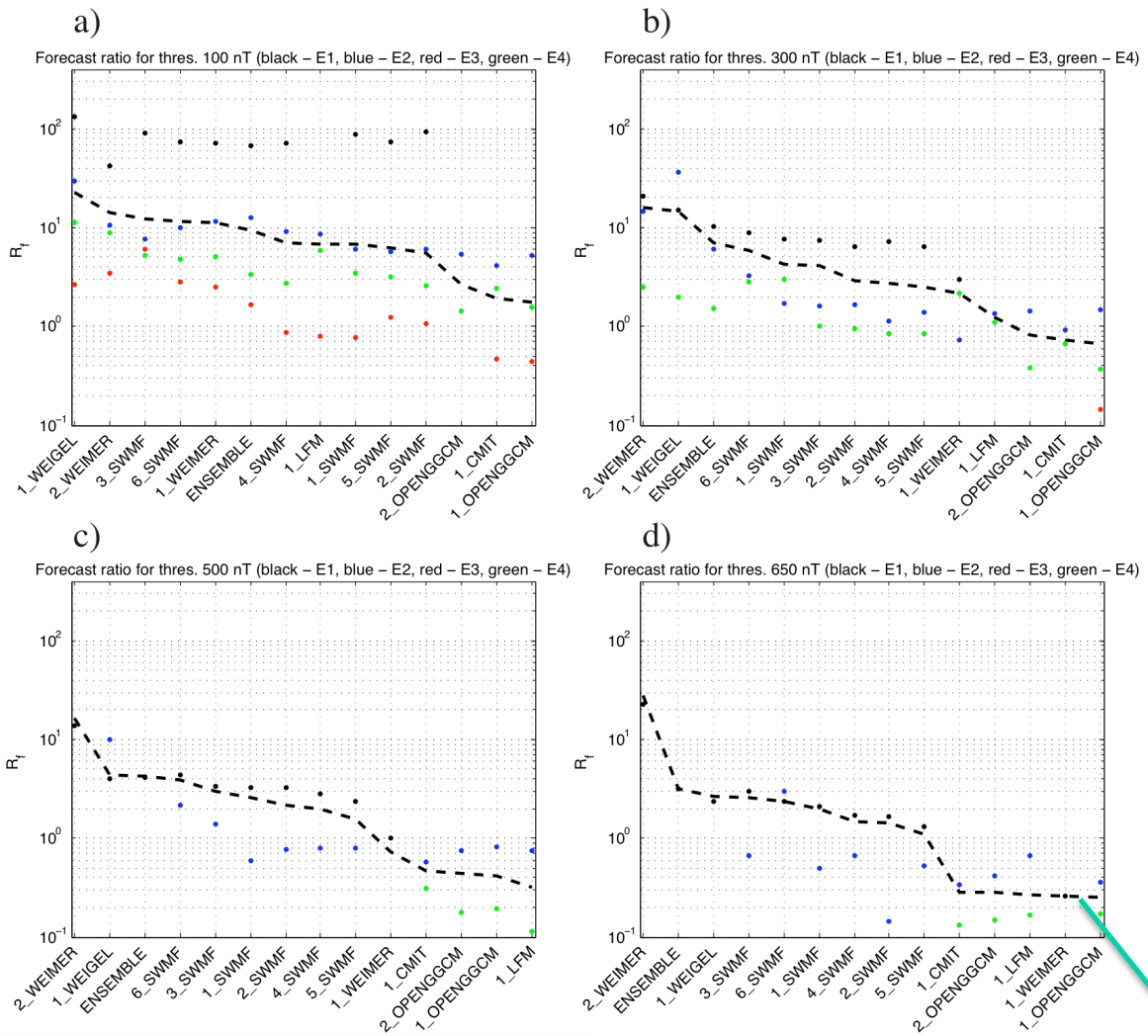
Metrics-based results

- In all figures averages (integration) over stations and, if applicable, over horizontal field components reported.
- Ranking based on averages (integration) over events.
- Caution: not all events included for all models/ setups.

Metrics-based results: *PE* and M_s

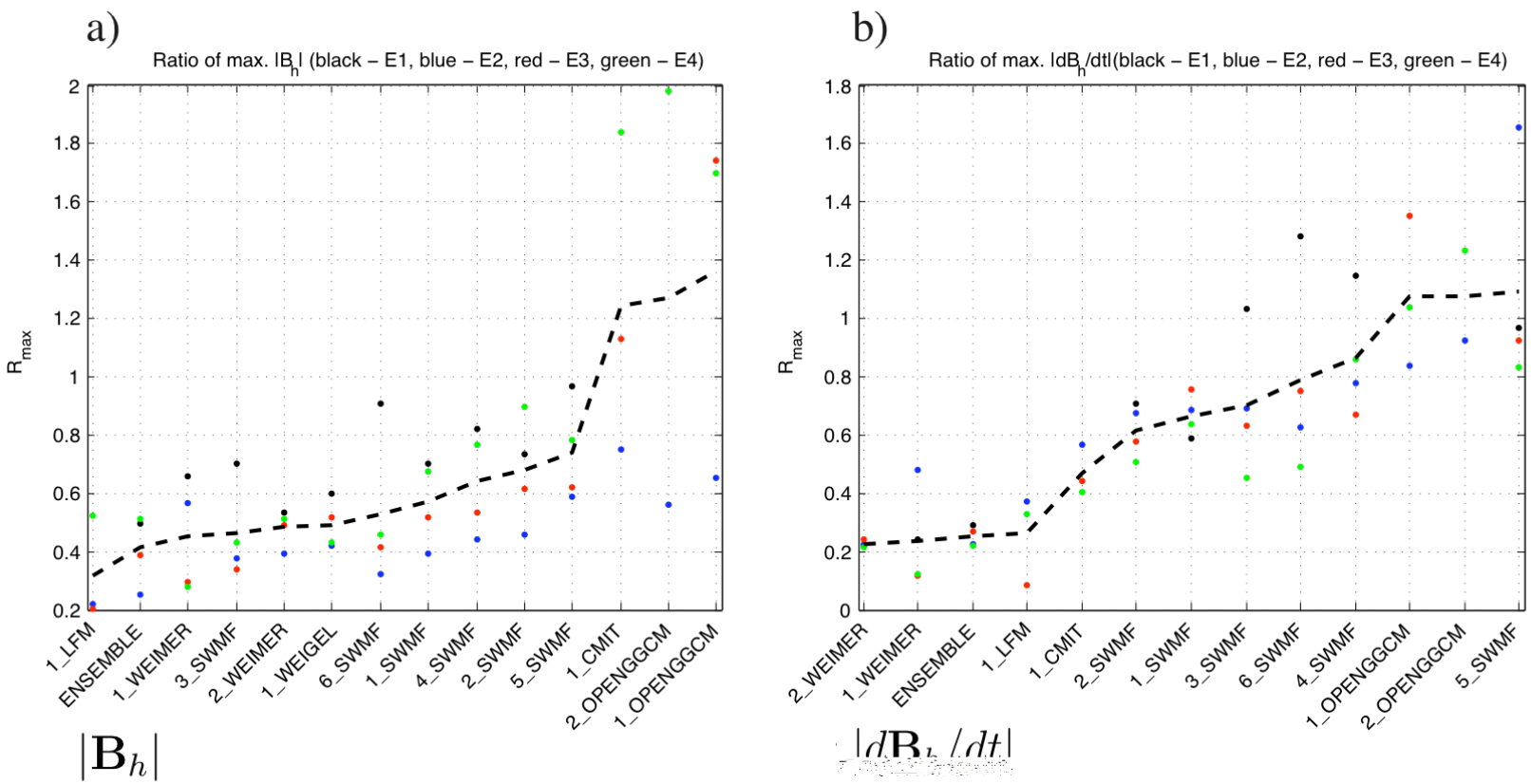


Metrics-based results: R_f for $|\mathrm{B}_h|$



Integration over events

Metrics-based results: R_{max}

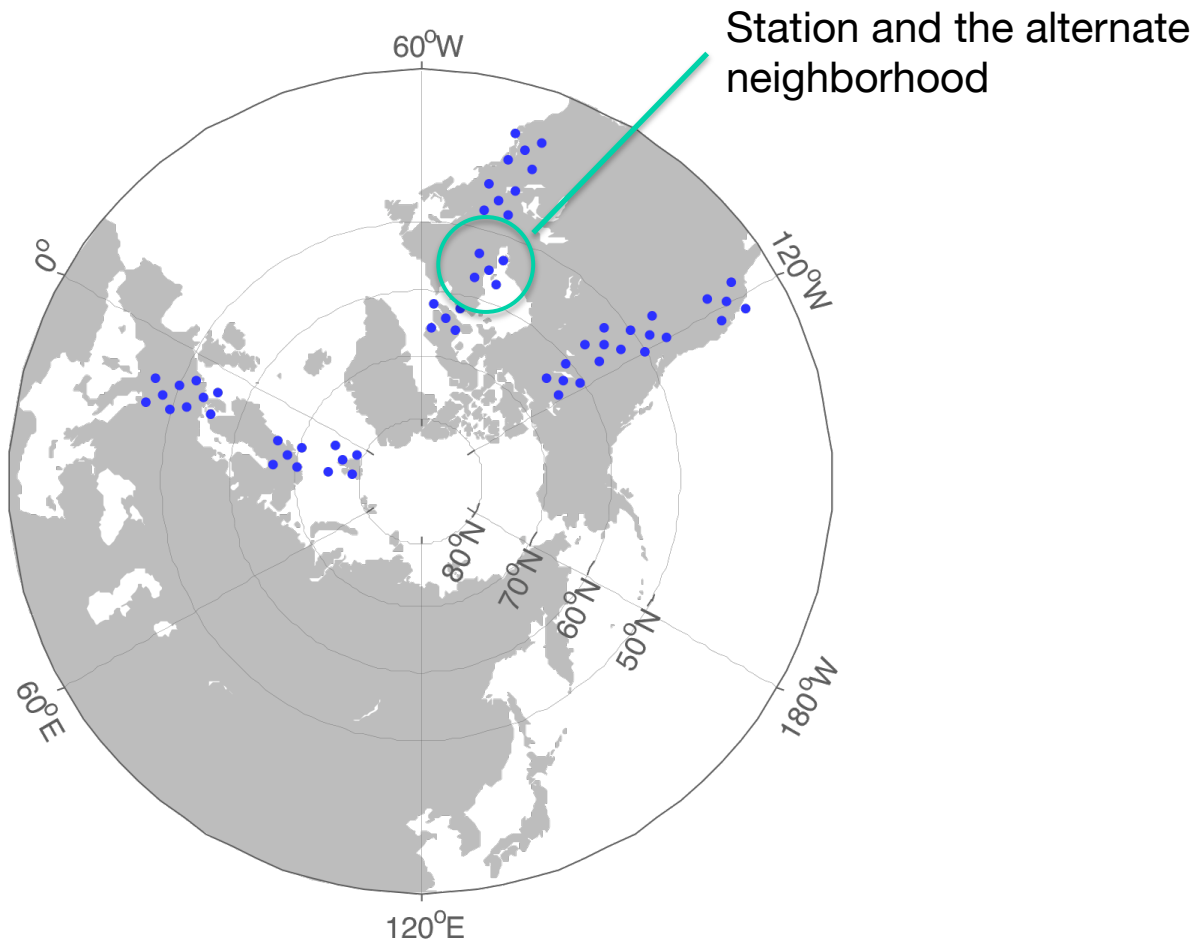


Note: no ranking here

Operational model selection activity

- CCMC is supporting NOAA SWPC's geospace model selection. The goal to select a model for predicting the ground magnetic field fluctuations.
- All major US global 3D MHD models and two empirical models participating the activity.
- Lessons learned in the GEM activity utilized in the selection activity.
- Threshold-based metrics as well as GEM events and set of ground magnetometer stations used in the activity.
- Additional "sensitivity tests" not part of the original GEM Challenge carried out in the activity.

Operational model selection activity



Summary

- Recent CCMC supported community-wide model validation efforts under GEM, CEDAR and SHINE programs.
- One of the ideas is to repeat the exercises every couple years to measure the progress in the field.
- Pulkkinen et al., Geospace Environment Modeling 2008-2009 Challenge: ground magnetic field perturbations, Space Weather, 2011.
- Rastaetter et al., Geospace Environment Modeling 2008-2009 Challenge: geostationary magnetic field perturbations, Space Weather, 2011.
- GEM Challenge lessons support directly NOAA SWPC's geospace model validation and selection process.