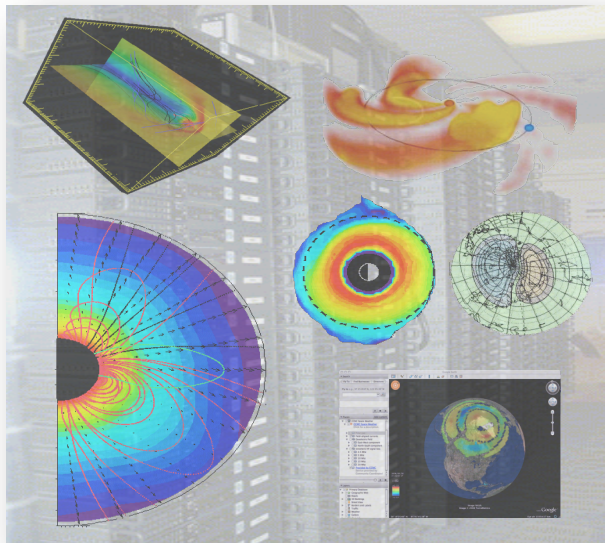
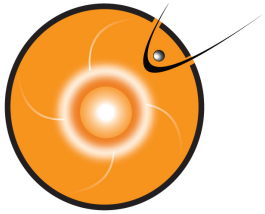


GEM 2008-2009 Challenge: ground magnetic field perturbations



Pulkkinen, A., M. Kuznetsova, A. Ridley, J. Raeder, D. Weimer, R. Weigel, M. Wiltberger, G. Millward, L. Rastätter, M. Hesse, H. J. Singer and A. Chulaki

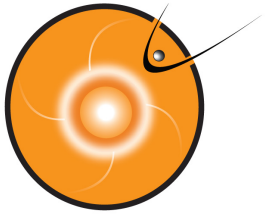




Contents

- Challenge setup.
- Metrics*.
- Model submissions.
- Metrics-based results.
- Discussion.

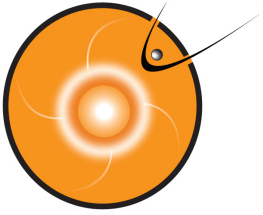
*Including introduction of two new metrics. NOAA/
SWPC interests addressed.



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



Challenge setup: stations

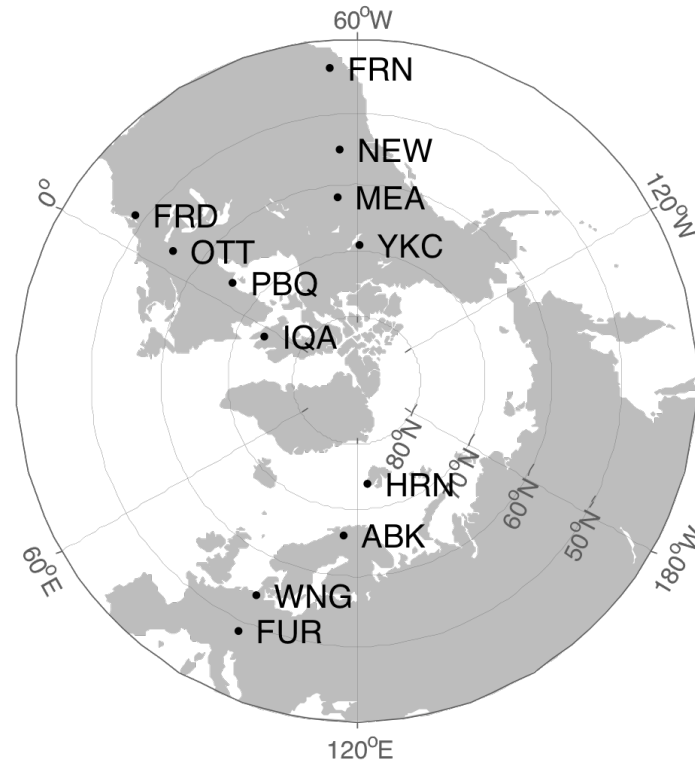
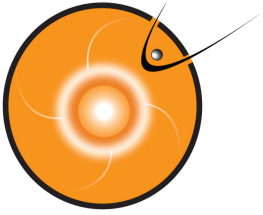


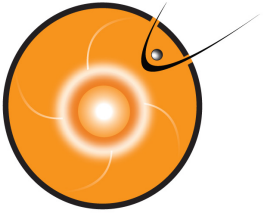
Figure 2. The locations and the station codes of the geomagnetic observatories used in the study. Geomagnetic dipole coordinates are used.



Metrics 1/4: prediction efficiency

$$PE = 1 - \frac{\langle (x_{obs} - x_{mod})^2 \rangle_i}{\sigma_{obs}^2}$$

- Perfect model prediction: $PE = 1$.

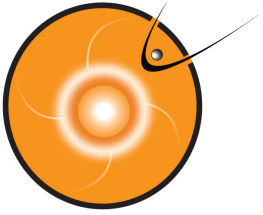


Metrics 2/4: log-spectral distance

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

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

- Perfect model prediction: $M_s = 0$.

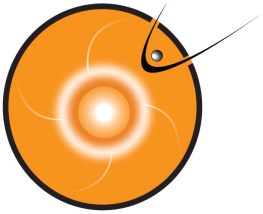


Metrics 3/4: utility metric (forecast ratio)

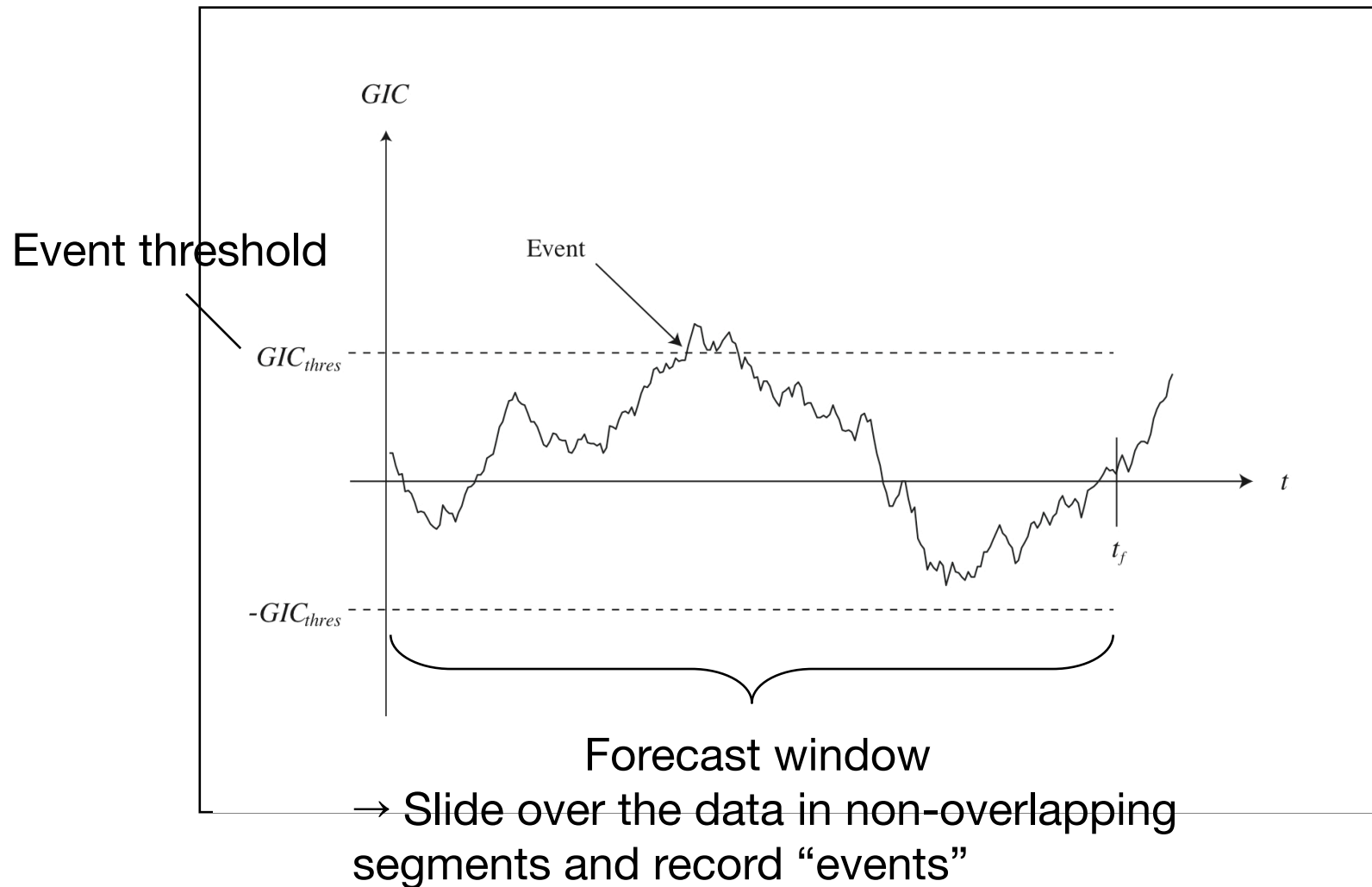
$$U_f = BN_H - CN_{\overline{H}}$$

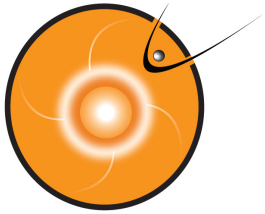
$$R_f = N_H / N_{\overline{H}}$$

- Perfect model prediction: $R_f = \text{Inf.}$
- 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)

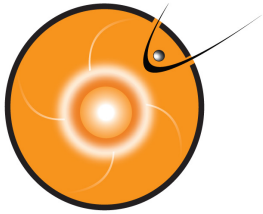




Metrics 4/4: ratio of maximum amplitudes

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

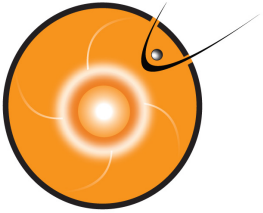
- Perfect model prediction: $R_{max} = 1$.
- Compute R_{max} for both $|\mathbf{B}_h| = \sqrt{B_x^2 + B_y^2}$ and $|\frac{d\mathbf{B}_h}{dt}|$



In addition, model ENSEMBLE

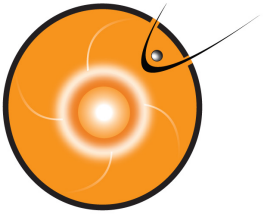
Model submissions

Model description	Identifier
CMIT 2.0, LFM # of cells: 40000, min. res. ... (RES. ?)	1_CMIT
LFM, # of cells 160000, min. res. $0.3 R_e$	1_LFM
OpenGGCM v3.1 coupled to CTIM, # of cells: 3 million, min. res. $0.3 R_e$	1_OPENGGCM
OpenGGCM v3.1 coupled to CTIM, # of cells: 6.5 million, min. res. $0.25 R_e$	2_OPENGGCM
SWMF v7.73, BATS-R-US # of cells: 2 million, min. res. $0.25 R_e$	1_SWMF
SWMF v7.73, BATS-R-US # of cells: 700000, min. res. $0.25 R_e$	2_SWMF
SWMF v8.01 BATS-R-US coupled to RCM, # of cells: 2 million, min. res. $0.25 R_e$	3_SWMF
SWMF v8.01, BATS-R-US # of cells: 3 million, min. res. $0.125 R_e$	4_SWMF
SWMF v8.01, BATS-R-US coupled to RCM, # of cells: 3 million, min. res. $0.125 R_e$	5_SWMF
SWMF v20090403, BATS-R-US coupled to RCM, # of cells 900000, min. res. $0.25 R_e$	6_SWMF
<i>Weimer</i> , 2005 [@], 4-minute output interpolated into 1 minute	1_WEIMER
New empirical model by D. Weimer for ground magnetic field perturbations, 4-minute output interpolated into 1 minute	2_WEIMER
<i>Weigel et al.</i> , 2003 [@], 30-minute output	1_WEIGEL

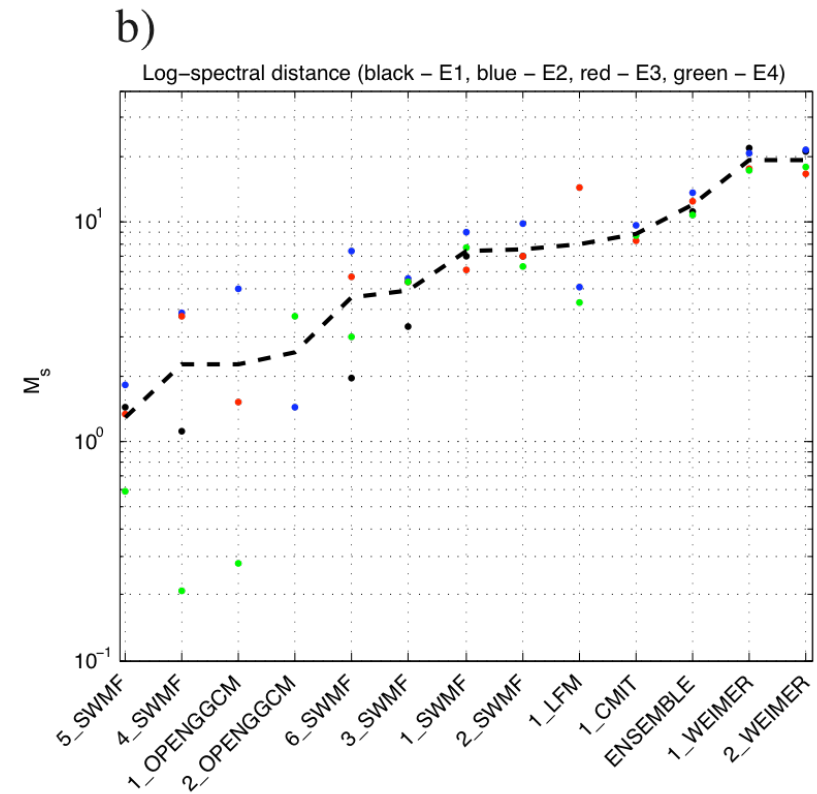
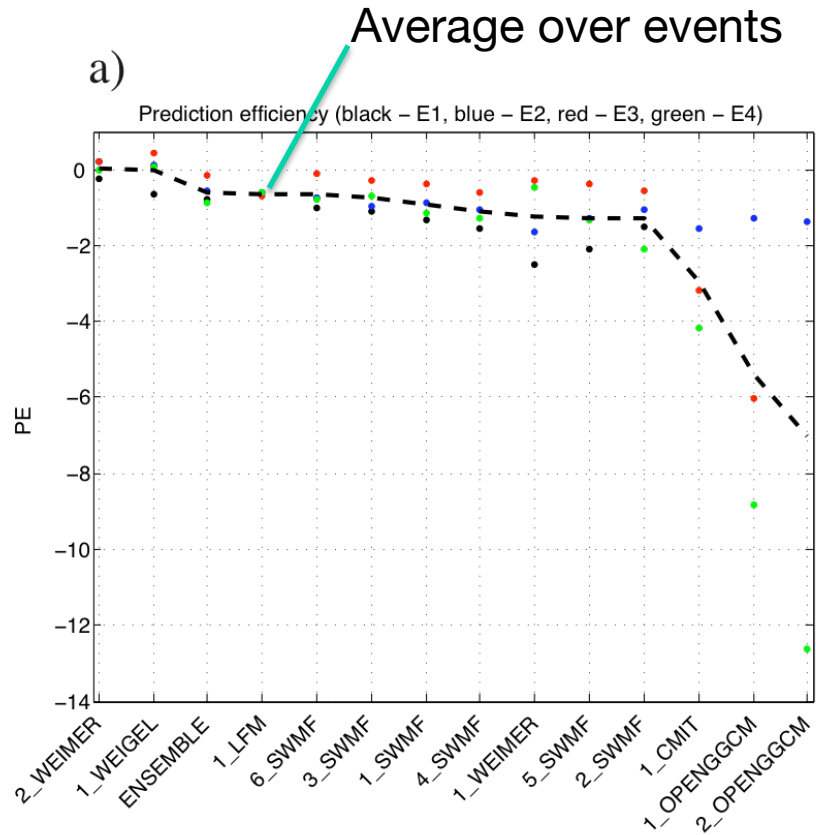


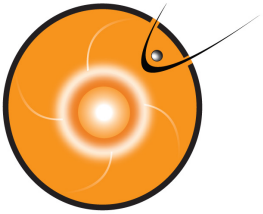
Metrics-based results

- 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.
- 1_WEIGEL not included in $|d\mathbf{B}_v/dt|$ - based or spectral analyses.

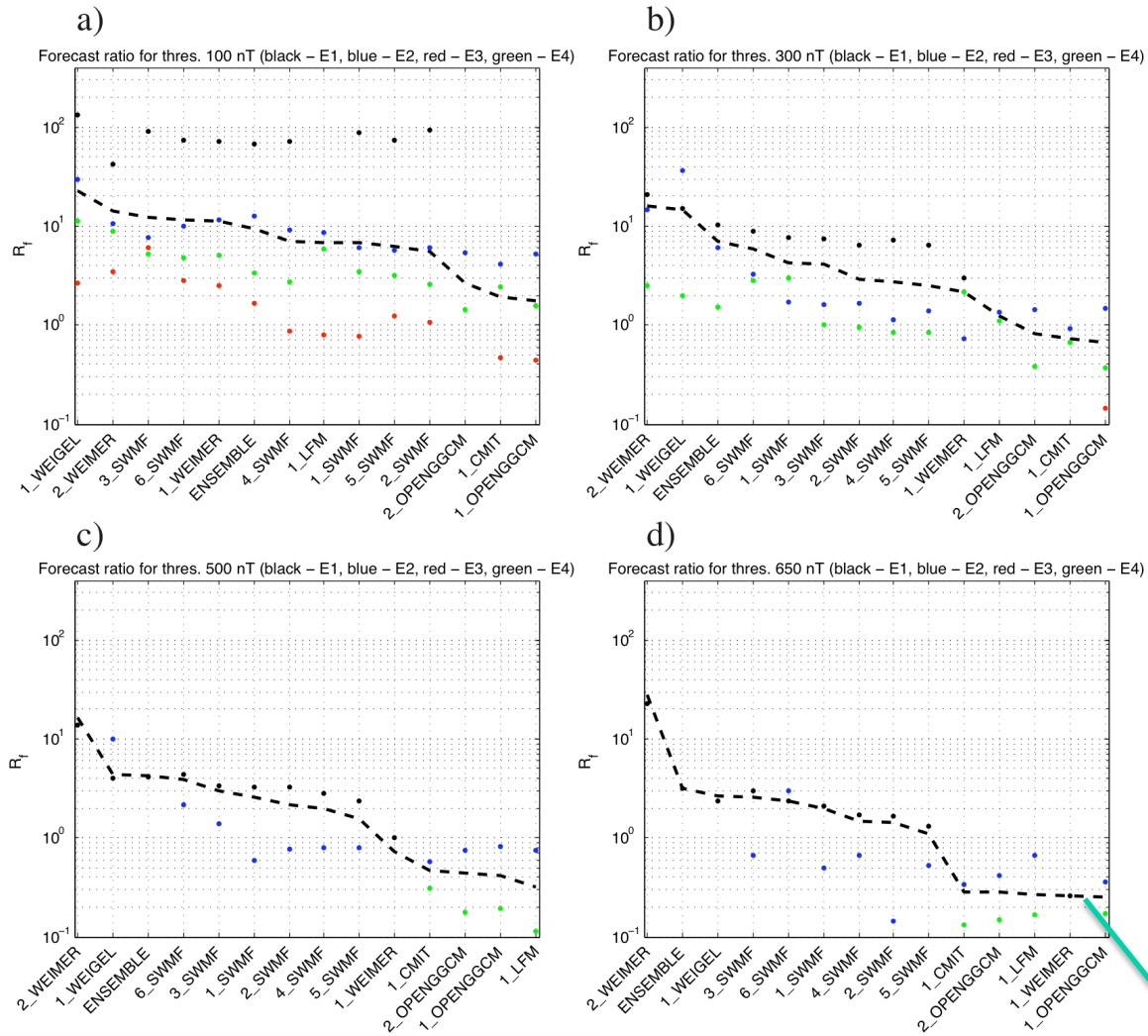


Metrics-based results: PE and M_s

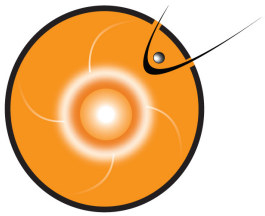




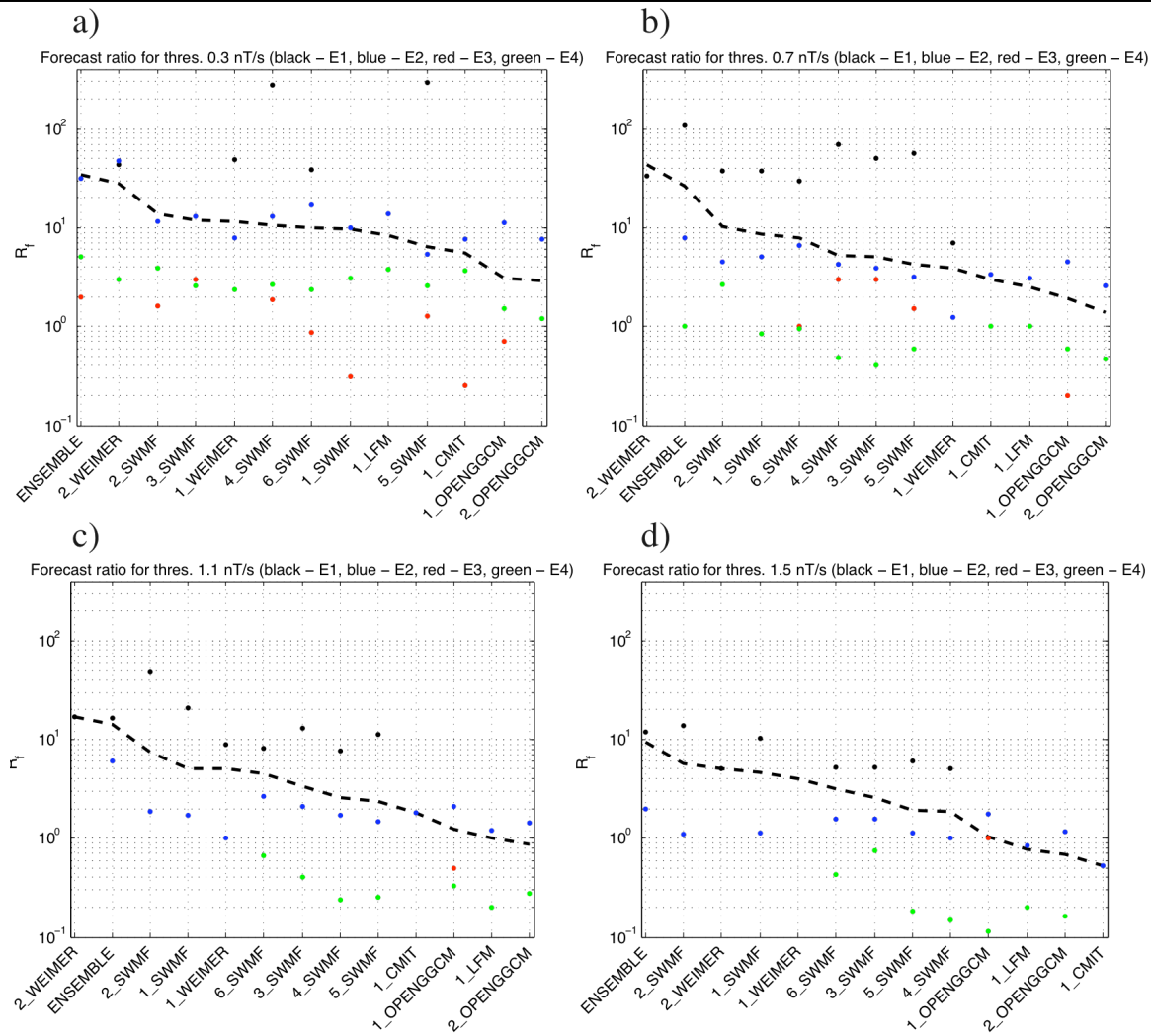
Metrics-based results: R_f for $|B_h|$

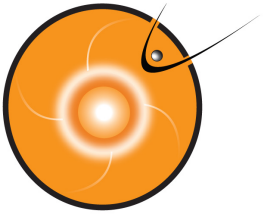


Integration over events

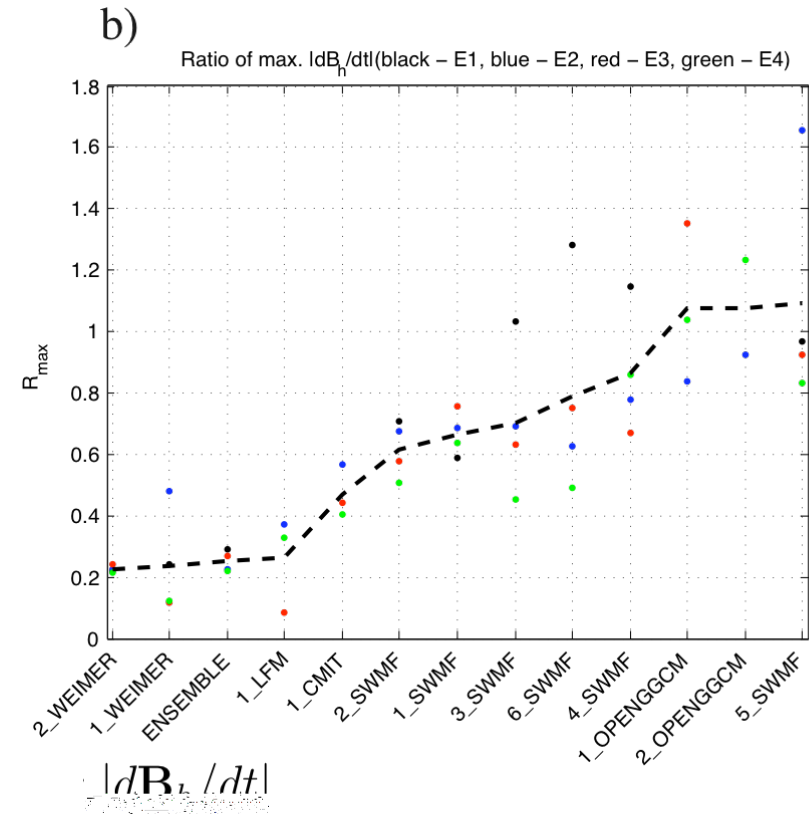
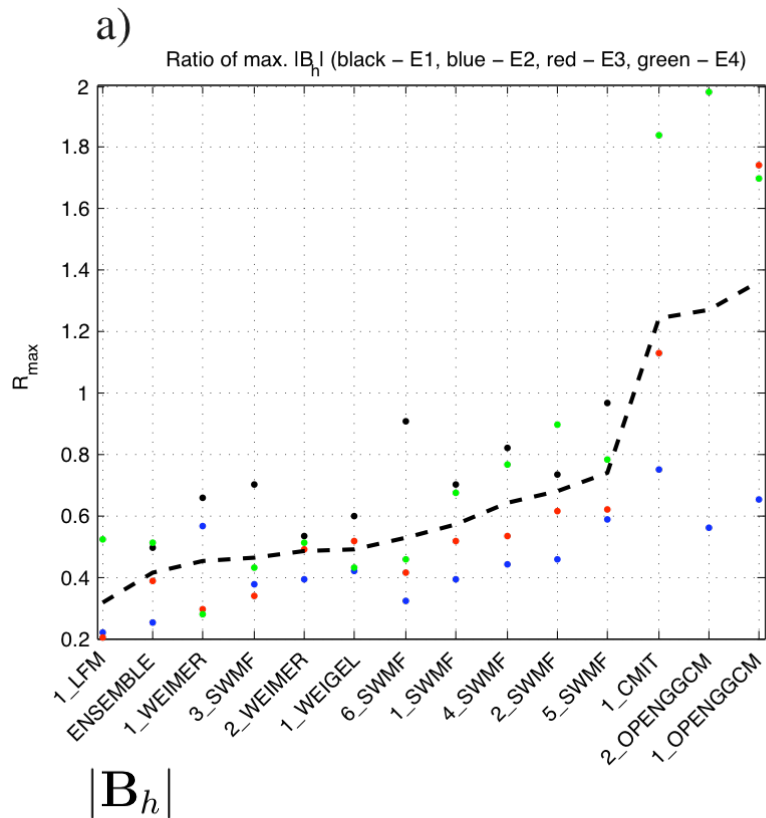


Metrics-based results: R_f for $|dB_z/dt|$

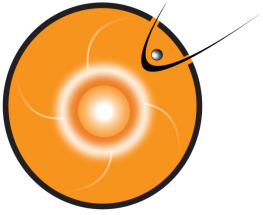




Metrics-based results: R_{max}



Note: no ranking here



Discussion

- Ranking depends on the used metric.
- Results vary between storm events.
- Paper under preparation: Pulkkinen et al., Geospace Environment Modeling 2008-2009 Challenge: ground magnetic field perturbations, to be submitted to Space Weather, early 2010. (include all metrics?)