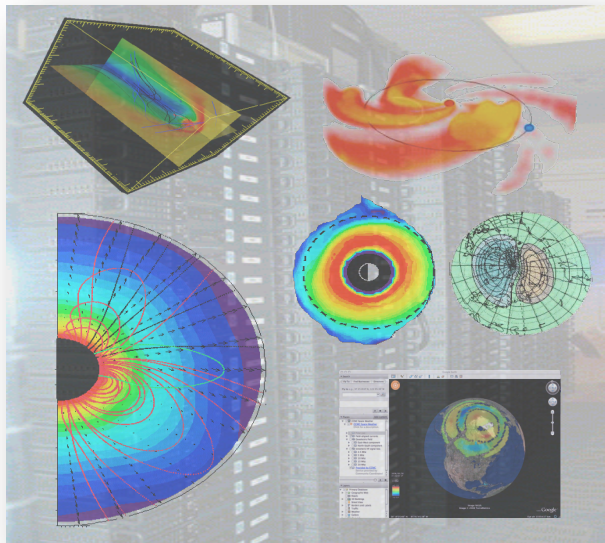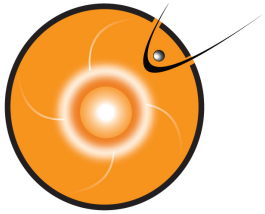# GEM 2008-2009 Challenge: ground magnetic field perturbations

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
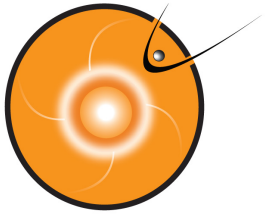
Contents

- Challenge setup.

- Metrics[*].

- Model submissions.
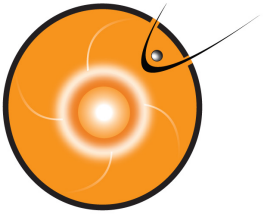
- Metrics-based results.

- 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.

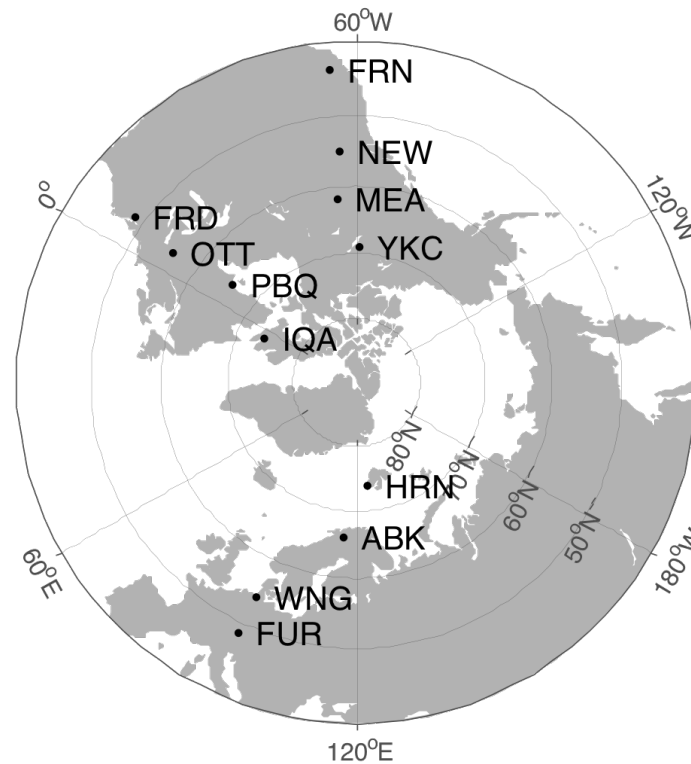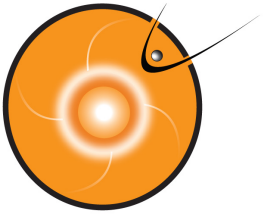| Event #	Date and time	min(Dst)	max(Kp)
1	October 29, 2003 06:00 UT - October 30, 06:00 UT	-353 nT	9
2	December 14, 2006 12:00 UT - December 16, 00:00 UT	-139 nT	8
3	August 31, 2001 00:00 UT - September 1, 00:00 UT	-40 nT	4
4	August 31, 2005 10:00 UT - September 1, 12:00 UT	-131 nT	7

Challenge setup: stations

Figure 2. The locations and the station codes of the geomagnetic observatories used in the study. Geomagnetic dipole coordinates are used.
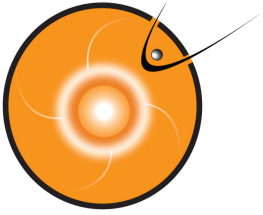
Metrics 1/4: prediction efficiency

$$PE = 1 - \frac{<(x_{obs} - x_{mod})^2>_i}{\sigma^2_{obs}}$$
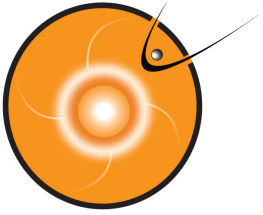
- Perfect model prediction: *PE* = 1.

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: $M_s = 0$.
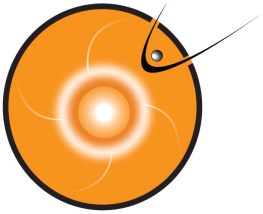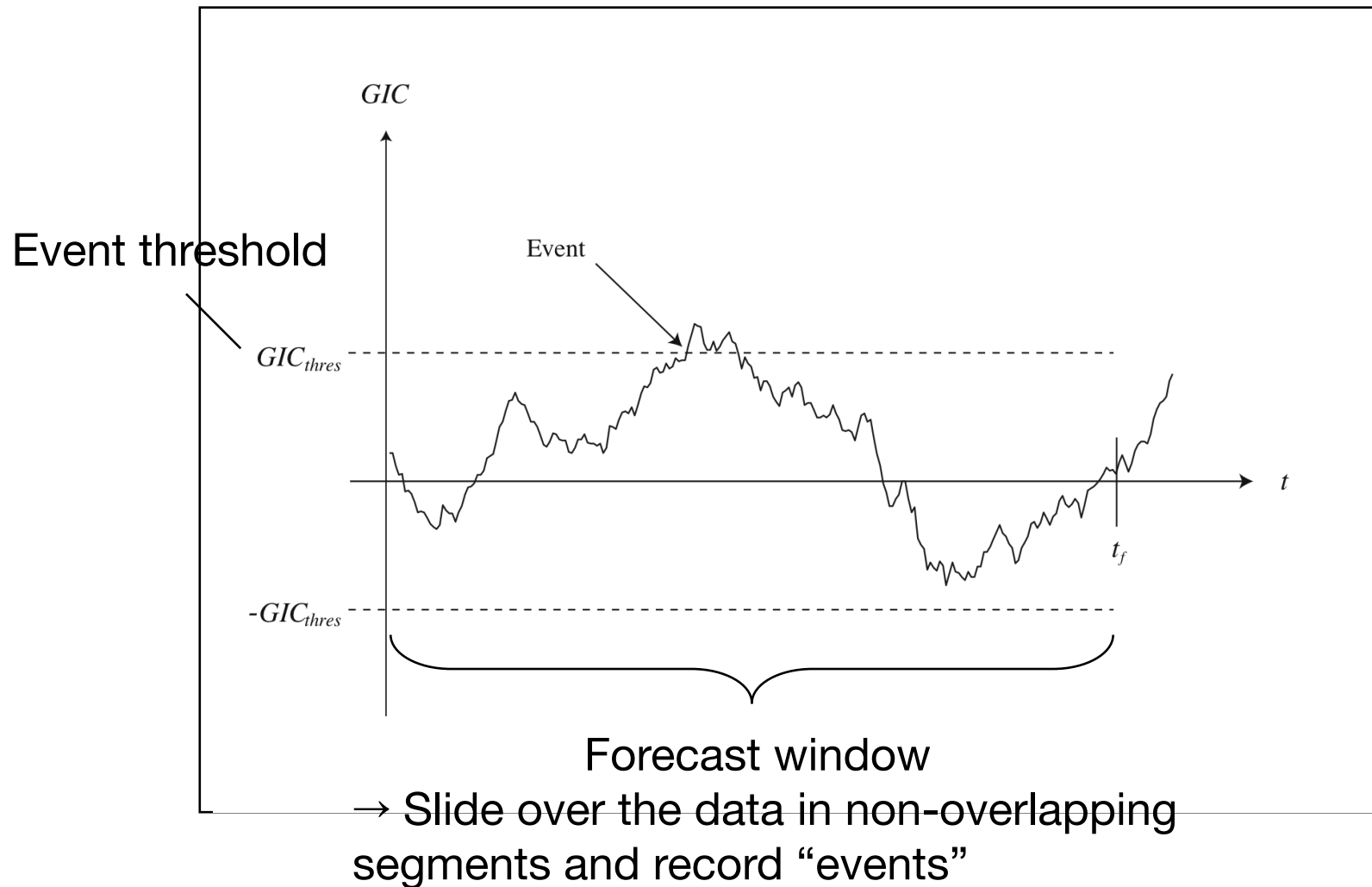
$$U_f = BN_H - CN_{\overline{H}}$$

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

- 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 $|d\mathbf{B}_\perp/dt|$

Metrics 3/4: utility metric (forecast ratio)

Event threshold

GIC

Event

GIC_{thres}

$-GIC_{thres}$

t

t_f

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

GEM, December 13, 2009, San Francisco, CA.
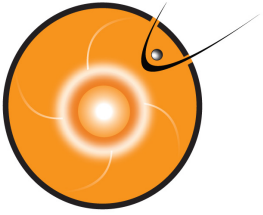
Metrics 4/4: ratio of maximum amplitudes

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

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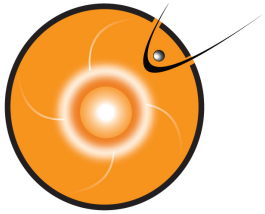- Compute R_{max} for both $|\mathbf{B}_h| = \sqrt{B_x^2 + B_y^2}$ and $|d\mathbf{B}_h/dt|$

Model submissions

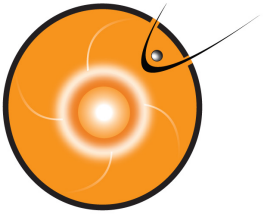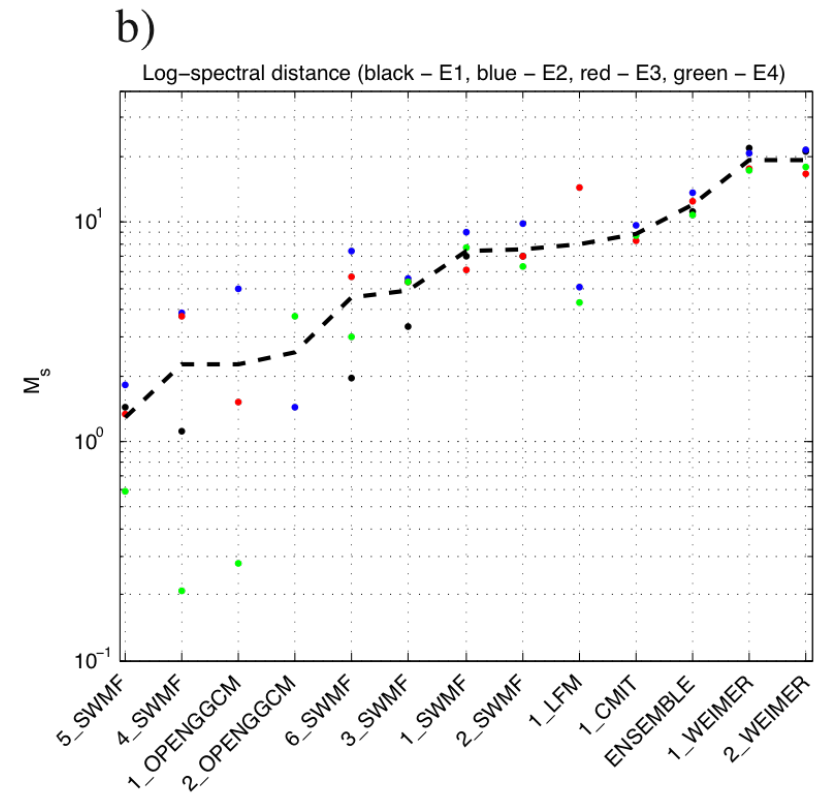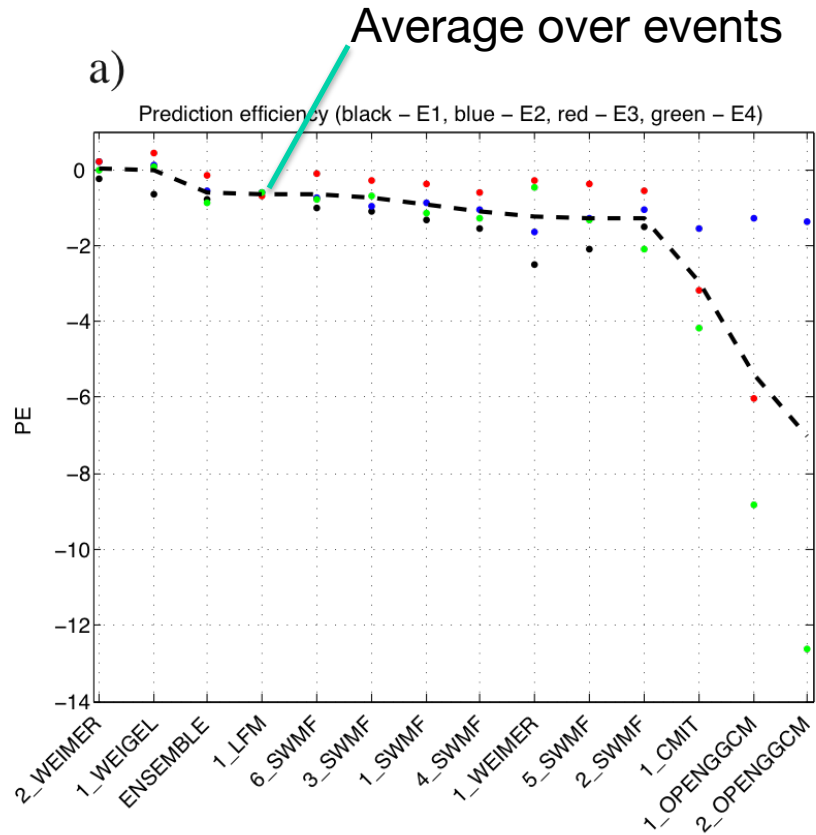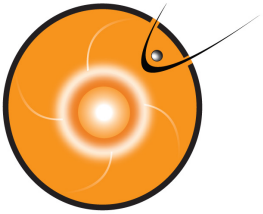| Model description	Identifier
CMIT 2.0, LFM # of cells: 40000, min. res. ... (RES. ?)	1_CMIT
LFM, # of cells 160000, min. res. 0.3 R_e	1_LFM
OpenGGCM v3.1 coupled to CTIM, # of cells: 3 million, min. res. 0.3 R_e	1_OPENGGCM
OpenGGCM v3.1 coupled to CTIM, # of cells: 6.5 million, min. res. 0.25 R_e	2_OPENGGCM
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
Weimer, 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
Weigel et al., 2003 [@], 30-minute output	1_WEIGEL
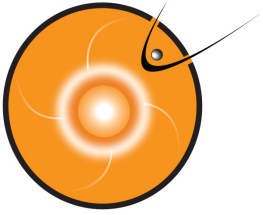
Metrics-based results

- 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 $|d\mathbf{B}_{\perp}/dt|$ - based or spectral analyses.
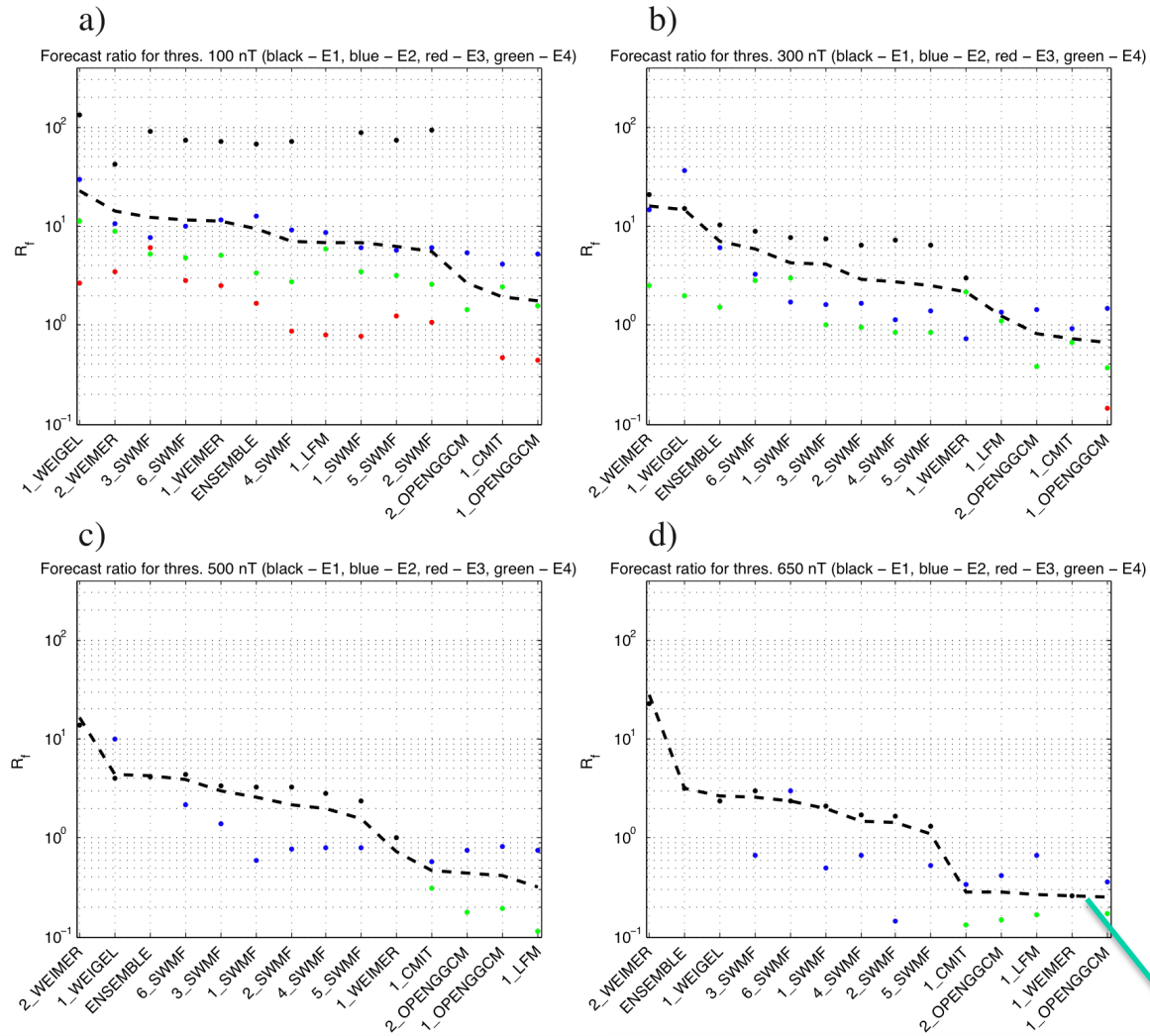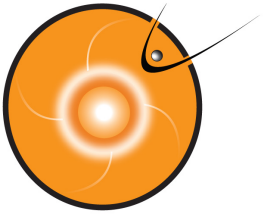
Metrics-based results: *PE* and M_s

Average over events

a) Prediction efficiency (black – E1, blue – E2, red – E3, green – E4)

b) Log−spectral distance (black – E1, blue – E2, red – E3, green – E4)

a) Forecast ratio for thres. 100 nT (black – E1, blue – E2, red – E3, green – E4)

b) Forecast ratio for thres. 300 nT (black – E1, blue – E2, red – E3, green – E4)

c) Forecast ratio for thres. 500 nT (black – E1, blue – E2, red – E3, green – E4)

d) Forecast ratio for thres. 650 nT (black – E1, blue – E2, red – E3, green – E4)

Integration over events

Metrics-based results: R_f for $|d\mathbf{B}_h/dt|$

a)

Forecast ratio for thres. 0.3 nT/s (black – E1, blue – E2, red – E3, green – E4)

b)

Forecast ratio for thres. 0.7 nT/s (black – E1, blue – E2, red – E3, green – E4)

c)

Forecast ratio for thres. 1.1 nT/s (black – E1, blue – E2, red – E3, green – E4)

d)

Forecast ratio for thres. 1.5 nT/s (black – E1, blue – E2, red – E3, green – E4)

GEM, December 13, 2009, San Francisco, CA.

Metrics-based results: R_{max}

a) Ratio of max. $|B_h|$ (black – E1, blue – E2, red – E3, green – E4)

b) Ratio of max. $|dB_h/dt|$ (black – E1, blue – E2, red – E3, green – E4)

$|\mathbf{B}_h|$

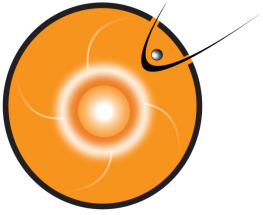$|d\mathbf{B}_h/dt|$
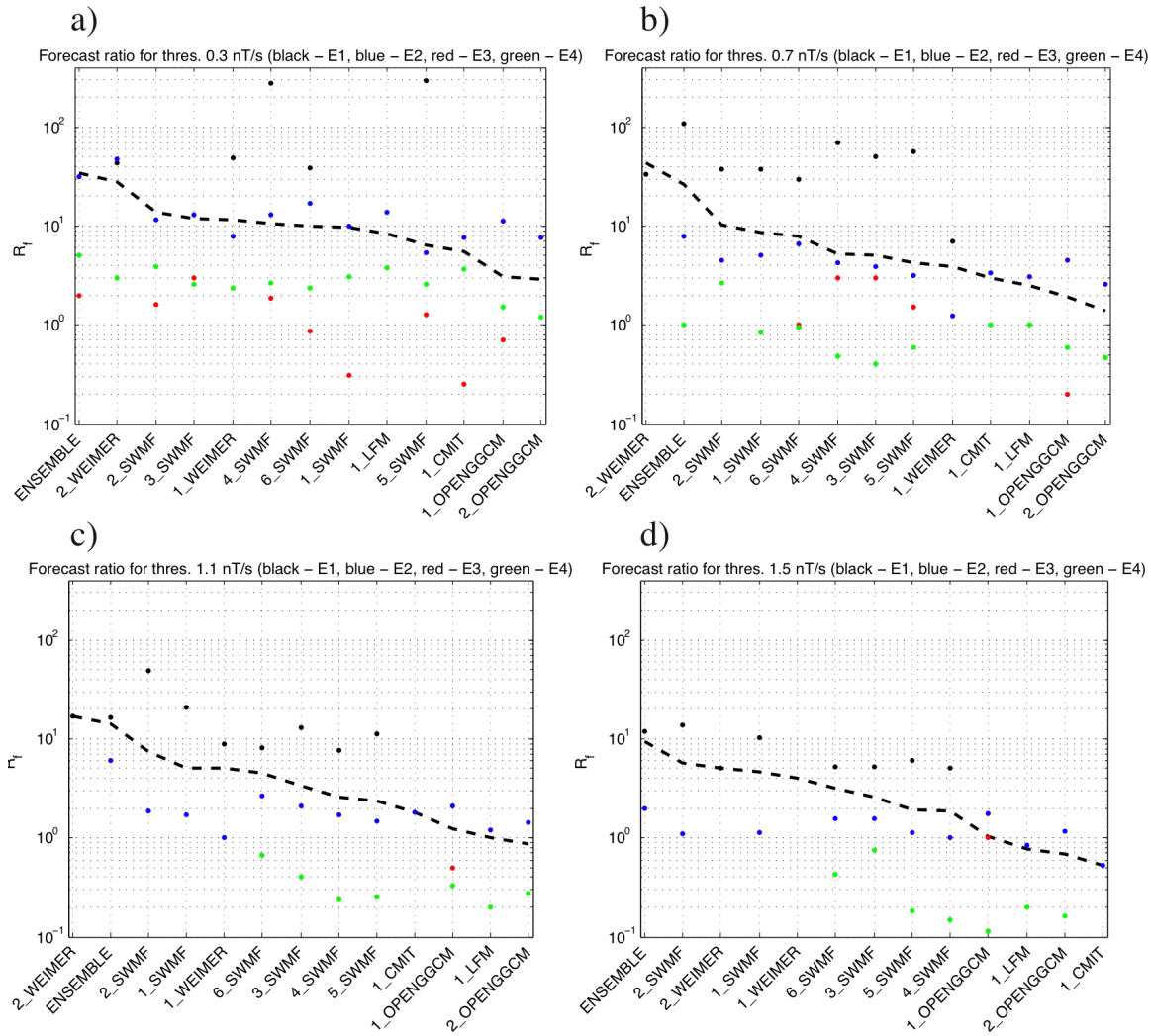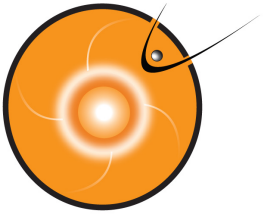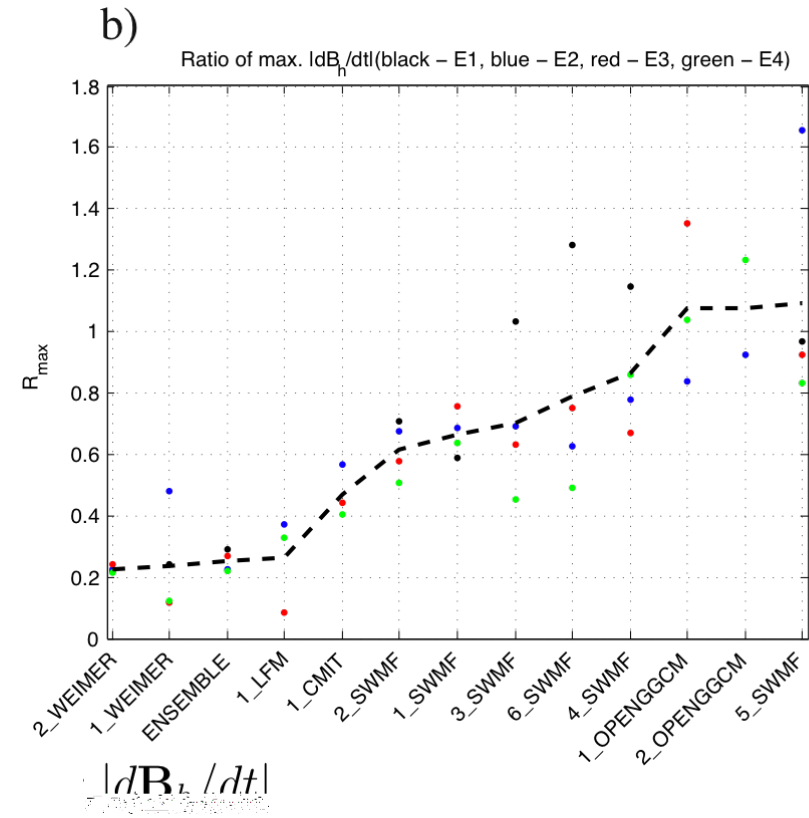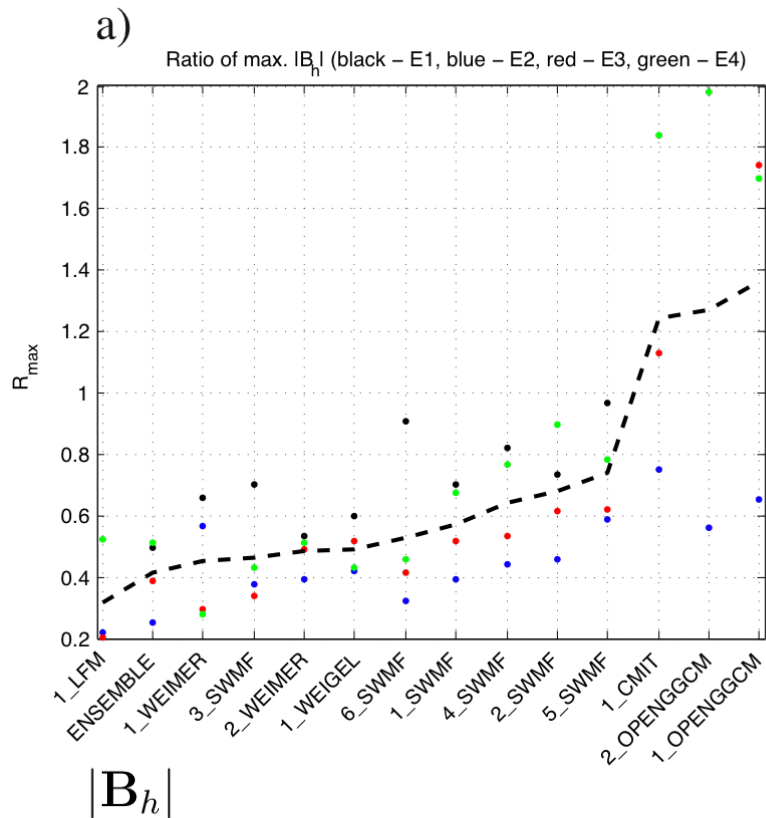
Note: no ranking here

Discussion

- Ranking depends on the used metric.
- Results vary between storm events.
- Pulkkinen et al., Geospace Environment Modeling 2008-2009 Challenge: ground magnetic field perturbations, to be submitted to Space Weather, 2010.