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

Stations in geomagnetic dipole coordinates
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:

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

Perfect model, \( PE=1 \)

• Log-spectral distance (GIC-related derivation)

\[ M_s(\tilde{x}_{obs}, \tilde{x}_{mod}) = \sqrt{\sum_{\omega} \left( \log \frac{\tilde{x}_{1|obs}}{\tilde{x}_{1|mod}} + \frac{\tilde{x}_{2|obs}}{\tilde{x}_{2|mod}} \right)^2} \]  

Perfect model, \( M_s=0 \)
<table>
<thead>
<tr>
<th>Model setting description</th>
<th>Identifier</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMIT 2.0, currents from TIEGCM</td>
<td>1.CMIT</td>
</tr>
<tr>
<td>LFM</td>
<td>1.LFM</td>
</tr>
<tr>
<td>Weimer (2005, JGR), 4-min. output interpolated to 1 min.</td>
<td>1.WEIMER</td>
</tr>
<tr>
<td>OpenGGCM v3.1, number of cells: 3 million</td>
<td>1.OPENGGGCM</td>
</tr>
<tr>
<td>OpenGGCM v3.1, number of cells: 6.5 million</td>
<td>2.OPENGGGCM</td>
</tr>
<tr>
<td>BATS-R-US v7.73, number of cells: 2 million</td>
<td>1.SWMF</td>
</tr>
<tr>
<td>BATS-R-US v7.73, number of cells: 700000</td>
<td>2.SWMF</td>
</tr>
<tr>
<td>BATS-R-US v8.01 coupled to RCM, number of cells: 2 million</td>
<td>3.SWMF</td>
</tr>
<tr>
<td>BATS-R-US v8.01, number of cells: 3 million</td>
<td>4.SWMF</td>
</tr>
<tr>
<td>BATS-R-US v8.01 coupled to RCM, number of cells: 3 million</td>
<td>5.SWMF</td>
</tr>
<tr>
<td>BATS-R-US v20090403 coupled to RCM, number of cells 900000</td>
<td>6.SWMF</td>
</tr>
</tbody>
</table>
Magnetic field time series via Metrics Tool

Summer GEM, June 21-26, 2009, Snowmass, CO.
# 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: BATSRSU 7.73, 2M cells, CCMC
- 2_SWMF: BATSRSU 7.73, 700k cells (real-time setup), CCMC
- 3_SWMF: BATSRSU 8.01 with RCM, 2M cells, CCMC
- 4_SWMF: BATSRSU 8.01, 3 M cells, CCMC
- 5_SWMF: BATSRSU 8.01 with RCM, 3M cells, CCMC
- 6_SWMF: SWMF V.20090403, BATSRSU+RCM2, 900k cells, RT on 64 pros., 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* will reset changes to the defaults specified by the previous run of this script.

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

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**Runs-on-Request:** Contact CCMC Staff
**Visualization:** Dr. Lutz Rastätter
Magnetic field time series via Metrics Tool

B_North from observatory file: abk_OBS_20061214.txt

Model runs:
- 6_SWMF
- 1_OPENGGCM
- 1_WEIMER

Plot: CCMC

hours from 2006/12/14 12:00
Magnetic field time series via Metrics Tool

![Graph showing magnetic field time series](image)

Model runs:
1. SWMF
2. SWMF
3. SWMF
4. SWMF
5. SWMF
6. SWMF
1. OPENGGCM
2. OPENGGCM
1. LFM
1. CMIT
1. WEIMER

Plot: CCMC
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

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

Mean over events

Model setting identifier

Summer GEM, June 21-26, 2009, Snowmass, CO.
Metrics results

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