Magnetopause challenge

Artificial solar wind conditions, Model runs were compared with Shue et al. (1998), Standoff on Sun-Earth line.

- **$B_z$ variation:** (-5 to -30 nT) $P_{dyn} = 1.33$ nT, near left side of valid range
- **Density variation:** ($V=600$, $N=5$ to 50): $P_{dyn}$ from 3.0 to 30 nPa.
Model runs compared to Shue et al.

SWMF (blue) and GUMICS (green) standoff larger than Shue, OpenGGCM (Version 3.1, yellow, red) below Shue. Shue model (black) valid only for $B_z$ larger than -20 nT.
Problems with modeling challenge

• Models not compared to observation data.
  – Statistical model (Shue 1998) used as comparison.
  – Solar wind inputs ($B_z < -20$) beyond validity range of Shue model.

• Models driven with unrealistic (very strong) driving conditions.

• Time period between changes of $B_z$ (2 hours) too short for models to reach steady state.
GEM, GEM-CEDAR challenges

• Use real events:
  • LANL plasma data, 4 spacecraft
  • GOES magnetic field (Bz<0 in dayside), 4 spacecraft
  • Events 1 and 2, 4 had multiple crossings

1. 2003/10/29 (doy 302) 06:00 UT – 2003/10/30 06:00 UT
2. 2006/12/14 (doy 348) 12:00 UT – 2006/12/16 00:00 UT
3. 2001/08/31 (doy 243) 00:00 UT – 2001/09/01 00:00 UT
4. 2005/08/31 (doy 243) 10:00 UT – 2005/09/01 12:00 UT
5. 2005/05/15 (doy 135) 00:00 UT – 2005/05/16 00:00 UT
6. 2005/07/09 (doy 190) 00:00 UT – 2005/07/12 00:00 UT
Real event comparisons

AGU storm (Dec. 14-16, 2006), Event 2 of 2008 GEM challenge

Use time series plotting and analysis developed for challenge.

MP crosses orbit only in strong events, i.e. the Halloween and AGU storms.

Other GEM events provide few or no comparisons.

geosynchronous orbit

Observed MP crossings of LANL satellites
New approach to visualization of magnetopause crossings

Time line plotter and skill score calculator at CCMC

New for plotter:

• Stackplot option

• Nightside indicator

Magnetopause crossing challenge:

• Binary information (inside or outside) recast into time series files (models and observations): 1-minuite cadence

• Analysis done for each LANL or GOES satellite separately
Halloween storm (2003/10/29-30)

Use experience from other studies (e.g., dBH/dt):
- Event-based contingency table to calculate POD, POFD, ...
  Heidke skill (here using 20-minute windows).

GOES-10

Variable: IO Observatory file: GOES10_in_or_out.txt

<table>
<thead>
<tr>
<th>Model Setting</th>
<th>T</th>
<th>OY</th>
<th>ON</th>
<th>H</th>
<th>F</th>
<th>M</th>
<th>N</th>
<th>A</th>
<th>B</th>
<th>POD</th>
<th>POFD</th>
<th>FAR</th>
<th>CSI</th>
<th>TSS</th>
<th>MTSS</th>
<th>HSS</th>
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N_Windows (T) number of windows considered to create events (T = Plot Interval Length / Event Window Length)

Events (OY) number of windows where at least one observation falls below threshold

NoEvents (ON) number of windows where observation does NOT fall below threshold

Hits (H) number of windows where model and observation fall below threshold at least once

FalseHits (F) number of windows where model does fall below threshold but observation does not

Misses (M) number of windows where model does not but at least one observation falls below threshold

NoForecast (N) number of windows where model and observation do NOT fall below threshold

Accuracy (A) \(\frac{(H+N)}{(H+N+H+F)}\) Range: \([0,1]\), perfect score: 1, no skill: 0

Bias (B) \(\frac{(H+F)}{(H+M)}\) Range: \([0, +\infty]\), perfect score: 1

POD probability of Detection \(\frac{H}{(H+M)}\) Range: \([0,1]\), perfect score: 1, no skill: 0

POFD probability of False Detection \(\frac{F}{(F+N)}\) Range: \([0,1]\), perfect score: 0

FAR False Alarm Ratio \(\frac{F}{(H+F)}\) Range: \([0,1]\), perfect score: 0

CSI (TS) Critical Success Index (Threat Score) \(\frac{H}{(H+M+N)}\) Range: \([0,1]\), perfect score: 1, no skill: 0

TSS True Skill Score \(\frac{POD-POFD}{H/(H+M)-F/(N+F)}\) Range: \([0,1]\), perfect score: 1, no skill: 0

MTSS Modified True Skill Score \(\frac{(H-M)}{(H-M)+2F/N}\) Range: \([0,1]\), perfect score: 1, no skill: 0

HSS Heidke Skill Score \(\frac{2(H-N-M+F)}{(H+M)(M+N)+(H+F)(F+N)}\) Range: \([-\infty, 1]\), perfect score: 1, no skill: 0
Extend Challenge

1. Perform all calculations with the runs and events we used for dB/dt study, Dst, K index validations and related studies.

Define New Events:

   - Multiple satellites cross magnetopause at different local times (not only near Sun-Earth line),
   - All crossings to occur within the interval of stationary solar wind
   - Average solar wind conditions within validity of Shue et al. and other statistical models.

   Yari Collado-Vega’s talk (coming up)

3. Consider dynamic solar wind events (e.g., Zhang et al, 2009):
   - THEMIS (CLUSTER, other) satellites arranged at different distances may capture motion of magnetopause.
   - Satellites may not cross the magnetopause but their presence could impose constraints on the magnetopause position.
05 March 2007

05 March 2007, 18:30 – 19:50 UT

Solar wind:
N ~ 10 - 11
Vx~380 ..-390
Vy~ -5 .. +5
Vz~ -40 ... -50
Bx~ -2 .. 0
By~ 0
Bz~ -5

ACE-L2

CL4, DS-P positions

M-Sphere
M-Sheath
28 Jan. 2012, 19:00 – 21:40 UT

THA and CL4 MP crossing

Solar wind:
N~0.5
Vx~420
Vy~N/A
Vz~N/A
Bx~5
By~5
Bz~1

Magnetosheath between 21:10 and 21:30 UT.
Southward IMF.
5 Dec. 2008, 21:10 – 22:00 UT

Simultaneous dawn flank crossing of Themis B and Themis C, 7 RE apart

Solar wind:
- N~6.5
- Vx~415
- Vy~10
- Vz~40
- Bx~6
- By~6
- Bz~5
New Event Summary

- 3 events with different satellite alignment
- Nearly stationary solar wind during MP crossings
- Short simulation intervals (<2 hours)

Next phase:
- Dynamic events:
  - FTE or reconnection events, MP at same location
  - changes of the MP position
14 Jun. 2007, 03:00 to 05:00 UT

5 THEMIS, 4 CLUSTER, Double Star TS1

FTEs observed (Dunlop et al. Ann. Geophys. 2011)

Solar wind:
N ~ 5 - 7
Vx ~ -395…-390
Vy ~ -20
Vz ~ 0 ..30
Bx ~ -9 … -7
By ~ 5
Bz ~ 3 … -5

ACE-L2

BL (CL, DS)
BN
|B|
BL (TH)
BN
|B|
CA (CL1, THB, OMNI)
Reconnection observed (Phan et al. GRL, 2006)

- GEOTAIL, WIND, IMP-8 (in sheath only)
- Solar wind?
  IMF: southward $B_z$, and duskward $B_y$.
- Reconnection was observed
  If reconnection were resolved by models, how would MP position change in models?