Poster 8, Session 1

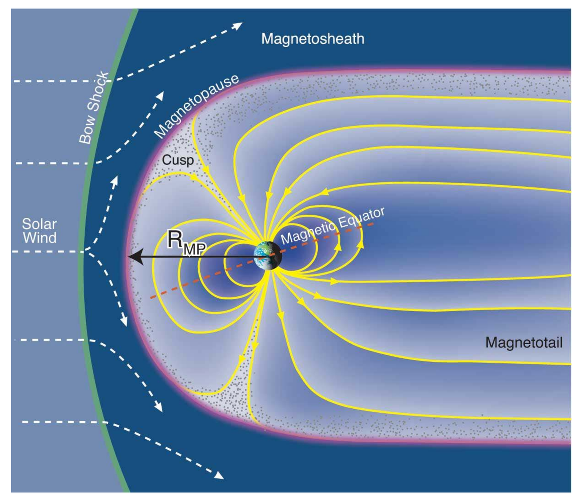
Real-Time Monitoring of the Dayside Geosynchronous Magnetopause Location

R.J. Redmon (NOAA/NGDC), T.M. Loto’aniu, M. Berguson, S.M. Codrescu, J. Shue, H.J. Singer, W.F. Rowland, W.F. Denig

Abstract

The magnetopause is a boundary separating the geospace magnetic environment from interplanetary space. Its location provides an important demarcation for satellite operators, the interpretation of plasma observations and a measure of the expected level of space weather activity. In support of the needs of space weather forecasters, we have transitioned a magnetopause product into operations using magnetic measurements from the current GOES series (13, 14, 15) and the Shue et al. (1998) model of the magnetopause. This paper presents the algorithm basis, the architecture resulting from the research to operations process, a statistical validation of product performance, future GOES-R era improvements, and a summary of the February 2014 event, which resulted in a geosynchronous magnetopause (GMC) crossing and degradation of a high-latitude aircraft navigation system.

Background



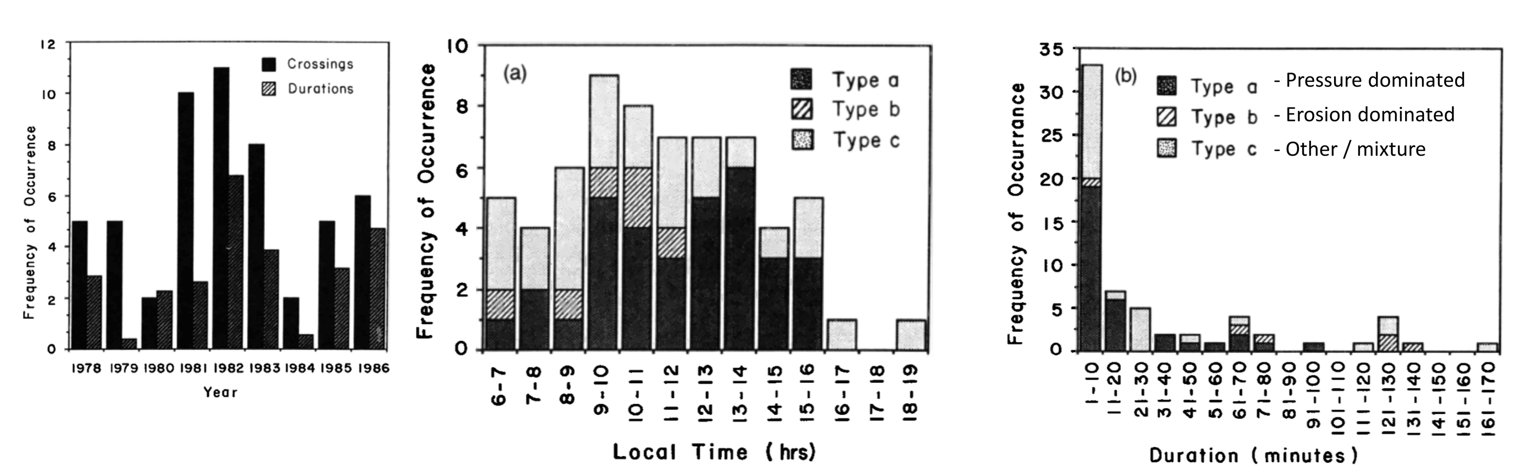
During periods of extreme space weather the combination of increased solar wind dynamic pressure and/or large negative IMF Bz act to compress and erode the terrestrial magnetosphere, occasionally inbounds of geostationary orbit (aka GMC). The bowshock demarks the interface where the solar wind first impacts geospace while the magnetopause bounds the region magnetically dominated by the earth generated field. The region sandwiched between these boundaries is the magnetosheath.

Why track the magnetopause boundary?

- Gauges the level of space weather activity and ultimately the strength of the SW energy coupling to geospace
- Substantial compression / erosion of the magnetosphere is often the first indicator of the arrival of a solar storm at Earth.
  - Results in elevated threat levels in space and on the ground, potentially leading to catastrophic system impacts.
- Geosynchronous satellites may find themselves in the magnetosheath or outside the magnetosphere.
  - The MP location provides an important context for the interpretation of other plasma measurements.
- Currently there are no magnetopause operational products within NOAA.

Historical Perspective

The first recorded GMC was observed by the ATS-1 spacecraft (GOES predecessor) in 1967 at 14-15LT (Opp, 1968; Cummings and Coleman, 1968). Rufenach et al., 1989 studied 64 GMCs recorded by GOES-2,5,6 from 1978-1986 to develop occurrence, duration, local time, and minimum Hp characterizations (adapted below):

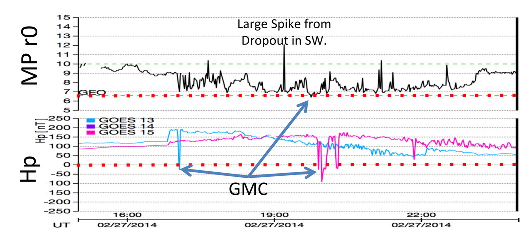


Algorithm Theoretical Basis

Why magnetic and particle observations, and model prediction?

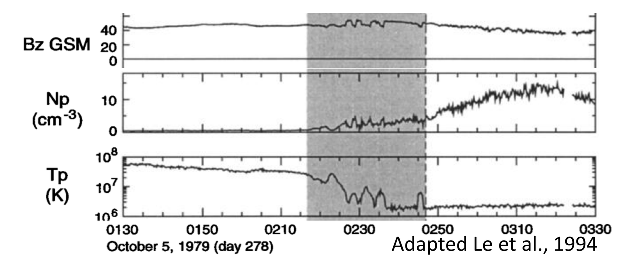
Magnetopause crossings into the magnetosheath generally result in strong cross-correlations between geo magnetic field and electron and ion temperature and density moments with the upstream solar wind (e.g. Suvorova et al., 2005). GMCs where IMF Bz is northward can be difficult to detect in the geo magnetic field alone (e.g. Le et al., 1994). The use of a magnetopause model extends the detection to periods where no dayside geo observations are available. Thus, for Real-Time monitoring in the GOES-R era, magnetic field measurements from MAG, particle moments from SEISS and the modeled boundary (Shue et al., 1998) will be used (Loto’aniu et al. 2011).

Ex 1: GOES Hp and Shue Model (agree):



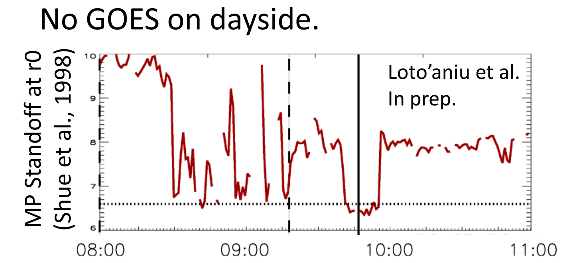
Feb-27, 2014. See far right panel for elaboration.

Ex 2: GMC in ions, not in Bz on ISEE-2.



Adapted Le et al., 1994

Ex 3: Shue r0 during Galaxy 15 anomaly. No GOES on dayside.



Testing Magnetopause Models

- Three models tested
  - SM – Shue et al., 1998
  - CM – Chao et al., 2001
  - PRM – Petrinec and Russell 1996
- Study Periods
  - 1999 - 2006
  - Yang et al., 1999 – 2000
- Model range of validity
- Local Times: dayside (6-18 and 8-16)
- Event Defined as GOES Hp < 0 nT.
- Shue et al., 1998 performed best when range of validity is considered.
  - For 0.5 nPa < Dp < 60 nPa, $|B_z|$< 20 nT

$$r_0 = \{10.22 + 1.29\tanh[0.184(B_z + 8.14)]\}(D_p)^{\frac{-1}{6.6}}$$

$$r = r_0\left(\frac{2}{1+\cos\theta}\right)^{\alpha} \qquad \alpha = (0.58 - 0.007B_z)[1 + 0.024\ln(D_p)]$$

[1]Predictions for MP as defined by the vector from Earth through GOES to MP as *r*

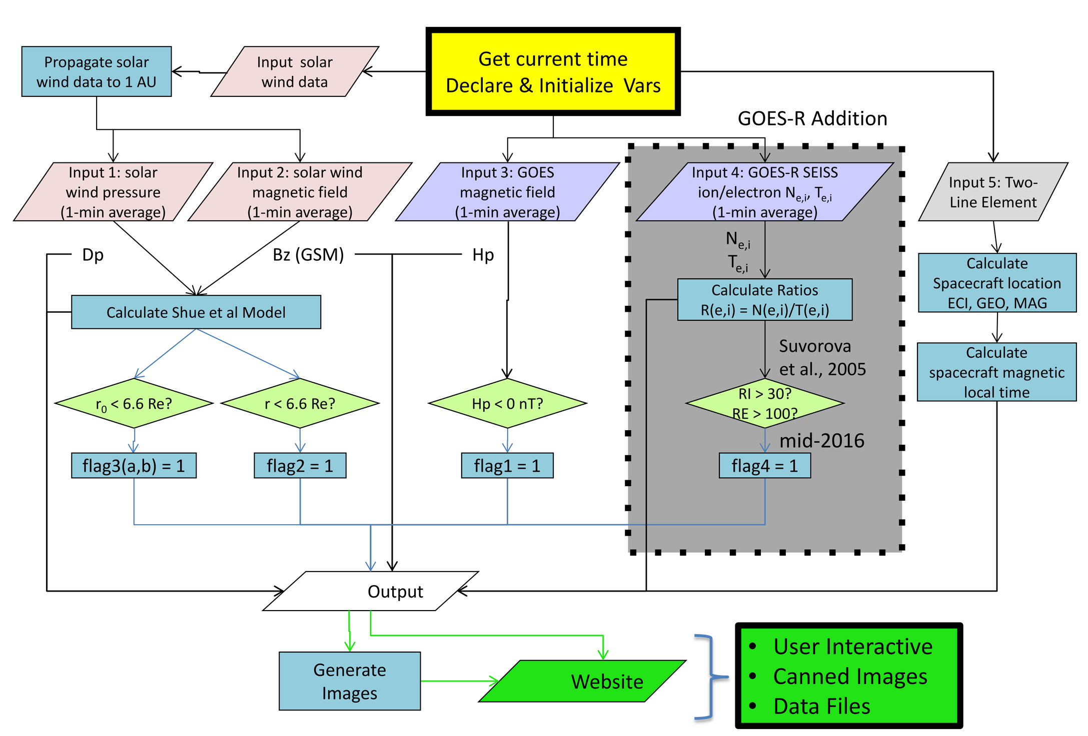
Study	Minutes	Year	No. SM	No. CM	No. PRM	PoD SM	PoD CM	PoD PRM
This study (SM)	1999	1999-2006	1130	-	-	56.5	-	-
This study (CM)	70	1999-2006	-	0	-	-	0	-
This study (PRM)	22	1999-2006	-	-	0	-	-	0
Yang et al. (2002)	1220	1999-2000	898	1027	1145	74	84	94
This study	563	1999-2000	321	322	396	57	57.2	70.3
This study	3856	1999-2006	1992	2463	2991	51.7	63.9	77.6
Predictions for magnetopause subsolar standoff distance r_0								
This study (SM)	1455	1999-2006	985	-	-	67.7	-	-
This study (CM)	49	1999-2006	-	0	-	-	0	-
This study(PRM)	21	1999-2006	-	-	0	-	-	0
This study	2451	1999-2006	1795	1865	2146	72.8	75.8	87.3

Legend:
– within valid ranges for each model, between 08-16 MLT
– same time range as Yang et al., includes points outside each model’s valid range, 08-16 MLT
– includes points outside each model’s valid range, 06-18 MLT
SM - Shue et al., 1998; CM - Chao et al., 1991; PRM - Petrinec and Russell 1996
Event: GOES Hp < 0 nT; Probability of Detection PoD = HT/(HT+MT), HT: Hit Time, MT: Miss Time
[1]Berguson et al., 2010; Loto’aniu et al., 2011.

Research To Operations

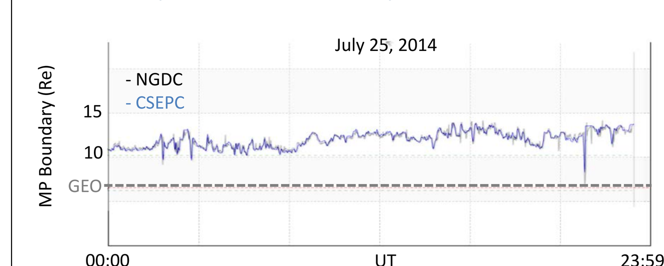
Research to Operations Considerations

- SW Propagation to Bowshock
  - Simple halfway-in-between method
- Product Validation
  - Compares very well to other implementations
- Robust Uptime
  - Automatic TLE cache update and Nagios monitoring system



Initial Comparison to other Real-Time Products

- ISTP PIXIE
  http://pixie.spasci.com/DynMod/
  - Operating since 1999; uses Shue et al, 1998
- NASA Community Coordinated Modeling Center
  http://ccmc.gsfc.nasa.gov/cgi-bin/display/RT_tools_AFWA.cgi?page=mpause
  - Uses Space Weather Modeling framework
  - Includes GOES MAG overlays
- Chinese Space Environment Prediction Center
  http://eng.sepc.ac.cn/MBS.php
  - Compares well for full day 2014-07-25



- Space Monitoring Data Center
  http://smdc.sinp.msu.ru/index.py?nav=rss&switchdiv=realtime
  - Skobeltsyn Institute of Nuclear Physics
  - Similarly compares well for 2014-07-25 full day

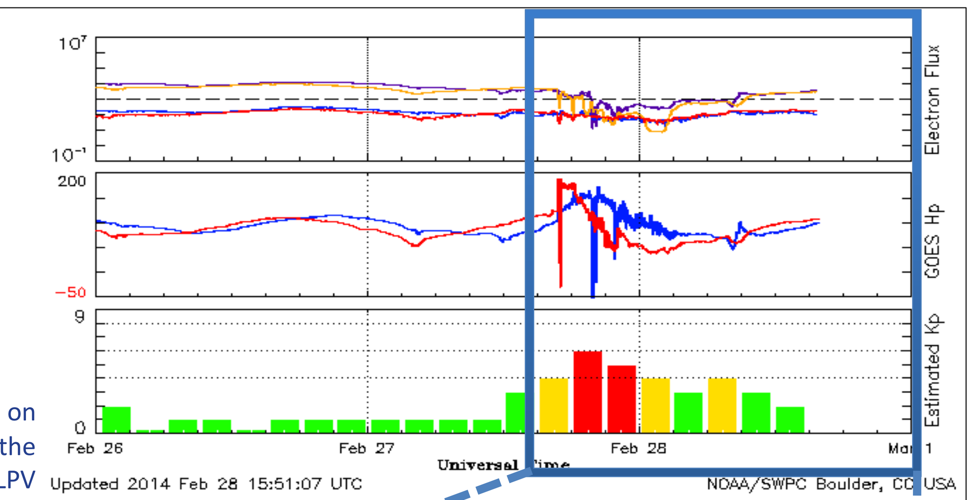
February 2014 Event (see Loto’aniu SM31A-4188 for comprehensive evaluation)

Summary of Space Weather

2014-02-25 X4.9 flare and CME from AR1967/AR1990

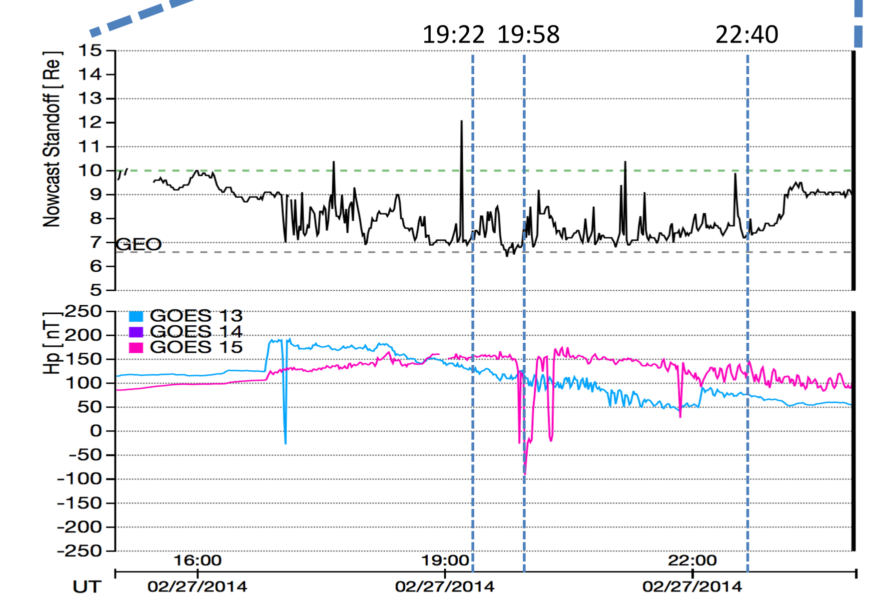
2014-02-27

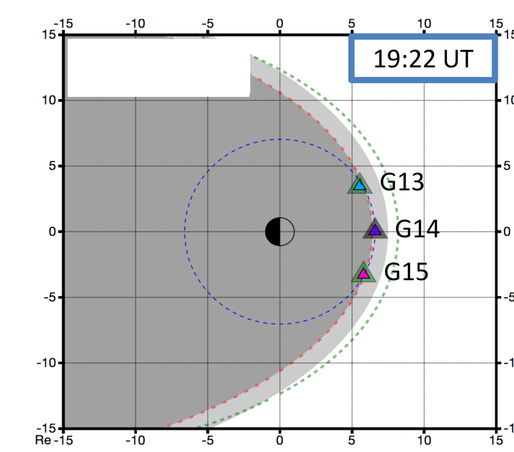
- 16:45 UT CME glancing impact → G2 storm
  - Kp reaches 7
- 17:04 UT (11.9 MLT) G13 GMC (weak)
- 19:54-20:03 UT (10.6 MLT) G15 GMC
  - Hp < 0 peaks at -123 nT
- 20:16-20:18 UT (11.0 MLT) G15 GMC
- 21:20 UT – FAA to SWPC - “An Ionospheric Storm began on 2/27/14. The Satellite Operations Specialists were alerted at the WAAS O&M by a Significant Event 757 at 2120 Zulu. So far, LPV and LPV200 service has not been available in Eastern Alaska and Northeastern CONUS. At times, North Central CONUS and all of Alaska have lost LPV and LPV200 Service.”

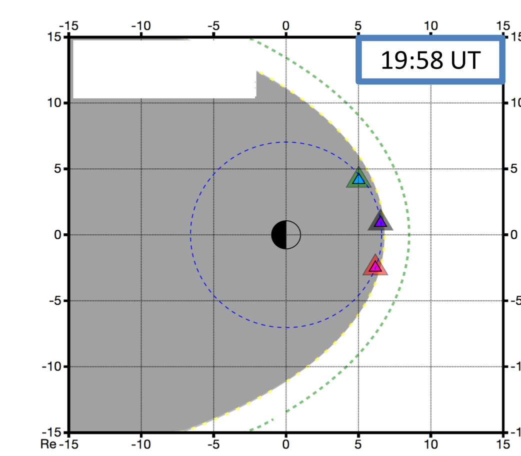


Three snapshots in time show GOES location and MP:

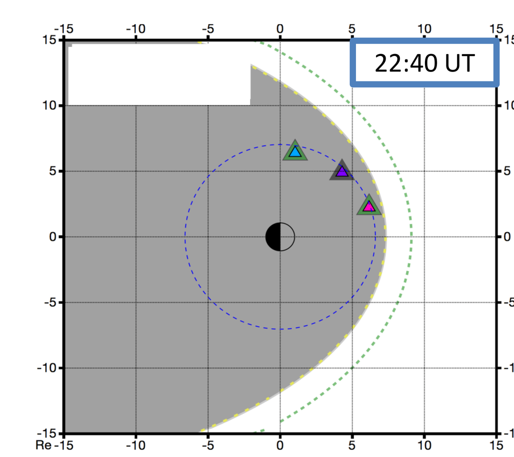
- 19:22 UT – Future GMC Forecasted (red ---)
- 19:58 UT – Nowcast of GMC (grey —)
  - Forecasting recovery (green - - -)
- 22:40 UT – Forecasting MP decompression (green - - -)







Legend 2D Graphics:
— Nowcast
---- Most Future
- - Next Greatest Impact



http://www.ngdc.noaa.gov/stp/mag_pause/

Rob.Redmon@noaa.gov

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