Solar Shield project - lessons learned and advances made

Pulkkinen, A., M. Hesse, S. Habib, F. Policelli, B. Damsky, L. Van der Zel, D. Fugate, W. Jacobs, E. Creamer

Contents

- Solar Shield overview.
- Solar Shield forecasting system.
  - Level 1^+ approach. The first tailored first-principles-based 2-3 day lead-time forecasts.
  - Level 2^+ approach. The first first-principles-based 30-60 min lead-time GIC forecasts.
- Coupling of the system to the SUNBURST research support tool.
- List of additional activities.
- Team recommendations.

Solar Shield overview

- In Solar Shield, we developed an experimental system to forecast space weather effects on the North American power grid; three-year project funded by NASA's Applied Sciences Program.
- Focus on first-principles-based space weather modeling.
- NASA/GSFC/CCMC and Electric Power Research Institute (EPRI) the key players.
- Final report was delivered to NASA Applied Sciences Program on April 1, 2010.

System requirements (summary)

- Two-level GIC forecasts:
  - Level 1 providing 1-2 day lead-time.
  - Level 2 providing 30-60 min. lead-time.
- Coupling to EPRI's SUNBURST research support tool.

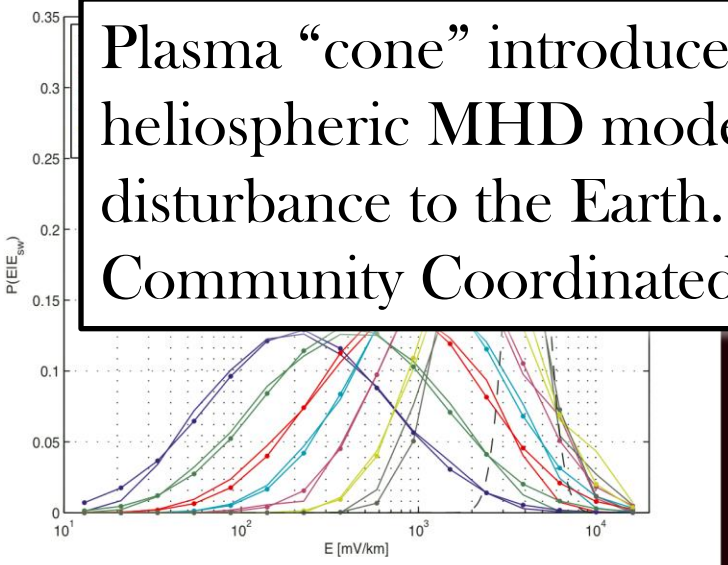
Used by the SUNBURST member utilities to monitor GIC.

Level 1 forecasts

Solar observations of eruptive events are used to compute “cone model” parameters. NASA/ESA SO

MHD output at the Earth used in a statistical model providing probabilistic estimate for GIC at individual nodes of the power grid. GIC forecast file is generated.

Plasma “cone” introduced to the inner boundary of a heliospheric MHD model. Model propagates the disturbance to the Earth. Computations carried out at the Community Coordinated Modeling Center.



EVEL1

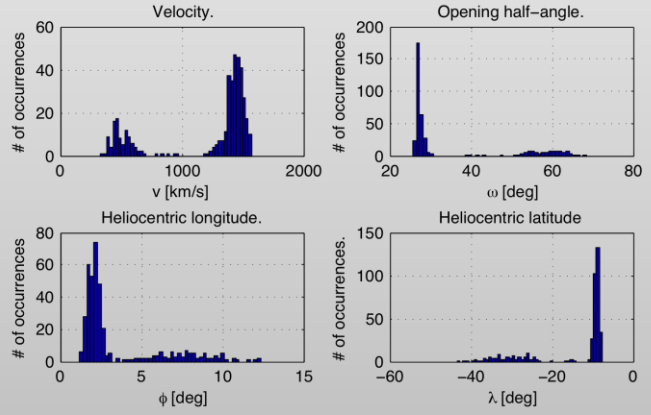
GIC2high ...

0 0 0 0 53.16 -99.29 45.39 -68.53
2006 12 14 14 6 76 15 153

Level 1 improvement: automatic determination of the cone model parameters

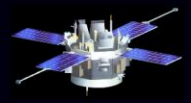
$$\min_{\{v,x_0,\omega,\theta\}} \left[\sum_i \left((y_i - \hat{y}_i)^2 + (z_i - \hat{z}_i)^2 \right) + \mu |\omega - \omega_0| \right]$$

Sequence of binary images generated from LASCO C3



Level 2 forecasts

Lagrange 1 observations used as boundary conditions for magnetospheric MHD. NASA's ACE



Magnetospheric MHD output used to drive geomagnetic induction and GIC code providing GIC at individual nodes of the power grid. GIC forecast file is generated.

% Level 2 GIC forecast produced by REALTIMEGIC_LEVEL2
%
% The format of the data is as follows:

Magnetospheric MHD model used to model the magnetospheric-ionospheric dynamics. Computations carried out at the Community Coordinated Modeling Center.

2008 03 19 11 06 31	-0.02	0.00	0.04	0.00
2008 03 19 11 08 31	0.00	0.00	0.01	0.00
2008 03 19 11 10 31	0.01	0.00	-0.03	0.00
2008 03 19 11 12 31	0.00	0.00	0.02	0.00
2008 03 19 11 14 31	0.02	0.00	0.04	0.00
2008 03 19 11 16 31	-0.00	0.00	-0.05	0.00
2008 03 19 11 18 31	-0.01	0.00	-0.07	0.00
2008 03 19 11 20 31	0.03	0.00	0.00	0.00

Level 2 improvement: usage of inner magnetospheric models

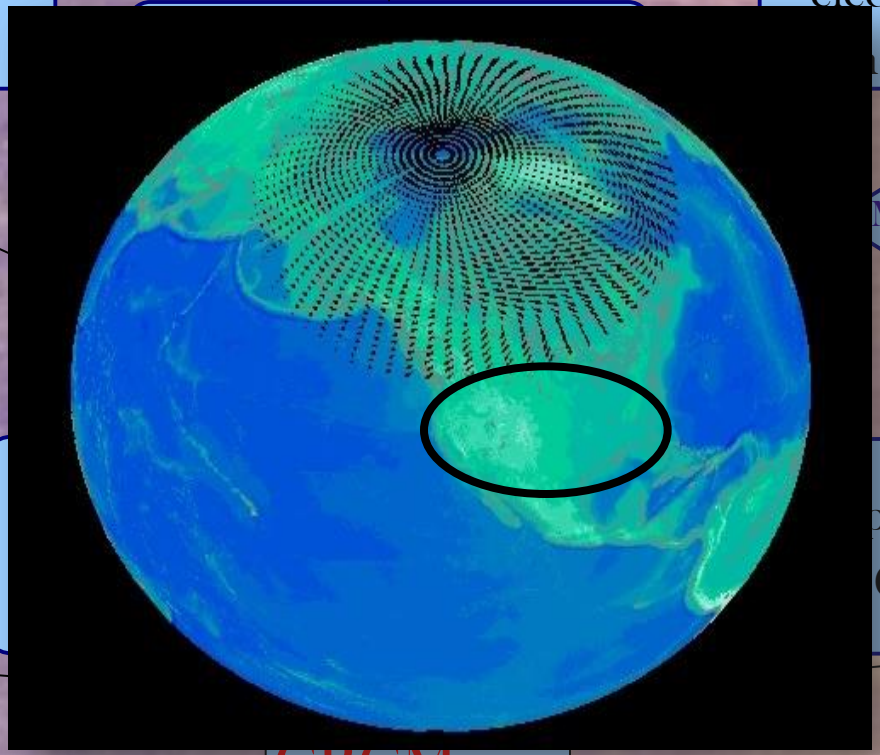
MHD BATSRUS run at the CCMC

MHD T, n

electric field potential
the ionosphere

KAMELEON
interpolation library

Linear
interpolation:
MHD ionosphere grid-
CRCM ionosphere
grid



Equatorial n,T
at the CRCM
polar boundary

potential in the ionosphere
CRCM polar boundary

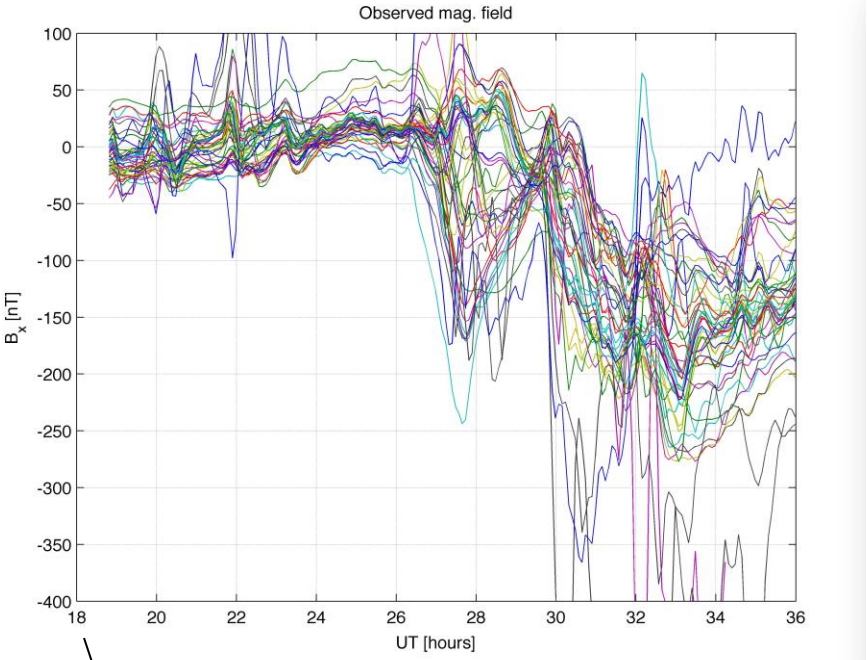
CRCM run

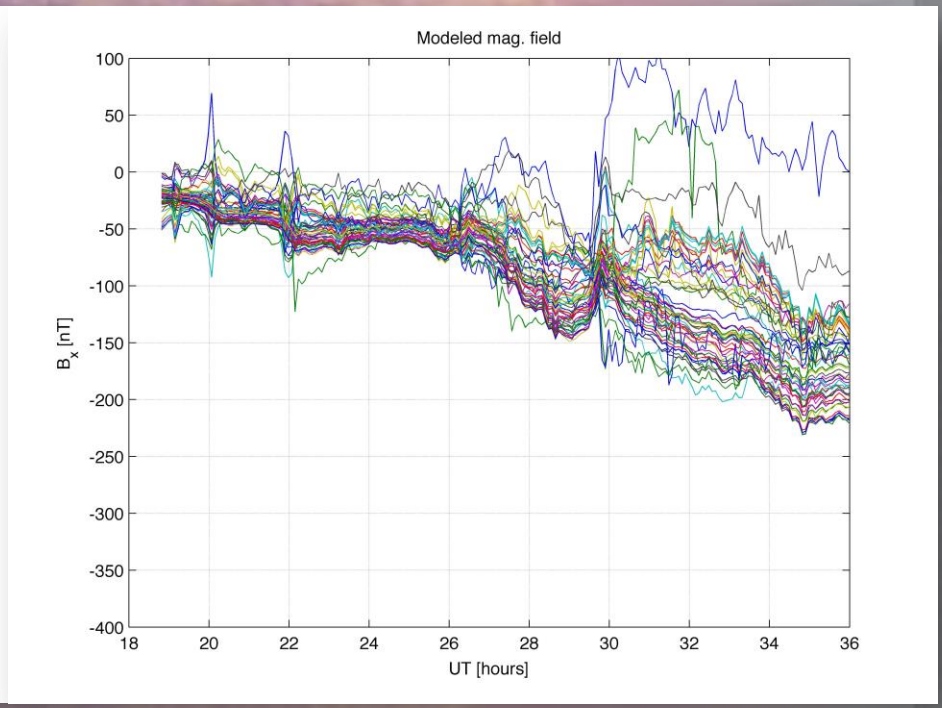
Region II Birkeland currents

3-D H+, e- fluxes

Self-consistent E-field

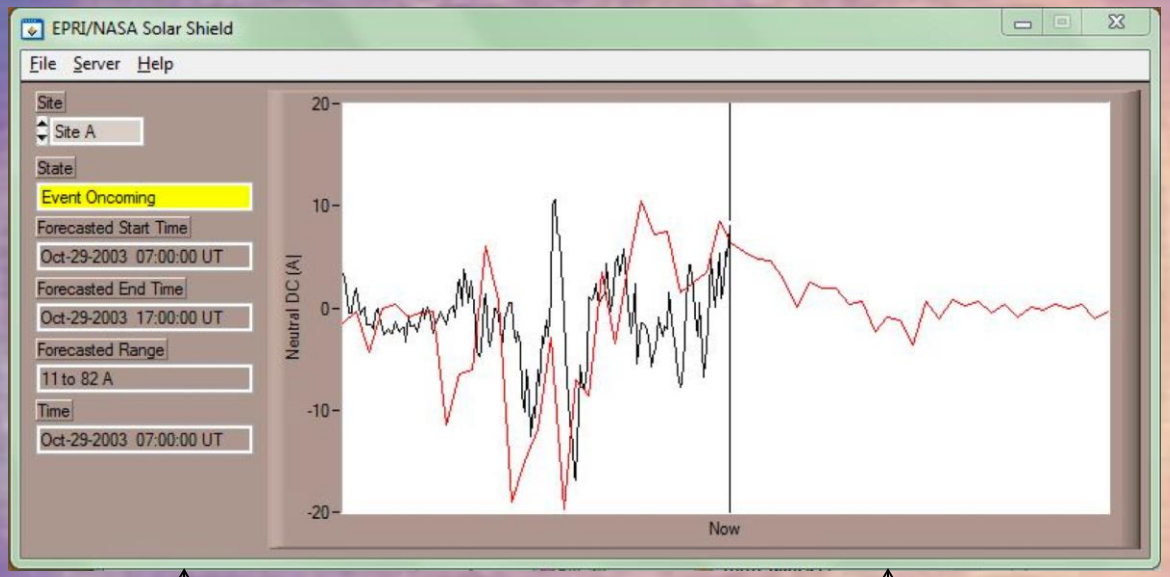
Level 2 improvement: usage of inner magnetospheric models





Hours from the beginning of August 11, 2000.

Coupling to the SUNBURST research support tool

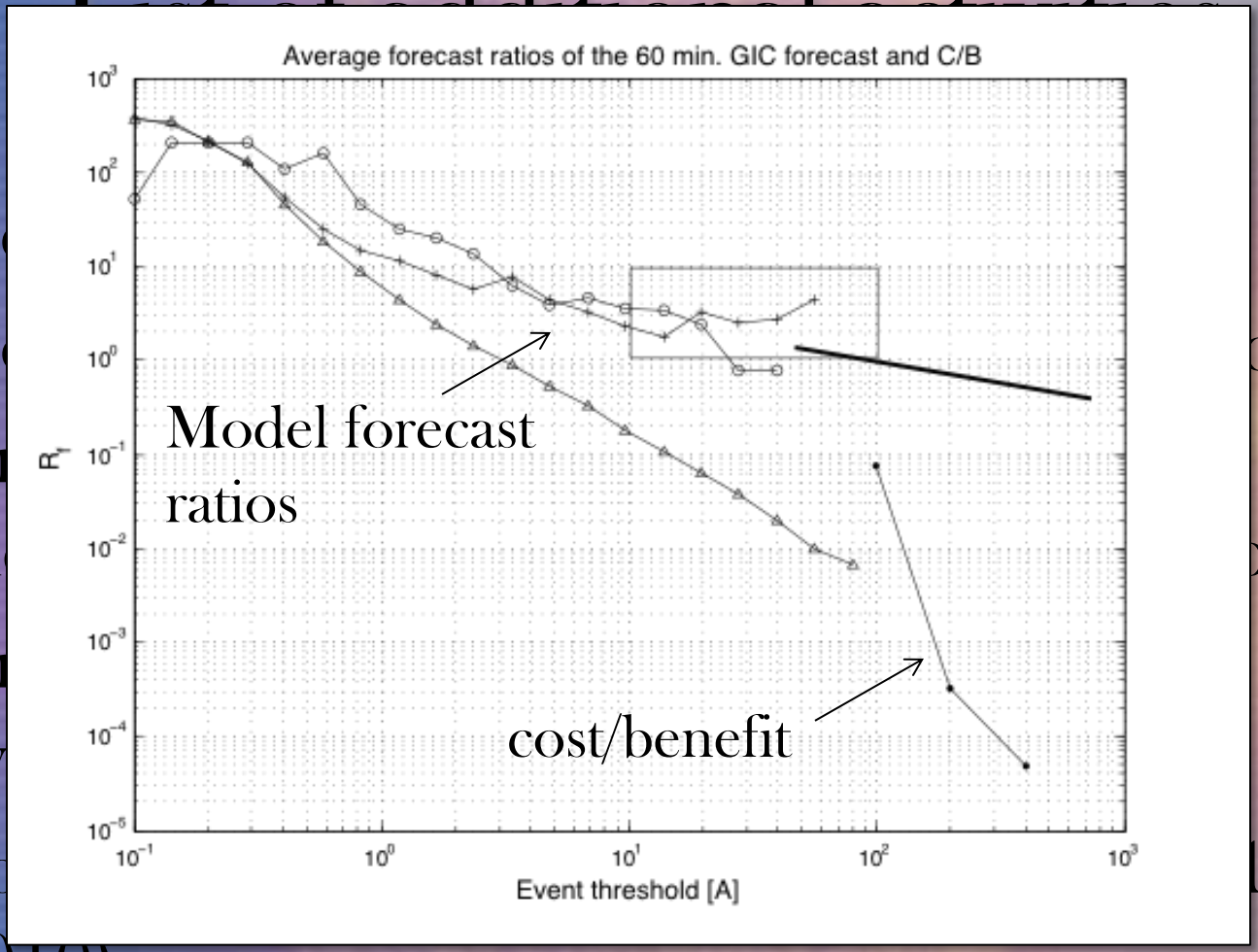



```
% Level 1 GIC forecast produced by REALTIMEGIC_LEVEL1
%
% The format of the data is as follows:
%  0  0  0  0  0  0 lat1    lon1     lat2     lon2     . . .
% yy mm dd hh mi GIC1low GIC1high GIC2low GIC2high . . .
%
  0 0 0 0    53.16  -99.29  45.39  -68.53
2006 12 14 14      6      76     15      153
```

```
% Level 2 GIC forecast produced by REALTIMEGIC_LEVEL2
%
% The format of the data is as follows:
%  0  0   0  0  0  0  0 lat1   lon1   lat2   lon2     . . .
%
  0 0 0 0 0 0 0    53.16  -99.29  45.39  -68.53
2008 03 19 11 02 31    -0.11    0.00    0.13    0.00
2008 03 19 11 04 31     0.02    0.00    0.03    0.00
2008 03 19 11 06 31    -0.02    0.00    0.04    0.00
2008 03 19 11 08 31     0.00    0.00    0.01    0.00
```

List of additional activities

- D
- D ol.
- A
  m rms.
- A
  ev
- Fo l,
  2010).



Team recommendations

- Level 2 part of the system is applicable only to high-latitude locations. Extension of the forecasting system to cover lower latitudes is needed for the application of the Level 2 approach to the US power grid.
- SUNBURST GIC dataset played a critical role in the establishment of the forecasting system. Installation of new GIC monitoring sites especially to the continental US would enable expansion and increased utility of the newly developed GIC forecasting system.
- Forecasting system (as many space weather applications) relies on aging ACE and SOHO spacecraft. Operational capacity providing robust streams of in situ solar wind and remote solar (coronagraph) data needs to be established.