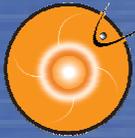


Geomagnetically Induced Currents

Antti Pulkkinen

¹The Catholic University of America
& ²NASA Goddard Space Flight
Center

¹Washington, DC, USA ²Greenbelt, MD,
USA



Why do we care?



- GIC causes saturation of power transformers:

- Transformer
- Electric

Severe Space Weather Events—Impacts on U.S. Infrastructure
<http://www.nap.edu/catalog/12507/>

NERC
NORTH AMERICAN ELECTRIC
RELIABILITY CORPORATION

2012 Special Reliability Assessment
Interim Report:

**Effects of Geomagnetic
Disturbances on the Bulk
Power System**

February 2012

SEVERE
UNDESIRABLE

High-Imp.
Event Risk
Bulk Power

A Jointly-Commis-
sioned by
North American El
and the U.S. Dept
2009 Workshop

RELIABILITY | ACCOUNTABILITY



Committee



NERC
NORTH AMERICAN ELECTRIC
RELIABILITY CORPORATION

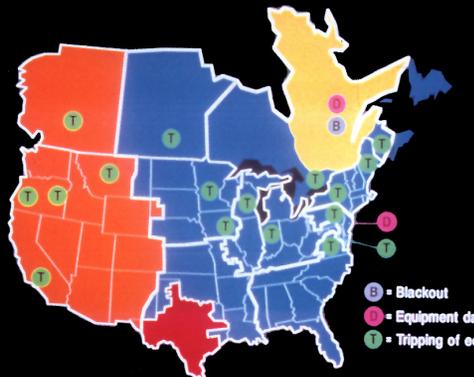
June 2010
www.nerc.com | www.doe.gov

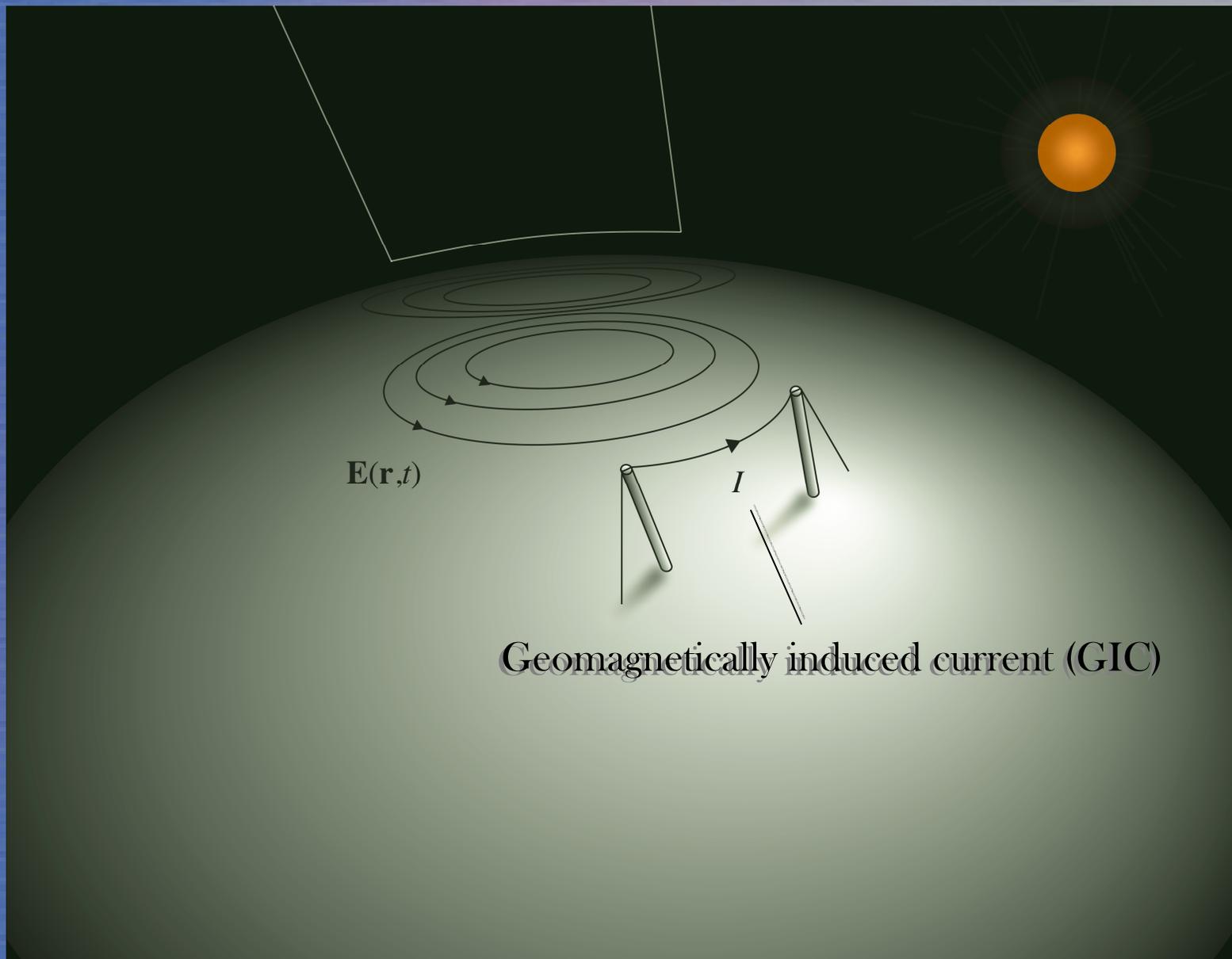
Washington, D.C.
www.nap.edu

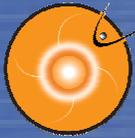
Copyright © National Academy of Sciences. All rights reserved.



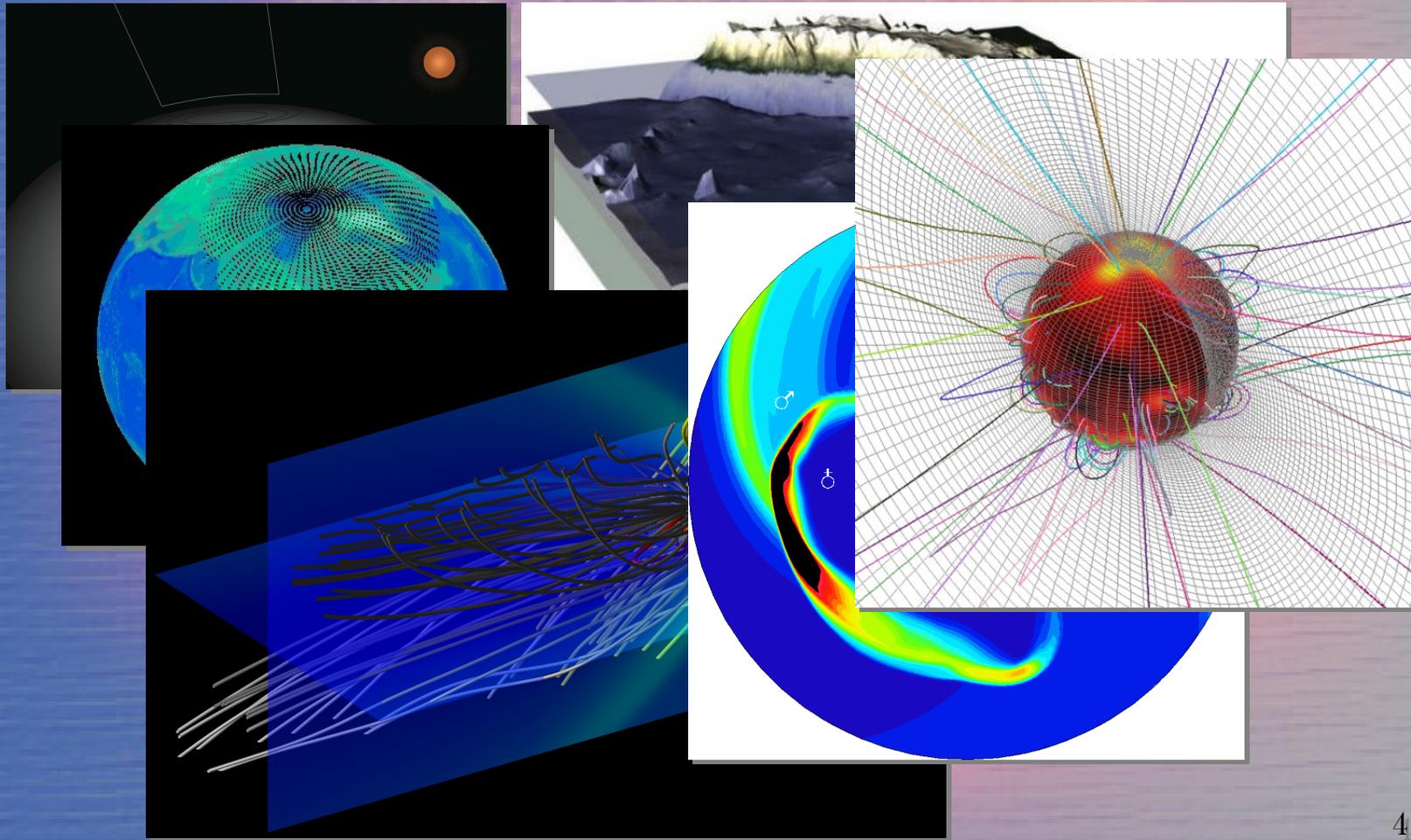
POWER SYSTEM EVENTS DUE TO SMD MARCH 13, 1989

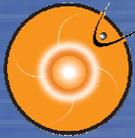






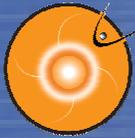
Overview of the GIC problem



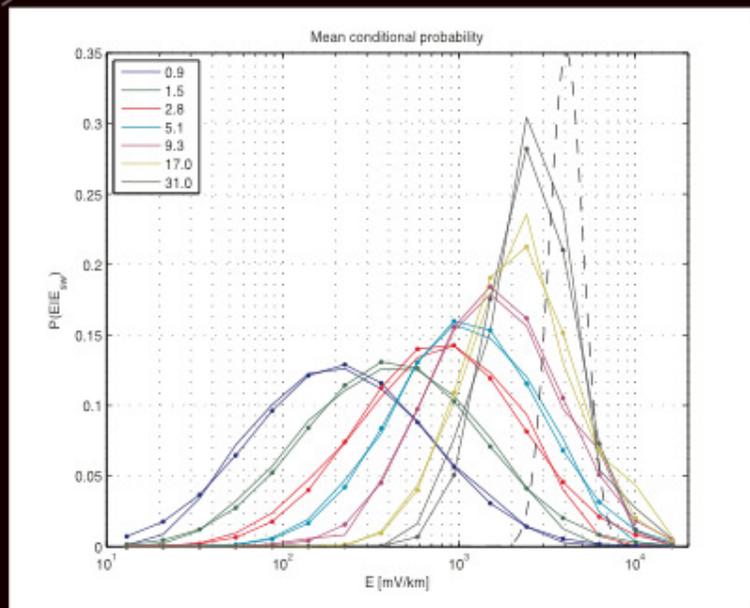
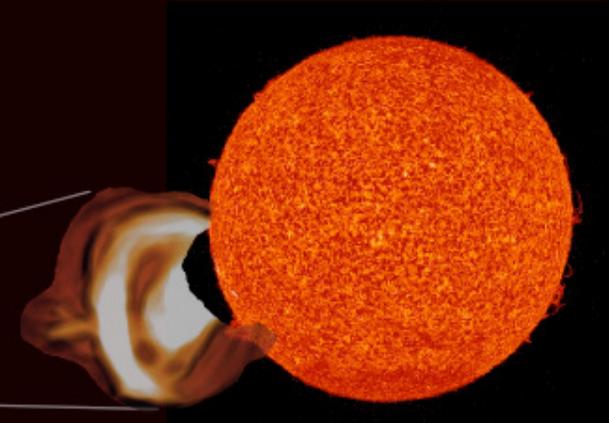
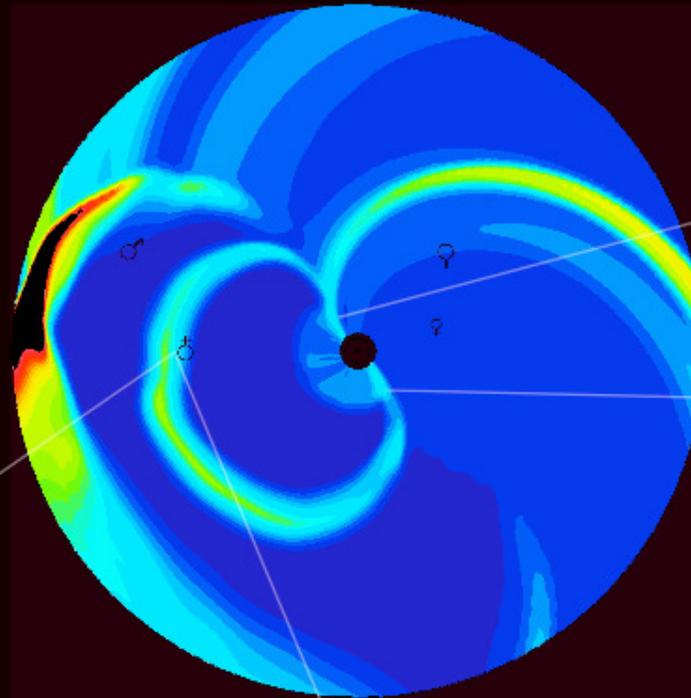


How NASA GSFC and CUA address these issues?

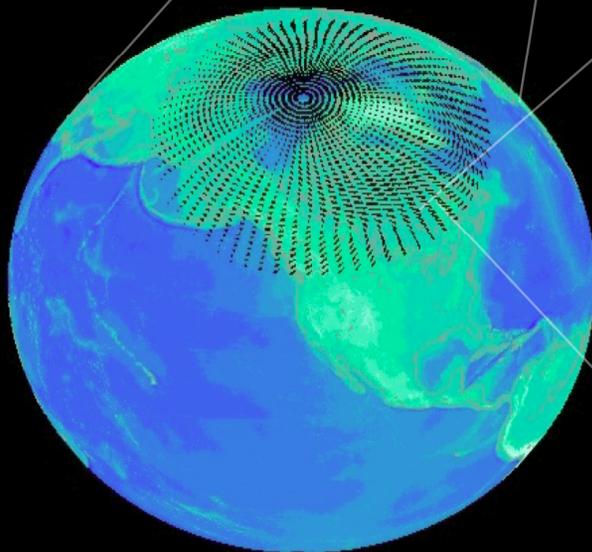
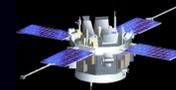
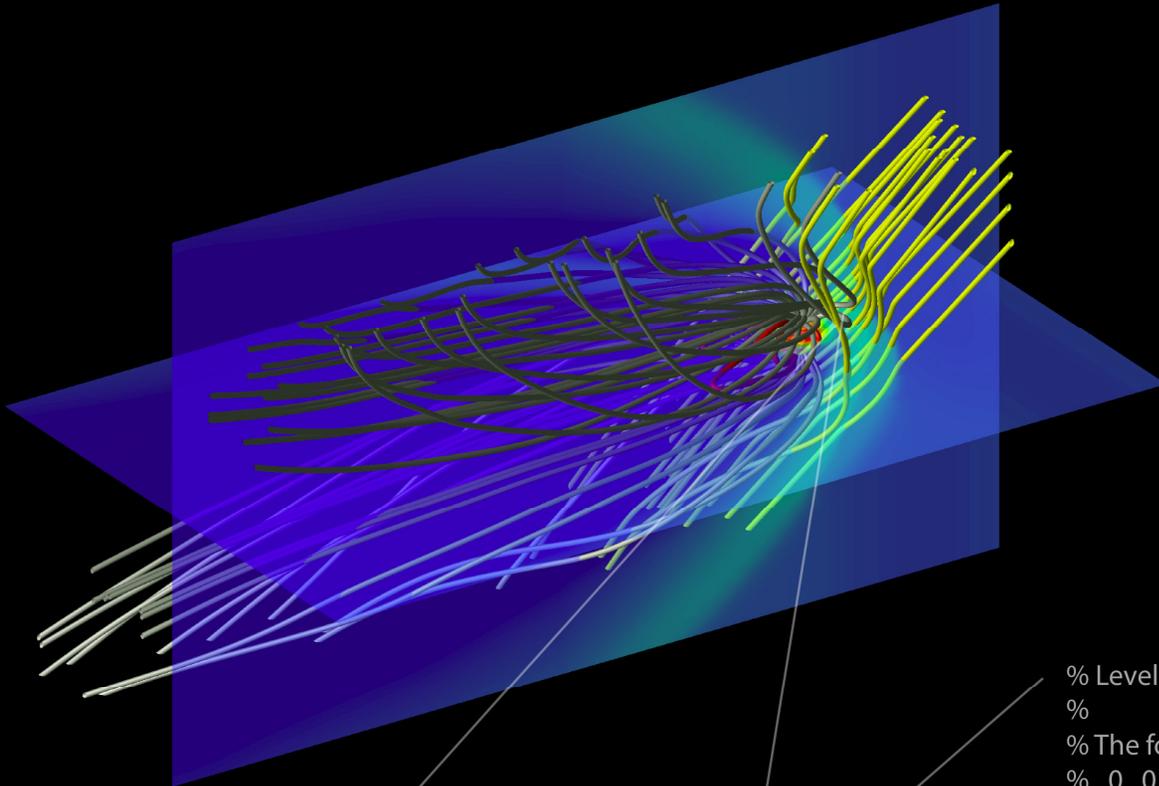
- Developing next generation forecasting capacity.
- Providing scientific analyses of extreme space weather conditions. These are being fed into further engineering analyses.



Next generation space weather forecasting



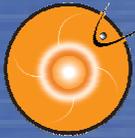
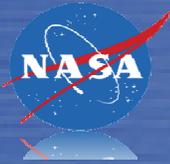
```
% Level 1 GIC forecast produced by REALTIMEGIC_LEVEL1
%
% The format of the data is as follows:
% 0 0 0 0 0 lat1 lon1 lat2 lon2 ...
% yy mm dd hh mi GIC1low GIC1high GIC2low GIC2high ...
%
0 0 0 0 53.16 -99.29 45.39 -68.53
2006 12 14 14 6 76 15 153
```



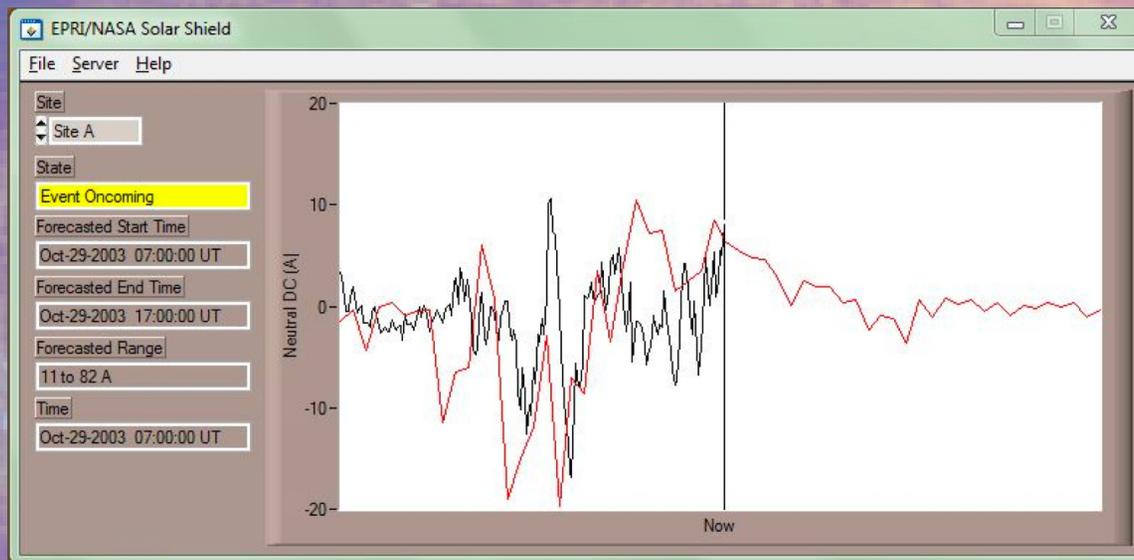
```

% Level 2 GIC forecast produced by REALTIMEGIC_LEVEL2
%
% The format of the data is as follows:
% 0 0 0 0 0 0 lat1 lon1 lat2 lon2 ...
% yy1 mm1 dd1 hh1 mi1 ss1 GIC1 0 GIC2 0 ...
% yy1 mm1 dd1 hh1 mi1 ss1 GIC1 0 GIC2 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
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

```

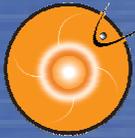
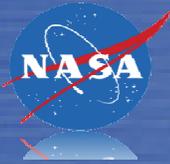


Coupling to the SUNBURST research support tool



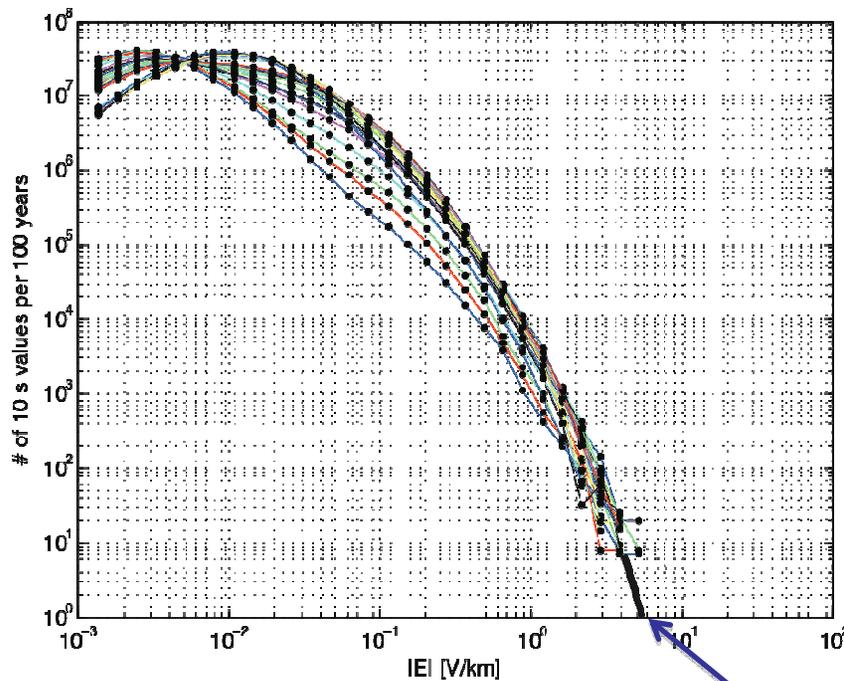
```
% Level 1 GIC forecast produced by REALTIMEGIC_LEVEL1
%
% The format of the data is as follows:
% 0 0 0 0 0 lat1 lon1 lat2 lon2 ...
% yy mm dd hh mi GIC1low GIC1high GIC2low GIC2high ...
%
0 0 0 0 53.16 -99.29 45.39 -68.53
2006 12 14 14 6 76 15 153
```

```
% Level 2 GIC forecast produced by REALTIMEGIC_LEVEL2
%
% The format of the data is as follows:
% 0 0 0 0 0 0 lat1 lon1 lat2 lon2 ...
%
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
```

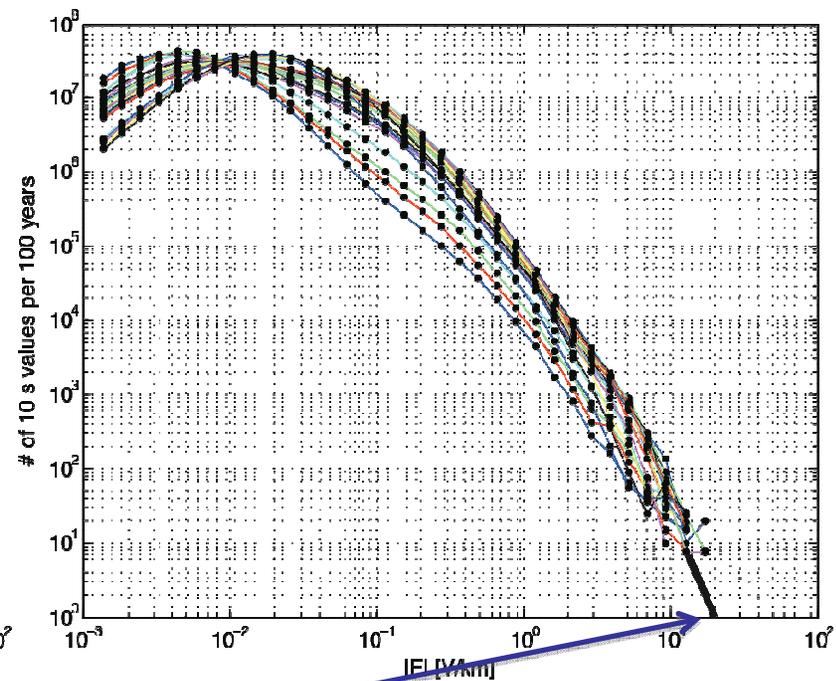


Analyses of extreme space weather conditions

a) British Columbia



b) Quebec



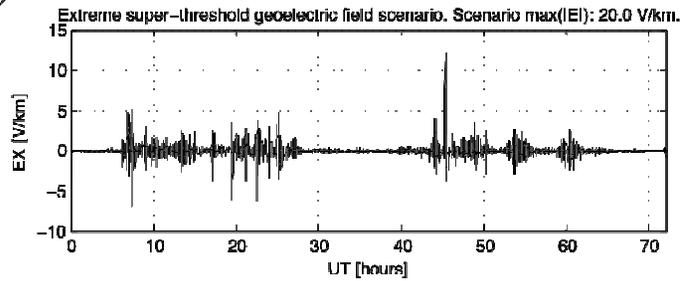
Data for 1993-2006

Visual extrapolation to 100-year amplitudes (well-justified if physics of the process remains the same)

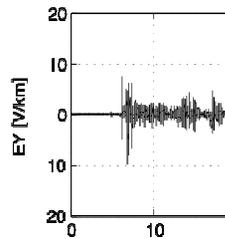
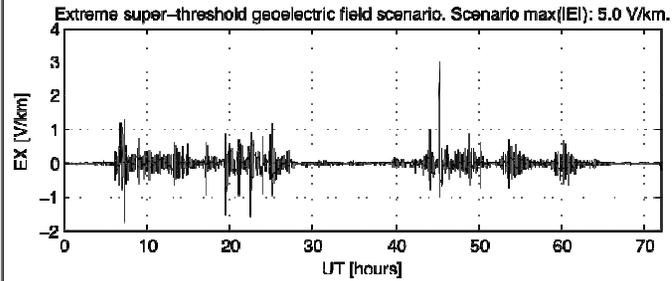
Resistive ground

Conducting ground

a)



b)

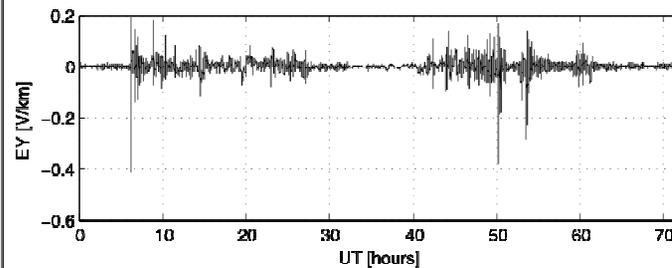
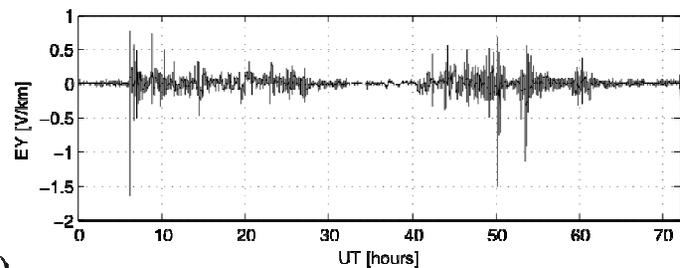
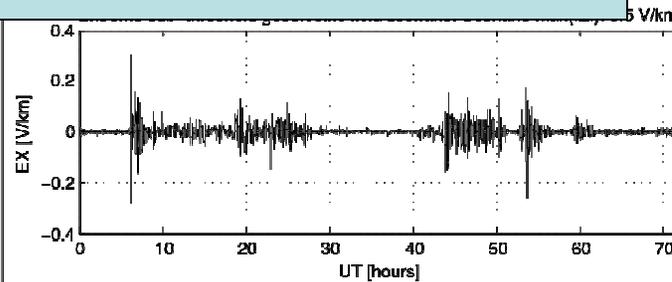
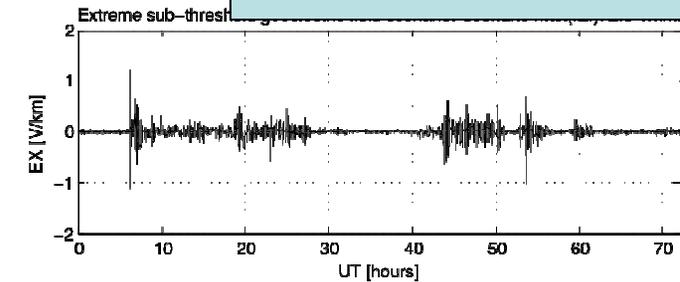


This data is publicly available for further engineering analyses.

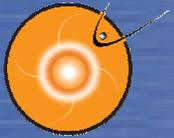
Above threshold geomagnetic latitude

Below threshold geomagnetic latitude

c)



d)



Summary

- GIC is a problem that needs to be addressed.
- Phenomenon the end link in the chain of complex space physical interactions.
- NASA GSFC and CUA address the problem both from the forecasting and extreme conditions analysis viewpoints.