Boosting GMD Resilience on the Power Grid

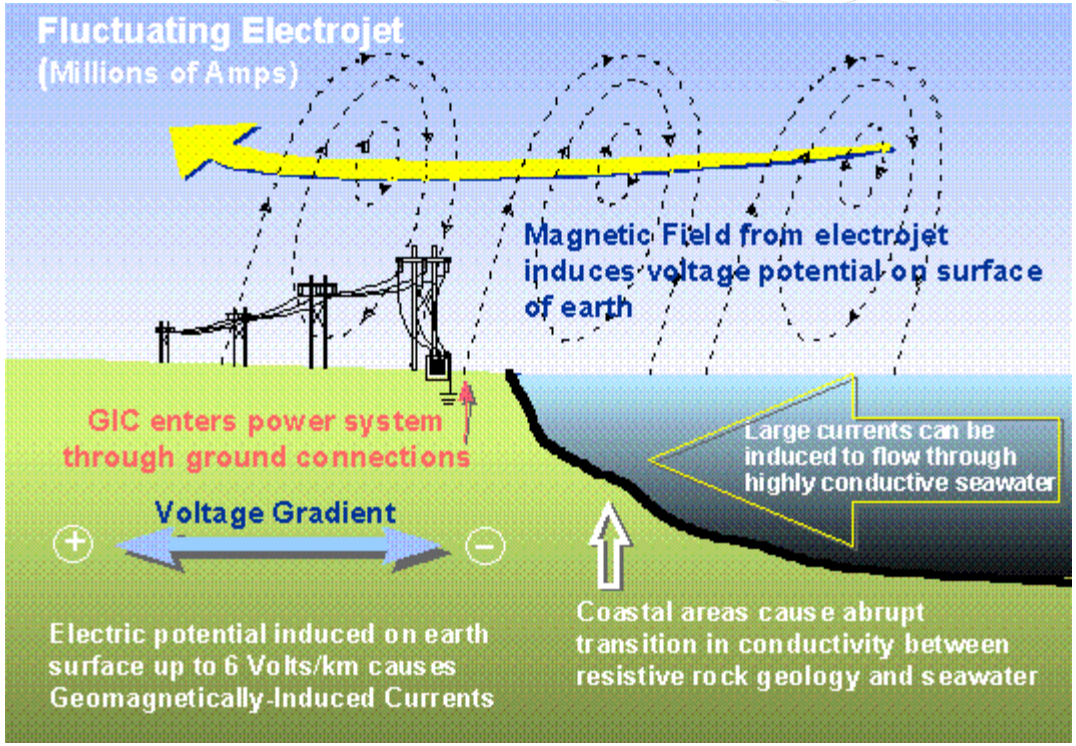
Effects of Geomagnetic Disturbances on Bulk Power Systems—Update to BRC

Frank Koza
Vice-Chair, NERC GMD Task Force

Space Weather Enterprise Forum
June 4, 2013

Frank Koza, Executive Director
PJM Interconnection

Space Weather Impacts to the Power Grid



Coronal Mass Ejection (CME) can induce currents in the Earth, entering the power grid through grounded connections in substations (transformers) or onto the high voltage transmission lines, resulting in:

- Transformer heating
- Protection system misoperation
- Depressed voltages

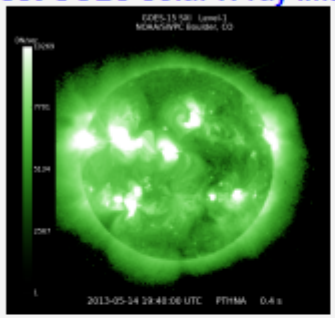
- Relying on Operational Mitigation – System operator intervention based on forecast and/or field measurements (FERC Order 779—Stage 1)
  - More GIC detectors being installed in the field
  - Improved forecast dissemination from SWPC
  - New analytical capability is becoming available in power analysis tools

1. Monitoring SWPC Forecasting Information

Space Weather Now

2013 May 14 19:46 UTC (May 14 13:46 MDT)

Latest GOES Solar X-ray Image



NOAA Scales Activity

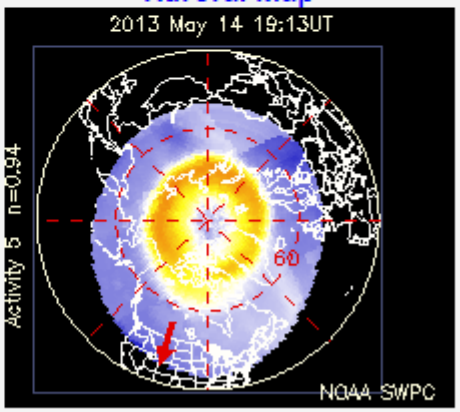
Range 1 (minor) to 5 (extreme)

NOAA Scale	Past 24 hrs	Current
Geomagnetic Storms	none	none
Solar Radiation Storms	none	none
Radio Blackouts	R3	none

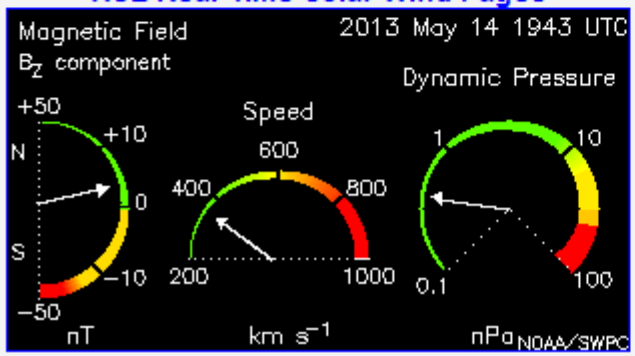
Alerts

Latest Alert: May 14 0249 UTC SUMMARY: 10cm Radio Burst

Auroral Map

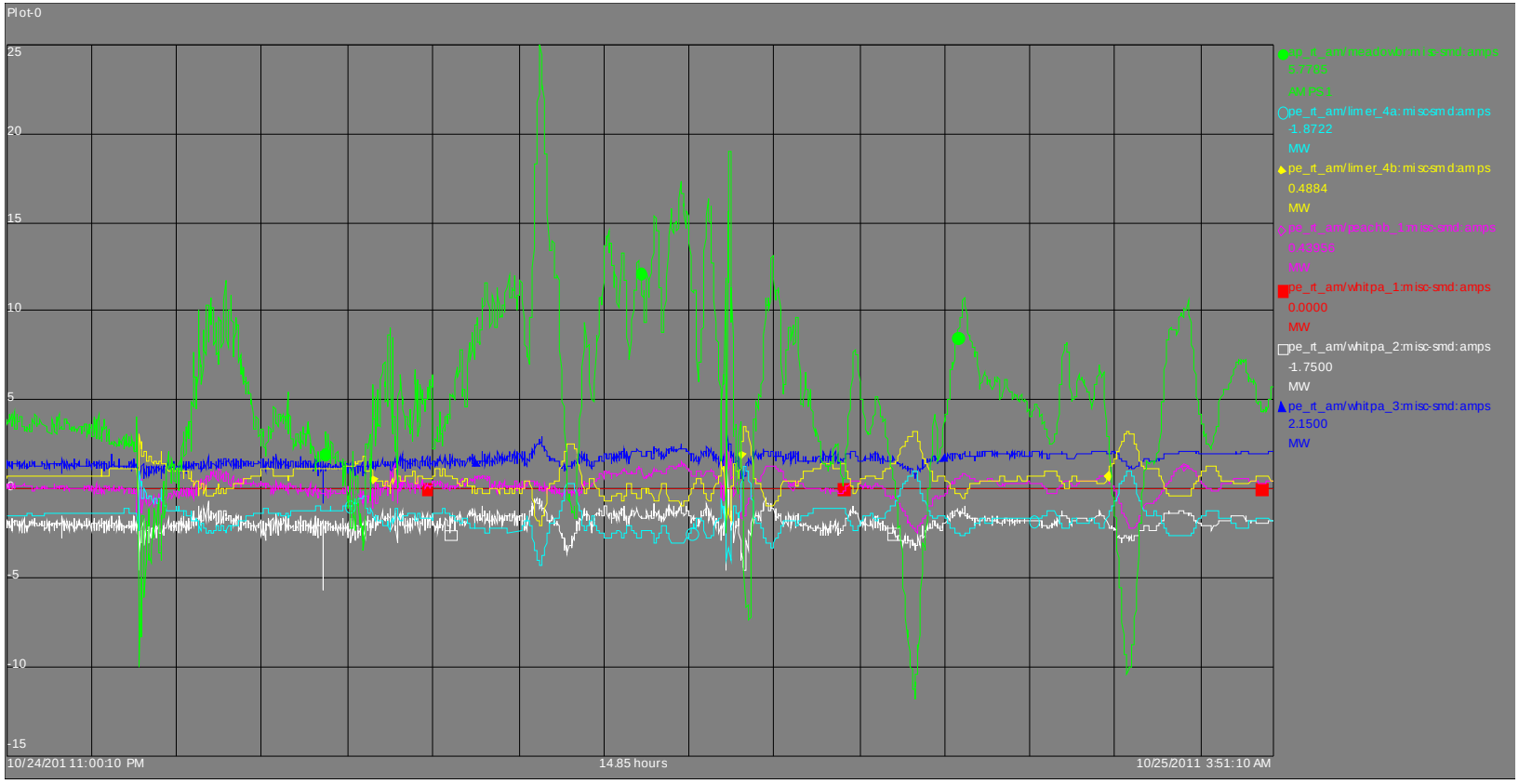


ACE Real-Time Solar Wind Pages

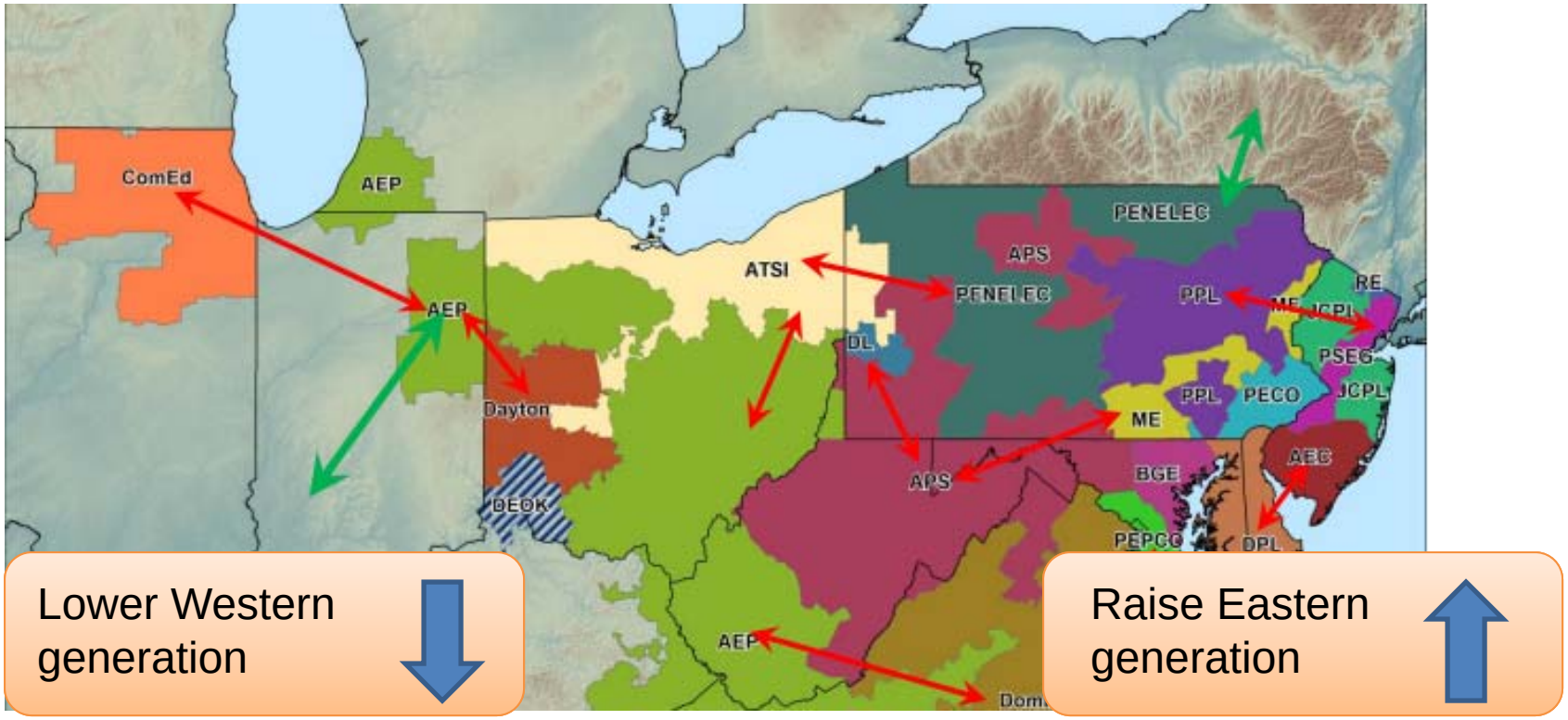


Solar Cycle Progression

2. Monitor GIC Detectors in Real Time



3. If GIC >10 amps sustained, then redispatch the system to reduce west to east flow



4. Increase voltage (reactive support)—prepare for low voltage and the loss of capacitors/generation

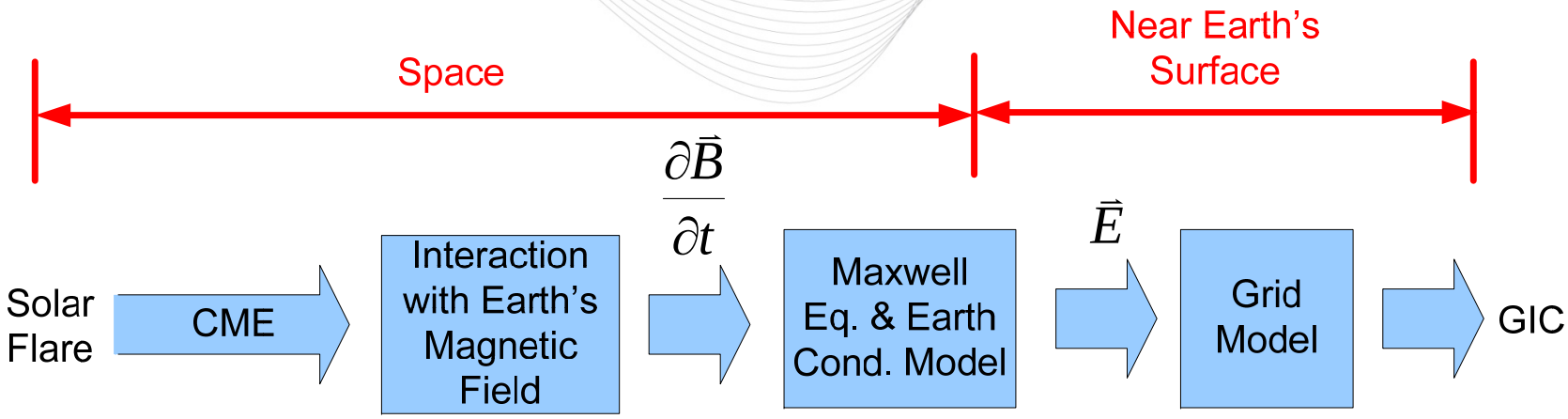
PJM BASE LINE VOLTAGE LIMITS

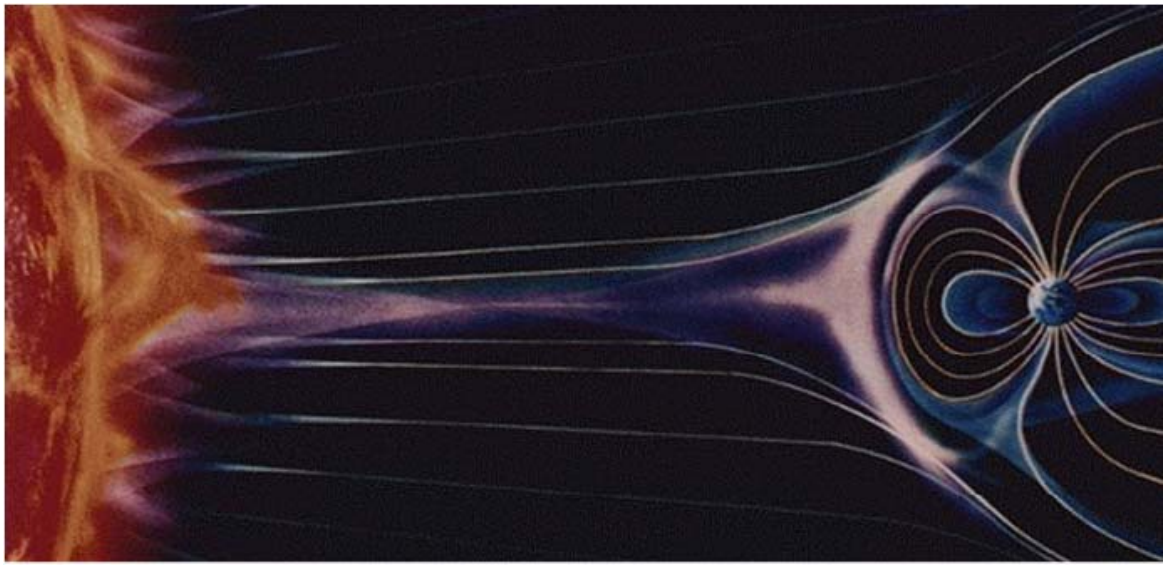
PJM Base Line Voltage Limits								
Limit	765 kV	500 kV	345 kV	230 kV	138 kV	115 kV	69 kV	34 kV
High	803.2 (1.05)	550 (1.10)	362 (1.05)	242 (1.05)	145 (1.05)	121 (1.05)	72.5 (1.05)	37.4 (1.10)
Normal Low	726.8 (.95)	500 (1.00)	328 (.95)	219 (.95)	131 (.95)	109 (.95)	65.5 (.95)	31.3 (.92)
Emergency Low*	703.8 (.92)	485 (.97)	317 (.92)	212 (.92)	127 (.92)	106 (.92)	63.5 (.92)	30.6 (.90)
Load Dump*	688.5 (.90)	475 (.95)	310 (.90)	207 (.90)	124 (.90)	103 (.90)	62 (.90)	0.0
Voltage Drop Warning*	2.5%	2.5%	4-6%	4-6%	4-6%	4-6%	4-6%	5%
Voltage Drop Violation*	5-8%**	5-8%**	5-8%	5-8%	5-10%	5-10%	5-10%	8%
* Refer to PJM Manual for Emergency Procedures (M-13) ** The voltage drop violation percentage may vary dependent on PJM analysis.								

Limits of Operational Mitigation

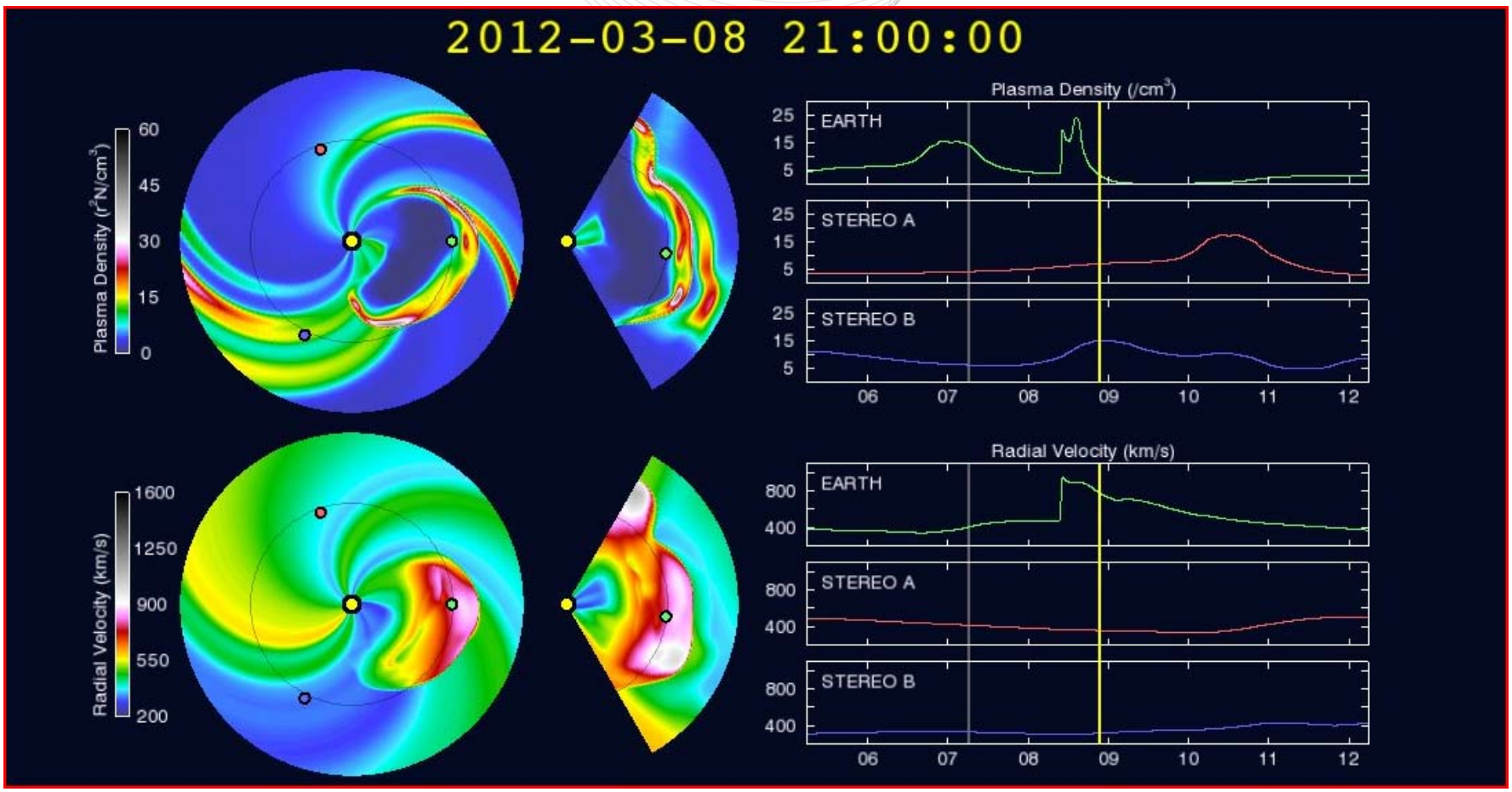
- In PJM's case, we have weathered space weather events (up to K-9)
- What would happen in an extreme event, e.g. a Carrington magnitude storm?
  - Answer: We don't know!
- Most likely scenario: Voltage collapse and blackout, with some transformer failures

Further Work by the Space Weather Enterprise Needed



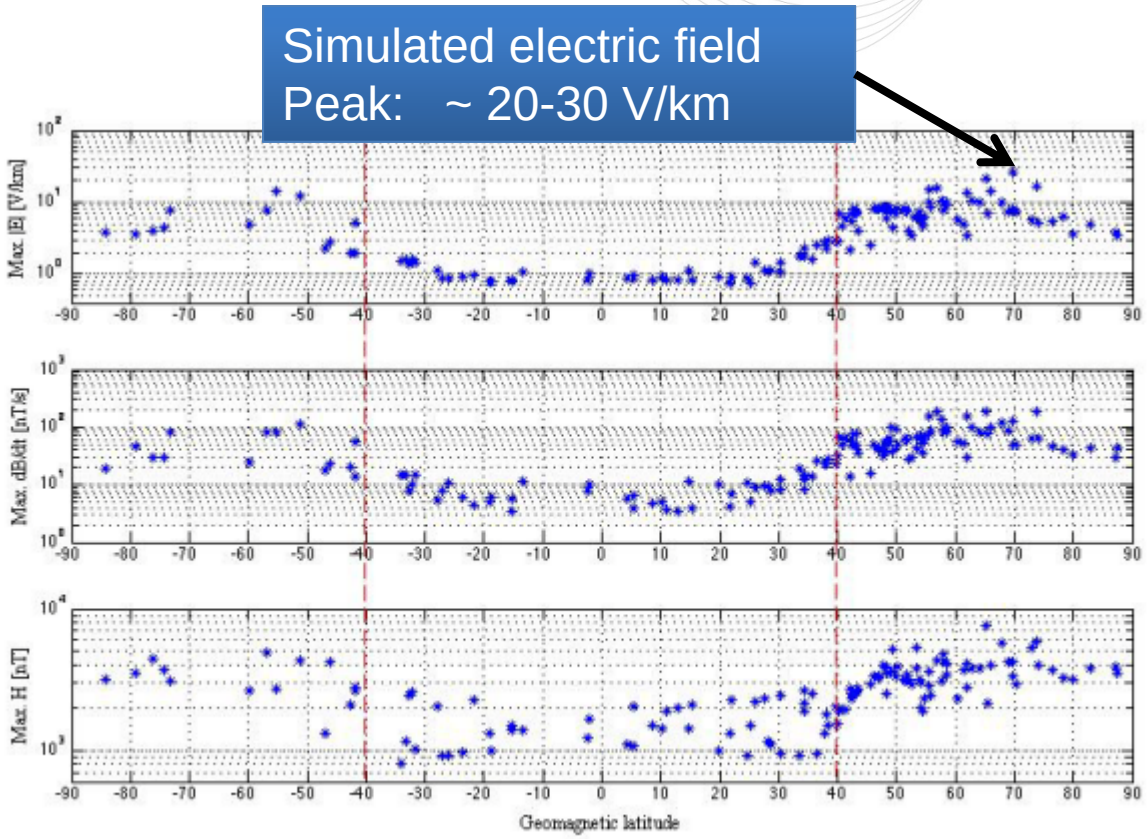


NASA Solar Wind Prediction



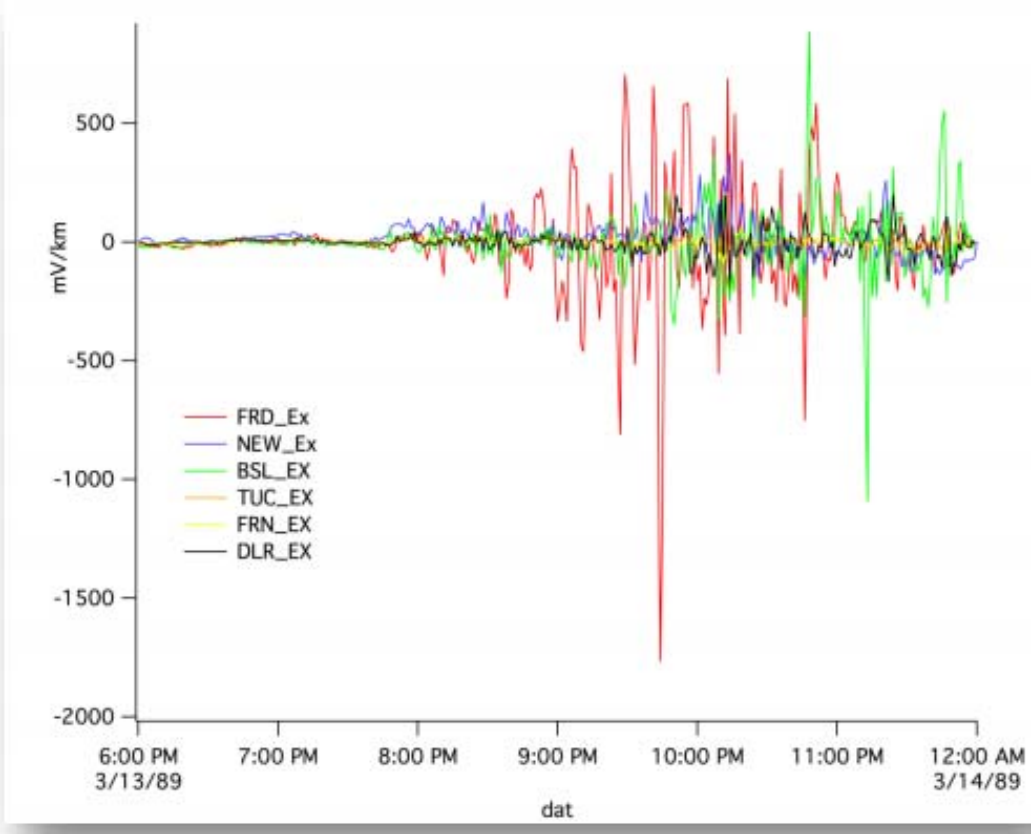
Source: WSA-Enlil Solar Wind Tool

NASA Goddard Simulations



NASA is developing simulations for the 1859 Carrington event

US Geological Survey (USGS)



USGS is developing a first order 1-D ground conductivity model for calculating the geoelectric field

Ground Induced Current (GIC) Calculation

- GIC calculation modules available for power system analysis
- Transmission owners and operators are studying GIC magnitudes and locations of vulnerability

Engineered Mitigation (FERC Order 779--Stage 2)

- NERC GMD Task Force to issue study guidelines for GMD vulnerability studies
- Equipment models are being developed for use by the system planners in reliability assessments
- The capabilities of “GIC blocking devices” are being investigated and test installations are proceeding
- More utilities are putting GIC withstand requirements into transformer purchase specifications

What's Also Needed --Transformer Testing

- Validation of transformer models
  - Three utilities have agreed to have their manufacturer test their production transformers prior to delivery, to assess the accuracy of the calculation models
  - Transformer manufacturers have been approached to expand the scope of testing on various transformer designs

Picture of the Future

- Validated models available to analyze equipment behavior (~1-2 years away)
- Analysis and understanding of the magnitude of the threat (~1-2 years away)
- Operational mitigation in place, based on analytically derived action triggers (~1-2 years away)
- Plans for engineered mitigation developed and implemented (~2-4 years away)
- More resilient equipment in the field – transformers, protection and control, generators (ongoing)

Summary

- Scientific community is making steady progress
  - Improved forecasting tools
  - Models of the earth conductivity are becoming available
  - Simulation of prior events is becoming available
- Industry “gets it!”
  - Asset owners are taking steps to understand the risks
  - Asset owners are installing additional monitoring capability
  - Asset owners purchasing more resilient equipment

Open question: What size event are we anticipating?