TIP 290: Modeling High-impact, Low-frequency Geomagnetic Disturbances using Magnetic Field Data from Solar-orbiting Spacecraft

Context

Research has found that solar g-modes are detectable from spacecraft measurements of solar wind. In helioseismology, g-mode or gravity waves are density waves which have gravity as their restoring force, hence the name "g-mode". Solar g-modes are oscillations that originate inside the Sun and can persist over thousands of years. Solar surface events such as flares and coronal mass ejections (CMEs) are thought to be driven by subsurface mixing processes, which implies a link between gravity modes and surface events. Flares and CMEs can in turn cause High-Impact, Low-Frequency (HILF) geomagnetic disturbances (GMDs) on Earth.

Therefore, detection of g-modes in the solar wind suggests that associated GMDs can be forecast six months or further into the future using spacecraft measurements.

Solar flares and coronal mass ejections (CMEs) cause changes in Earth's magnetic field when their trajectories intersect with Earth's own. In general, changes in magnetic fields can induce currents in power lines. Large-enough solar flares and CMEs can cause an induced current strong enough in a power system that equipment damage and widespread service disruptions result.

The geomagnetic storm on March 13, 1989 resulted in the collapse of the Hydro-Québec power grid within 90 seconds, leaving millions of customers without power for as long as nine hours. The same storm caused tripping or failure of transmission equipment across North America. The cost of the March, 1989 geomagnetic disturbance was approximately $13.2 million dollars in Québec alone.

Description

This project focused on prediction of GMDs over a longer time horizon than is provided by NOAA and NRCan. The goal was to investigate the empirical relationship between solar gravity modes (g-modes) and solar flares/CMEs. If persistent g-modes can be used to predict the probability of geomagnetic disturbances and their magnitudes, then a predictive model would allow BPA to manage associated risks. The project aims to develop a forecasting method capable of predicting solar flare events and associated CMEs that will impact the Earth's magnetic field enough to affect power transmission services.

The project achieves it goals through meeting the following tasks:

(A) explore and develop a predictive model for the magnitude of SF/CME events using solar wind data from the ACE spacecraft;

(B) Model and predict solar proton events and their magnitudes.

(C) Develop transfer functions to model and predict magnitudes of geomagnetically induced currents (GICs) from the proton events in (B);

(D) package results in a software tool for future use.

The first task examined reconstructions of g-modes and observed solar flare events carefully to determine if there are any apparent correlations. Correlations were used to develop a prediction model that takes g-mode reconstructions as inputs and the probability of a solar flare event as an output.

Results from tasks (A) and (B) involve time horizons of one to six months, providing some guidance as to what a worst-case scenario might be, as well as when it is likely to occur. This type of forecasting is sometimes referred to as the "100-year problem."

Benefits

Providing more accurate predictive information on GMDs would allow BPA to improve its overall readiness for such an event, which could include: allocate resources with increased efficacy; step-up time frames on power system upgrades or alter maintenance schedules that would allow the power system to be able to cope with a forecast GMD and subsequent geomagnetically induced current (GIC); take equipment offline or delay the rollout of new equipment until a forecast GMD event has passed, potentially saving the new equipment from damage.

Having probabilistic predictive forecasts of GMD events over an extended time horizon would also enable BPA to integrate the probability of various outcomes into their risk management framework when making strategic or long-term decisions, as well as operational decisions. This could reduce costs and increase system reliability over the long term.

Accomplishments

The project confirmed the empirical relationship between solar gravity modes (g-modes) and solar flares/CMEs.

A forecasting methodology was developed to predict solar flare events and associated CMEs that may impact the Earth's magnetic field enough to affect power transmission services.

Due to the difficulty of the research, Tasks C and D were not fully realized within the timeframe of the project.

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Project Start Date: October 1, 2012

Project End Date: September 30, 2015

Deliverables

Final Report: *BPA TIP 290-Modeling high impact low frequency geomagnetic disturbances: Prediction of the magnitude of solar flare/coronal mass ejections and of local effects on geomagnetically induced currents.*
By David J. Thomson (PI), David Riegert, and Aaron Springford

The report includes:

- Supporting data from Ulysses and ACE satellites, solar flare data and geomagnetic data.
- Forecast of flare probabilities; quantification of forecast reliability.
- Description of the techniques used for analysis, including software to perform the analysis.
- Discussion of potential follow-on projects.

Other Deliverables include:

- Copies of manuscripts submitted for publication in refereed journals.

Related Projects:

TIP 359: Improved System Modeling for GMD and EMP Assessments

Participating Organizations

Queen's University at Kingston, Ontario, Canada

Project Cost

Total Project Cost: $199,000

For More Information Contact:

Technology Innovation Project Management Officer:
TechnologyInnovation@bpa.gov