



The Space Weather Underground project: Early Results from northern New England, including observations of the Gannon Storm

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SWUG Design

Our goal is to construct an array of fluxgate magnetometers across northern New England for the purpose of measuring transient ionospheric activity. With only 6 nodes active and 7 more nearing deployment, we see correlated time variability daily and transients at least weekly. Transient activity in clear response to the arrival of interplanetary shocks as recorded by the ACE spacecraft have been seen both with north-south and east-west ionospheric currents generally followed by multiple hours of variability. There is no doubt that the magnetometers are capable of performing the proposed research. In several events studied so far, patterns in arrival times at the various nodes are clearly resolved.

The mag technology is based on the SAM-III 3-axis fluxgate sold by Reeve Engineers in Anchorage Alaska.

Outdoor deployments, which are desired, incorporate photovoltaics and radio data link so that separation from buildings is relatively easy to accommodate.

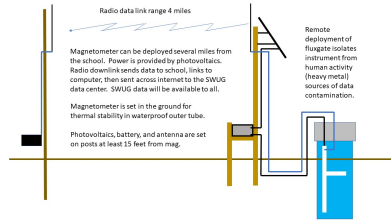
The radio data link is controlled by Arduinos.

Mags are deployed in the ground to maintain near-constant temperatures.

Each mag node costs approx. \$1100 including deployment hardware.

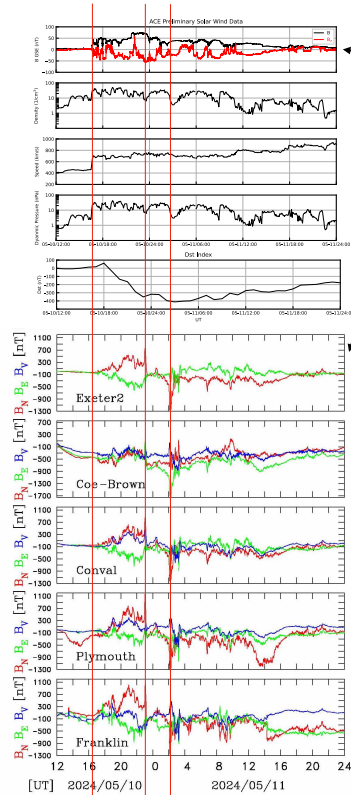
SAM-III provides 1 nT and 1 sec resolution, although we generally run at 2 sec resolution to obtain cleaner data.

Mags are calibrated on the benchtop prior to deployment and run as variometers. Absolute magnetic measurements are not promised.



School	City	Latitude	Longitude
Coe-Brown Academy	Northwood, NH	43.22	-71.21
CONVAL	Peterborough, NH	42.91	-71.94
Oyster River HS	Durham, NH	43.15	-70.94
Phillips-Exeter Academy	Exeter, NH	43.1	-70.92
Franklin Academy	Malone, NY	44.85	-74.29
Plymouth High School	Plymouth, NH	43.76	-71.69
Northeast Kingdom Astronomy Foundation	Peachment, VT		

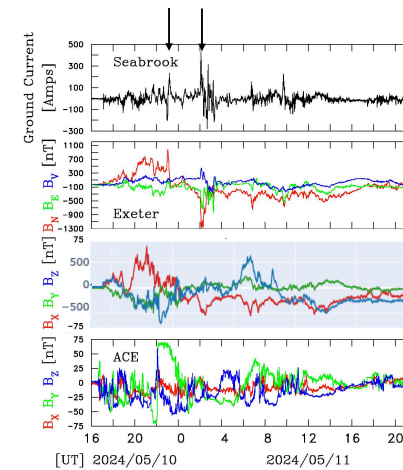
May 10, 2024 Storm



Solar wind data from the Gannon Storm on May 10/11.

The top panel shows a very strong solar wind magnetic field, with B_z largely negative. The solar wind density is orders of magnitude higher than typical conditions, carried by a solar wind with speeds first bumping up to ~750 km/s and then surging close to 900 km/s. Propagation delays from L1 to Earth are roughly 30 minutes under these conditions. The 5th panel shows Dst levels, as low as ~-400 nT.

SWUG data from the May 10/11 storm, showing observations from 5 local high school SWUG sites. Panels show SWUG data from the various high schools. The minimal variability in the observations is quite striking for such an arrangement of closely-spaced magnetometers. Although these are very low-cost instruments, their value in supporting regional studies (e.g., of GIC effects) appears to be very promising.

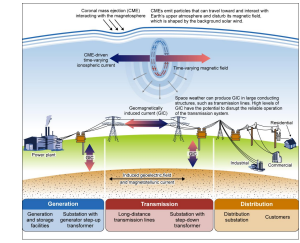


ABOVE: This plot shows a comparison of locally measured GICs, the SWUG magnetic signature from Exeter, model results (explained below) and the ACE solar wind data. The instrument at Exeter was roughly 10 km away from the GIC location.

The model results (3rd panel) resemble the measured data (2nd panel) reasonably well, except for a spike observed in the Seabrook GIC data around 23 UT. While a corresponding spike is present in the Exeter data, there is no such signature in the model run. Clearly, though, the second GIC (near 2 UT) does show up in both the observed data and the model run (where it is much weaker than the actual observations).

LEFT: The event was modeled with the objective of predicting ground magnetometer signals. This was a multi-step effort using MAGE (Multiscale Atmosphere-Geospace Environment model) version 1.0, which includes the TIEGCM with GAMERA and RCM for a fully coupled geospace simulation. It was driven by upstream solar wind conditions derived from a combination of THEMIS, MMS, and WIND measurements to get the most accurate solar wind inputs possible. For more information, please see Wiltberger et al., at GP52A-05, on Friday morning.

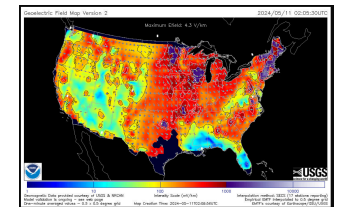
Geomagnetically induced currents



How GIC are produced:

- Ionospheric currents (~100 km altitude) are significantly enhanced during storms and highly dynamic.
- That current induces a geoelectric field in the ground beneath the ionospheric current.
- The geoelectric field drives the current in the ground, subject to the conductivity of the ground (or sea).

From "Critical Infrastructure Protection: Protecting the Electric Grid from Geomagnetic Disturbances", United States Government Accountability Office, Report to the Committee on Homeland Security and Governmental Affairs, United States Senate.



From spaceweather.com: "On May 10-11, geoelectric amplitudes exceeded 10 V/km in Virginia and 9 V/km in the upper Midwest," says Jeffrey Love, a key member of the collaboration at the USGS. "These are very high. For comparison, we estimate that geoelectric amplitudes reached almost 22 V/km in Virginia during the March 1989 storm."

In northern New England, GICs were measured to be 430 A at a nearby electrical station. As can be seen from the map, the New England region appears to support strong GICs, likely related to a complex land/sea interface and

Conclusions

1. This study shows that low-cost magnetometers built and installed by high school teachers and students can provide important measurements in support of space weather and other scientific studies.
2. The magnetometer data show strong perturbations across southern/central New Hampshire associated with the Gannon storm. Nearby (within ~10 km of Exeter), a GIC current of 430 A was measured.
3. Magnetic perturbations due to the storm were modeled/predicted using the MAGE model and compare very well with the SWUG observations. Two spikes in the data were not reproduced with the model, perhaps due to unknown magnetotelluric effects.
4. The New Hampshire coastline is ideal for GIC MT studies because of the land-sea interface and favorable magnetotelluric conditions.