Direct Burial Broadband Seismic Instrumentation for Polar Environments

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Abstract

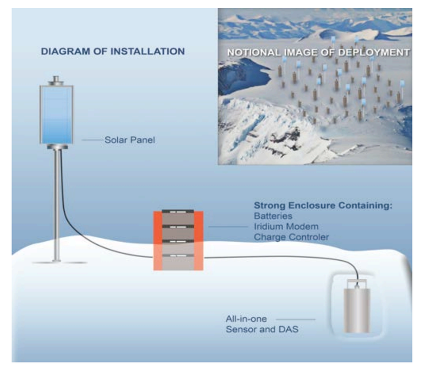
The integrated broadband Meridian Posthole and Compact seismic systems have been engineered and tested for extreme polar environments. Ten percent of the Earth's surface is covered in glacial ice and the dynamics of these environments is a strategic concern for all. The development for these systems was driven by researchers needing to densify observations in ice covered regions with difficult and limited logistics. Funding from an NSF MRI award GEOICE and investment from the vendor enabled researchers to write the specifications for polar hardening a hybrid family of instruments that can operate at -55C autonomously with very little power, ~1 watt for the Meridian Compact system and ~1.5 watts for the Meridian 120PH. Tilt tolerance in unstable ice and snow conditions was a concern and these instruments have a range of up to +/-5 degrees. The form factor, extreme temperature tolerance and power requirements of the instruments has reduced the bulk of a complete station by 1/2 for the medium band systems and simplified installation greatly allowing more instruments to be deployed with limited support and a lighter logistical load. These systems are being tested in the Antarctic at South Pole Station and McMurdo for the second year and the investment has encouraged other instrument and power system vendors to offer polar rated equipment including SOH telemetry for ancillary support.

Motivation

Polar autonomous seismic stations must operate without regular intervention, and must operate over l time periods ranging from months to many years.
Logistics and a challenging polar environment are the crux of most polar research, the distribution of cost for the USA's NSF Polar research program is 50% operational and 50% science. We report on the development of a new NSF MRI-supported community seismic capability for studying ice-covered regions - the Geophysical Earth Observatory for Ice Covered Environments (GEOICE). This project is fundamentally motivated by the need to densify and optimize the collection of high-quality data relevent to key solid Earth and cryosphere science questions
The instrument capability will include a hybrid seismograph pool of broadband and intermediate elements, for observation of both long-period (e.g.long period surface waves and slow sources) and intermediate- to-short-period (e.g. teleseismic body waves, local seismicity impulsive or extended glaciogenic signal) including developing the ancillary systems needed to support operation.

Ross Ice Shelf Experiment, photo by Rob Anthony

MEVO Experiment, photo by Pnina Miller



GEOICE Enclosures and Ancillary Polar Developments

Rechargeable Winter-over Systems - Designed for -20°C

Battery Type	Total Weight (lbs)	Total Volume (ft3)	Cost (USD)	Number in Twin Otter
AGM (SunExtender 12V, 108Ah, x6.2	646	63.1	$9425	2
LiFePO4 (SmartBattery, 12V, 100Ah, x4.3	388	42.3	$14220	4

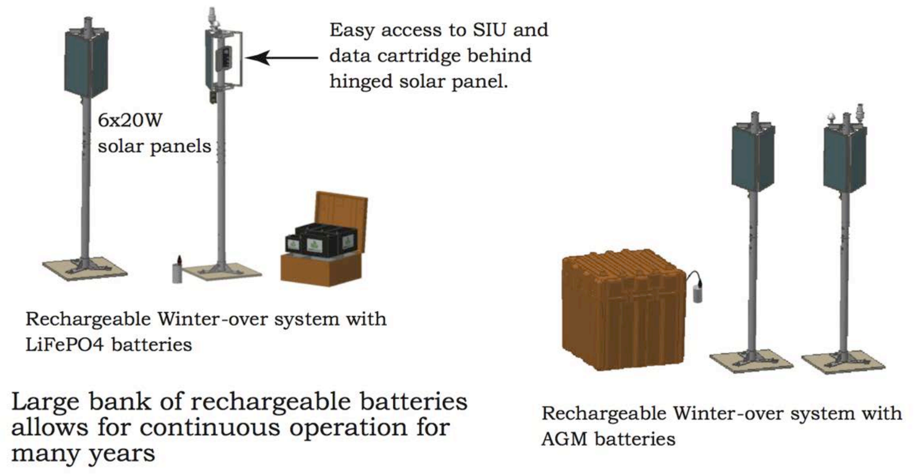
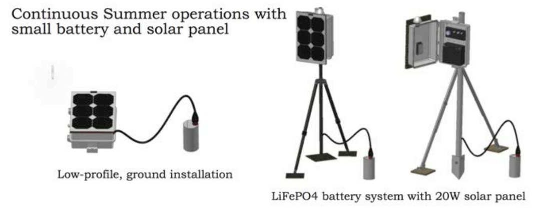


Table of multi-year systems using either lithium or lead acid rechargable batteries.

As part of the GEOICE development the IRIS PASSCAL Polar Engineering is developing the enclosures, power systems, telemetry and deployment plans for both short term and multi-year deployments using both primary and secondary battery systems. All systems are engineered for the polar temperatures and quick deployment with the minimal logistics. Iridium telemetry is being tested for both SOH and limited data return with the goal to eventually return data products created at the station when solar power or wind power is available. The figure below is example of a summer season short term deployment scenario and the number of stations that can be carried in a typical deployment by a Twin Otter aircraft.

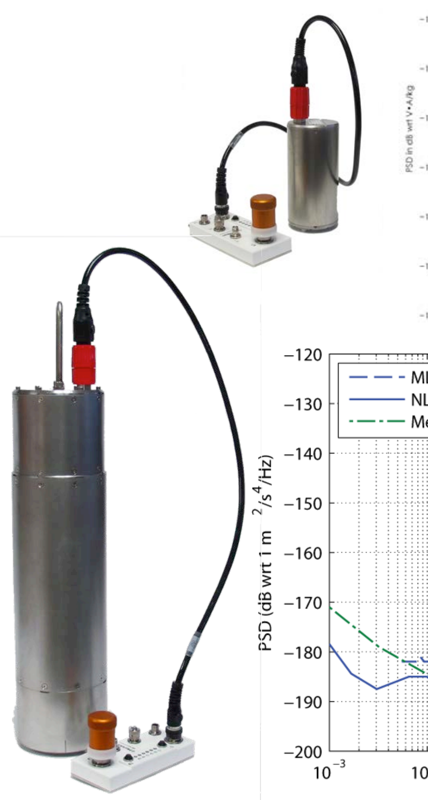
Summer Solar Systems

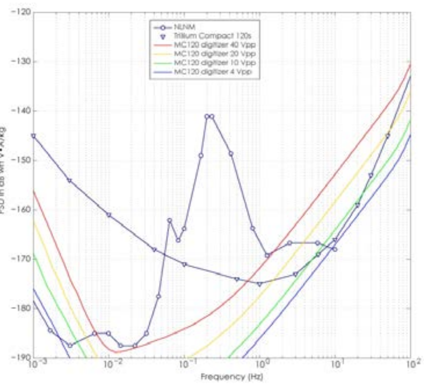
Battery Type	Total Weight (lbs)	Total Volume (ft3)	Cost (USD)	Number in Twin Otter
AGM (SunExtender,12V, 42Ah, xl)	65	4.2	$360	21
LiFeP04 (SmartBattery, 12V, 35Ah , x l)	30	1.5	$660	47

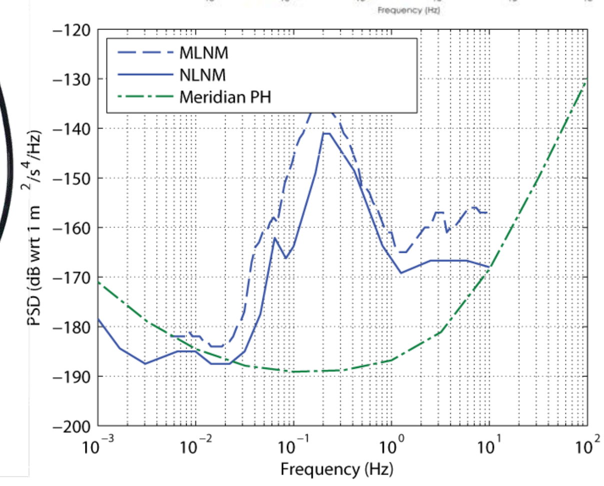


Sensors and Digitizers

Meridian PH and Compact PH is a fully integrated digital seismometer featuring a Trillium Compact seismometer or a Trillium PH sensor paired with a 24-bit digital recorder inside a waterproof, stainless steel vessel. The all-in-one design simplifies and ruggedizes the deployment, making this instrument ideal for large transportable arrays and many other applications where portability and rapid deployment are important.
Data is retrieved via a waterproof data cartridge from the IP68 rated surface interface unit (SIU) or telemetered to a network operations center. The Meridian systems are based on polar proven direct burial type sensors that have been deployed for as long as 3 years in polar environments. There are over 40 deployed in Antarctica presently and the Meridian development is the next logical step in reducing the cost, volume and weight of polar rated seismic stations. Cost of seismic equipment and volume of enclosures could be reduced by ~30% over the systems deployed in Antarctica multi year stations today.

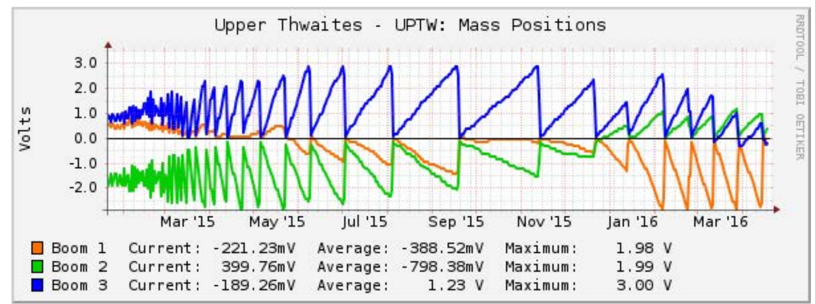






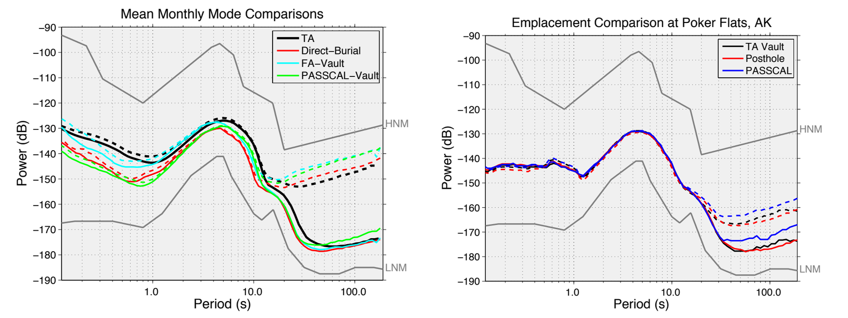
Tilt Tolerance of Meridian T120PH Sensor
A Trillium 120PA traditional pier style sensor re-centers every 0.2 degrees of tilt up to max tilt of 1.5 degrees = 7 times
The Trillium 120PH sensor re-centers every 0.1 degrees of tilt up to max tilt of 5.0 degrees = 50 times

Station re-centers at Upper Thwaits Glacier Antarctica
Stations located in high snow accumulation areas routinely need re-centering, the greater tilt range of the newer posthole sensors will allow them to successfully operate autonomously for more seasons.



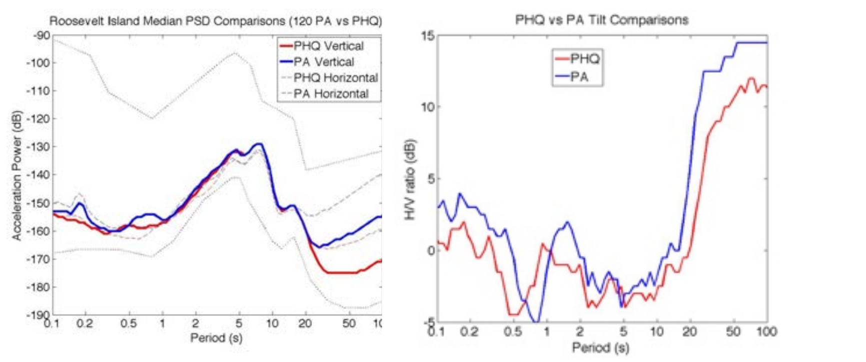
Posthole Type Sensors Vs. Traditional Pier Style instruments

The IRIS PASSCAL instrument pool until recently had only traditional pier style broad band seismic sensors requiring researchers to construct vaults for effective data gathering and protecting the instruments. The sensors were not designed for the typical use case of a portable broadband experiments and this has caused both data loss and data quality issues even though much effort was put into engineering around the problem. Vendors now provide purpose built instrumentation for this research application. Recent analysis of deployments by Sweet has demonstrated direct burial techniques to have lower installation caused noise when compared to the temporary vault deployments and comparable to Earthscope Transportable Array deployments. Sweet is currently conducting the same research on polar deployments where data now exist.



Justin, et al as presented at AGU 2015

There is some data for stations deployed near the Ross Ice Shelf that suggest direct bury techniques in snow can have benefits too. An analysis by Rob Anthony[1] compares PDFs of a pier style Trillium 120PA in a PASSCAL vault and a Trillium T120PHQ posthole style sensor. Both are located on Roosevelt Island - so are NOT on floating ice (which is exceptionally sensitive to long-period infragravity waves). The PHQ is much more stable at long periods, especially > 50 seconds. The posthole PHQ is 10-20 dB quieter beyond 50 seconds on both components. The posthole starts being quieter around 20 seconds (especially the horizontals) and just continues to get quieter out to 100 seconds. Neither sensor is particularly tilty compared to comparable POLENET sensors, although the posthole has a slightly lower H/V ratio at long periods. It looks like the posthole might be a few dB quieter at short periods (< 1 seconds) too. This is just one year of data from two sensors located about 70 km apart.



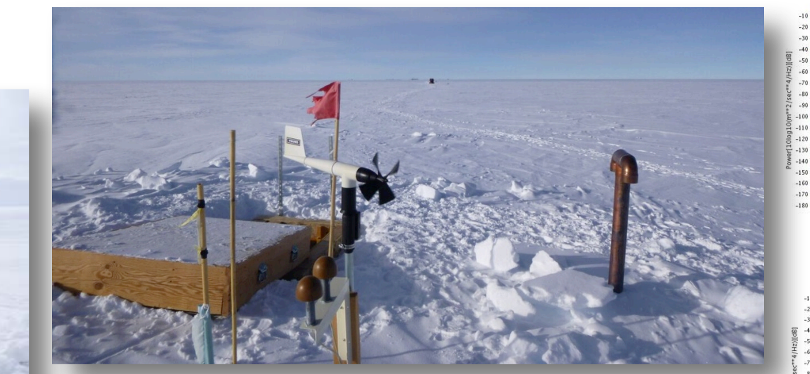
Rick Aster on left and Doug Bloomquist on right deploying T120PHQ sensors during the Ross Ice Shelf Experiments

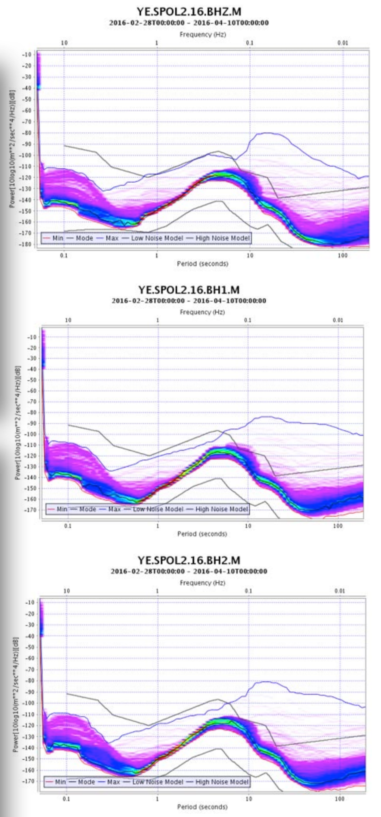
1 Bromirski, P. D., A. Diez, P. Gerstoft, R. A. Stephen, T. Bolmer, D. A. Wiens, R. C. Aster, and A. Nyblade (2015), Ross ice shelf vibrations, Geophys. Res. Lett.,42, doi:10.1002/2015GL065284

On going testing…

GEOICE sensors and deployment systems are being tested in multiyear deployments at South Pole Station SPRESO Seismic, Castle Rock near McMurdo Station Antarctica, Taku Glacier Alaska and the PASSCAL Instrument Center at New Mexico Tech.

SPRESO





Castle Rock

Taku Glacier Alaska

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Justin R. Sweet(2015), Posthole Broadband Sensor Emplacement vs. Surface Vaults: Observations of Comparative Noise Performance and Trade-offs. AGU Abstracts
Photos, ancillary system, testing, results provided by the IRIS PASSCAL at New Mexico Tech, IRIS Instrument Services and IRIS Data Management Services. Direct Burial in snow versus vault in snow analysis provided by Rob Anthony, Colorado State University.