The Greenland Ice Sheet monitoring Network (GLISN)

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Background

The GreenLand Ice Sheet monitoring Network (GLISN) is a new, international, broadband seismic capability for Greenland, being installed and implemented through the joint collaboration of Denmark, Canada, France, Germany, Italy, Japan, Norway, Poland, Switzerland, and USA. GLISN is a real-time sensor array of seismic stations to enhance and upgrade the performance of the sparse Greenland seismic infrastructure for detecting, locating, and characterizing glacial earthquakes and other cryo-seismic phenomena, and contribute to our understanding of Ice Sheet dynamics. Complementing data from satellites, geodesy, and other sources, and in concert with these technologies, GLISN will provide a powerful tool for detecting change, and will advance new frontiers of research in the glacial systems; the underlying geological and geophysical processes affecting the Greenland Ice Sheet; interactions between oceans, climate, and the cryosphere; and other multidisciplinary areas of interest to geoscience and climate dynamics.

The glacial processes that induce seismic events (internal deformation, sliding at the base, disintegration at the calving front, drainage of supra-glacial lakes) are all integral to the overall dynamics of glaciers, and seismic observations of glaciers therefore provide a quantitative means for monitoring changes in their behavior over time. Long-term seismic monitoring of the Greenland Ice Sheet will contribute to identifying possible unsuspected mechanisms and metrics relevant to ice sheet collapse, and will provide new constraints on Ice Sheet dynamic processes and their potential roles in sea-level rise during the coming decades. GLISN will provide a new, fiducial reference network in and around Greenland for monitoring these phenomena in real-time, and for the broad seismological study of Earth and earthquakes.

During the summer of 2010, 9 stations were installed or upgraded inGreenland. Sites visited under the GLISN project include Nord (NOR – USA, Denmark), Daneborg (DBG – USA, Denmark, Germany), Ittoqqortoormiit (SCO – USA, Denmark), Tasilaq (ANGG – USA, Denmark), Narsarsuaq (NRS – USA, Denmark), Nuuk (NUUK – USA, Germany, Denmark), Nuugaatsiaq (NUUG – Switzerland, Denmark), Summit Camp (SUMG – Germany) and Thule (TULEG – USA, Denmark). Work in Summer 2011 is in progress and will include the installation of 3 stations on the polar plateau (NEEM camp - USA Denmark; Raven Camp - USA; and ICE-S -USA, Japan). In addition, new stations will be installed at Soedalen (USA) and Ivittuut (France)

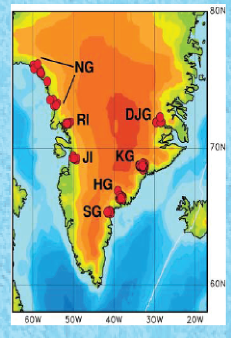
Data are flowing into the data centers at the IRIS DMC, and at the ORFEUS and GEOFON data centers for all but NOR and DBG (telemetry under development) and all data are free and open to the public. Data can be accessed by using the IRIS virtual network code _GLISN. Please see www.iris.edu/mda/_GLISN for information on GLISN station metadata and data access.

Glacial earthquakes

The largest glacial seismic signals are produced by a new class of seismic events discovered by Ekström et al. (2003), located primarily at Greenland's largest outlet glaciers. These "glacial earthquakes" generate long-period ($T > 25$ sec) surface waves equivalent in strength to those radiated by up to moment-magnitude-5 earthquakes. These events radiate little high-frequency energy and release 1000x more seismic moment than previously reported seismic phenomena associated with glaciers (Tsai and Ekström, 2007).

More than 200 such glacial earthquakes were detected worldwide for 1993-2006. More than 95% occurred on Greenland, in close proximity to major outlet glaciers (see figure to the right). Ekström et al. (2006) found (1) a clear seasonal signal, and (2) a significant increase in the frequency of glacial earthquakes in 2002–2005 . These fluctuations correlate positively with seasonal hydrology, and multi-year flow increases, calving-front retreat, and thinning at many outlet glaciers. The sliding direction inferred from glacial earthquakes and overall glacier flow directions agree well.

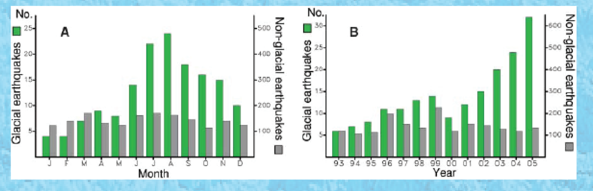
Fieldwork demonstrates that glacial earthquakes are coeval with large calving events where ~1 km^3 of ice is lost from glacier termini (Nettles et al., 2008; Amundson et al., 2008), and with rapid acceleration of the glacier as a whole. The glacial earthquakes thus serve as markers of abrupt changes in glacier flow—perhaps because calving has unplugged its outlet to the sea—and represent an opportunity to study forces acting on the calving front in detail.

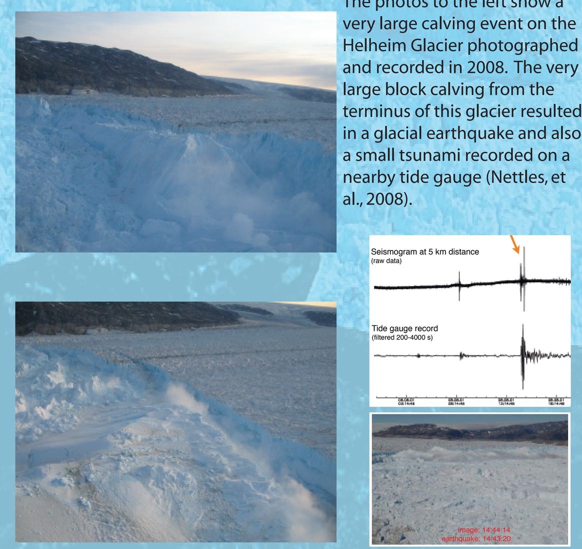


The topographic map to the left shows the location of ~136 glacial earthquakes observed on the GSN between 1993 and 2005 (corresponding to the yellow shaded areas on the large map to the right).

The charts below show the seasonality of these events relative to non-glacial earthquakes located using the same algorithms. Note that during this time period, there is a larger rate of occurrence for these events in the summer months (suggesting a tie to thermal processes) as well as an increase in the number of these events per year with time, suggesting the driving mechanisms are changing.

(Figures from Ekstrom, et al, 2006).

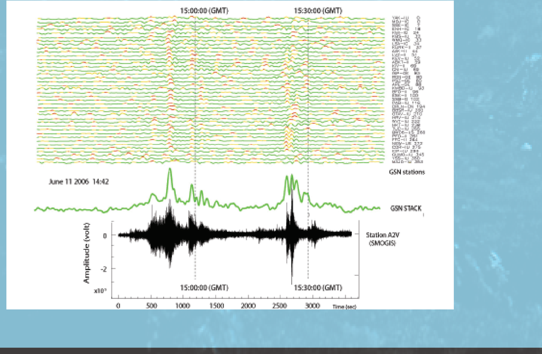




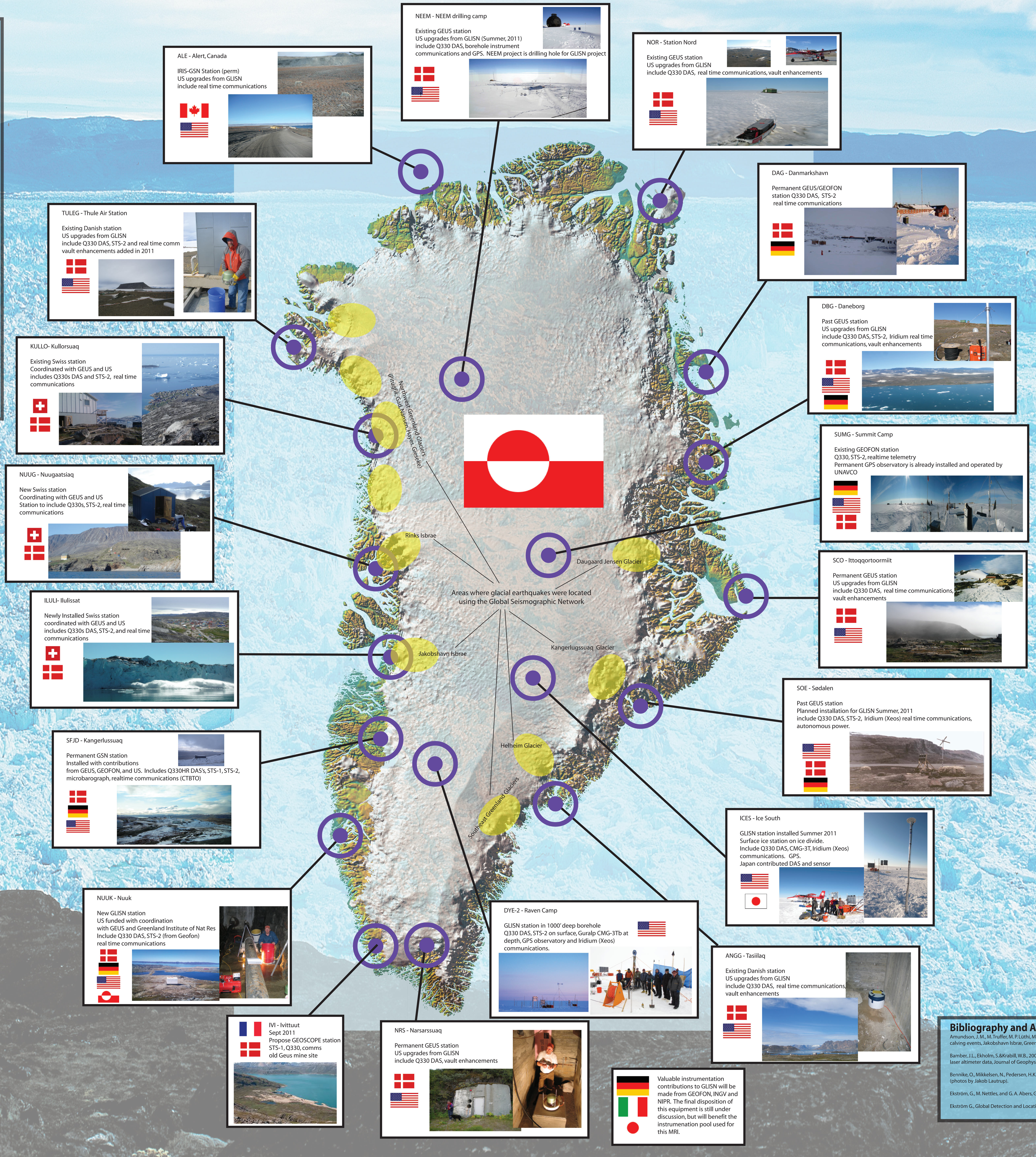
The photos to the left show a very large calving event on the Helheim Glacier photographed and recorded in 2008. The very large block calving from the terminus of this glacier resulted in a glacial earthquake and also a small tsunami recorded on a nearby tide gauge (Nettles, et al., 2008).

Glacial rumblings

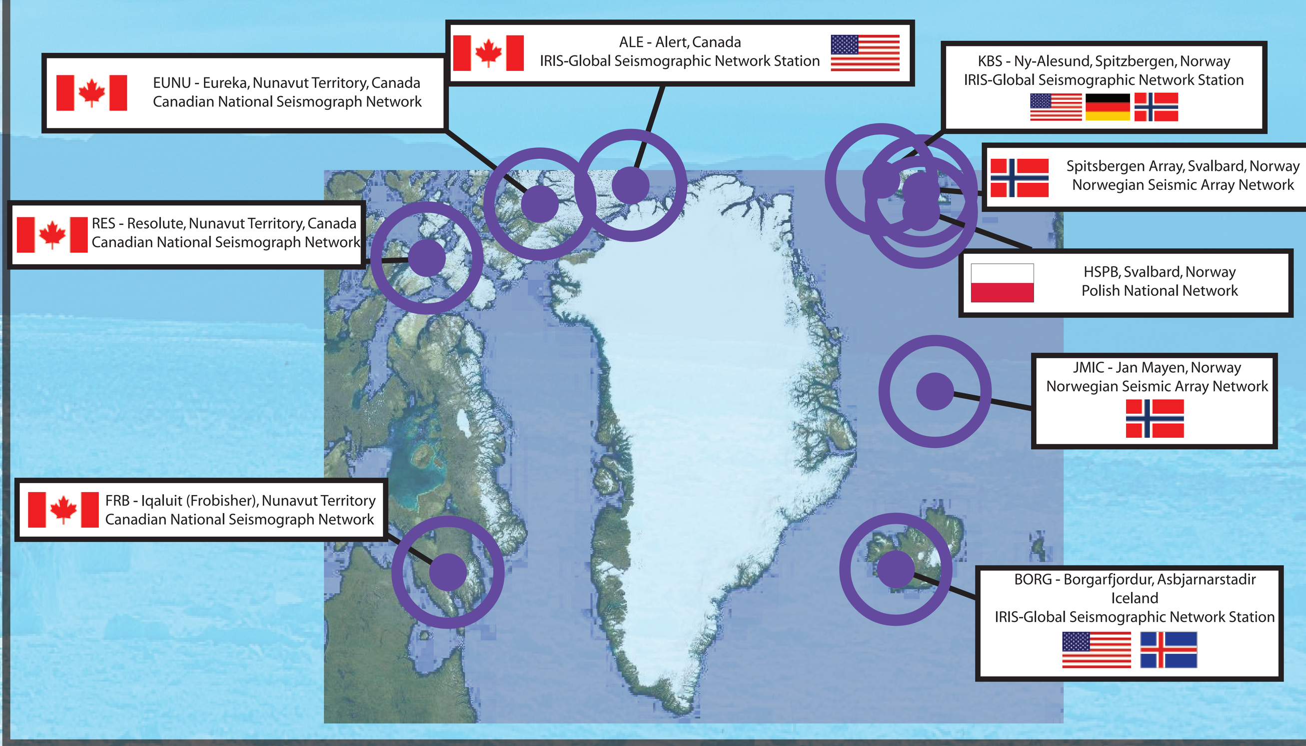
A second recently discovered class of seismic event on Greenland involves a sustained seismic-wave tremor-like radiation called 'glacial rumbling' (Rial et al., 2009), observed thus far only by a local seismic deployment near the Jakobshavn glacier. With extraordinarily long duration (10-40 minutes, see figure at right/bottom), glacial rumblings occur about once every two days. Likely triggered by calving, the rumblings propagate up the Jakobshavn glacier and end with a 'culminating phase.' Rial et al. (2009) suggest that the rumblings could be related to mechanisms of rapid ice-sheet disintegration. A few of the detected rumblings are coincident in time with the GSN detection of glacial earthquakes discussed above. Does this imply that glacial rumblings and glacial earthquakes share a common dynamics, such as mass wasting, sliding, ice flux, and terminal collapse in sequence, from calving to culmination? This hypothesis is difficult to assess from the observations at a single outlet glacier. If a characteristic mass-wasting process of thus far unknown glacier dynamics is responsible, we expect that GLISN will help discover its origin.



To date, resolution of the kinematics of glacial earthquakes remain crude. Broadband analysis of the events is difficult at teleseismic distances, owing to the weak high-frequency content of the signal. Uncertainties in the geographical locations of the events are of the order 20-30 km, but will be improved when data from GLISN are available.



Additional data contributions to GLISN from near-Greenland International seismic stations



Instrumentation

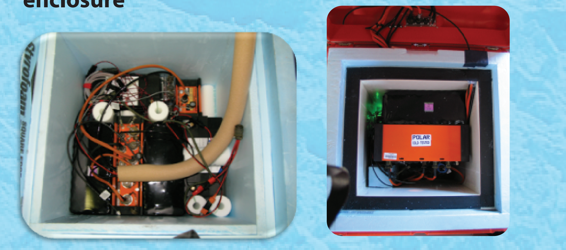
The goal of the GLISN instrumentation plan is to have standardized, state-of-the-art, broadband seismic stations with real time telemetry, robust operations to allow continuous data recovery throughout the year, deep archive on site to ensure a complete data set if there are telemetry gaps. The foundation for the GLISN station is the Quanterra Q330 6-channel, 24-bit data acquisition system and the Streckeisen STS-2 VBB triaxial seismometer. In areas where there will be temperatures below the operating floor of the STS-2 (borehole on ice plateau stations), the cold-rated Guralp CMG-3Tb borehole seismometer will be used to assure proper operations in the extreme cold.

Enclosures for the instrumentation will be designed to protect against the elements expected at the specific sites. At many locations, we will utilize existing buildings and infrastructure and designs will be simple packaging. In those locations where more extreme environmental protection is required (plateau sites, far-north locations, etc), we have a wealth of experience in designing extreme cold enclosures that have proven to be robust in the Antarctic extremes.

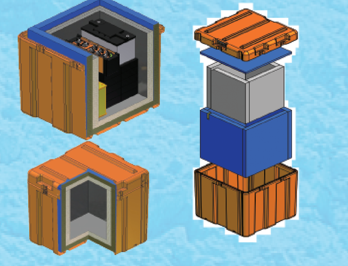
Local power will be used where available, but we will design automonous power systems for the more remote sites as appropriate. This will be primarily Solar systems with a rechargeable battery bank with a primary Lithium thionyl primary battery system to allow weeks to months of autonomy from the sun (depending on the latitude).

Telemetry, where available, will be provide with Telegreenland ADSL lines. The Greenlandic government has a program to provide all villages with ADSL data circuits. Therefore, most of the locations of the GLISN stations will have access to real time high-speed Internet connections. At those sites with no ADSL (7 sites), we are developing an Iridium RUDICS telemetry system, integrated with the Q330 DAS to allow real time data flow (developed under contract with Xeos Technologies, Halifax).

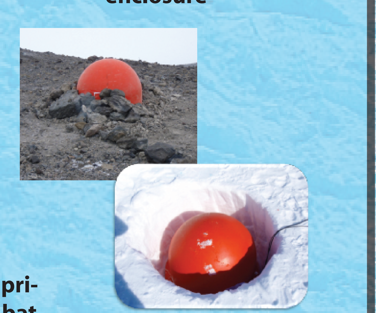
Q330, baler, and batteries in environmental enclosure



Multi-layer, vacuum panel extreme-cold enclosure

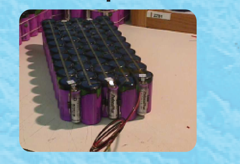


dual walled seismometer enclosure



Various solar panel mount designs for multiple site conditions and power requirements

Lithium Thionyl Chloride primary battery pack. D-cell batteries ganged to provide 190 A-h/pack



Xeos Iridium RUDICs system for real time telemetry: Currently used for SOH and data snippets, and command and control. RUDICS 2.4 Kb/s RT under development

Bibliography and Acknowledgements

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Photos

Background photo from Bennike et al, 2004. Other images are from GEUS, IRIS-PASSCAL, IRIS-GSN and ETH photo collections

DATA

All data from GLISN are free and open and can be accessed through the IRIS data management centers using the virtual network **_GLISN**