SIIOS in Alaska - Active Source Comparative Test for an Europa Lander Seismometer

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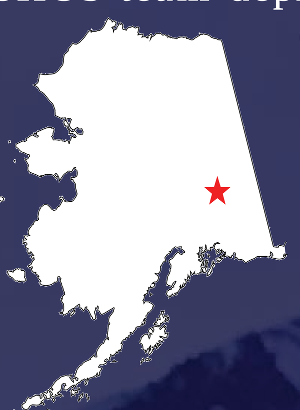
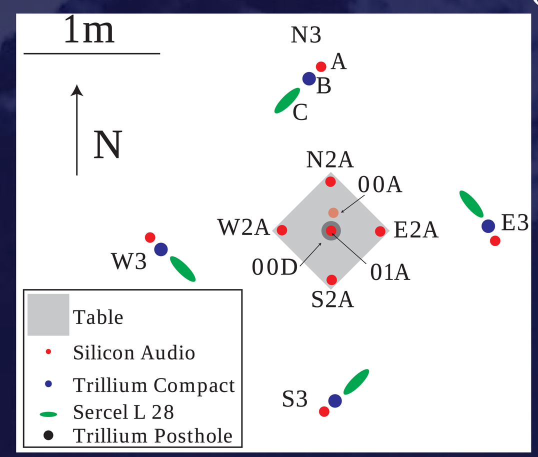
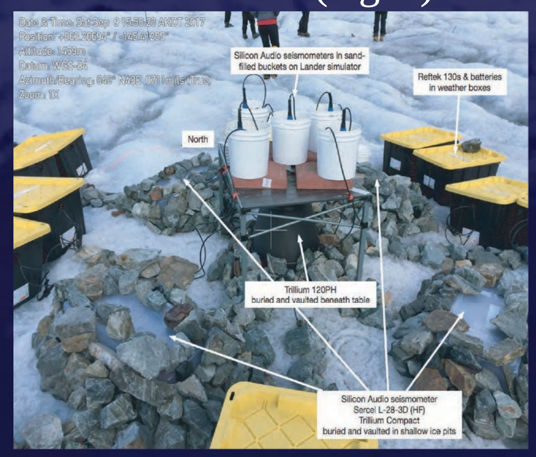
Introduction

Icy worlds such as Europa and Enceladus have thick icy shells covering subsurface oceans [1-3]. Due to the potential habitability of the subsurface ocean, Europa has become a target for a potential lander mission [4,5]. Since seismomology is the preeminate method for constraining the thickness of the icy shell, one component of the payload could be a seismometer . The seismometer would be tasked with constraining the seismicity of the ice shell and investigating the interior of Europa. The Seismometer to Investigate Ice and Ocean Structure (SIIOS) uses flight-ready instrumentation to develop analytical approaches for seismic studies of icy bodies. In September of 2017, the SIIOS team deployed the short aperature seismic array on Gulkana Glacier.



Location of SIIOS in Alaska (left) and on Gulkana (right)





Schematic of Array in map view (left) and photo of deployment (right)

Field Tests: Gulkana Glacier

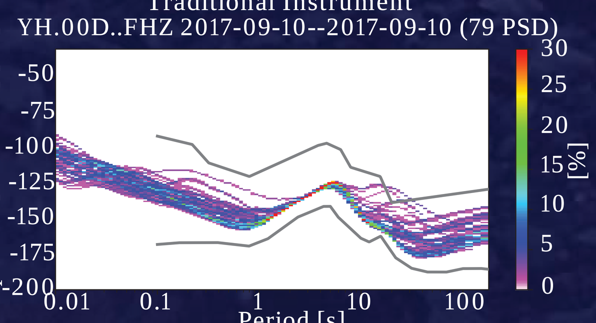
While no perfect terrestrial analog for Europa exists, Gulkana is used as an analog site because it is accessible, well-studied, and has thick ice with passive sources that mimic those on icy worlds. Gulkana is located about 200 km from Fairbanks Alaska, and is considered a "benchmark" glacier by the USGS [6]. Its ice can be hundreds of meters thick [7] and sources of seismicity include ice-quakes and water drainage events.

Seismic instruments were placed in a small array to mimic potential placements on a lander mission. We are particularly interested in comparing a flight-ready instrument (Silicon Audio, station 00A) with a more traditional seismometer (Trillium Posthole, 00D). The flight ready instrument is smaller, lighter, and requires less power, but needs to be tested in the field.

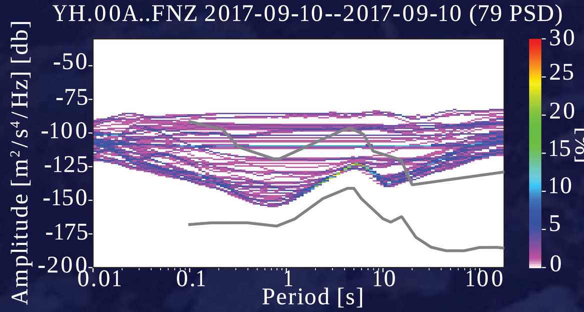
The signal response of the seismometers were determined using probability density functions (PDF) of power spectral densities (PSD) from a 24 hour period. Calculations used the ObsPy code, PSSD, [8] based on McNamara and Buland, 2004 [9]. The traditional seismometer had lower noise than the flight-ready instruments. The flight-ready instrument on the table was susceptible to interference from the table's resonance.

Instrument	Mass	Dimensions	Power Requirement
Silicon Audio (Flight Ready)	1 Kg	5'' X 3"	69 mW
Trillium Post Hole (Traditional)	16 Kg	5.63" X 17''	560 mW
Trillium Compact	3.3 Kg	3.90" X 4.65"	<180 mW
Sercel L 28's	2 Kg	3.2'' x 7.9"x2.3''	

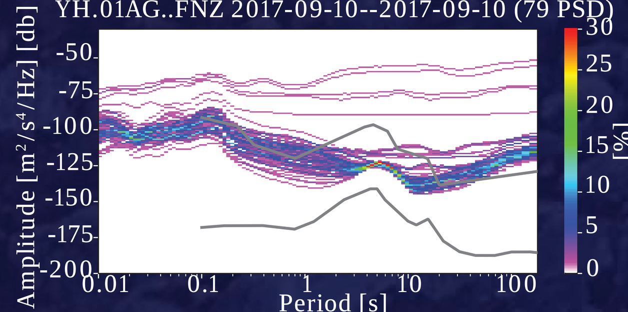
Traditional Instrument



Flight Ready Instrument



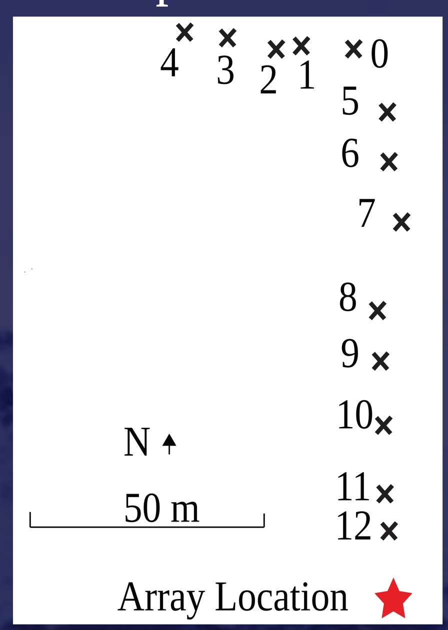
Flight Ready (On Table)



Active Source Experiment

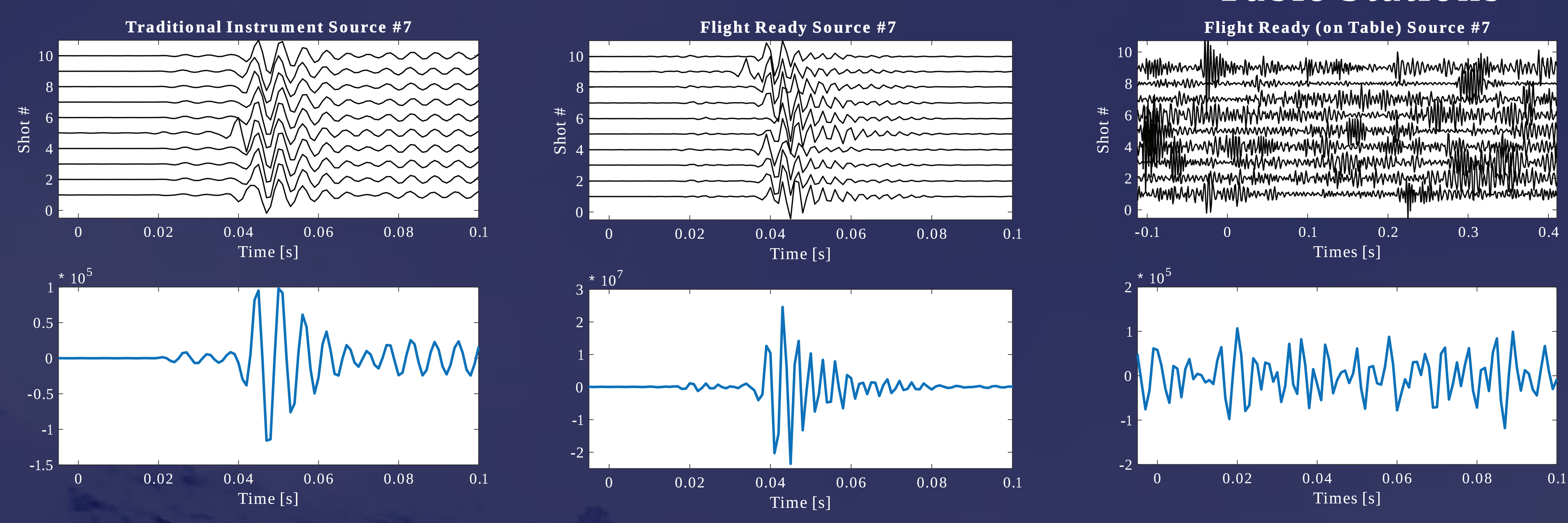
An active source experiment was conducted using a 20lb sledgehammer striking a 1/2-inch thick aluminium plate. The experiment was tested at tweleve different locations. At each location about ten hammer strikes were recorded and then stacked to enhance the signal-to-noise ratios. Stations on the ground had clearer signals than those on the table. A highpass filter of 90Hz was applied to the table data to remove the effects of the table's resonance. In some instances, the active sources could not be identified over the background noise.

Active Source Experiment



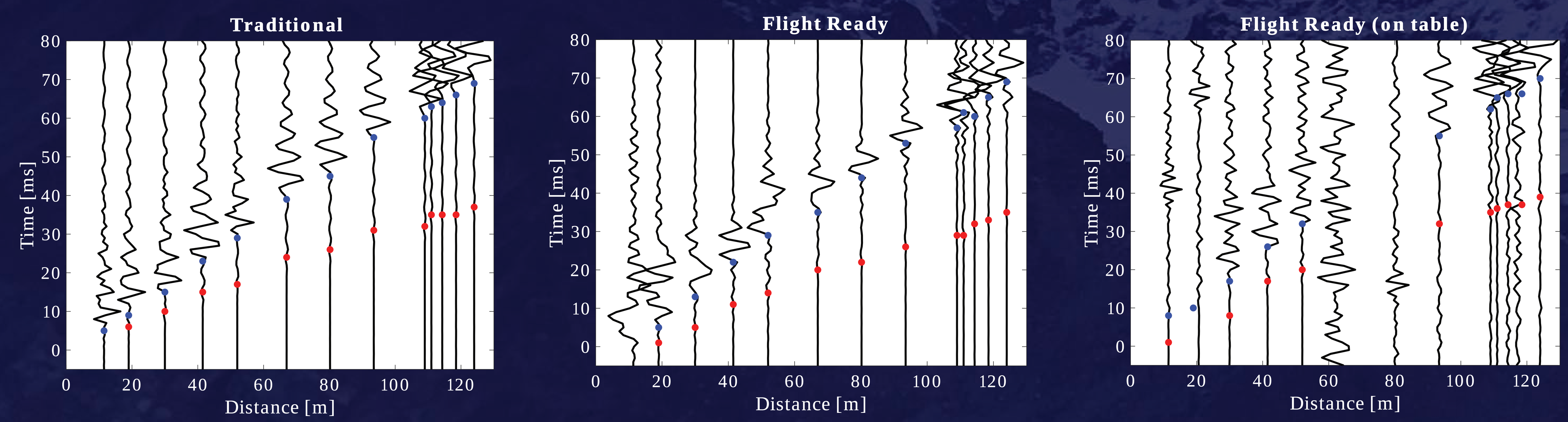
Ground Stations

Table Stations



Moveouts

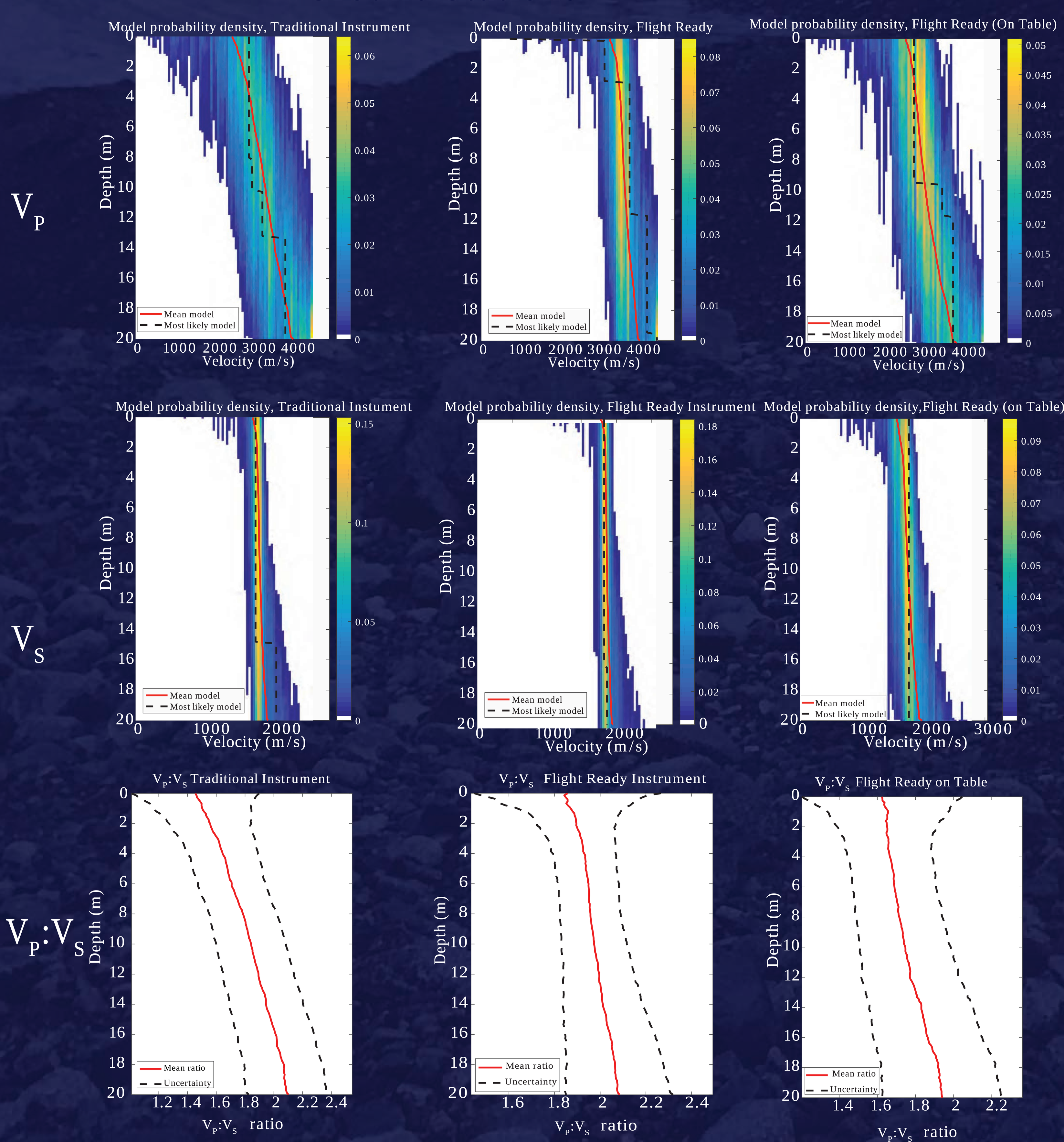
Moveouts of Compressional (P) (red) waves and Shear (S) (blue) waves for the traditional and flight-ready ground stations (00D, 00A) and one flight-ready table station (01AG). The P and S waves of nearby events could not be distinguished for the ground stations. The table-based station had more noise for events at greater distances which prevented identification of all P and S waves.



Structure Inversion Results

Ground Stations

Table Station



V_P

V_S

$V_P:V_S$

The arrival times of the P and S waves, and the source locations were the inputs for a Bayesian Inversion Model to constrain the P and S wave velocity structures. The Bayesian code uses a reversible-jump Markov Chain Monte-Carlo algorithm [10] to generate plausible velocity models. A transdimensional approach [11] alters the velocity and/or depth of each layer, as well as add/remove layers. A model is accepted or rejected based on its ability to fit the data given the number of layers [12].

The inversion results indicate the the P wave velocity slowly increases with depth but is typically around 3000-4000 m/s, consistent with known values for ice [13,14]. All three stations showed the S-wave velocity is nearly constant with depth at 2000 m/s, also consistent with known values.

Although the flight-ready instrument placed on the table could not identify all known active sources, there were enough data points to recover the glacier's structure.

Future Work

In addition to active sources, passive sources from large teleseismic events will be investigated. The Bayesian Inversion model can be re-run to determine the efficiacy of each instrument for constraining deeper structure.

We will also attempt to locate and identify local passive sources such as icequakes, rockfalls, and drainage events. Another Bayesian Invesion code will use P and S arrival times and amplitudes of the three components to locate known events.

In the Summer of 2018, SIIOS will be deployed in Greenland above a drained lake, another terrestrial analog for Europa. This experiment will continue to explore the capabilities of the flight-ready Silicon Audio seismometer.

Conclusions

Data from the active source experiment revealed that:

•The flight ready Silicon Audio produces comparable, high quality, data to traditional instrumentation.

• Instrumentation placed on a table (to simulate an in-vault placement) required a high pass filter to remove signals from the table. The arrival times could not always be identified due to higher background noise.

• The ground station instrumentation were able to constrain seismic velocities in ice with less uncertainty than instrumentation installed on the table.

• The internal structure of the ice was recoved by all three stations.

References

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