SIIOS IN ALASKA- ACTIVE SOURCE COMPARATIVE TEST FOR AN EUROPA LANDER SEISMOMETER. A. G. Marusiak[1], N. C. Schmerr[1], R. C. Weber[2], D. N. DellaGiustina[3], S. H. Bailey[3], V. J. Bray[3], E. C. Pettit[4], C. Carr[4], N. Wagner[4], P. Dahl[5], B. Avenson[6], M. Siegler[7], [1]University of Maryland, Department of Geology, College Park MD, marusiak@umd.edu [2]NASA Marshall Space Flight Center, Huntsville, AL,[3] University of Arizona, Lunar and Planetary Laboratory, Tucson, AZ ,[4]University of Alaska Fairbanks, Fairbanks, AL, [5]Applied Physics Laboratory University of Washington, Seattle Washington, [6]Silicon Audio, Austin, TX,[7] Planetary Science Institute, Tucson, AZ.

Introduction: The icy worlds, including Europa and Enceladus have thick ice shells covering subsurface oceans, that may be capable of harboring life [1-3]. Due to the potential habitability of its subsurface ocean, Europa has become a target for a potential lander mission [4, 5]. This mission will carry seismometers as part of its payload and they would be tasked with constraining sources of seismic activity in the ice shell, as well as determining the ice shell thickness and subsurface ocean depth. The Seismometer to Investigate Ice and Ocean Structure (SIIOS) uses field tests of flight-ready instruments to develop potential analytical approaches for seismic studies on icy bodies.

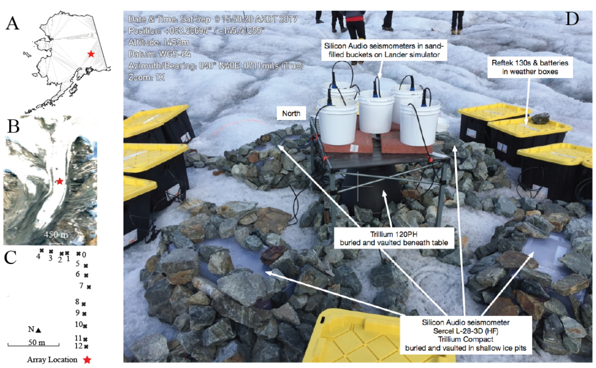

Figure 1. A) The red star indicates the location of Gulkana Glacier (63.16° N, 145.24° W). B) The red star indicates the location of the SIIOS array. C) The crosses represent the location of the active sources relative to the array (red star). D) SIIOS array facing North.

In September 2017, the SIIOS team deployed a short aperture seismic array on Gulkana Glacier in Alaska, (Fig. 1). Glacial ice thickness ranges from tens to hundreds of meters [6], much thinner than the Europan ice shell [7-10]. Despite the difference in ice thickness, Gulkana provides an opportunity to study the influence of diurnal signals on the motion of the glacier, and internal layering consisting of ice, water, and rock [11]. The SIIOS array of instruments was deployed both on the ice, and on top of the mock lander (Fig. 2), with the goal of examining the performance of a 1- 2 meter array of instruments both on the ground vs. on the lander platform.

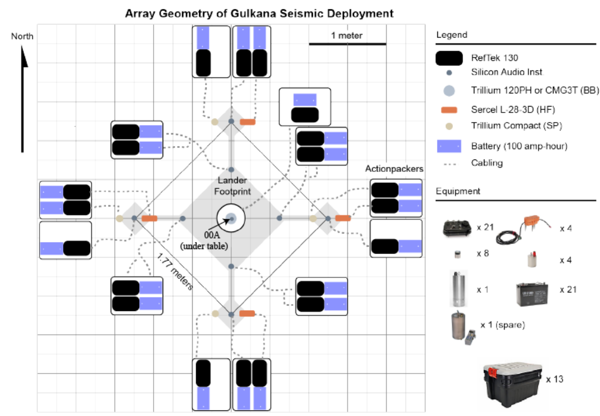

Figure 2. Seismic array configuration at Gulkana Glacier. A SIIOS and a Trillium 120 PH seismometer are placed under the table. Five SIIOS instruments are placed on the table. Each of the 4 legs of the table is instrumented with a Trillium Compact, L-23 geophone, and SIIOS seismometers.

Active Source Experiment: To study the array performance, we completed an active source experiment at Gulkana Glacier on Sept. 9th, 2017. A 20-lb sledge hammer striking a 1/2-inch thick aluminum plate was used to generate the seismic signals. The experiment was tested at twelve different locations (Fig. 1C). At each location 10 hammer strikes were repeated to provide data for stacking shots; timing was obtained with a GPS Synchronizer with 1-2 microsecond accuracy. Each shot from the same source was stacked using 1 second prior to time of the strike until 2 seconds after.

The stacks were arranged into moveout plots using the known time and distance of the active sources (Fig. 3). We determined the first breaking compressional (P) and shear (S) wave arrival times and calculated a simple linear fit to determine the average P and S velocities (Fig. 4). Using the data from the Silicon Audio seismometer located on the ground, at the center of the array (00A), the P-wave velocity (V_p) was 3600 ± 80 m/s and the S-wave velocity (V_s) was 1800 ± 30 m/s. The V_p/V_s ratio is about 2.0 ± 0.4 which is consistent with seismic velocities of ice [12, 13]. However, this fit does take into account vertical layering within the ice.

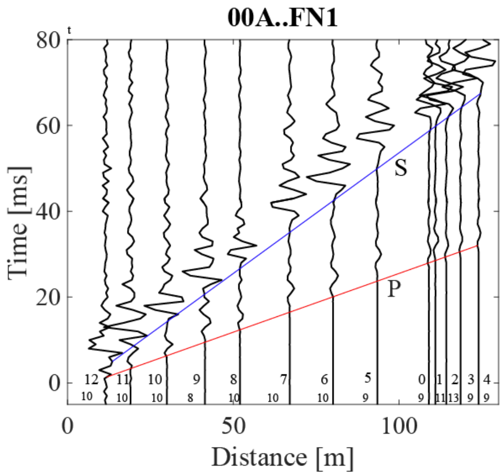

Figure 3. Example moveout from the active sources recorded at Station 00A. The larger, top number indicates the source, and the smaller, bottom number are the number of events used to create the final stack.

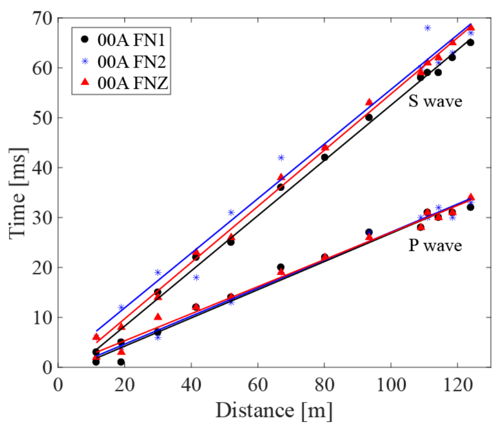

Figure 4. First breaks for the S- and P-wave arrivals for station 00A at the array center.

To determine the one-dimensional layering structure of the ice, an inversion code was applied to the P-wave arrivals. This code uses Bayesian Inversion methods [14-16] to determine the P-wave velocity as a function of depth (Fig. 5). The inversion results show a layered velocity structure, with P-wave velocity increasing from about 2500 to 4100 m/s with depth. For the uppermost 10 m, where the P waves travel, the velocity is about 3600 m/s, consistent with our linear fit.

Future Work: We will continue picking S- and P-arrival times and the resulting one-dimensional inversions for all stations. This will allow us to compare the ability of each station to constrain the velocity structure of the glacier. We will also investigate any reflections to determine if the depth to the bedrock can be constrained. Another test of the seismometers efficacy will be a location algorithm that will quantify the seismometers' abilities to locate known events. Overall, the results will quantify each station's ability to locate seismic events and determine ice structure. Our results can be used to determine which instruments and placements are viable to future missions to icy worlds.

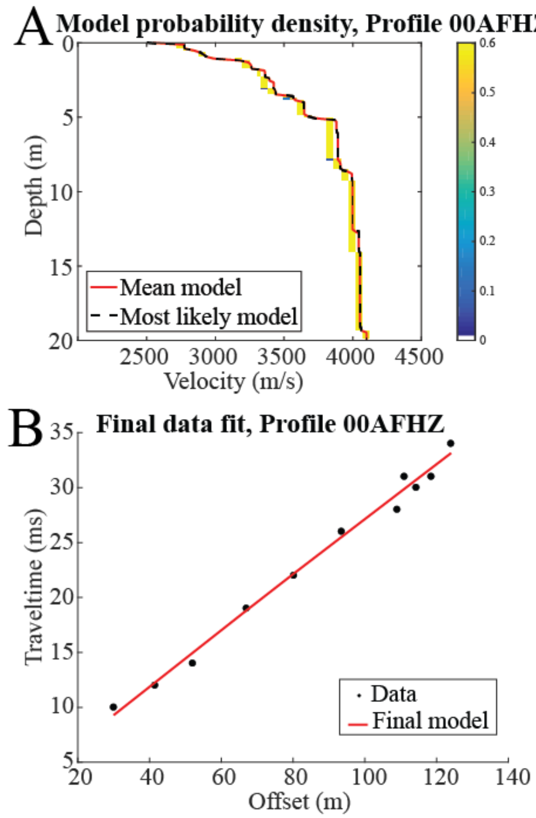

Figure 5. A) Model probabilities for velocity as a function of depth. B) Final model fit with data.

Acknowledgements: This work was supported by NASA PSTAR Grant #80NSSC17K0229. Field work was conducted with the help of Emilie Sinkler and Susan Detweiler and the SIIOS team.

References:

[1] Kargel et al., (2000) *Icarus, 148,* 226-265. [2] Reynolds et al., (1983) *Icarus, 56,* 245-254. [3] Marion et al. (2003) *Astrobiology, 3,* 785-811. [4] Hand et al. (2017) *Report of the Europa Science Definition Team*. [5] Pappalardo et al., (2013) *Astrobiology*, *13.* [6] O'Neel et al., (2014) *Climatic Change, 123* ,329-341. [7] Nimmo et al., (2007) *Icarus, 191,* 183-192, [8] Wahr et al., (2006) *JGR Planets*, *111.* [9] Nimmo et al., (2003) *GRL*, *30.* [10] Anderson et al., (1998) *Science, 281,* 2019-2022. [11] Josberger et al., (2007), *Annals of Glaciology, 46,* 291-296. [12] Petrenko and Whitworth, (1999) *Physics of Ice, OUP Oxford.* [13] Podolskiy et al., (2016) *Review of Geophysics, 54,* 708-78. [14] Bodin and Sambridge (2009) *GJI, 178,* 1411-1436. [15] Green (1995) *Biometrika, 82* 711-732. [16] Metropolis et al., (1953) *Journal of Chemical Physics, 21,* 1087-1092.