SEISMIC INVESTIGATION OF ANTARCTIC ICE-SHELF RIFTS AS AN ANALOG FOR THE FRACTURED SHELLS OF ICY-OCEAN WORLDS. K. G. Olsen[1,2], N. C. Schmerr[3], S. Light[3], T. A. Hurford[1], K. M. Brunt[1,3], [1]NASA Goddard Space Flight Center, Greenbelt, MD (kira.olsen@nasa.gov), [2]USRA, Columbia, MD, [3]University of Maryland, College Park, MD.

Introduction: Antarctica's ice shelves are the closest terrestrial analog to the shells of icy-ocean worlds (Figure 1). These ice shelves form the floating margins of the Antarctic ice sheet, and can extend hundreds of kilometers from the ice sheet's grounding line, forming coherent bodies of relatively thick (100's of m) ice (Figure 1b). Like the shells of icy moons, Antarctica's ice shelves are subject to tidal stresses, as daily ocean tides circulate through the sub-ice-shelf cavity and flex the ice shelf. This makes them a valuable analog environment to study in order to advance our understanding of the structure, deformation, and evolution of icy-ocean worlds.

One of the most intriguing features of the shells of icy moons, like Europa and Enceladus, is the complex network of fractures observed within the icy shell [1, 2], which may provide conduits to the subsurface, and are likely the sources of significant seismic activity [3]. Terrestrial ice shelves also contain major fractures, or rifts, which can extend to lengths of over 100 km. In advance of future lander-based data collection on icy-ocean worlds, on-ice observations along Antarctic ice-shelf rifts present an opportunity for studying deformation and seismicity of floating ice subject to cyclic tidal stresses.

We conduct the first seismic investigation of a terrestrial ice shelf as an analog for an icy world, focusing on a pair of rifts within the interior of Antarctica's Ross Ice Shelf (RIS), the largest ice shelf in the world. Future seismic study of icy-ocean worlds will be the primary way of placing observational constraints on interior structure of these bodies [4], and will be part of the upcoming Dragonfly mission to Titan. Understanding the specific characteristics of ice-generated seismicity is therefore critical in advance of icy-world missions, as is the development of methodologies to effectively analyze returned datasets.

We analyze a two-year catalog of seismic data collected by on-ice seismographs deployed on the flanks of two icy rifts on the RIS. We investigate the relationship between tidal stresses and ice seismicity recorded at the RIS rifts, and demonstrate the presence of abundant seismic activity, which is modulated by both the amplitude and rate of tensile stress applied across a rift [5]. These findings suggest that a single seismic station located within ~5 km of a rift on an icy world will likely record significant seismic activity, at magnitudes at least as small as icequakes recorded at RIS rifts (M_L -3). The RIS rifts we investigate have lengths and widths similar to Enceladus' Tiger Stripe Fractures [6]. We combine observational constraints from the Antarctic rifts with calculated values of stresses across the Tiger Stripe Fractures to project the timing and location of seismic activity along these fractures throughout Enceladus' orbit.

We also explore the ability of rift icequakes to constrain layer thicknesses beneath a seismic station. We test a methodology for stacking large numbers of rift icequakes to resolve seismic reflections generated at the ice-ocean and ocean-crust interfaces and recorded in the body-wave coda. The RIS offers an ideal location to develop and test this methodology on Earth ahead of implementation on icy-world missions.

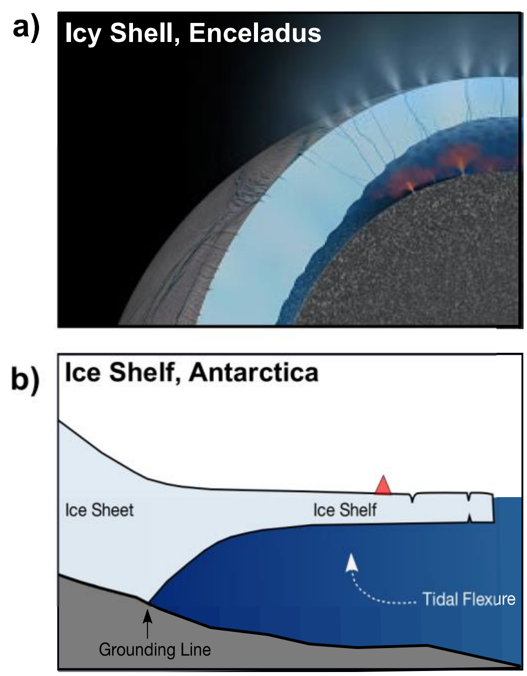

Figure 1. a) Artist's rendition of interior structure of Enceladus, showing (top to bottom) ice, water, rocky core. Image credit NASA. b) Diagram (not to scale) of ice-shelf geometry on Earth showing (top to bottom) ice, water, rocky crust. Red triangle represents an on-ice seismometer such as those used in this study.

References: [1] Greenberg et al. (1998) *Icarus, 135,* 64-78. [2] Porco et al. (2006) *Science, 311,* 1393-1401. [3] Hurford et al. (2020) *Icarus, 338*. [4] Vance et al. (2018) *Astrobiology, 18,* 37-53. [5] Olsen et al. (2021) *JGR: Planets, **in review***. [6] Crow-Willard & Pappalardo (2015) *JGR: Planets, 120,* 928-950.