Constraining the thickness of Europa's ice shell with observations of Rayleigh and flexural wave dispersion: Insights from synthetic waveform modeling

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ABSTRACT:
On Earth, measuring the dispersion of seismic surface waves has proven to be one of the most powerful means of understanding the structure of the crust and uppermost mantle. Surface wave dispersion studies take advantage of the depth dependent sensitivity of surface wave group and/or phase velocity, and can naturally be applied to imaging the interiors of other planetary bodies. On Europa, surface waves are expected to be strongly dispersive due to the presence of a global ocean layer below the outer ice shell, which introduces long period vertically polarized surface waves known as flexural waves[1,2]. Here, we explore the possibility that a single seismometer on Europa could constrain the thickness of the outer ice shell using measurements of Rayleigh and flexural wave dispersion from natural ice fracturing events. We simulate seismic wave propagation through structural models of Europa's interior (Fig 1A) using the spectral element method (SEM) code AxiSEM[3] . We then measure the surface wave group velocity dispersion of SEM synthetics at periods between 10 – 250 s and invert for the ice shell structure using a Markov chain Monte Carlo approach. We find that for thin ice shells (less than about 10 km), group velocity inversions accurately recover ice shell thickness. For thicker shells, group velocity at relatively short period (T < 25 s) is difficult to measure due to the interference of fundamental and higher order mode surface waves (Fig 1B), which biases inferences of ice shell thickness. However, group velocity measurements of long period flexural waves may still be useful for recovering ice shell thickness, suggesting that broadband sensitivity should be a requirement for a future seismic instrument sent to Europa.

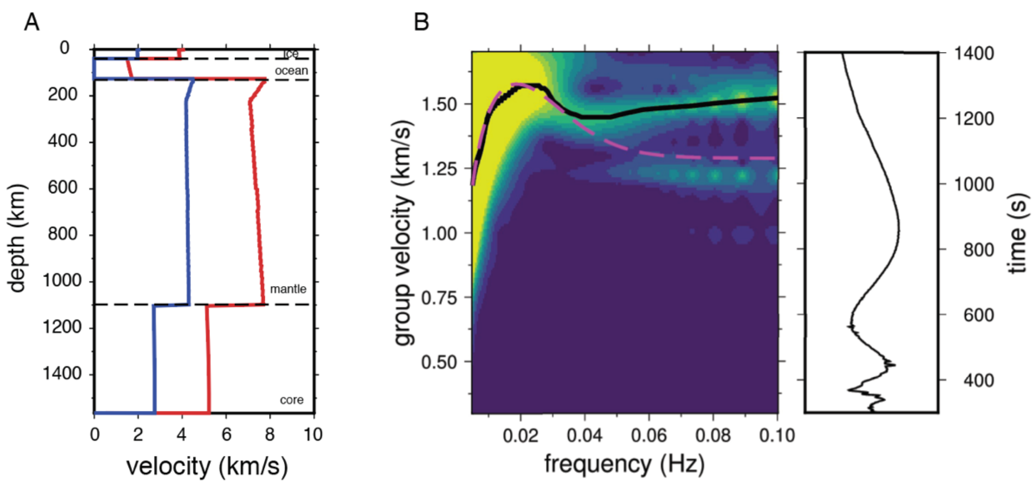

Figure 1. (A) Structural model of Europa's interior with a 20 km thick outer ice shell. V_P is shown in red and V_S is shown in blue. (B) The left panel shows a group velocity dispersion plot of an SEM synthetic that was computed using a 20 km thick ice shell model and an event distance of 20 degrees. The black and pink dashed lines show the measured group velocity and predicted fundamental mode group velocity, respectively. The right panel shows the SEM synthetic that was used in the dispersion analysis.

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