EUROPA'S LIKELY ICY THICKNESS: PULLING ICE SHELLS OUT OF A HAT. S. M. Howell[1], M. Smith[1], R. Otis[1], [1]NASA Jet Propulsion Laboratory, California Institute of Technology (samuel.m.howell@jpl.nasa.gov)

Introduction: Understanding ice shell thickness and the role of geologic mixing is of critical importance to the habitability of Europa. There, radiation processing at the surface is expected to produce oxidants [1], supported by remote observations [2], and water-rock reactions at the seafloor are expected to be reducing [1], as is the case on Earth. If geologic activity within the ice shell allows the interaction of oxidants and reductants within the ice, ocean, or at the ice-ocean interface, a sustained reduction-oxidation (redox) potential could allow the emergence or continuation of past or present life.

However, the thickness of the ice shell and therefore the potential for geologic material exchange are unknown [3,4], with thickness predictions ranging three orders of magnitude from the hundreds of meters to the full H_2O layer thickness of ~130 km [e.g. 3].

While the thickness of Europa's ice shell is underconstrained by the current knowledge of the body, it is not *unconstrained*. That is, while there are many possible ice shell thicknesses, not all ice shell thicknesses are equally plausible. In this study, we survey the current knowledge of Europa, and quantify distributions in the unknowns that control ice shell thickness. We then create a Monte Carlo simulation of 10^7 plausible Europa's with ice shells in thermodynamic equilibrium, and condition the result into a probability distribution for ice shell thickness.

Monte Carlo Method: We begin by assuming an ice shell in thermodynamic equilibrium, always including an upper conductive layer and sometimes including an isothermal convecting ductile layer. We assume the heat flux out of the icy lithosphere radiated to space is equal to the heat flux into the base of the lithosphere from the silicate interior plus the internal heat generated by tidal dissipation within a ductile convecting asthenosphere, integrated over the depth of the asthenosphere [e.g. 5].

The first step in our Monte Carlo process is to sample an interior heat flux at random from a distribution. Because the uncertainty around the CBE silicate heat flux is logarithmic and not linear, we select a log-normal distribution. Similarly, we select a log-normal distribution to describe the melting temperature viscosity of the convecting interior, which directly controls the amount of tidal heat that is dissipated.

Next, we bound the thickness of the conductive layer. We determine a maximum thickness by sampling the distribution for silicate heat flux, as well as considering the critical thickness at which a conductive layer would begin convecting. We estimate a minimum thickness by sampling the interior viscosity and considering the maximum amount of tidal heat that could be generated in a convecting layer equal to the full H_2O thickness.

We then select a conductive thickness from the allowed range using a uniform distribution, and calculate the corresponding convective thickness.

Results and Perspectives: The result for a CBE Europa is shown in Fig. 1. Additionally, we explore the sensitivities of the result to our assumptions for CBE values and distributions, as well as to future knowledge of Europa. We predict a most-likely thickness of 20.0 km and a median likely thickness of 23.5 km.

We find that it is difficult to shift the result toward lower ice shell thicknesses because the heat required to thin an ice shell increases to infinity as the thickness decreases to zero. Indeed, the peak in likely thickness shifts little when our assumptions are revised or new knowledge is assumed. Instead, new results from the planned NASA Europa Clipper and ESA JUICE missions are likely to change the extent and shape of the tails of this distribution.

The probability distribution of Europa's ice shell thickness will better inform the scientific approach and technical design for future concepts to penetrate the ice shell and access the interior ocean.

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References:

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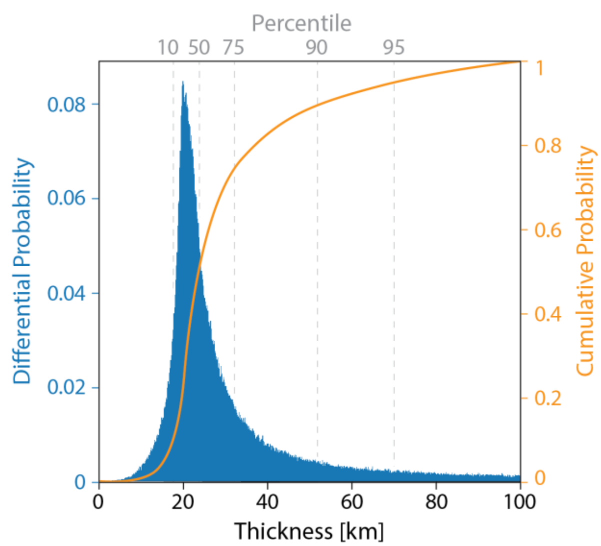

Figure 1 | Current best estimate probability distribution for Europa's ice shell thickness taken from 10^7 simulations.