PRELIMINARY RESULTS FROM SIMULATIONS MAPPING MOBILE LID CONVECTIVE REGIME IN ICY SHELLS. C. M. Cooper[1], Simon A. Kattenhorn[2] , Louise M. Prockter[3], G. Wesley Patterson[4], Geoffrey C. Collins[5], and Alyssa R. Rhoden[6], [1]Washington State University, Pullman WA, cmcooper@wsu.edu; [2]University of Alaska, Anchorage AK; [3]Lunar and Planetary Institute, Houston TX; [4]Johns Hopkins University Applied Physics Laboratory, Laurel MD; [5]Wheaton College, Norton MA; [6]Arizona State University, Tempe AZ.

Introduction: Recent observational evidence points to the existence of plate tectonics on Europa [1]. To date, this is only other body besides Earth to demonstrate active plate tectonics. The evolution of a planetary body's interior from its hot origins to the present day state dictates surfaces processes ranging from habitability to plate tectonics and provides the energy for surface processes such as volcanism, earthquakes, rifting and mountain building. These processes directly determine the presence and composition of a planet's atmosphere and, in the Earth's case, ocean, as well as global-scale climate. While the initial study laid out the observational evidence and conceptual framework for how plate tectonics might operate on Europa, the theoretical foundation for such behavior still needs to be fully developed. We present initial work on the viability of plate tectonics occurring on Europa applying the criteria outlined in prior studies on Earth and other terrestrial bodies [2] but scaled to Europa conditions and the material properties of ice.

Plate tectonics is one mode of the surface manifestation of convection within a planet's interior. In order for it to occur, the surface must be able to behave as a collection of coherent, rigid plates that can return into the interior along subduction zones. This behavior is dependent on the material properties of the surface as well as the strength of the convection that drives the motion. The criteria for plate tectonics has been explored in prior studies for terrestrial bodies such as Earth, Mars and Venus (e.g., [2]), but has been limited for icy moons (e.g., [3]). Convection of a planetary body's interior does not always lead to plate tectonics on the surface. Rather, several modes of surface expression can occur including stagnant lid convection (with no discernible surface expression), episodic overturn (periods of quiescence followed by full overturn of the surface) or mobile-lid convection (the surface continuously deforming along plate boundaries allowing it to remain active and mobile). There is evidence for each of these modes of convection within our own solar system operating either currently or in the past. For example, given the relatively young age of craters on the surface of Venus, it is likely that Venus has undergone at least one episodic overturn within its history. Mars, on the other hand, has a history that suggests more of a stagnant lid convection, but with the potential of plate tectonics operating at some point in the past. Mobile-lid convection is somewhat akin to plate tectonics, which has been in operation on the Earth for, at least, the past three billions years and now appears to be active and present on Europa [1]. The transitions between these domains have been mapped out for terrestrial bodies and depend on the tradeoffs between multiple parameters such as the strength, thickness and buoyancy of the "plate" material, the strength of convection, as well as the size of the planetary body [2],[4]. Similar studies have been done for convection within icy moons, but they have focused on the tradeoff only between yield stress and shell thickness[5] or used velocity boundary conditions on the side walls that may geometically impose deformation to occur. We have found that using the free slip velocity boundary on the side walls within the simulation rather than a periodic or wrap around velocity boundary condition strongly influences the location and presence of plastic deformation. This may shift some of the transitions between convective regimes observed by [6].

Methods/Preliminary Results: We will present preliminary results from 2D simulations that couple ice convection with surface deformation. Given the uncertainty of the characteristics of the ice shell (e.g., rheology, thickness, etc.), we have mapped out the range of parameters that allow for plate tectonics to occur on Europa. Surface velocity, average internal temperature, and surface heat flux will be used to delineate between the different convective regimes. For example, scenarios that produce stagnant lid convection are defined by low to negligible lateral surface velocities, high average internal temperatures and low surface heat flux. Mobile-lid regimes are defined by continual surface lateral velocity values (often with edges of plates marked by a significant change in velocity), average internal temperatures and higher surface heat flux values. Episodic convection regimes will cycle between the characteristics demonstrative of stagnant lid and mobile-lid convection. For more classic plate tectonic behavior, the lateral velocity across the surface of the simulation will look like a step function with constant velocity values over a single "plate".

We also link surface observables to the models by comparing the relative length scale of the plates within the simulations to the observed regions on Europa. The simulations also allow us to constrain the strength of the material of the shell required to localize deformation. These values will then be compared against other studies that have estimated the strength of the

shell based on observed deformation. All simulations were run using the numerical code Underworld, which has been used primarily for mantle convection studies, but can be modified to simulate convection within an ice shell

This work not only provides new insight into the evolution of the icy satellite, but also extends our knowledge of how plate tectonics operates. Our knowledge of plate tectonics has been framed by the premise that there was only once place observed to currently demonstrate the behavior - the Earth. As such, much of the discussion has focused on Earth-centric constraints or pitted the Earth against other terrestrial planets such as Venus and Mars who have very different tectonic regimes. Opening up the conversation to another "successful" location for this type of behavior will broaden our insight into the behavior and expand our ability to understand when plate tectonics began on Earth and its connections to the atmosphere, oceans and biosphere.

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