OPENING THE ICE SHELL: THE ROLE OF SUBSURFACE LAKES AND BASAL FRACTURES IN ICE SHELL-OCEAN INTERACTIONS C. C. Walker[1] and B. E. Schmidt[1], [1]Georgia Institute of Technology, 311 Ferst Drive, Atlanta, GA 30332 (cat.walker@eas.gatech.edu; britneys@eas.gatech.edu).

Introduction: The observation of water plumes from Enceladus' south pole [e.g., 1] and the recent discovery of putative water plumes at Europa [2] hint at two ideas; first, that there exist buried reservoirs of water in local or global form beneath some depth of ice, and second, that there exist deep, open fractures that have penetrated through that depth of ice. The eruptions have been linked to tensile forces at the surface stemming from tidal effects that control the opening of surface fractures [3, 4, 5]. With an ~100 km deep ocean atop a silicate interior [e.g., 6, 7, 8], Europa is an intriguing target for astrobiological study. While debate continues as to how we might detect "life" in the plumes as a representative of the ocean below, it remains to be shown how exactly ocean water from the subsurface ocean could even reach the surface. While seemingly simple, the study of fracture penetration is highly dependent on ice shell, surface and interior structure, defect and stress distribution, and ice properties in general (e.g., strength, cohesion). Tidally-induced stresses for both Europa and Enceladus, specifically, have been investigated in terms of their ability to open rifts to sufficient width in order to allow for subsurface water escape, but these calculations often over-simplify the problem of fracture propagation to achieve results. Hence, while obvious from observations that water is indeed escaping somehow, it remains unclear as to how existing stresses are enough to open fractures up to the depths estimated. Such ice shell-ocean interaction must occur over geologically short timescales in order for Europa to be habitable. Thus, areas of active geology have strong implications for the recycling of the ice shell, and the habitability of the ice shell itself.

Propagation of basal fractures and process timescale: For subsurface water to erupt onto the surface, a surface- or base-initiated fracture must vertically propagate and penetrate the entire shell thickness to create a channel from the liquid reservoir below to the surface. We consider two processes in the formation of terrains observed on Europa: the propagation of fracture systems and their coalescence.

Initiation and penetration of a surface crevasse is driven by stress at/near the surface. At depth, these forces are opposed by the compressive overburden pressure from the weight of the ice. Tensile stresses at the surface and within the brittle surface layer must be great enough to overcome the compressive stress at the base to allow for full fracture penetration of the shell. Aside from the whole problem of basal fracture propagation as opposed to surface fractures, a factor that is often ignored in fracture studies is the role of highly-fractured materials in fracture propagation. The stress-shadow effect and fracture interaction, phenomena observed both in Earth's ice shelves and in other media, such as wave-breaker walls, airplane propellers, Arctic permafrost, mud flats in Death Valley, and others [9], make a significant difference in fracture penetration depth of both surface and basal cracks [10]. Additionally, even on Earth [11] showed that it is unlikely that surface fractures alone could lead to fully ice-penetrating features, and we find the same result here. To address the problem of crck penetration to a subsurface reservoir, we model the propagation of cracks that initiate at the bottom of the ice shell, and illustrate the parameters that might affect their propagation height towards the surface. We model water pressure within the crack dependent upon reservoir size and depth below the surface. The work of [12 and 13] showed that it is likely that Europa's chaos terrains formed after the surface above a perched water pocket flexed and allowed cracks to initiate at the base of the ice lid. Additionally, we present a characteristic timescale of this process based on local energy balance [14]. We will discuss the implications of this process timescale on the likelihood that the observed water plumes represent a water body that interacts with the outer ice shell on an astrobiologically-relevant timescale.

References: [1] Porco, C. C. et al. (2006) *Science, 311,* 1393–1401. [2] Roth, L. et al. (2013) *Science, 343*, 171-174. [3] Hurford, T.A. et al. (2007) *Nature, 447*, 292-294. [4] Smith-Konter, B. and Pappalardo, R.T. (2008) *Icarus, 198*, 435-451. [5] Olgin, J.G., et al. (2011) *GRL, 380*, L02201. [6] Khurana, K. K., et al. (1999) *Nature, 395*, 777-780. [7] Kivelson, M. G., et al. (1999) *JGR, 104*, 4609-4625. [8] Zimmer, C., Khurana, K. K. and Kivelson, M. G. (2000) *Icarus, 147*, 329-347. [9] Parker, A.P. (1998) Army Armament Research Con-tractor Report, ARCCB-CR-98009. [10] Walker, C. C. and J. N. Bassis (2013), *LPSC 2013 Abstracts*, 2139. [11] Bassis, J. N. and Walker, C. C. (2011), *Proc. Royal Soc. A.,* 468, 913–931. [12] Schmidt, B. E. et al. (2011), *Nature, 479*, 502-505. [13] Walker, C. C. and B. E Schmidt (2015), *GRL*, in press. [14] Grady, D. E. and Kipp, M. E. (1995) *Int. J. Sol. and Struct., 32*, 2779-2791.