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The Search for a Habitable Europa: Radar, Water and an Active Ice Shell

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Abstract

Future Europa exploration will seek to characterize the distribution of shallow subsurface water as well as to understand the formation of surface features through dynamic ice-shell processes. Radar sounding will be a critical tool for detecting these features, and should be of primary interest to the astrobiology community for understanding how and where life might arise on Europa. To develop successful instrumentation and data interpretation techniques for exploring Europa, we must leverage analogous terrestrial environments and processes. Airborne ice penetrating radar is now a mature tool in terrestrial studies of Earth's ice sheets, and orbital examples have been successful at the Moon and Mars.

1. Introduction

It is a distinct possibility that water within or just below the ice on Europa has played a role in forming some of its dynamic terrain. Observations of some of Europa's geology suggests that water and brines existed in the near subsurface and enabled the formation of surface features, and recent work indicates the surface is active [1]. Here we describe how three ice environments may be linked to the habitability and activity on Europa, and show how they can be detected directly using radar.

2. Sounding Terrestrial Analogues

The University of Texas High Capability Airborne Radar Sounder (HiCARS) developed to study Antarctic ice sheet dynamics has been configured to test observation scenarios for Europa. We discuss recent results from the dual-frequency 2.5 & 60 MHz HiCARS systems over analogous Greenland and Antarctic floating ice analogs as a demonstration of the potential of radar sounding to understand Europa's subsurface.

2.1 Water Lenses (see Figure 1)

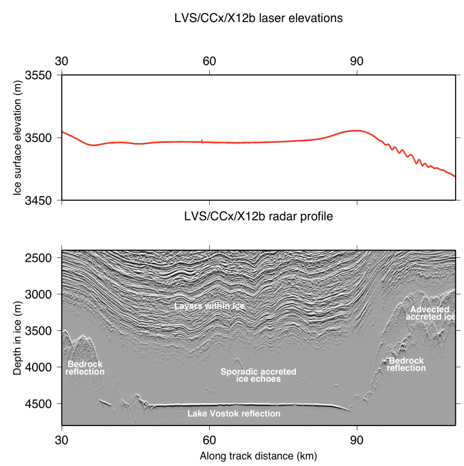

Figure 1: Example of coupled altimetry/radar sounding observations of a terrestrial subglacial water lens; Lake Vostok, Antarctica. Airborne laser derived surface elevations are compared to a depth corrected, differentiated radargram of Lake Vostok. Ice flow is from left to right. The deformation of the ice water interface in response to the changes in surface slope are visible at 90 km. Accreted basal ice is also observed freezing to the downslope, shallower edge of the lake. Sounding 4.5 km of ice is demonstrated-equivalent to a pressure depth of 27 km on Europa [3].

A reanalysis of Galileo spacecraft images of Europa indicates surface collapse is occurring above large liquid water melt lenses driven by heat rising through the ice from a subsurface ocean [1]. This analysis also indicates that *water survives today* within 3 km of the surface, and in some regions water volumes are comparable to Lake Superior. This analysis implies liquid water formed—and is still forming—the chaos terrain that covers ~50% of Europa's surface [2]. Similar water lenses – subglacial lakes –

shaped by analogous surface-driven hydraulic gradients are routinely explored by radar on Earth.

2.2 Water-filled Fractures (see Figure 2)

Ridges and fractures dominate Europa's surface. Whether they form by injection of water, or water is formed within them by frictional heat, it will be vital to measure the distribution of fluid in fractures as a test of their formation and activity. Rupturing water-filled fractures above melt lenses may be indicative of active chaos formation [1]. In addition, fractures are likely locations for chemical gradients that life can exploit, so they are potential habitats.

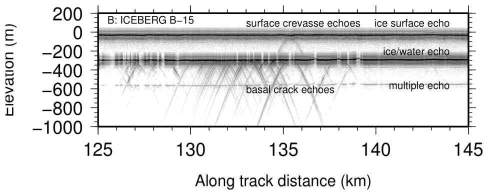

Figure 2: HiCARS radargram of Antarctic iceberg B15 [4]. In this figure, echoes from cracks both at the surface and at the base of the iceberg can be seen. The strong (thick black line) return of the ice-ocean interface is detected, as is brine entering the ice at a near-surface crack tip. As brine conduits and pockets may be sources of energy for biology as well as for communication between the surface and interior, detecting this water is of particular interest regardless of the shell thickness.

2.3 Brine Rich Ice (see Figure 3)

Brine rich ice may exist at the base of the ice shell, but also by brine infiltration from basal cracks or through shallow ice above melt lenses [1]. While bioavailable carbon may be limited on Europa, organic compound and nutrient concentrations may be amplified within the ice by 2 or 3 orders of magnitude, given the right temperature and salinity conditions [2]. The underside of sea ice for example, represents the most concentrated zone of life along a column thousands of meters in length, from the atmosphere to the sea floor [2]. Basal melt occurring below terrestrial floating ice is directly analogous to processes that may operate on Europa if the shell is "thin," and will be similar to processes occurring instead within the ice sheet in the case of a thicker, multi-layer ice sheet where enriched brines may remain liquid within the shell. Accreting marine ice rich in water and impurities may occur in both a thick- and thin-shelled Europa, and is indicative of an ice-ocean interface even if the return from the ocean cannot be detected. Such ice will have increased absorption, similar to terrestrial brine-laden layers.

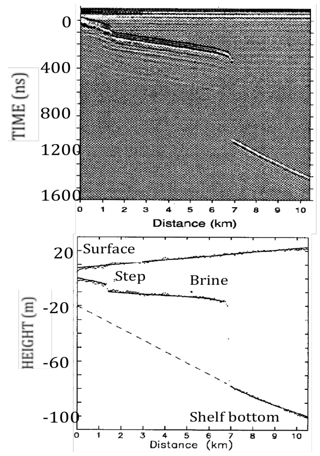

Figure 3: Radar echogram (top) recorded over a brine layer in the McMurdo Ice Shelf, Antarctica. Interpreted brine layer depth, ice shelf elevation, and ice shelf bottom elevations (bottom) illustrating that the bottom of the shelf is masked by the easily-imaged brine layer [5].

References

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