REVISITING THE SALT DISTRIBUTION COEFFICIENT FOR ICY OCEAN WORLDS. N. S. Wolfenbarger[1], K. M. Soderlund[1] and D. D. Blankenship[1], [1] Institute for Geophysics, University of Texas at Austin, J.J. Pickle Research Campus, Bldg. 196; 10100 Burnet Road (R2200), Austin TX 78758-4445 (nwolfenb@utexas.edu).

Introduction: The endogenic contribution to the salinity of the ice crusts of icy ocean worlds is governed by the salinity of the ocean and the thermally-driven evolution of the ice.

When ocean water freezes a majority of the salt is rejected during crystallization; however, a non-negligible fraction is preserved in the ice, either within the crystal lattice or along grain boundaries [1]. The salt distribution coefficient is a measure of the fraction of salt incorporated into the ice from the source water. It is thought to be a function of the freezing rate the accretionary mechanism [2-3].

Empirically-derived relationships for salt distribution coefficient, inferred from natural samples of accreted ice, can serve to better inform models of ice-ocean exchange and constrain bulk properties of the ice crust. Here we summarize existing empirically-derived salt distribution coefficient relationships, evaluate these relationships in context of additional published ice core data, and discuss where these relationships might be applicable to processes on icy ocean worlds.

Implications for ice salinity: There have been two distinct mechanisms of ice accretion observed in Earth's oceans: the accumulation and consolidation of individual ice crystals that nucleate within a supercooled water column, referred to here as marine ice, and the propagation of a freezing front underneath an existing ice column driven by conduction of heat through the ice column, referred to here as sea ice [3-4]. Marine ice is an order of magnitude less saline than sea ice on average, likely due to both a lower freezing rate and the unique desalination mechanisms associated with its formation [5].

Empirically-derived salt distribution coefficient relationships exist for sea ice, but not marine ice [2]. Freezing rates of sea ice may be inferred from their isotopic composition; however this technique has never been applied to marine ice [6]. The applicability of this technique to marine ice will be examined against estimates of freezing rates to derive an empirical relationship for salt distribution coefficient in marine ice.

Application to icy ocean worlds: Empirically-derived salt distribution coefficients are invaluable to constraining expected salinities for accreted ices on icy ocean worlds. It is possible bulk ice properties may be well approximated by the zero rate limit of empirically-derived salt distribution coefficient for sea ice.

Fractures that might exist at the base of icy crusts could be home to marine ice, generated as ocean water rises adiabatically to an ice-ocean interface in a lower pressure environment. Hypothesized regions of relative thinning in the ice crust may experience marine ice accumulation at relatively low freezing rates, similar to those experienced underneath Antarctic ice shelves [7].

Significance: Understanding the incorporation of oceanic material into ice crusts is critical to evaluating the habitability of icy ocean worlds. The properties of the accreted ice, including salinity, in part govern the feasibility of exchange processes between the surface and subsurface. These exchange processes are thought to govern the potential for life on icy ocean worlds, such as Europa.

Ice-penetrating radar signals are sensitive to the salinity of ice. The concentration of chlorides incorporated within the ice lattice influences the signal attenuation experienced by radar [8]. The Radar for Europa Assessment and Sounding: Ocean to Near-surface (REASON) instrument on Europa Clipper may be able to leverage attenuation to constrain the thermocompositional state of Europa's ice shell [9].

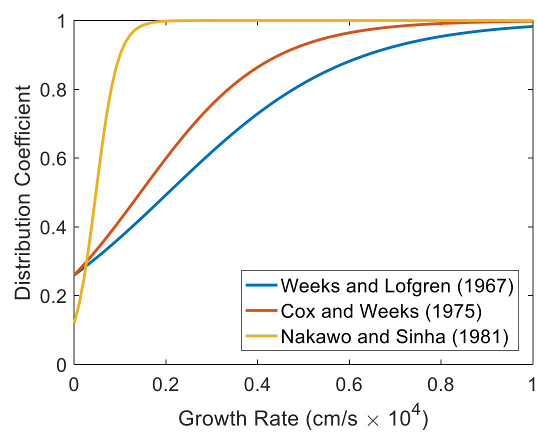

Figure 1. Salt distribution coefficient as a function of ice growth rate from Weeks and Ackley (1986).

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