Insights into Ice-Ocean Interactions on Earth and Europa

Sub-Ice Marine and Planetary-analog Ecosystems

Europa and Earth appear to be drastically different worlds, yet below their icy crusts the two likely share similar oceanic conditions including temperatures, pressures (relatively), and potentially salinity. Earth’s ice shelves and ocean provide an important analog for the physiochemical, and potentially microbial, characteristics of icy worlds. NASA’s ASTEP program funded SIMPLE to help address the fundamental processes occurring at ice-ocean interfaces, the extent and limitations of life in sub-ice environments, and how environmental properties and biological communities interact. The technologies supported by SIMPLE are also supporting the ice-penetrating radar on the upcoming Europa Flagship mission, and will hopefully inform future in situ ocean world exploration. Here, we present results from CTD and imaging data gathered beneath the McMurdo Ice Shelf (MIS) to highlight how the ice and ocean interact in a European analog environment.

The MIS is “ice-staved,” an ideal place to study basal accretion and melt. As supercooled water flows upward along the basal slope of the shelf, frazil ice precipitates and rises, accumulating at the interface (Fig. 2). In thermally stable regions, platelet ice grows in situ and contributes to the marine ice layer. The thickest sub-shelf marine accretions on Earth exceed ~500 m.

Results

Over the course of three field seasons, we observed temporal and spatial variation in both water column and platelet accumulation trends. The single dive from 2017 shows the most heterogeneous waters in an area of ablation (Fig. 4). 2014 study sites recorded more homogeneous waters with large and varied structures of platelet accumulations at the interface (Fig. 5). In 2015, a time series of casts over the month of November through the ice at SIMPLE Camp shows Antarctic Surface Water (ASW) at 120 m depth, transitioning to Antarctic Bottom Water below 450 m (Fig 6). Bottom depth was 529 m. Sub-ice casts (2012, 2014) are generally fresher (<0.05 PSU) at the interface and slightly colder than the 2015 sea ice casts. Most interesting is the differences observed between dives 11 (ebb) and 17 (high), in which temperature-salinity trends near the ice interface invert, and may suggest that tidal influence changes the interaction over short windows during high tide. Sources of error potentially include vehicle noise and sensor configurations, thus this conclusion is preliminary pending continued analysis.

Future Work

We have just begun to analyze the full data sets from each field season. We will correlate these results with finer detailed analysis of the CTD and other sensor data (including pH, dissolved oxygen, sonar, imagery and in situ water samples). Additional sub-shelf ROV and AUV studies are planned to further constrain the relationship between oceanographic conditions and ice growth. Future field expeditions will return to areas with biological communities, search for more, and work to advance AUV and life detection technology in support of continued planetary exploration.