Idiosyncrasies of Measurements and Mixing in Seawater Near Freezing

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Supercooling associated with pressure effects on the freezing temperature appears to be an important feature of ice shelf/ocean interaction, capable of significant mass redistribution as water circulates in the shelf cavity, and also providing supercooled water in the ocean beyond the terminus. While describing property exchanges between floating ice shelves and the underlying ocean has traditionally utilized parameterizations and models obtained from observations under drifting sea ice, guidance from measurements in supercooled conditions is rare. This results partly from the fact that supercooling is seldom observed under pack ice, but also from the difficulty of measuring in an environment where instruments provide attractive nucleation sites.

During a study of air-ice-ocean interaction under fast ice in Freemansundet, Svalbard, with strong tidal forcing in water near freezing, we observed the following unexpected behavior in three different conductivity measuring instruments deployed at different depths in nearby locations. During maximum current velocities but at different times, the three C sensors would show sudden drops in conductivity that would persist for 30-60 minutes, then just as suddenly revert to values near those observed before the event. Considered in isolation, the drops were "believable" in the sense that salinity (calculated from temperature and conductivity) would differ by less than one practical salinity unit (psu) from the apparent ambient level, and similarly the inferred supercooling would be less than about 0.2 kelvins. However, from several lines of reasoning, we believe that although the events did signal the presence of supercooled water, the actual change is salinity was minor, hence the magnitude of supercooling was also much smaller. Although perhaps just a curiosity, we believe these events are significant, both because of their implications for properly measuring characteristics of supercooled water, and also providing insight into mixing processes involving different water masses near their respective freezing temperatures.

From the perspective of instrument response, our interpretation of the conductivity drop events is that as a front in salinity (density) structure was advected back and forth past our instruments in a strong tidal flow (~2 kt), supercooled water embedded within the front nucleated a thin layer of ice on the electrode elements that changed the geometry of the sensor enough to modify the conductivity reading. As the front passed, the thin ice film was melted (or eroded) by water that was not supercooled and the cell geometry returned to normal. The implication is that in similar circumstances, our usual instruments for measuring conductivity may be susceptible to nucleation in a way that does not make the reading nonsensical.

From a scientific perspective, a more intriguing aspect of the Freemansundet measurements is that they suggest a process whereby a sharp horizontal front in salinity is sheared under a solid surface (fast ice), leading to vertical mixing of the two water types. Since density depends almost exclusively on salinity, the direction of flow is important for determining the stability of the near surface water column and mixing efficiency. This is apparent in our stress measurements. If the mixing was *conservative* (i.e., salt and heat mixed at the same rate), then no supercooling would occur. Instead, the presence of transient supercooling implies that heat is mixed out of the fresher (slightly warmer) water type faster than salt is mixed in. This apparent double-diffusive mechanism for producing supercooling in a highly turbulent flow, has not to our knowledge been considered before, and may be important in areas where frontal structures exist, including under ice shelves.