Idiosyncrasies of Measurements and Mixing in Seawater Near Freezing

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in collaboration with
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Sontek ADV Ocean (5 Mhz)

SBE 4 std C

SBE 7 mC

Turbulence Instrument Cluster (TIC)

Sontek ADV Ocean (5 Mhz)
UNESCO formula for freezing temperature:

\[ T_f(S, p) = -0.0575S + 1.710523 \times 10^{-3} S^{3/2} - 2.154996 \times 10^{-4} S^2 - 7.53 \times 10^{-3} p \]
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**Hypothesis:** Conductivity drops because supercooled water nucleates on the cell surface, reducing its dimension, not because frazil crystals enter the duct. The drops thus signal the presence of supercooled water, but not its true salinity.
tidal current

RDCP salinity (adj)

TIC (1 m) salinity
Section of CTD stations started about mid-day on March 23 (day 82).
View in the next slides is toward the southeast.

Fast ice in Freeman Sound
Open pack ice Storr Fjord
Salinity contours from the survey on Mar 23, for elevations above the Freeman Sound sill. Distance is measured along 225°T out of Freeman Sound. Time of the station is shown at top.
Total displacement during the flood tide in the afternoon of Mar 23:
\(~14\, \text{km}\)
The survey began at about the start of the flood tide, so later in the afternoon, the ship was encountering water that had advected toward the fast ice. This plot adjusts the distance relative to the first station (at 11:54) by integrating the upper ocean velocity along 45° for the time difference for each station.
The range in salinity matches closely the difference across the front observed during the earlier CTD survey.
Consider an idealized front separating two water masses at freezing temperature, moving toward the fast ice:

- Fresher, warmer
- Saltier, cooler

Fast ice
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On the ebb tide, denser water underruns lighter, stabilizing the boundary layer, and reducing turbulence scales.
In the $1^{1/2}$ tidal cycles we observed with the TICs on Mar 23, the flood and ebb velocities were about the same, and there was significant shear between 1 and 3 m below the interface.
However, there was a clear asymmetry in the response of the Reynolds stress, indicated here by the friction velocity

\[ u_* = \tau^{1/2} \]

[Graph showing current speed changes]
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On the ebb, turbulence is suppressed.

\[ u_* = \frac{\tau}{\rho} \]

\[ F_{\text{L}} = \frac{1}{2} \rho U^2 \]

\[ \tau = \rho \frac{dU}{dn} \]
But vertical shear alone cannot account for the transient supercooling events: If turbulent mixing is conservative (i.e., salt and heat mixed at the same rate) then a mixture of water masses initially at their respective freezing points would remain at freezing.

\[ K_H = K_s, \text{ no supercooling} \]
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Second Hypothesis: The transient supercooling events result from double-diffusive mixing (heat transferred faster than salt) as the front passes our instrumentation.
$K_H > K_S$, mixed water in the advancing frontal region will supercool.
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Same for retreat (ebb), although the mixing will be less intense because of buoyancy effects.
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(b) Near horizontal frontal boundaries between water masses with different salinities and temperatures near freezing, supercooling may result from vertical property mixing associated with boundary layer shear.