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14. ABSTRACT

This project enhanced one of the main objectives of the SeaState Program, namely the study of feedbacks between the upper ocean and ice formation, by collecting high-resolution observations of temperature and salinity near the ice edge. The SeaState Departmental Research Initiative investigated mechanisms driving and modulating ice formation during the late summer ice formation as a function of surface conditions and forcing. Coincident with surface flux and wave measurements, we used an underway temperature and salinity profiling system (uCTD) to characterize the conditions of the upper ocean. With the other measurements planned in the field program, this provided estimates of the ocean heat content, and allow us to study the evolution of fresh water lenses isolating the ice edge from the open water during most of the melt season, and affecting ice formation.

15. SUBJECT TERMS
Arctic. Sea State. Stratification. Temperature. Salinity. Upper Ocean.

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Ice-Ocean Dynamics During Ice Formation

N00014-15-1-2744
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Major Goals*

The main objective of this project is to collect direct temperature and salinity profiles of the upper ocean in the Arctic, to (1) characterize over greater spatial and temporal scales the structure of temperature and salinity in the upper 100 m of the water column ahead, at and inside the ice edge, (2) estimate ice-ocean heat and salt fluxes associated with new ice formation by measuring upper ocean heat and freshwater content, and (3) investigate the fate of the strong ice-edge density front, associated with fresh and cold water, during periods of ice formation and ice edge advance.

a) b)

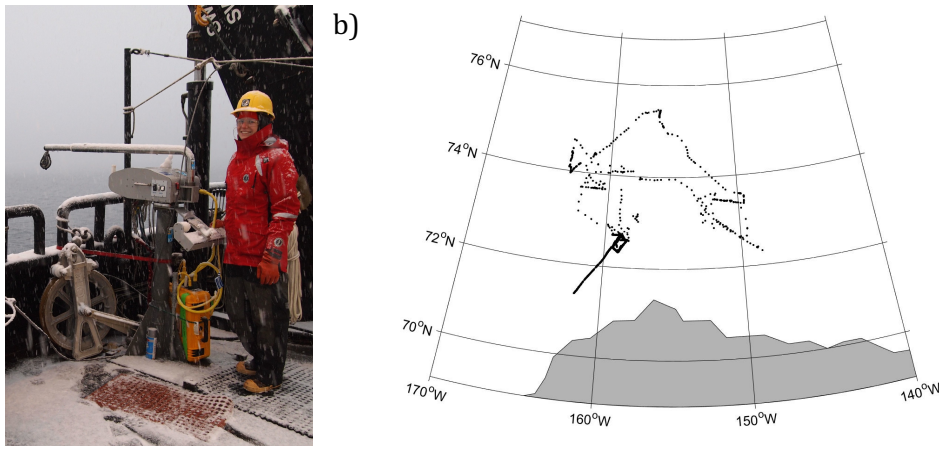

Figure 1. (a) uCTD system mounted on the back of the Norseman II, in October 2014, during the MIZ recovery cruise. (b) Locations of the 4325 profiles obtained from the uCTD during the SeaState cruise in 2015.

Accomplished

During the SeaState cruise n the R/V Sikuliaq in Fall 2015, a total of 4325 profiles of upper ocean temperature and salinity were collected from underway CTD (uCTD, Figure 1), a ship-based light-weight sampling system that offers rapid setup and flexible sampling to provide a capability that is highly efficient for acquiring high precision ocean measurements over much greater spatial and temporal scales, while also freeing-up ship time for other activities.

Temperature and conductivity sensors respond with different time constant to variable signals, so we need to match the response of the conductivity cell to that of the temperature sensor, so that we can 'remove' the temperature effect from the

conductivity to get salinity (see Ferrari and Rudnick, 2000, JGR for details for a constant fall speed). Because the fall rate is changing, the time lag between the sensors changes too (Ullman and Hebert, 2014). For all probes used during the cruise, the best lag has a strong dependence on fall rate (Fig. 4). Empirical fits to individual segments are used for the processing.

The recovery cruise at the end of September 2014, on R/V *Norseman II,* provided us with an opportunity to conduct over two days of very high-resolution sampling of the region near the ice edge (Fig. 2). Sections of temperature and salinity extending from the ice edge roughly 15 km into open water sampled by the Underway CTD. Profile spacing ranges from about 200 m near the ice to a little under 1 km further away. A time series of sections was collected to capture the time evolution of the sharp temperature-salinity front that marks the ice edge. The sections also reveal thickening of the 22-23σ_θ density layer, above the location where the signature of the Pacific summer water (water with T>0°C near 60m) disappears (Fig. 3).

In particular, we are collaborating with Sharon Stammerjohn to present a description of the upper ocean conditions during October and November 2016, as the ice was forming.

We are contributing to a manuscript on 'Storm-driven mixing and the delay of the autumn ice advance in the Beaufort Sea', by Madison Smith (Ph.D. student with Jim Thomson).

Training

Nothing to report.

Dissemination

Underway CTD has been fully processed and documented. It is available on the shared data repository, along with all the other data from the Sea State DRI, to all PIs and collaborators.

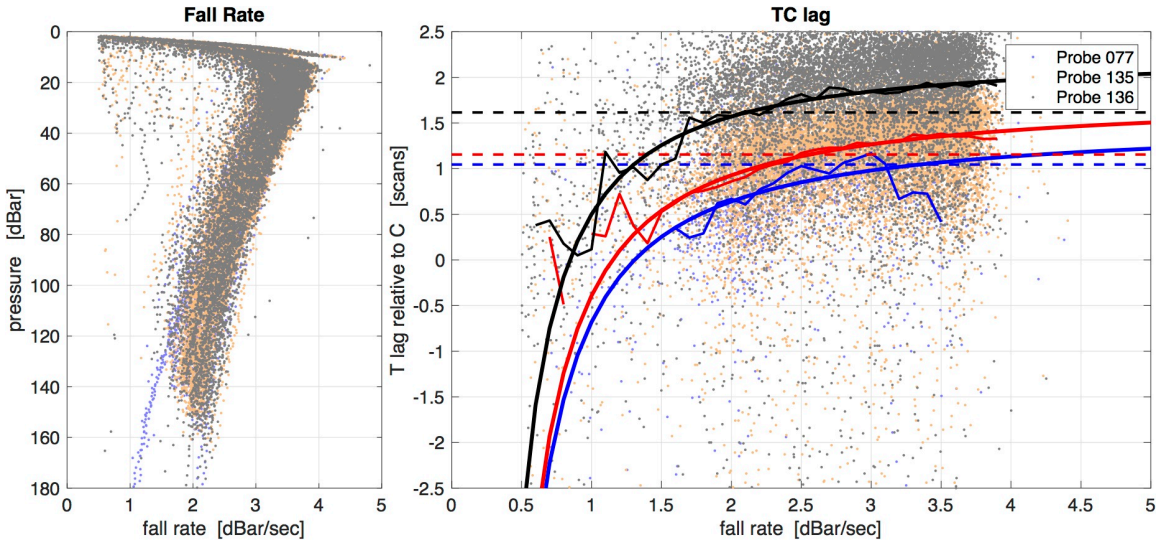

Figure 4. (a) Fall rate vs pressure, for the 3 different probes used during Sea State cruise. (b) 4-sec estimates of best lag between T and C, and binned data, and fits, for the 3 different probes.

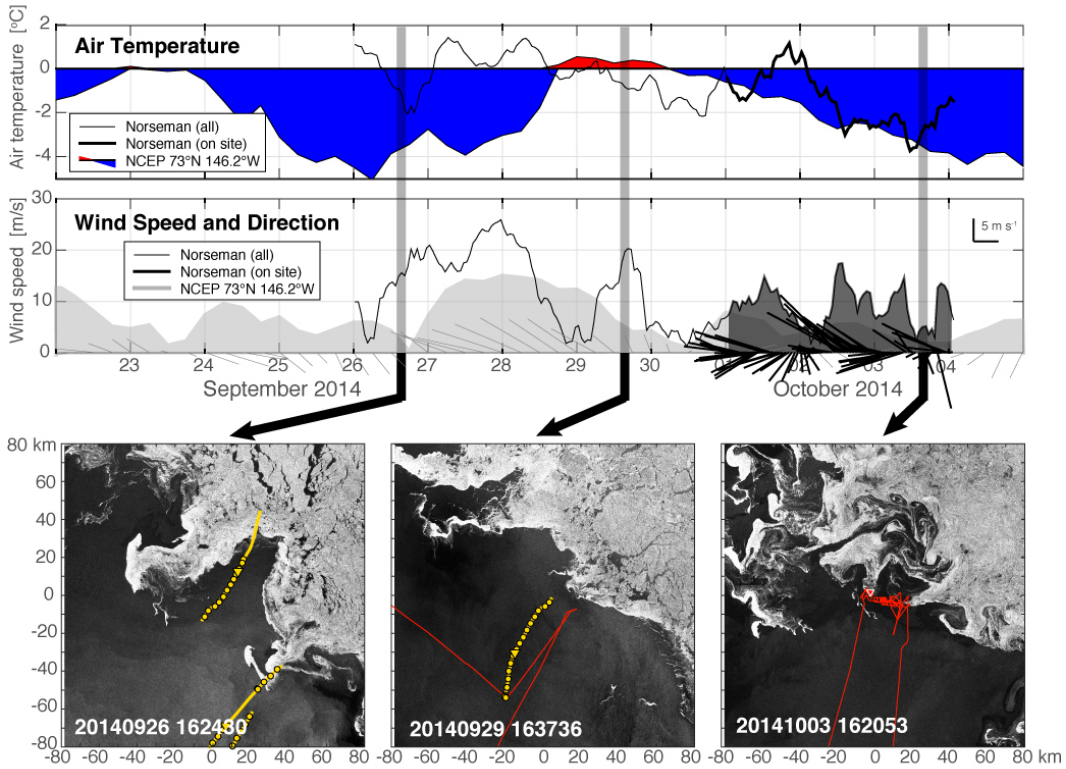

Figure 2. Time series of air temperature (top – freezing showing in blue) and wind speed and direction (central panel), both from NCEP reanalysis at the ice edge (73°N 145°W) and recorded from R/V Norseman during the recovery cruise. Satellite SAR images at representative times during the ice edge sampling are shown on the bottom row, along with glider (yellow, surfacing shown by circles) and ship (red) tracks. Tracks are shown +/-2 days from the time of the image. Locations of gliders or ship at the time of the image are shown with triangles.

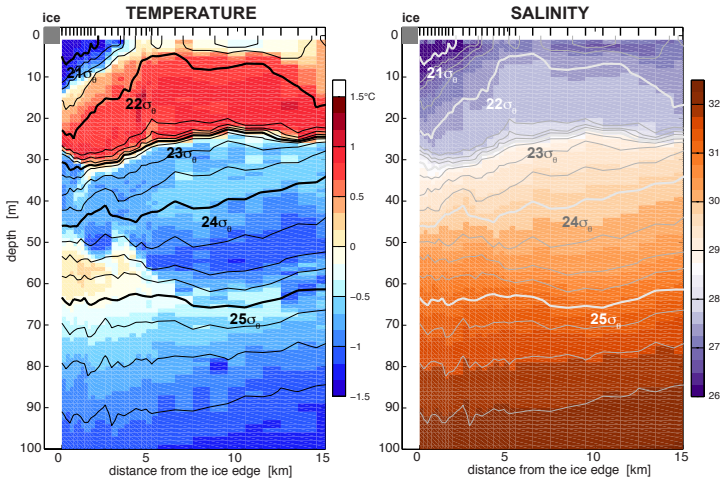

Figure 3. Temperature and salinity from the ice edge to about 15 km, sampled by the underway CTD during the Norseman II cruise (02 Oct 2014). Profile locations (36 casts) are indicated on the top axis. Potential density is contoured. Note the sharp temperature and salinity front near the ice edge, as well as the broadening of the 22-23σ_θ density layer above the location where the signature of the Pacific summer water (water with T>0°C near 60m) disappears, 5-10 km from the ice edge.

Plans*

We are working on understanding the distribution and evolution of the Pacific Summer Water. The first ice-edge section collected from the Sikuliaq (Fig. 4) from inside the ice (p2) to about 5 km out (p8) shows that the PSW is also eroded right at the ice edge, but it is stronger out of the ice, as opposed to under the ice during the MIZ program. We are considering larger regional scales to understand if this difference is due to the PSW circulation (the section in Sea State was near the shelf break), or due to local dynamics.

The high-resolutions surveys obtained during Sea State DRI allows us to duscover and investigate the variability on a very small scale. For example, the profiles just inside the ice (p2 and p10) are taken only 2 km and about 7h apart, but show very different water mass properties in the PSW. This variability can be put into its local and regional context using the ship radar (e.g., Lund, Graber, et al.; Fig. 4a,b), and remote sensing (Graber et al.; Fig 2).

A new student, Sam Brenner, is joining the graduate program at UW and will also look at this data.

Honors

Nothing to report.

Tech Transfer

Nothing to report.

Participants

Luc Rainville.

Upload*

Students

Nothing to report.

Products

Nothing to report.

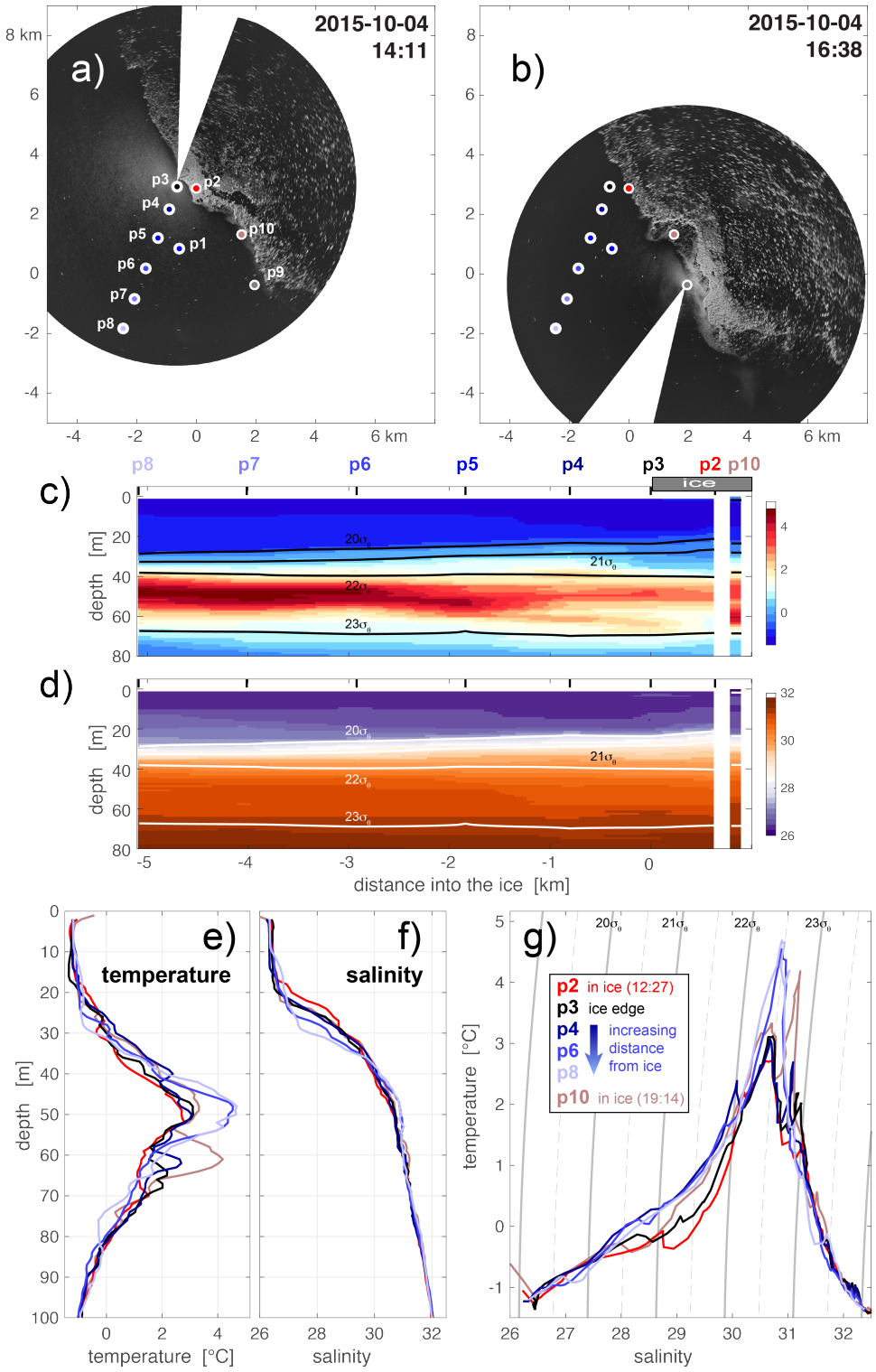

Figure 4. Ice-edge sampling from during the Sikuliaq cruise, on 04 October 2015. (a,b) Ship radar images of the ice edge, separated by about 4 hours. Position of the uCTD profiles (labeled p1 to p10) are indicated. Temperature (c) and Salinity (d) section from within the ice to 5 km away from the edge. Temperature (e), salinity (f) vs depth and T-S diagram of selected profiles are also plotted.