

Ocean Profile Measurements During the Seasonal Ice Zone Reconnaissance Surveys

James Morison
Polar Science Center, APL-UW
1013 NE 40th St.
Seattle, WA 98105
phone: (206) 543 1394 fax: (206) 616 3142 email: morison@apl.washington.edu

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LONG-TERM GOALS

This grant is part of the Seasonal Ice Zone Reconnaissance Surveys (SIZRS) program of repeated ocean, ice, and atmospheric measurements across the Beaufort-Chukchi sea seasonal sea ice zone (SIZ) utilizing US Coast Guard Arctic Domain Awareness (ADA) flights of opportunity. This report covers our grant to make ocean temperature, salinity, velocity and mixing profile measurements across the SIZ. Our long-term goal is to track and understand the interplay among the ice, atmosphere, and ocean contributing to the rapid decline in summer ice extent that has occurred in recent years. The SIZ is the region between maximum winter sea ice extent and minimum summer sea ice extent. As such, it contains the full range of positions of the marginal ice zone (MIZ) where sea ice interacts with open water.

OBJECTIVES

The overarching objectives for SIZRS are to determine seasonal variations in air-ice-ocean characteristics across the SIZ extending over several years and for a variety of SIZ conditions, investigate and test hypotheses about the physical processes that occur within the SIZ that require data from all components of SIZRS, and improve predictive models of the SIZ through model validation and through the determination of observing system requirements.

For the ocean profiles component of SIZRS, our objective is to determine variations in ocean characteristics across the SIZ extending over several years and for a wide variety of SIZ conditions.

APPROACH

Our approach is to deploy Aircraft eXpendable CTDs (AXCTD) and Aircraft eXpendable Current Profilers (AXCP) across the Beaufort and Chukchi Sea SIZ aboard US Coast Guard Arctic Domain Awareness (ADA) C-130 flights. The U.S. Coast Guard Arctic Domain Awareness (ADA) flights offer the way to make regular measurements over long ranges in the Beaufort and Chukchi seas at no cost for the platform. SIZRS includes a set of core measurements needed to, make complete atmosphere-ice-ocean column measurements across the SIZ, make a section of ice conditions across the SIZ, and deploy drifting buoys to give time series of surface conditions. Specifically, the core elements are

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listed in Table 1 for the SIZRS Coordination Grant. The AXCTD and AXCP ocean profile measurements of this grant are illustrated in Figure 1.

ADA flights prior to this year were conducted twice per month from March through November. On these flights, we conduct atmosphere-ice-ocean observations at least once per month. This year, at our

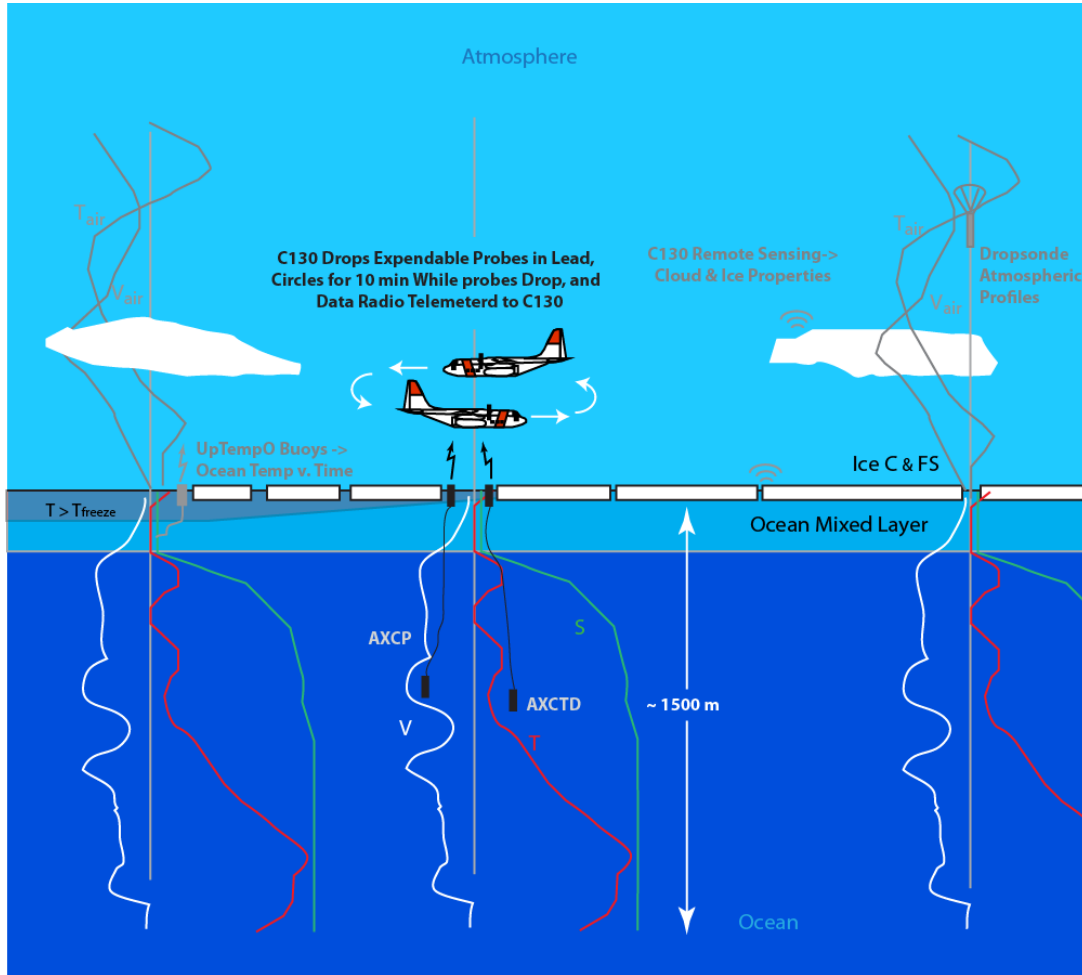


Figure 1. Schematic of the SIZRS ocean column AXCTD & AXCP profiles. Stations will be made in five locations across the SIZ (3 shown) with at least one each in open water, MIZ, and pack ice. Buoys will provide upper ocean time series at several locations. The aircraft remote sensing will measure ice & cloud properties.

request, instead of two one-day missions per month, the Coast Guard substituted single multi-day missions operated out of Fairbanks in July, August, and September. With forward staging like this, we have been able to conduct flights farther into the Arctic Ocean and on two lines of longitude (150°W and 140 °W) on consecutive days. These include lines of about 5 stations across the SIZ, typically at 72, 73, 74, 75 and 76°N in 2014, with profile measurements through the complete air-ice-ocean column (Fig. 1). Other stations can be made to examine particularly active regions of ice retreat or advance.

We have used the AXCTDs successfully in prior surveys, primarily from smaller aircraft, and developed the method for dropping the Sippican-TSK AXCTD from C-130 aircraft during one test mission with the Alaska Air National Guard Search and Rescue Squadron in Anchorage, Alaska and with three Coast Guard ADA flights, one on September 30, 2009, one on May 25, 2010 (Fig. 6), and one during a buoy deployment flight Oct. 26, 2010. In addition to the Sippican-TSK (Tsurumi-Seiki) AXCTD expendable probes, the equipment includes a TSK AXCTD TS-RX100W Receiver (Ch.14), a T.S.K. AXCTD TS-MK150N Converter, a Marantz PMD-660 Solid State Sound Recorder, and a Macintosh laptop computer.

During an AXCTD deployment, once the aircraft nears the nominal station location, we search for an open lead at least 100 m wide and free of newly formed ice. The aircraft flies down the lead at an altitude of 60-120 m, and the AXCTD is deployed by hand from the side “paratrooper” door or the open rear ramp. It parachutes to the lead surface, a float inflates on contact with water, and after a short delay, the CTD probe drops from the float unit. Data is transmitted from the probe to the buoy via an ~1500-m copper wire spooled from the probe and the float. While the aircraft circles at 100 to 300 m, the data is transmitted from the float to the aircraft as 172 MHz FM radio signal (channel 14). The data transmission is received by the T.S.K. TS-RX100W through one of the standard aircraft VHF antennas. The raw reception is converted to engineering units by the TSK Converter and recorded on the laptop computer. A backup recording of the raw received signal is made with the solid-state sound recorder. Based on comparison among AXCTD drops and surface CTD stations we find AXCTD are accurate to 0.02 psu and 0.02°C [McPhee *et al.*, 2009].

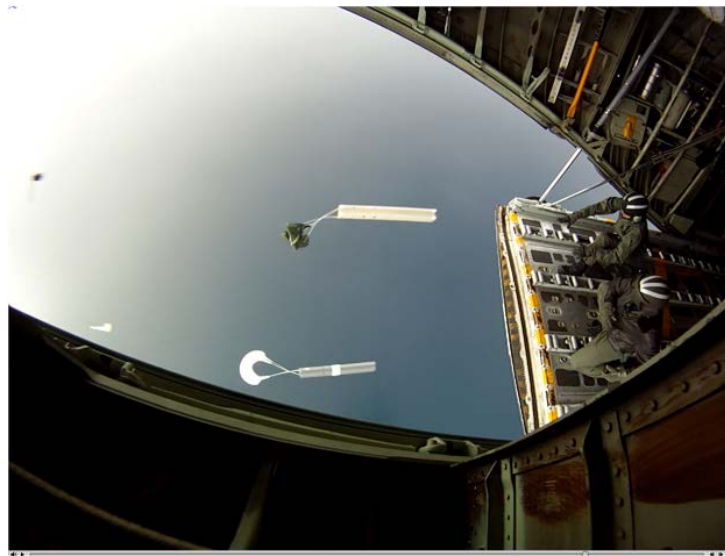


Figure 2. AXCTD (gray) and AXCP (white) being hand-launched simultaneously from rear ramp of USCG C-130H during August 2013 SIZRS flight.

We have been using expendable current profilers (XCP) as part of the NPEO and Switchyard surveys and analyzing their data as part of our NSF Arctic Ocean Mixing Grant (<http://psc.apl.washington.edu/northpole/Mixing.html>). The AXCP use a surface float and dropped probe similar to the AXCTD arrangement described above. The AXCP radio uplink receiver and recording equipment are the same as the equipment used in our lightweight NPEO equipment, which includes an ICOM IC-R20 receiver set to 172 MHz wide-band FM and a Marantz PMD-660 Solid

State Sound Recorder. In the SIZRS application, we use the same manual deployment through the paratrooper door for the AXCP that we use for the AXCTD. At each station, the two types of probe are dropped simultaneously (Fig. 2). We use the same aircraft VHF antenna through a splitter to feed both receivers, and we use AXCP transmitting at 170.5 MHz (Channel 12) to allow simultaneous radio reception and recording of AXCTD and AXCP. The raw AXCP transmission recorded on the Marantz recorder is played back through a sound card to a laptop computer with XCP processing software developed here at the UW Applied Physics Laboratory by John Dunlap for the inventor of the XCP, Tom Sanford. Dunlap has developed a special Arctic version of the software, which is better suited than the standard Sippican deck units to the high geomagnetic latitude and commonly weak velocity shear of the Arctic Ocean. The raw audio-frequency content of the AXCP transmission is recorded on the solid state recorder as a backup.

WORK COMPLETED

SIZRS has nearly completed its third and most intense season working with USCG Air Station Kodiak. The coordination effort has assembled and submitted documentation needed for USCG approval of all the UW SIZRS instruments to be used on the ADA flights including the AXCTD and AXCP. Only the AXCTD were approved for the 2012 flights, but we completed the required SOFT tests, and the AXCP (and other SIZRS instruments) received approval before the 2013 sampling began.

Since our last report, we made one SIZRS flight in November of 2013, delayed due to the government shutdown. The results were limited to two stations due to limited daylight. Using the AXCTDs and AXCPs, as well as the atmospheric Dropsondes we have conducted 7 SIZRS flights in 2014. These were on June 17, July 23 and 24, August 13 and 14, and September 25, and 26. These included AXCTD and AXCP in conjunction with UpTempO deployments on July 24 and August 14. In 2013 we began supporting our oceanography graduate student, Sarah Dewey, to work through comparative analyses of the 2012 data and results of some of this work in 2014 are discussed in the following section.

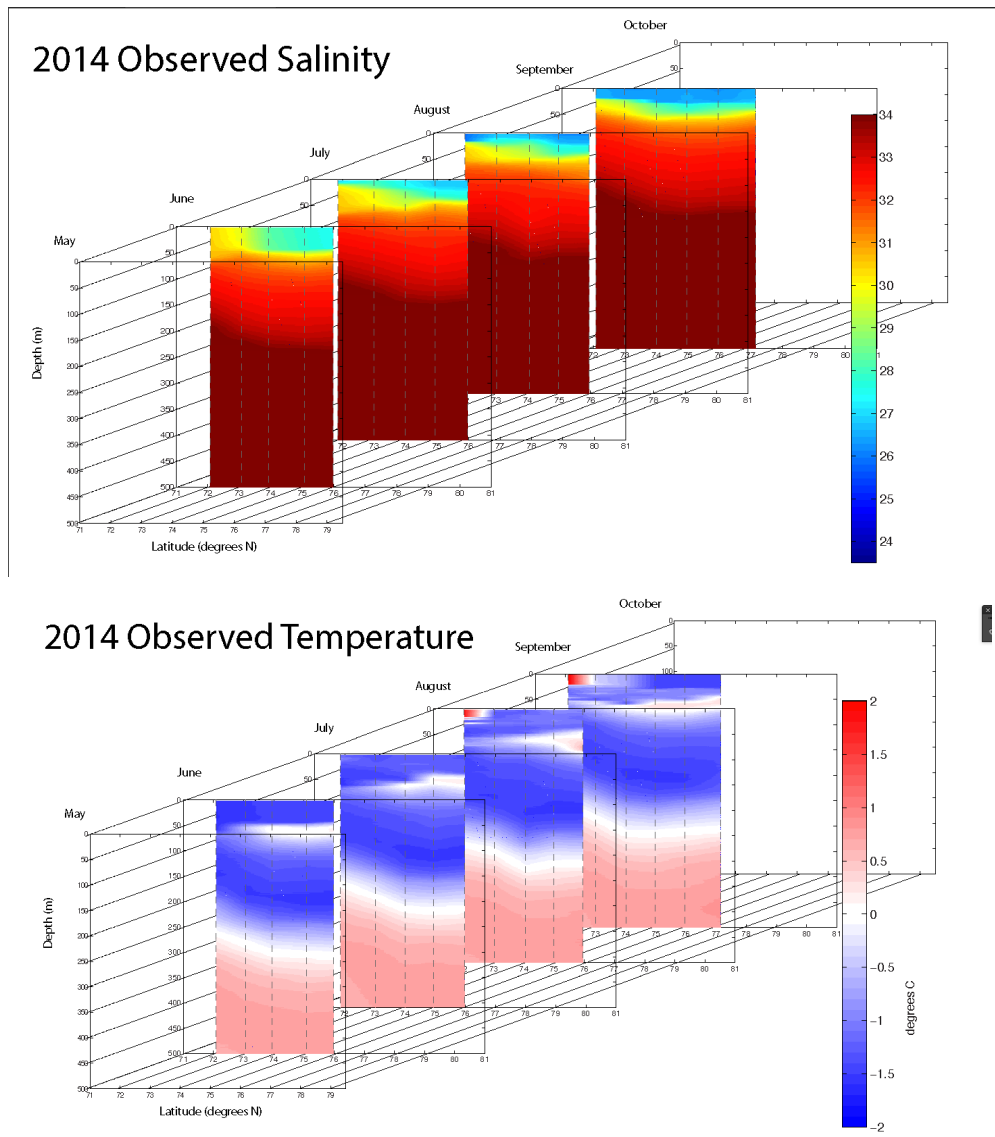


Figure 3. Ocean salinities (a) and temperatures (b) measured once per month by AXCTD during the 2014 SIZRS flights.

RESULTS

In 2012, the sea extent reached a new record minimum with the edge at 80°N in the Beaufort Sea. The ice extent in 2014 has been greater than in 2012 throughout the summer, and the 2014 ocean data suggest one reason this may have been true: the initial condition in the upper ocean was colder and more saline in 2014.

Figure 1 shows the monthly evolution of salinity and temperature through 2014 measured by SIZRS AXCTDs along 150°W. The pattern of upper-ocean freshening as the 2014 season progressed is apparent and generally consistent with the pattern in previous years.

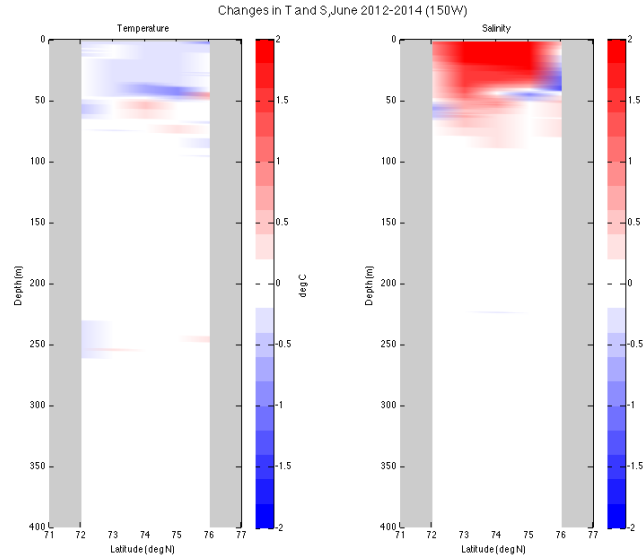


Figure 4. Difference between June 2014 and June 2012 temperature (left) and salinity (right) measured with SIZRS AXCTDs along 150°W.

The appearance of warm near-surface water in the developing open water regions at the south end of the section is also typical. We find that the surface temperature extrema in late-season open water areas (e.g., 72°N) exceed the surface temperatures in similar open water areas south of the ice edge during 2012's season of minimal ice extent. The onset of freezing is apparent in the northernmost latitudes of September's temperature section, where a uniform -2°C layer extends as far south as 75°N. However, while the southern extrema of this year's ocean data show a near-surface layer warmer than that just south of the ice edge in 2012, the overall change from 2012 to 2014 has been an increase in salinity (Fig. 4 right) and a decrease in temperature (Fig. 4 left) at repeat stations.

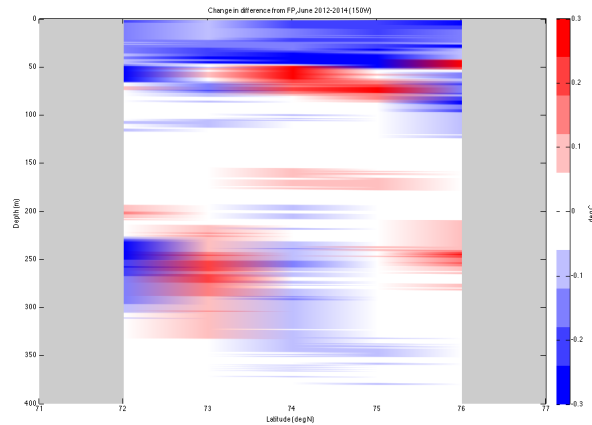


Figure 5. Difference between June 2014 and June 2012 elevation above the freezing point measured with SIZRS AXCTDs along 150°W.

This increase in salinity and decrease June 2014 relative to June 2012 across all comparable latitudes of the 150°W line result in the water temperature in the upper 50 m being closer to the freezing point than in 2014 (Fig. 5). This at least reduces the initial potential for the ocean to melt the ice cover in 2014. The consequent reduced melting early in the summer delays the onset of sea-ice-albedo feedback in accelerating melt throughout the season and thus reduces the melt-back of the ice edge. The reduction in upper ocean temperatures may also explain our 2014 visual observations of isolated thin layers of ice growth in open leads even in July and August, something we have never seen before.

IMPACT/APPLICATIONS

The SIZRS effort is a pioneering program in the use of aircraft expendable ocean and atmosphere sensor probes in tracking changes in the sea-ice environment of the Arctic. It will lead to greater availability of synoptic snapshots of environmental properties over extended ranges.

RELATED PROJECTS

See Table 1 of the report for “Seasonal Ice Zone Reconnaissance Surveys”, grant number: N00014-12-1-0231.

REFERENCES

McPhee, M. G., A. Proshutinsky, J. Morison, M. Steele, and M. Alkire (2009), Rapid change in freshwater content of the Arctic Ocean, *Geophysical Research Letters*, 36(L10602, doi:10.1029/2009GL037525.).

PUBLICATIONS

S. Dewey, J. Morison, R. Andersen, J. Zhang, and M. Steele (2014). “Aerial Surveys of the Beaufort Sea Seasonal Ice Zone in 2012”, presented at AGU Ocean Sciences Conference, Honolulu, Hawaii.