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Autonomous Observations of the Upper Ocean Stratification and Velocity Fields About the Seasonally-Retreating Marginal Ice Zone

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Award Number: N00014-12-1-0140
http://www.whoi.edu/itp | http://www.apl.washington.edu/project/project.php?id=miz

LONG-TERM GOALS

The PI group seeks to observe the upper Arctic Ocean using autonomous instrumentation and build understanding of the physical processes controlling the evolving thermohaline stratification, the ocean currents and air-ice-sea interactions on time scales of minutes to interannual.

OBJECTIVES

As a contribution to the Marginal Ice Zone DRI, this research element is designed to observe the seasonal evolution of the upper-ocean stratification, document the time-varying ocean currents and

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1. REPORT DATE **30 SEP 2013**	2. REPORT TYPE	3. DATES COVERED **00-00-2013 to 00-00-2013**

4. TITLE AND SUBTITLE **Autonomous Observations of the Upper Ocean Stratification and Velocity Fields About the Seasonally-Retreating Marginal Ice Zone**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Woods Hole Oceanographic Institution,Clark Laboratory,266 Woods Hole Road,Woods Hole ,MA,02543**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

characterize the turbulent ice-ocean exchanges of heat, salt and momentum as the sea ice cover retreats poleward in spring/summer.

APPROACH

The specific approach of this element of the MIZ DRI is to deploy Ice-Tethered Profilers with Velocity (ITP-V) to sample the ocean and return those observations to the PIs in near-real time. The ITP-Vs will provide the MIZ group with vertical profiles of temperature, salinity and horizontal velocity at 3-hour resolution, as well as direct vertical turbulent flux estimates from just below the ice-ocean interface several times per day. The ITP-V is a variant of the ITP system that has contributed to sustained observations of the Arctic Ocean below sea ice since 2004. The ITP concept is, in short, Argo of the Arctic - a play on the international program maintaining an array of profiling floats throughout the temperate oceans. Briefly, the ITP system consists of three main components: a buoyant surface instrument package that typically sits atop an ice floe, a weighted, wire-rope tether of arbitrary length (up to 800 m) suspended from the surface package, and an instrumented underwater unit that travels up and down the wire tether (Figure 1). The current design of the ITP surface expression is a conical-shaped buoy that houses a controller, inductive modem electronics, a GPS receiver, and an Iridium satellite phone with associated antennae and batteries within a watertight aluminum housing capped by an ultra-high-molecular- weight (UHMW) polyethylene dome. The electronics case sits within a foam body designed to provide buoyancy for the plastic-jacketed wire rope tether and end weight should the ice fracture or melt, and to provide modest protection in the event of ice ridging. The profiler unit (much like an Argo float in shape and size) mounts on the tether and cycles vertically along it. Via an inductive modem, raw sensor and associated engineering data files are relayed from the underwater vehicle to the surface buoy at the completion of each one-way profile, which then transmits them to a logger computer at WHOI by satellite. The ITP-V instruments add a multi-axis acoustic-travel-time current meter and associated attitude/motion measuring unit to the standard ITP sensor suite to make direct, 3-D observations of ocean flow (Figure 2).

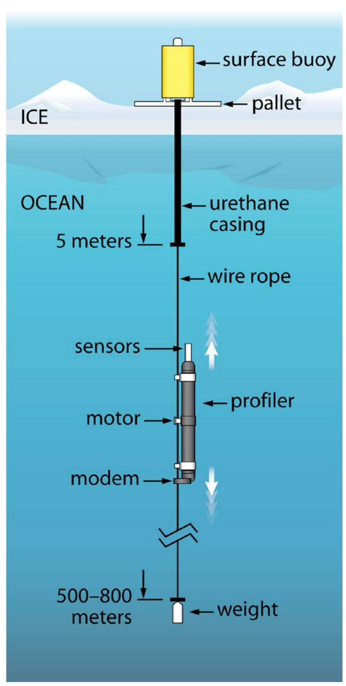

Figure 1 (left) Schematic drawing of the Ice-Tethered Profiler instrument system.

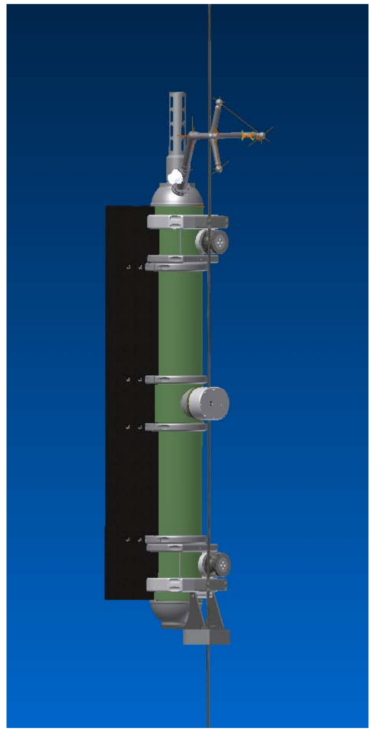

Figure 2 (right) Engineering drawing of the Ice-Tethered Profiler with Velocity instrument system.

For the full MIZ field program in Spring 2014, it is planned to deploy 4 ITP-V systems in an approximate north-south line spanning the seasonal sweep of the MIZ. Fellow MIZ investigators will field complementary sensor systems in conjunction with the ITPVs as well as deploy drifting and mobile instruments to sample the ocean around the ITP-V array.

In preparation for the main field program, the PI's planned to construct and field one ITP-V in conjunction with the 2013 cruise of the Beaufort Gyre Observing System program (see http://www.whoi.edu/page.do?pid=66296) to test improvements made to the initial prototypes of the ITP-V instrument.

WORK COMPLETED

Changes were identified to the initial ITP-V design to improve the quality of the ocean velocity data derived from the instrument. The two main changes were a redesigned configuration of the acoustic transponders of the Nobska-MAVS acoustic current meter (ACM) and incorporation of a different Inertial Measurement Unit and Attitude Heading Reference System (IMU/AHRS). The former was motivated by analysis of prototype data that suggested that vortex shedding from the standard MAVS transducer supports introduced noise into the velocity observations. The new design is optimized for a profiler that orients into the flow, with no bluff structures upstream of any of the velocity measurement paths. The newly-available VN-100 unit from VectorNav Technologies, LLC, offers superior performance to the original sensor in the initial ITP-V prototype. The PIs worked with the ACM instrument vendor, Nobska, Inc. to incorporate these changes to the ITPV ACM.

A key step in the qualification of the fully-assembled ITP-V instrument is to establish the relative orientation of the coordinate system of the VN-100 IMU/AHRS (mounted on a board inside the ITP-V pressure case) relative to that of the ACM (defined by the transducer sting), and establish bias offsets in the accelerometer and flux gate compass channels. To determine the relative orientation, a jig was designed and constructed to support an ITP-V unit in various attitudes relative to true horizontal and local magnetic north (Figure 3). After aligning the ACM sting with the jig, and the jig with local magnetic north, data from 360-degree spins through various axes are analyzed to determine the relative orientations of the sensor coordinate systems.

Figure 3. Photograph of an ITP-V in the jig during a test spin to quantify sensor relative orientations. (Actual spin tests are conducted outside in an area free from artificial magnetic fields.

As planned, a new prototype ITP-V unit was constructed, tested at WHOI, transported north, and on August 25, deployed in a multi-instrument Ice-Based Observatory cluster at 76 55.4' N, 138 50.9' W, Figure 4. The ITP-V is transmitting data now and the PIs are starting to examine the raw observations and document instrument performance.

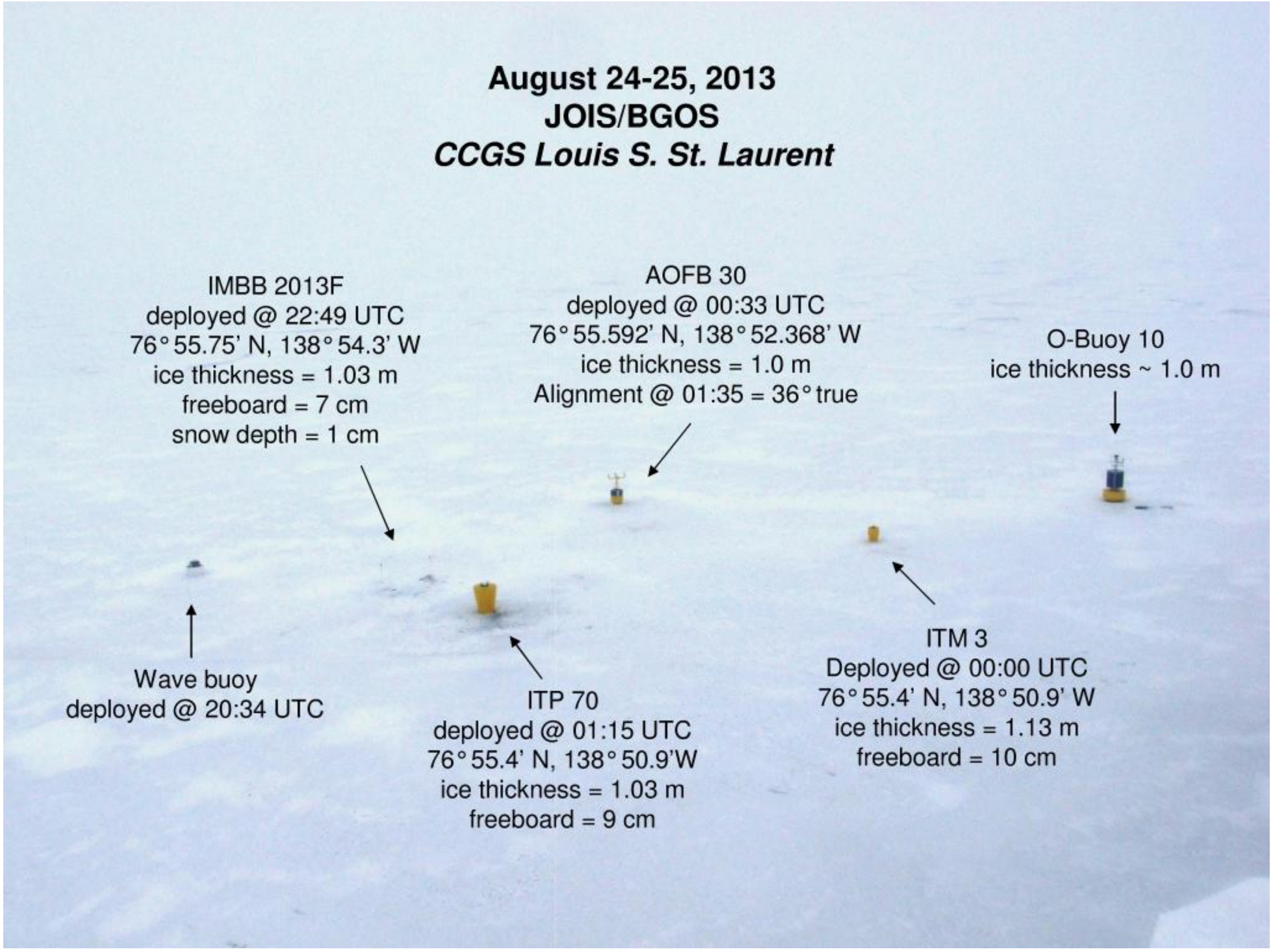

Figure 4. Aerial photograph of the Ice-Based Observatory deployed on August 25 that includes the test ITP-V (system ITP 70).

RESULTS

In addition to the completed work outlined in the previous section, the present grant provided partial support for the Cole et al. (2013) paper submitted to the Journal of Physical Oceanography. The abstract from that work follows:

The ice-ocean system is investigated on inertial to monthly timescales using winter 2009-2010 observations from the first Ice-Tethered Profiler (ITP) equipped with a velocity sensor (ITP-V). Fluctuations in surface winds, ice velocity, and ocean velocity at 7 m depth were correlated. Observed ocean velocity was primarily directed to the right of ice velocity and spiraled clockwise while decaying with depth through the mixed layer. Inertial and tidal motions of the ice and in the underlying ocean were observed throughout the record. Just below the ice-ocean interface, direct estimates of the turbulent vertical heat, salt, and momentum fluxes and the turbulent dissipation rate were obtained. Periods of elevated internal wave activity were associated with changes to turbulent heat and salt fluxes as well as stratification primarily within the mixed layer. Turbulent heat and salt fluxes were correlated particularly when the mixed layer was closest to the freezing temperature. An improved heat flux parameterization is suggested which accounts for this correlation. Momentum flux is adequately related to velocity shear using a constant ice-ocean drag coefficient, mixing length based on the planetary and geometric scales, or Rossby similarity theory. Ekman viscosity described velocity shear over the mixed layer. The ice-ocean drag coefficient was elevated for certain directions of the ice-ocean shear, implying an ice topography that was characterized by linear ridges. Mixing length was best estimated using the wavenumber of the beginning of the inertial subrange or a variable drag coefficient. Analyses of this and future ITP-V data sets will advance understanding of ice-ocean interactions and their parameterizations in numerical models.

IMPACT/APPLICATIONS

Observations and insights deriving from the MIZ program will, as noted above, advance understanding of ice-ocean interactions and their parameterizations in numerical models. In turn, predictions and assessments of the future state of the Arctic Ocean will result.

Improvements to the velocity measurement system of moored, profiling instruments developed under present funding will have application to other instrument systems.

RELATED PROJECTS

The present project, a component of the Marginal Ice Zone DRI (see http://www.apl.washington.edu/project/project.php?id=miz) is related to all the fellow MIZ projects. The closest connection is with the project " Acquisition of Ice-Tethered Profilers with Velocity (ITP-V) Instruments as a contribution to the Marginal Ice Zone DRI," Award Number: N00014-12-1-0799.

PUBLICATIONS

The present grant has provided partial support for following research paper:

Cole, S.T., M.-L. Timmermans, J.M. Toole, R.A. Krishfield and F.T. Thwaites, 2013. Ekman veering, internal waves, and turbulence observed under Arctic sea-ice. *Journal of Physical Oceanography*, [reviewed, submitted].