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14. ABSTRACT
We propose development, fabrication and initial testing of an autonomous ice station that will host underwater vehicles in ice-covered regions of the Arctic. The ice station will be a hybrid system that will support both vehicle infrastructure and sensor technology, with monitoring capability on, within and below the ice, plus communications, navigation and docking for underwater vehicles. The project is envisioned as a multi-year effort; this proposal covers the first stage of the work: the design and fabrication in preparation for deployment as early as autumn 2017 or spring/summer 2018.

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FINAL REPORT

Autonomous Arctic Ice Station

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LONG-TERM GOALS

The major goals of this project are the development, fabrication and initial testing of an autonomous ice station that will host underwater vehicles in ice-covered regions of the Arctic. The ice station will be a hybrid system that will support both vehicle infrastructure and sensor technology, with monitoring capability on, within and below the ice, plus communications, navigation and docking for underwater vehicles. The project is envisioned as a multi-year effort; this initial phase covers the first stage of the work: the design and fabrication, then the deployment in 2018 during opportunities with other ONR projects in the Arctic.

OBJECTIVES

The motivation for development of this capability is the desire to support autonomous vehicles beneath the ice, with eventual goals to include the ability to download and transmit vehicle data, and provide a docking platform and charging station for vehicles. Vehicle tasks may include mapping the underside of the ice, surveying changes in ice morphology in response to dynamic events, and observations of the upper part of the water column synoptically with sensing of atmospheric and ice parameters. The ice station will complement various environmental instrumentation systems such as the sophisticated NPS ice-mass balance buoys and WHOI ice-tethered profilers. The design is intended to support a variety of unmanned platforms, including autonomous underwater vehicles (AUVs) and gliders. Small unmanned vehicles are well suited for operation under ice, but at present this can only done with a ship or manned presence on the ice. This limits the locations and durations of surveys, and does not allow repeated mapping over time scales of months, e.g. through the seasonal evolution of the marginal ice zone. This station represents a first step towards an entirely autonomous vehicle support structure on the ice, without the need for logistically expensive manned presence and recovery. Supported vehicles are likely to be small, relatively inexpensive vehicles, so that recovery is unnecessary once the data is recovered.

APPROACH

The approach brings together various technologies demonstrated successfully during the Marginal Ice Zone (MIZ) DRI. The measurements made with MIZ technology included sea ice motion, meteorological conditions, ice and snow thickness and temperature, plus small scale currents under the ice. The work proposed here will include sensors that will monitor the local conditions around the ice station so that factors governing longevity can be estimated, plus short and long-range acoustic systems to allow the station to upload data from vehicles back to shore so that they need not be recovered. "Virtual docking" by parking the vehicle under the ice between surveys, as well as docking to a cable, will be supported. The result will be a support system that is suitable for testing of a long-term deployment of an inexpensive AUV in the vicinity of the station performing multiple missions in response to local events of interest, and transmission of data back to shore. This provides the first step towards the eventual goal of a network of autonomous stations that permit vehicle transits between stations, docking, and recharging, allowing near-continuous autonomous mobile presence in the Arctic.

WORK COMPLETED

The initial activities included design of the ice-tethered buoy along with the fabrication. The design is partially based on the size, shape and style of the MIZ buoys that were deployed on the ice in 2014. For the MIZ system none of the buoys were deployed in open water, so they did not have to go through the freeze-in process, but instead started out on relatively large 1 meter thick (or greater) ice flows. However, the deployment on ice was possible because of an air-supported winter campaign organized out of Sach's Harbour, NWT, Canada. This is possible for some deployments, but in general the most reliable access to the Beaufort is via ice breakers (US or Canadian) in late summer and early fall. In recent years the central and southern part of the Beaufort has been ice-free in that period, or with ice that is not sufficiently robust to support the deployment of ice-based instruments. However, this is dependent upon how far north the vessel is willing and able to travel. For example, during the CANAPE deployment cruise in 2016, the moorings were in locations that were ice-free except for patches of rafted leftovers that were too small to work on, and the same was true during the CANAPE recovery in 2017.

Thus a specific objective of the design effort is ensuring that the buoy can be deployed in open water and then survive the freeze-in process. This requires that the buoy be able to withstand the rigors of drifting in open water for at least several weeks, and potentially up to two months between the deployment time and the time that the ice freezes solid and does not break up again. The likelihood of freeze up and then subsequent break up of the ice during the transition period creates a time of peril for the buoy as pieces of ice that are a few centimeters thick break up and then are washed over the buoy or rafted into larger and thicker sections that then push up against the buoy and go over the top of it and then freeze.

An additional complication is that the buoy includes a cable that hangs below where the docking station for autonomous vehicles will be located. The cable is potentially subject to snap loads if the buoy falls faster than the subsea package as the vertical speed increases with increasing wave height. Thus the cable must be stronger than required for the version that was ice-tethered and it must be fabricated with a steel strength member rather than Kevlar, which is subject to failure under fatigue due to cyclic stress.

The results of the design work so far have provided an approach to sensing the physical parameters associated with the system, including the tension of the cable and hose, the depth of the hose, temperature along the buoy hull, attitude and motion of the buoy and cameras to observe the nearby ice conditions. These represent a cost-effective approach to measuring the important parameters that determine buoy safety and longevity.

The second phase of work included the fabrication, assembly, software development and testing prior to shipment for deployment. The buoy consisted of three main sections: the surface piece with electronic subsystems, batteries and antennas, the bottom app suspension piece with hose and cable, and finally the lower acoustic transducer cage.

The buoy design is larger than the original MIZ unit so that it can hold additional electronics for the sensors, otherwise it is very similar. The components include:

1. Controller. A Linux -based controller was used to keep the data collection and telemetry schedule, waking up at programmed intervals to sample sensors and then transmit the data to shore via satellite.
2. Acoustic Modem. A low-frequency WHOI micro-modem operating at 950 Hz listened for transmissions from the SODA moored navigation sources.
3. Cameras. Two cameras were installed to take pictures at low resolution of the surrounding area.
4. Thermistor Chain. A high-resolution array of thermistors was installed on the exterior of the buoy to measure the temperature locally.
5. Pressure. A pressure sensor was installed at the bottom of the reinforced hose to measure the depth at that point.
6. Attitude. Internally a multi-axis attitude sensor measured the tilt and motion.
7. Tension. A strain gauge installed at the bottom of the buoy housing measured the load on the buoy from the weight of the hose and cable.
8. Other sensors included internal temperature and ambient pressure.
9. Telemetry. An Iridium terminal with local embedded controller was used by the Linux controller to upload data sampled by the sensors or logged by the acoustic modem.

The suspension components included:

1. Hose. A short section of urethane-filled hose with a strength member was below the buoy where the ice provides the most shear forces. Conductors for the acoustic transducer and sensors are embedded within the urethane.
2. Cable. A double armored cable with conductors in the center handles loads during deployment and both static and dynamic tensions. While it is very heavy, it ensures the integrity of the electrical conductors.

At the bottom, a small aluminum cage hold the low frequency transducer, which is transmit and receive capable.

RESULTS

Two identical buoys were fabricated and then shipped to Dutch Harbor for final assembly and integration before the SODA cruise aboard the Coast Guard ice breaker Healy. They were configured for sampling once per day, but with a fast mode for checkout just before they were deployed. The buoys were installed at two sensor stations along with other SODA instruments, including the ice mass balance systems from the Naval Postgraduate School and thermistor chains plus meteorological sensors from BAS.

The deployments were done in parallel with other operations such as preparing ice-tethered profilers and took only one hour after the hole in the ice was drilled. After they were installed data flowed back to shore via satellite, and monitoring was done from there as well.

The sensors on both buoys were functional after deployment and the data was plotted and distributed by email to engineers at WHOI for monitoring. The plots included all of the sensors described above, except for the cameras that were turned off after a few weeks because it was so dark. Data such as the tension on the cable was very stable, and similarly, the pressure reading from the end of the hose did not vary significantly. Buoy attitude was also stable. Temperature followed expected trends as winter began and the days grew short.

The acoustic modem on one buoy that was placed near the north science mooring was very useful because it was able to receive the regular acoustic transmissions from science mooring C and the two north navigation moorings. It was possible to keep track of the transmissions from those navigation sources and confirm they were on time and accurate. Eventually one source began to have noticeable clock drift. The source will be recovered and checked during the 2019 recovery cruise.

Unfortunately one of the buoys stopped reporting in the Fall, and the other one January of 2019. However, both had provided significant amounts of data from the sensors, but not during the melt cycle.

IMPACT/APPLICATIONS

The buoy design was comprehensive and reflected the desire to have complete sensing of the platform for engineering monitoring. This approach will be useful in subsequent field trials and Arctic experiments. The joint design of the buoy basic platform plus the acoustic subsystem is an advantageous combination that will hopefully find utility in the future.

TRANSITIONS

The project will transition into the AMOS INP, and likely to other naval programs after its completion.

RELATED PROJECTS

SODA and AMOS.