AXIS—An Autonomous Expendable Instrument System

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ABSTRACT

Expendable bathythermographs (XBT) to profile upper-ocean temperatures from vessels in motion have been in use for some 50 years now. Developed originally for navy use, they were soon adapted by oceanographers to map out upper-ocean thermal structure and its space–-time variability from both research vessels and merchant marine vessels in regular traffic. These activities continue today. This paper describes a new technology—the Autonomous Expendable Instrument System (AXIS)—that has been developed to provide the capability to deploy XBT probes on a predefined schedule, or adaptively in response to specific events without the presence of an observer on board. AXIS is a completely self-contained system that can hold up to 12 expendable probes [XBTs, XCTDs, expendable sound velocimeter (XSV)] in any combination. A single-board Linux computer keeps track of what probes are available, takes commands from ashore via Iridium satellite on what deployment schedule to follow, and records and forwards the probe data immediately with a time stamp and the GPS position. This paper provides a brief overview of its operation, capabilities, and some examples of how it is improving coverage along two lines in the Atlantic.

1. Introduction

The bathythermograph (BT), an instrument to profile the upper-ocean temperature structure, saw heavy use during World War II as an effective way to determine the sound velocity structure for antisubmarine warfare. After the war the BT also became widely used as a simple yet effective way to determine upper-ocean heat storage and to characterize mesoscale oceanographic features, such as the path of the Gulf Stream (Stommel 1958). The navies of the world continued to use the bathythermograph to meet their own needs, but as submarines increased their operational capabilities, the need to profile temperature to greater depth became increasingly urgent. This led to the development of the expendable bathythermograph (XBT) in the 1960s. This flashlight-sized torpedo-shaped expendable device could quickly and accurately profile temperature to typically either 450 or 760 m (the T4 and T7 probes, respectively). This new tool was soon put to work to chart the upper-ocean thermal structure of the Gulf Stream and the slope sea and Sargasso Sea to its north and south, respectively. The *Gulf Stream Monthly Summary*, published between 1966 and 1975 by the U.S. Naval Oceanographic Office, was very effective in bringing the dynamic Gulf Stream and eddy-rich surroundings to the attention of the wider oceanographic community (e.g., Kim and Rossby 1979). In the early 1970s as the International Decade of Ocean Exploration (IDOE) got underway, the XBT was used extensively for synoptic studies of rings, eddies, and fronts in all oceans. Dantzler (1977) used these data to construct maps of the mean depth of the 15°C isotherm across the North Atlantic and the distribution of eddy potential energy. XBTs have even been used from ships and aircraft to conduct repeat synoptic surveys for real-time forecasting of ocean fronts (Robinson et al. 1996; Glenn and Robinson 1995; Alappattu and Wang 2015). Starting in 1976 XBTs became widely used to determine oceanic variability along select routes across the Pacific. White

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and Bernstein (1979) discuss the design of this trans–North Pacific XBT sampling program [North Pacific Experiment (NORPAX)]. Later, White (1995) and Festa and Molinari (1992) discuss the design of global upper-ocean temperature sampling programs from ships of opportunity (SOOP). The XBTs from these programs, together with less frequent but full-ocean depth hydrographic sections, have been quite valuable in studies of low-frequency ocean variability and long-term trends. Indeed, the early start of the SOOP has given us a valuable archive for assessing oceanic heat content variability since the 1970s (Levitus et al. 2000, 2001, 2009; Goni et al. 2010). The next section provides a brief background and overview of existing capabilities, and makes the case for developing the Autonomous Expendable Instrument System (AXIS). Section 3 gives a technical overview of AXIS and how it is programmed and used. Section 4 gives some examples of how AXIS has been able to provide new observational capabilities that could not be accomplished by any other means. A brief summary concludes the paper.

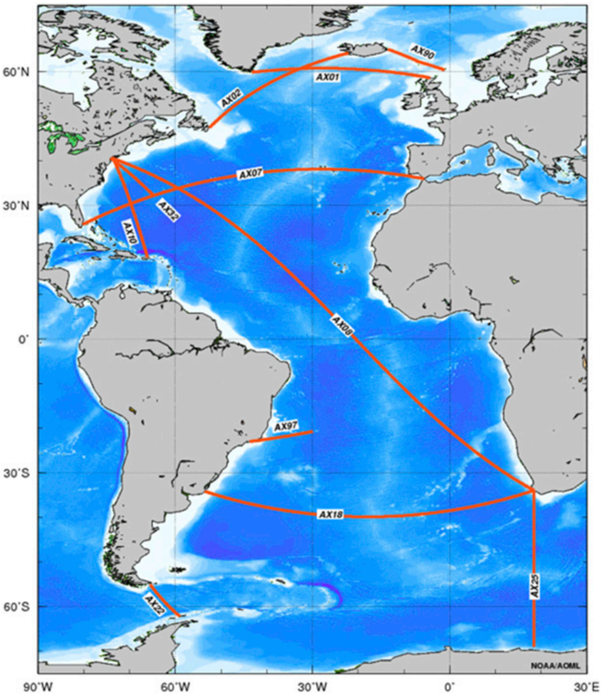

FIG. 1. Map of all active XBT lines in the Atlantic.

2. Background, existing capabilities, and the need for a new system

What makes the XBT so attractive is that it can be deployed over the side or stern of a vessel underway at full speed (15–20 kt; 7.65–10.2 m s^{-1}) to profile temperature to typically ~900 m. The temperature measurement, in the form of a temperature-sensitive resistance, is relayed from the descending probe over a pair of very fine copper wires that is simultaneously spooled out from the probe as it descends, and from a canister in the vessel-mounted launcher. The end result of this process is a detailed profile of upper-ocean temperature structure, obtained at low cost without slowing or stopping the vessel. Today, it might be argued that the XBT is no longer relevant given the global fleet of ~4000 Argo profiling floats, hundreds of surface drifters, and a growing fleet of gliders prowling the ocean. In fact, however, none of these can match the spatially dense near-synoptic sampling afforded by XBTs deployed from vessels in regular service, and which can, if needed, be dovetailed to satellite altimetry to produce upper-ocean currents in near–real time. Used this way the XBT complements these widely distributed but relatively sparse arrays of instruments very effectively. Ocean-spanning high-density XBT transects are routinely occupied by merchant vessels along commercial shipping routes in all ocean basins. Figure 1 shows all active XBT lines in the Atlantic (http://www.aoml.noaa.gov/phod/hdenxbt/index.php).

To reduce the strain of uninterrupted 24-h service deploying XBTs on these long routes, several groups have developed systems that enable automated serial deployment of XBTs (see, e.g., the Scripps unit at http://www-hrx.ucsd.edu/pics/al2.jpg), but by and large such systems still require the attention of a rider or observer on board. While ship owners and their crews are, in general, very accommodating to the needs of science, we have recognized, both in our own research and through discussions with colleagues involved in XBT operations aboard commercial vessels, a need for more efficient and flexible deployment methods for expendable probes. To meet this growing need for both sustained and targeted XBT sampling, we describe here a novel, fully autonomous approach to the deployment of expendable probes. AXIS is a completely self-contained XBT launching system that holds up to 12 expendable probes of any kind and is controlled from shore via the Iridium satellite communications system. Designated shipboard personnel keep an eye on AXIS and refill it as necessary. While this system was originally developed to meet some specific project needs, we see tremendous untapped potential for AXIS deployed on merchant marine vessels because it greatly reduces the need for a rider or observer on board if the ship's crew is willing and able to provide reliable support to reload AXIS with probes for sustained ocean observation along transoceanic sections. The objective, where possible, is to facilitate sampling and improve scientific return with only minimal demand upon the vessel crew.

FIG. 2. View of AXIS on the *Norröna*. The two antennas are for GPS (white) and Iridium (black). The XBT launch chute bends down and away from the back of the ship.

3. AXIS

a. Physical description

Physically, AXIS is fully self-contained in a 0.6 m × 0.6 m × 0.9 m all-weather container. It weighs close to 40 kg, of which about one-third is due to the plastic all-weather container. A ready-to-go system can be installed by a qualified technician in an hour or so. It is best to mount AXIS externally to a railing as low as possible at the transom to minimize the effect of wind on the XBT wire. This has been a very successful approach with the two installations with which we work. It is powered either by a rechargeable battery and solar panel or by vessel power. It has two antennas, one for GPS and one for Iridium. Underneath the AXIS container, which is preferably suspended over an aft railing of the vessel, a curved tube extends down and out; this is the launch chute through which the XBT probe is released (Fig. 2). Figure 3 shows schematically the two principal mechanical features that give AXIS its unique capability. The left panel shows the carousel with its 12 slots, one for each probe canister. The right panel shows how the carousel is rotated to position the next probe over the launch chute, the pipe that extends underneath. The panel also shows the rack and pinion needed to pull the pin from the XBT at launch time. Once pulled, the pin falls into a bucket underneath (not shown). Figure 4 shows AXIS with the outer cover open to gain access to the carousel underneath the flat plate in the center. By loosening the two black knobs to the right in the left panel, the plate opens up and the 12-probe carousel comes into view (right panel). The breech mechanism that connects the canister to the electronics sits in the cover plate. The round "saucer" next to it with the hole in its center fits into the post in the center of the carousel to ensure that the three breech pins sit exactly on top of the probe.

The only manual interaction with AXIS occurs when it needs to be loaded with additional probes. A crewmember opens the all-weather cover, loosens the two knobs, and lifts the plate. The empty canisters are removed and new ones are inserted. Then the plate is lowered, black knobs are tightened, and the all-weather cover is secured. Everything continues under program or remote control. In most applications AXIS operates on a well-defined schedule, which the bosun knows and thus knows when to reload AXIS. A small "do not disturb" red light-emitting diode (LED) comes on when AXIS is checking its carousel position and when it is doing an inventory or an XBT deployment.

Functionally, AXIS consists of three principal components: a control unit; a power supply (batteries or wired); and one or more probe launch carousels (a single control unit can handle multiple carousels), each holding two half-circles with six probe slots in each. This arrangement provides a compact but highly scalable system that is adaptable to many types of applications. For operation on a research vessel, only a single-launch carousel may be required. For a SOOP ship, using several carousels could reduce the frequency for at-sea reloading by the designated crewmember(s). Having two or more carousels also provides a measure of fault tolerance. If AXIS fails, or if a batch of bad XBTs prevents good operation, then the XBT section will be incomplete. But after repair the section can be retaken at the next available opportunity.

b. AXIS functional overview

The AXIS functionality is implemented through four units: the GPS Wake Supervisor (GWS), the AXIS system controller (ASC), the launcher control module (LCM), and the Lockheed Martin MK21 Ethernet (Fig. 5). The GWS runs the real-time clock, gets GPS fixes, powers up ASC if AXIS has reached one of the predefined criteria: StartDateTime, PositionStart, or user-defined wake-up for start-up. The ASC is the "brain" of system; it controls the LCM and MK21 DAQ. It checks the status of MK21 before initiating XBT launch. It handles all shore-side communication through Iridium. In normal operation AXIS releases probes

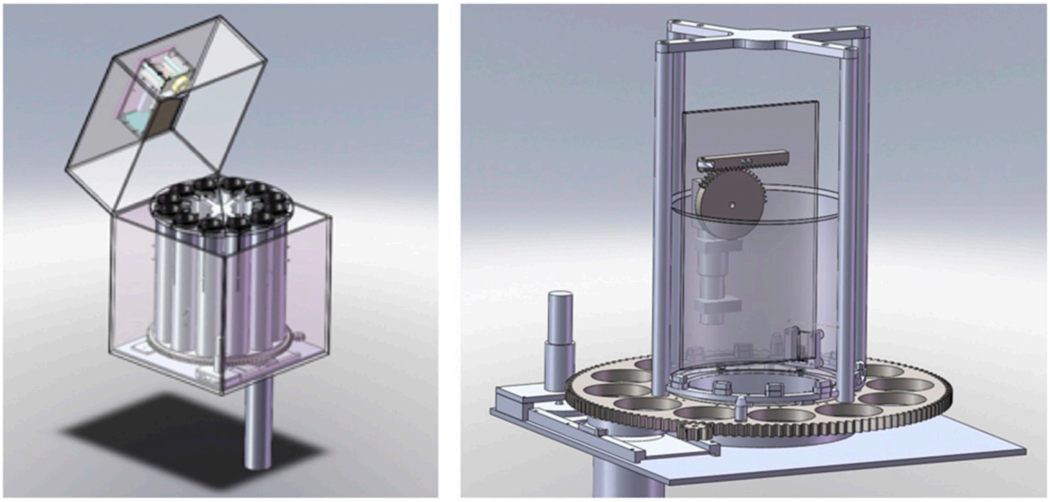

FIG. 3. Simplified view of the AXIS mechanics. (left) Carousel with its 12 slots for expendable probe canisters. The carousel is rotated so that the next probe to be launched is positioned above the launch chute and the tube extending below. (right) Gear mechanism for rotating the carousel. The toothed wheel and rod above is the rack and pinion mechanism that moves back and forth to pull the probe pin.

according to a predefined plan, such as when the vessel passes a certain longitude or latitude, but one can also contact AXIS (via Iridium) and release probes "manually." The LCM is the controller for all of the mechanical movements; upon command from the ASC, it opens the exit door through which the probe falls, moves the carousel position to the desired position, and plunges the breech pins into the top of new probe. After circuit and continuity tests by the MK21, it initiates pin pull, causing the probe to be launched and the circuit is completed when probe hits water. The MK21 Ethernet board is essentially a standard probe data acquisition board from Lockheed Martin with a few modifications so it can be controlled from ASC. All information needed for autonomous operation is stored in the Mission Parameter file, and information on the probes stored in the carousel(s) is stored in the Inventory file (see the appendix for a more detailed description of these).

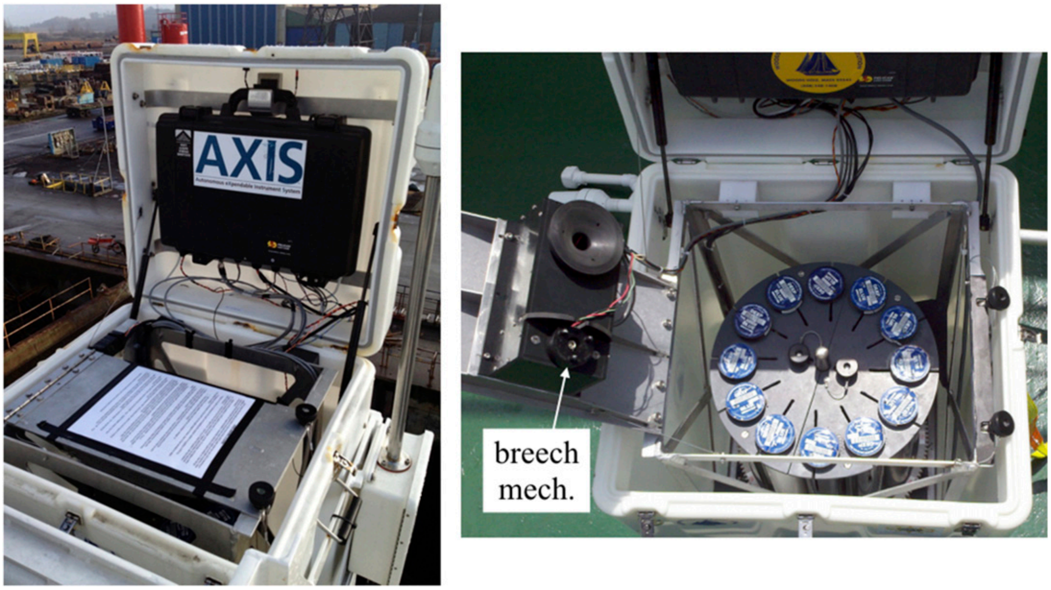

FIG. 4. (left) AXIS with its weather cover open. All electronics are housed in the black box in the cover. It is never opened. (right) Carousel with 12 probe canisters in place with the cover open. Note the breech mechanism.

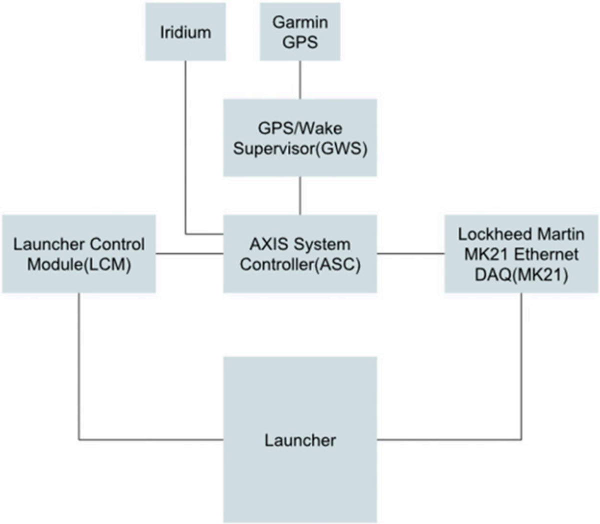

FIG. 5. Block diagram of the AXIS operating system.

The sequence of events to launch a probe and to report a profile can be summarized as follows:

- At the appropriate moment, the ASC will apply power to the LCM and the MK21 acquisition system and open the exit door. It then requests the appropriate rotation of the probe magazine and the closing of the breech mechanism.
- Via a high-level software interface with the MK21, the LCM will initiate communication with the probe and provide the LCM with a clear-to-launch message.
- The LCM will then pull the pin and deploy the probe.
- Upon completion of the drop, the ASC will close the exit door and open the breech mechanism. The MK21 will send a copy of the resulting data file to the ASC over Ethernet while archiving the original data on a flash-based storage system.
- If the postdrop status from the LCM is satisfactory, then power to the LCM and MK21 is removed. In the event of probe failure or premature wire breakage, multiple deployment attempts (up to a user-defined limit) can be initiated.
- Once a data file is received at the ASC, it is relayed to a shore-side server over the Iridium link along with ancillary time, position, and a log of all activities associated with each deployment.
- Depending on the application, data received on the shore-side server may be subjected to additional quality control measures. We archive all data at Stony Brook University (http://po.msrc.sunysb.edu/Oleander/XBT/NOAA_XBT.html), as well as forward all data to the NOAA Atlantic Oceanographic and Meteorological Laboratory (AOML) XBT data center (http://www.aoml.noaa.gov/data/). The forwarded data are precisely as produced by the MK21 Ethernet system. We do not apply any corrections for fall rate or drop height. All probes are made by Lockheed Martin Sippican, but the only metadata provided are probe type, not manufacture date or serial number. A funded enhancement for AXIS includes an optical reader to determine what type of probe sits in each slot. This will remove any need to externally enter this information.

Two AXIS systems have been in operation for nearly 10 years now. In that time we have learned about some of the sensitive items and how to address them. AXIS involves moving parts in a marine environment, yet there have been surprisingly few failures of critical components. One example of an unanticipated problem was the main bearing for the carousel. The bearing is made of a low friction plastic machined to tight tolerances to make sure the carousel remains steady. This plastic, however, absorbs moisture and in the process swells, causing binding of the bearing. Subsequent machining now makes provision for this effect. Other issues that have arisen over the years have been addressed as they occur, and the units seem quite robust at this time. One thing we have learned, the hard way, is that the pin bucket needs to be emptied after about 300 launches to prevent interference with the pin puller.

4. Typical AXIS data

Two AXIS systems have been installed so far, one on the Container Vessel (CV) *Oleander*, which operates between Hamilton, Bermuda, and Port Elizabeth, New Jersey, and one on the high-seas ferry Motor Ferry (MF) *Norröna*, which operates out of the Faroe Islands to Denmark and Iceland. The *Oleander* AXIS operation was motivated by the need to extend the ongoing XBT program begun in 1978 to include the full Gulf Stream and Sargasso Sea in a single synoptic transect. Not only could we extend the XBT lines, but AXIS enabled us to increase the sampling to the same standard as other high-density lines: a probe every 25 km. Thus, AXIS not only continues, but it strengthens a program that started nearly 40 years ago. The *Norröna* line had no XBT capability at all, so the addition of AXIS now gives us monthly synoptic views of the inflow into the Nordic seas between Scotland, the Faroe Islands, and Iceland. The following sections give examples of the data AXIS now provides. All XBT data are publicly available (http://po.msrc.sunysb.edu/Oleander/XBT/NOAA_XBT.html; http://po.msrc.sunysb.edu/Norrona/xbt.html).

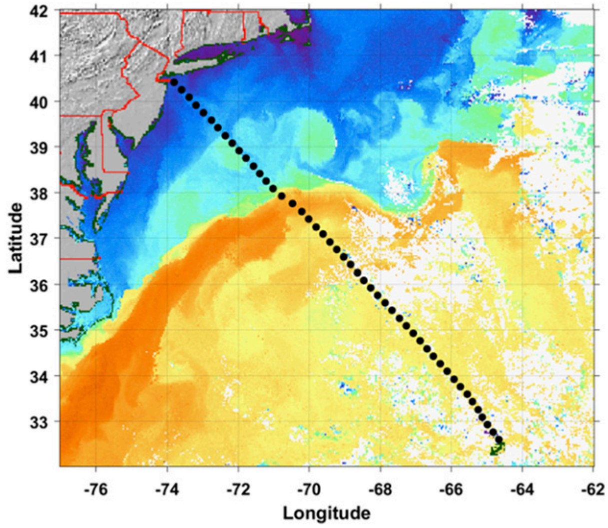

FIG. 6. A 7-day composite view of sea surface temperature off the U.S. East Coast; the compositing eliminates much of the cloud coverage. The dots are the XBT sites (see Fig. 7). (SST image courtesy of the Ocean Remote Sensing Group within The Johns Hopkins University Applied Physics Laboratory.)

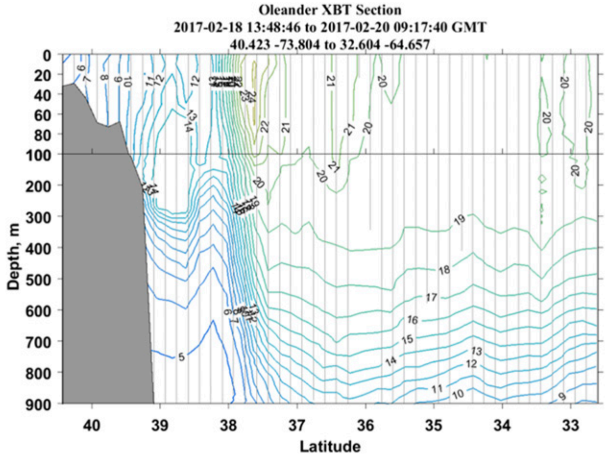

FIG. 7. Temperature along the *Oleander* section between New Jersey and Bermuda. Each gray line is an XBT profile. Note the sharp Gulf Stream at ~37.5°–38°N and the bolus of 14°C water between 38.5° and 39°N. The warm Sargasso Sea is well mixed to nearly 300 m.

a. The Oleander *XBT dataset*

The *Oleander* and its predecessors have been participating in the NOAA National Marine Fisheries Service's SOOP since 1978, which up until the installation of the AXIS system in 2012 always required a rider to deploy the XBTs. Because of the initial interests of the program on the fisheries of the New England continental shelf, the requirement for a rider was adequate, aside from the manpower cost factor. With the expansion of the areas of interest with the advent of the ADCP program, there was a need to expand the XBT coverage to the slope sea, to the Gulf Stream, and into the Sargasso Sea—that was too much for a rider to cover, as the ship takes nearly 3 days to transit from New Jersey to Bermuda. As a result, the offshore half of the XBT section was covered during the return trip with a time gap of about 3 days in the section. Now with the deployment of the AXIS system, the XBT section can be completed in a single transit and with the same high spatial resolution, 25-km spacing as with other high-resolution SOOP lines (Fig. 6). The resulting temperature field in Fig. 7 shows the well-defined Gulf Stream between 37.5° and 38°N as to be expected from Fig. 6. It also shows a bolus of warm (~14°C) water between 38.5° and 39°N, what is likely the remnant of a warm core ring after overwintering. One sees a hint of it in sea surface temperature in Fig. 6. The Sargasso Sea is well mixed at 20°C to nearly 300-m depth. No sign at present of the classic 18°C Water (Worthington 1976).

Another advantage of the AXIS system is that it enables us to sample episodic events that fall outside the routine sampling schedule. One such event for the *Oleander* was the passage of Hurricane Joaquin in early October 2015. The *Oleander* was scheduled to make its run to Bermuda just as the hurricane was passing just west of Bermuda. To avoid the hurricane winds, the ship passed west and south behind the hurricane. We were watching the progress of both the hurricane and the ship; this presented us with an excellent opportunity to drop some probes into the hurricane's wake. So, the AXIS system was alerted and a mission to drop three probes was sent to the ship. The results are shown in Fig. 8. The westernmost profile of the three profiles (blue) was more than 200 km away from the path of the storm. The other two profiles show an interesting difference with the eastern profile (red), which was just to the right of the hurricane's path, showing a very distinct deepening of the mixed layer from around 50 to about 85 m and cooled nearly a degree relative to the green profile, which was on the hurricane's western flank and thus exposed to much weaker winds. This redistribution is due to convective mixing, not actual loss of heat because the heat stored in the surface layer is so large relative to what can be lost during the hurricane's passage. The shallower upper-ocean thermal structure (red and green) relative to the blue remote profile is very likely due to a hurricane-driven surface divergence that lifts the thermal field under the hurricane (upwelling) and pushes the field down at distance (Ginis 2002). This example shows how the flexibility of AXIS can be used to sample not only long-term climatic scale processes but also short-lived and opportunistic events.

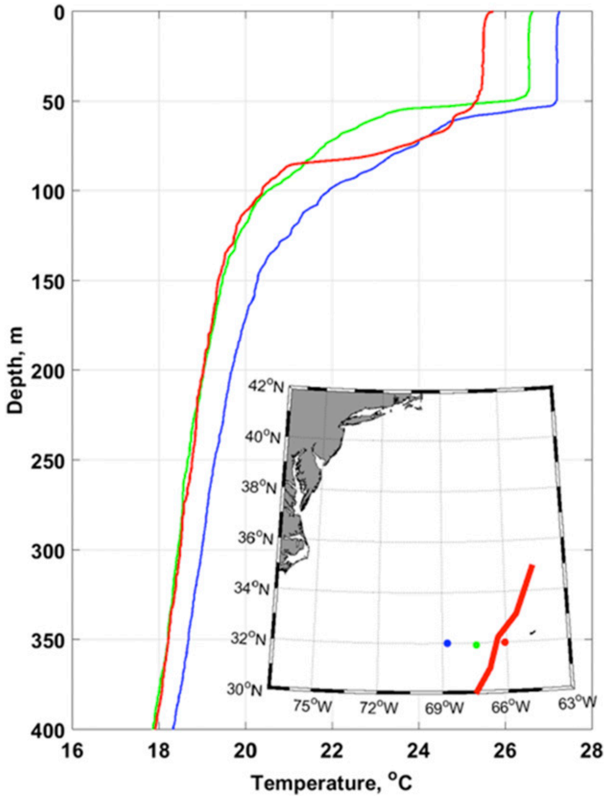

FIG. 8. Three XBT profiles taken from the *Oleander* as it passed behind Hurricane Joaquin. The blue profile is ~200 km west of the hurricane path, the green one is at the western flank, and the red one is just east of the hurricane center, where the winds are very strong. The red line shows the path of the center of the hurricane.

b. *The* Norröna *dataset*

The key advantage of SOOP operations is the repeat nature of their operations, which when combined with a device like the AXIS system can deliver information on both short- and long-term oceanic variability. In the fall of 2013, the MS *Norröna* was equipped with AXIS and with the help of the ship's crew, monthly XBT sections commenced across the Faroe–Shetland Channel and along the Iceland–Faroe Ridge (Fig. 9).

The Faroe–Shetland Channel is the area through which the slope current normally flows along the Scottish slope carrying warm North Atlantic Water into the Nordic seas. Figure 10 shows the mean temperature distribution in the channel, including the warm water hugging the Scotland slope. This is essentially the classic picture of the temperature field in the channel [see Helland-Hansen and Nansen (1909), for perhaps the earliest description]. But thanks to the repeat sampling, we now have a far better handle on how much conditions can vary in the channel. Figure 11 shows a Hovmöller diagram of the depth of the 5°C isotherm, which approximately separates the warm North Atlantic Water from the cold southward-flowing water at depth. Whereas Fig. 10 shows that on average the 5°C isotherm rises up from nearly 600 m along the Scottish shelf to ~400 m along the Faroes slope Fig. 11 shows how much the isotherm actually can vary in depth, especially along the western side of the channel. Between 4° and 4.5°W, the 5°C isotherm's depth varies between about 500 m to less than 200 m during the 30 months of data shown, while the time scale varies from 2–3 months to more than a year. An annual fit to the 5°C isotherm suggests that there is about a 50-m-depth variation that occurs along the Faroes slope about 3 months earlier than along the Scottish slope. However, this estimate is based upon only 30 months of data. Much more variability is associated with the shorter-term fluctuations with a typical time scale of 6 months. On top of these seasonal and shorter-term variations is a decrease in the depth of the 5°C isotherm in 2015 by nearly 200 m compared to a year earlier. This sampling program is ongoing, and we hope these initial results will provide a strong incentive to continue it along with the ADCP current measurement program on board the *Norröna* (e.g., Childers et al. 2014).

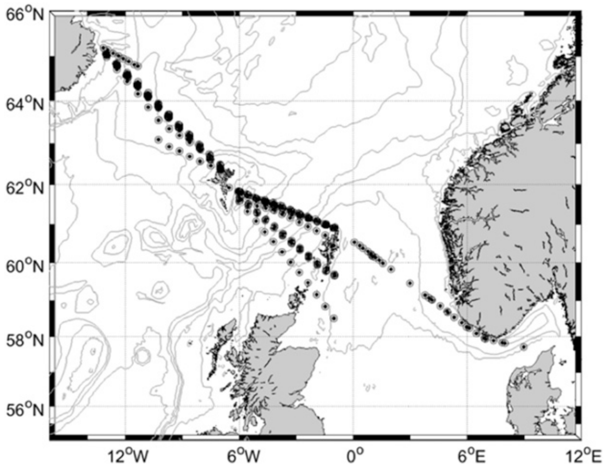

FIG. 9. Location of all XBTs that have been taken by the *Norröna* AXIS since September 2013.

5. Summary

In much the same way that a cabled observatory provides researchers with access to instrumentation in the coastal ocean, the advent of reliable and affordable two-way satellite communication enables remote interaction with a variety of autonomous platforms and devices spread over the globe. In the not-too-distant future, a network of AXIS-equipped ships could allow for adaptive probe deployment strategies (perhaps motivated by

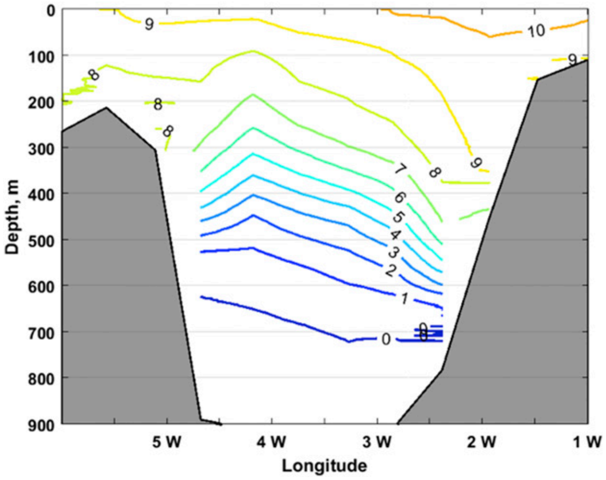

FIG. 10. Mean temperature in the Faroe–Shetland Channel. Faroe shelf to the left and just north of Shetland to the right.

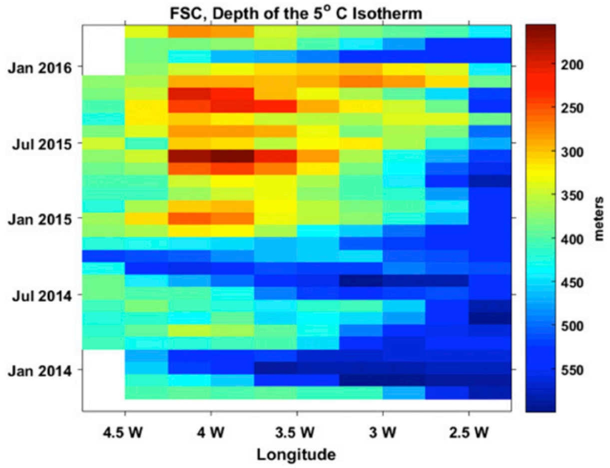

FIG. 11. Hovmöller diagram of the depth of the 5°C isotherm in the Faroe–Shetland Channel.

features observed in satellite remote sensing (altimetry or surface temperature), including those that will come into view with the upcoming Surface Water Ocean Topography (SWOT) mission that will resolve sea surface height to smaller scales than presently possible (https://directory.eoportal.org/web/eoportal/satellite-missions/s/swot). Since AXIS does not require an observer, one can readily increase the sampling density to resolve fronts in detail, as well as increase the temporal sampling rate to monthly or even shorter time scales (subject to vessel availability) if desired. This improved capability will substantially strengthen our water column observational skills in dynamically active regions, such as fronts and boundary currents, and thereby provide an effective complement to the global Argo system.

Two AXIS systems have been in operation for a total of nearly 10 years. One AXIS is on the MV *Oleander*, which operates out of Bermuda to Port Elizabeth on a weekly schedule. After a rebuild of AXIS in 2012, we take XBT sections monthly on the *Oleander*. Starting in 2016 the sampling has been further increased to a probe every 25 km, requiring a crewmember to load AXIS four times (four boxes) during the vessel's 60-h transit. The other AXIS has been in operation since 2013 on the high-seas ferry MS *Norröna*, which operates from the Faroe Islands to Denmark and Iceland, also on a weekly schedule. In both cases, the data from these high-resolution sections are immediately posted on the Global Telecommunications System. The data are also posted on a website at Stony Brook University. Despite the harsh conditions under which these systems operate and the fact that this is entirely new technology, they have clearly proven their worth. The *Oleander* AXIS entered service just about when NOAA could no longer send an observer, and the *Norröna* XBT line would simply not have been possible, since Argo floats cannot reach into these waters between Scotland, the Faroe Islands, and Iceland. In both cases designated members of the ship's crew keep an eye on AXIS and reload as necessary.

AXIS operates autonomously, releasing probes either by position, distance, or elapsed time. Shore-side investigators can also track AXIS and command it to release probes when the vessel crosses features of interest. As an example, the AXIS on the *Oleander* was programmed to release XBT probes just as the ship passed through the wake of Hurricane Joaquin, revealing the deepened mixed layer as a result. This greatly enhances the role SOOP can play in ocean observation: with modest investment of shore-side attention, it can be ready to release probes, whether the basic XBT or the XCTD, which also profiles salinity, as the vessel passes over fronts or feature of interest. This is above and beyond the basic need to implement and maintain a cost-effective means for monitoring ocean developments along selected routes for sustained periods of time.

Acknowledgments. We thank Lockheed Martin Sippican for allowing WHOI to use its proprietary software development tools. These allowed us to provide a high-level interface to the MK21 without reinvention of the critical probe control aspects. Initial development of AXIS mechanical design elements was made possible by awards from the Cecil H. and Ida M. Green Technology Innovation Fund and the Sealark Foundation to the team of Dave Fratantoni, Keith von der Heydt (WHOI), and Terry Hammar (WHOI). Construction of the first full AXIS prototype was supported by a technology grant from the National Science Foundation (OCE-0926853) and the second one through an NSF-funded (OCE-1061185) subcontract from the University of Rhode Island. We are grateful to Dr. Jon Hare and his group at the Northeast Fisheries Fisheries Center for their terrific support in installing and operating the prototype AXIS on the MV *Oleander*. We thank the three reviewers for their careful reading and helpful questions, comments, and suggestions.

APPENDIX

Mission and Parameter Files

Two important data files complete the AXIS system. The first one contains the Mission file parameters. These are defined as follows:

MSSN	Metadata for user
GPSI	Wake-up interval to get GPS fix
ISUI	Wake-up ASC if number of wake-ups > this
MODE	Defines mission off or time- or location-based drops
STDT	Start date if time-based drops
TTND	Time to next drop (time-based spacing)
PSST	Position start, latitude, or longitude, which when exceeded triggers probe drop
RLAT	Reference latitude
RLON	Reference longitude
DTND	Distance to next drop (distance-based spacing)
RTRY	Number of retries before deleting probe from drop list
RMDT	If disk space gets tight, remove older data files
DSQC	Drop sequence count
DPSQ	List of probes in drop sequence

The second file is the Inventory file. It contains all information regarding the probes that have been loaded. It inventories all probes as follows:

CC	Carousel (in case of multiple launchers)
PP	Position (1–12)
TT	Type of probe (can handle all MK21 compatible probes)
SS	Status (0–3: available, drop OK, drop-failed, and get inventory, respectively)

The probe parameters 0–11 refer to the following:

T4
T5
T6
T7
T10
T11FS
DeepBlue
FastDeep
XSV1
XSV2
XSV3
XCTD1

With a modification (that is being implemented with a bar code reader), the system will be able to read and identify what type of probe is loaded in the carousel positions.

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