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Arctic Technology Evaluation 2014 Oil-in-Ice Demonstration Report

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Arctic Technology Evaluation 2014 Oil-in-Ice Demonstration Report

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16. Abstract (MAXIMUM 200 WORDS) <p>The RDC deployed multiple technologies in 2014 off of the USCGC Healy north of Alaska, evaluated their performance in the Arctic environment, and assessed their utility to enhance Coast Guard capabilities. This report focuses on the oil response portion of the demonstration. The RDC's oil-in-ice research goal in Arctic Shield 2014 was to collect data to provide information about tracking simulated oil (oranges and dye) near the ice edge and simulated oil interactions with the ice edge.</p> <p>Most of the objectives were met for the oil-in-ice demonstration. The wind prevented some systems from being deployed simultaneously and the fog did not permit the cameras to identify the targets on some days. The oranges and dye appeared to work as surrogates; but more oranges and a longer lasting dye would be more useful. Drifting buoys moved about 18 miles in 40 hours and collected good data. Images of the dye and oranges were collected from the aerostat and unmanned aerial vehicles. The information was entered into the Environmental Response Management Application (ERMA) as would be done in an actual response.</p> <p>The next steps should include identifying more robust systems and conducting more realistic multi-ship demonstrations to exercise the equipment on multiple platforms and evaluate the coordination requirements needed between vessels.</p>					
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EXECUTIVE SUMMARY

In 2013, the USCG R&D Center (RDC) brought several unmanned technologies onboard USCGC Healy and evaluated their performance in the cold weather environment as part of Arctic Shield. Based on lessons learned in 2013, the RDC deployed new and improved technologies in 2014, evaluated their performance in the Arctic environment, and assessed their utility to enhance Coast Guard capabilities. This report focuses on the oil response portion of this demonstration. The RDC's oil-in-ice research goal in Arctic Shield 2014 was to collect data to provide information about tracking simulated oil near the ice edge and simulated oil interactions with the ice edge. The intent was to provide information about the tasks, equipment, and timing that may be required during an actual oil spill

The objective of the oil-in-ice demonstration was to conduct a field deployment using dye and oranges to simulate oil and test systems including unmanned aerial, surface and underwater vehicles, aerostat mounted sensors, and visual sightings to track the oil surrogates. Data was collected from the ship's sensors, an aerostat, an unmanned surface vehicle (Wave Glider®) and a small unmanned aerial system (sUAS), the Puma AE. Drift and wind data were collected by a Consolidated Surface Instrument Float with Tracking Buoy (SWIFT) and 4 oil tracking buoys (iSPHERES) that were deployed in the water and on two ice floes. Collected data included specific environmental parameters (e.g. wind speed and direction), photographs and videos. Oranges and fluorescent dye were deployed into the water to serve as simulated oil. The demonstration was scheduled to occur over a 48-hour period; but the weather did not permit deployment of some of the equipment during this specific time frame. Data was still collected by sensors simultaneously with some information collected about 20 miles away, farther away from the ship than originally planned. The information was entered into the Environmental Response Management Application (ERMA) provided by NOAA that served as the Common Operating Picture (COP) for this demonstration, as would be done during an actual response.

Most of the objectives were met for the oil-in-ice demonstration. The wind prevented some systems from being deployed simultaneously; and the fog did not permit the cameras to identify the targets. The oranges and dye appeared to work as surrogates; but more oranges and a longer lasting dye would be more useful. The iSPHERE and SWIFT buoys drifted about 18 miles in 40 hours; and worked and collected good data. Both would be useful during an actual event, if there are difficulties in keeping the oil in sight. Images of the dye and oranges were collected from the aerostat and Puma AE. The oranges and the buoys generally ended up in the same location. Deploying multiple systems on a single vessel, as done during this demonstration, is not recommended during an actual spill.

Data was passed to ERMA, but further analysis is needed to determine usefulness and quality of the data from all of the sensors. Standard data organization protocols should be developed, so that the data is submitted in the same format from each sensor for any reporting. During an actual response, having a computer programmer available to facilitate efficient information management is mandatory to automate data processing methods more efficiently to support data collection during the next operational period.

Tracking oil in the Arctic will be difficult, as expected. But it may be even more difficult to do the research needed to determine how the oil will move. While many other investigators are recording general turbulence and mixing at the ice edge, it is dangerous to launch small boats in swells and choppy waves in order to place buoys and/or simulants into the water and recover them.



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The next steps should include: identifying more robust systems; conducting more realistic multi-ship demonstrations to exercise the equipment on multiple platforms; and evaluating the coordination requirements needed between vessels.



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LIST OF ACRONYMS, ABBREVIATIONS, AND SYMBOLS

AK	Alaska
ALOFTCON	Aloft Conning Station
ASB	Arctic Survey Boat
AUV	Autonomous Underwater Vehicle
CG	Coast Guard
USCGC	United States Coast Guard Cutter
COP	Common Operating Picture
CTD	Conductivity Temperature Depth Measurement
D17	District 17
ERMA	Environmental Response Management Application
FOL	Forward Operating Location
GIS	Geographic Information Systems
GPS	Global Positioning System
IR	Infrared
ISR	Intelligence, Surveillance and Reconnaissance
MIZ	Marginal Ice Zone
NOAA	National Oceanic and Atmospheric Administration
PPE	Personal protective equipment
Puma AE	Puma All Environment
RDC	Research & Development Center
ROV	Remotely operated vehicle
SO	Safety Officer
SOP	Standard Operating Procedure
SWIFT	Consolidated Surface Wave Instrument Float with Tracking
sUAS	Small Unmanned Aerial System
TBD	To be determined
U.S.	United States
sUAS	Small Unmanned Aerial System
USCG	United States Coast Guard
USV	Unmanned Surface Vehicle
UUV	Unmanned Underwater Vehicle
WAGB	Polar Class Icebreaker



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1 OVERVIEW

The US Coast Guard 17th District (D17) covers the entire state of Alaska. Most of their assets for people and equipment are stationed below the Arctic Circle. Since 2007, D17 has been sending equipment and personnel to Nome, Kotzebue, or Barrow to establish a Forward Operating Location (FOL), as well as deploying cutters to the Bering, Chukchi, and Beaufort Seas. These deployments have included C-130 aircraft, H-65 and H-60 helicopters, buoy tenders, communications equipment, a High Endurance Cutter; and, in FY2013, a patrol boat (USCG D17, 2014). The enhanced Coast Guard presence is primarily in response to the added traffic in the region (most notably, oil company vessels supporting drilling operations). Representatives from the USCG Research and Development Center (RDC) first supported this effort as an observer at the FOL in Barrow in 2008. The RDC returned in 2012 as both observers and participants and participation was expanded in 2013. While all of the multiple Coast Guard's missions need to be addressed for this area, its Marine Environmental Protection mission was the RDC focus in Arctic Shield 2012, 2013, and secondary focus in 2014.

A large amount of work has been done to evaluate and develop methods and equipment to respond to oil spills in the Arctic; a comprehensive sample of efforts is not provided here. There have been oil-in-ice workshops, multiple general reviews, multiple manuals and specific analysis (Dickins, 2011, National Commission, 2010, AMOP, 2010, and SINTEF, 2010). There is also a large joint industry project trying to identify and close the response gaps (Mullin, 2014). Unfortunately, there have been limited recent efforts to exercise the equipment and methods in an operational setting to determine specific deployment schemes in the ice, due to the lack of availability of ice-strengthened ships or icebreakers. The RDC has conducted several demonstrations in the Great Lakes that attempted to address some of the issues (Hansen, 2014). BP Exploration and Alaska Clean Seas carried out a demonstration off of the North Slope of Alaska (Bronson et. al, 2002) that concluded there is an upper limit of 10 percent ice on the water for their mechanical recovery equipment to operate.

As part of both Coast Guard's Seventeenth District's exercises - Arctic Shield 2012 and 2013- the RDC was involved with the deployment of oil spill response equipment off of Alaska. These occurred just off of Barrow in 2012; and in the ice about 300 miles north of Barrow in 2013. In 2013, the RDC brought several unmanned technologies onboard USCGC Healy and evaluated their performance in the cold weather environment. Based on lessons learned in 2013, the RDC deployed new and improved technologies in 2014, evaluated their performance in the Arctic environment, and assessed their utility to enhance Coast Guard capabilities. This report focuses on the oil response portion of the demonstration.

1.1 Purpose

The RDC's oil-in-ice research goal in Arctic Shield 2014 was to collect data to provide information about tracking simulated oil near the ice edge and simulated oil interactions with the ice edge. The intent was to provide information about the tasks, equipment, and timing that may be required during an actual oil spill.

1.2 Background

One of the objectives of Arctic Shield 2013 was to evaluate remote sensors for use during an oil spill, using frozen oranges and peat moss as oil surrogates. The RDC encountered problem with both of these surrogates. In 2013, the oranges were frozen over the previous 2 months, resulting in a darker color and smaller size due to shrinkage, making them difficult to see. The peat moss could only be seen if scattered directly on the snow or



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ice and is not readily detectable when it is in the water. In 2014, fluorescent dye and fresh oranges were used. Fresh oranges were acquired in Seward, Alaska and kept in a refrigerated (not freezer) space.

1.3 Objectives

The objective of the oil-in-ice demonstration was to conduct a field deployment using dye and oranges to simulate oil and test sensors to track the oil surrogates including unmanned aerial, surface and underwater vehicles, aerostat mounted sensors, and visual sightings. An additional objective was to evaluate ice detection using radar. Specific objectives were:

- 1.) Collect data for modelers that track the position of the oranges and dye on an hourly basis.
- 2.) Identify technologies that can be used to track oil every 4-6 hours during a spill.
- 3.) Collect sufficient environmental data to support the above collection objectives.
- 4.) Evaluate each piece of equipment individually to assess its effectiveness in tracking the oil surrogates.
- 5.) Evaluate launch/recovery issues, data collection and data analysis processes/procedures.
- 6.) Develop tactics, techniques and procedures for each technology individually and simultaneously.
- 7.) Make recommendations for future Arctic tests or spill response.

The operational area for the demonstration was 600-1,000 kilometers north of Barrow, Alaska (see Figure 1). For the first two days (August 16-17) the operations were near the southern conductivity, temperature and depth (CTD) cast where the shelf slope occurs as seen in Figure 1. The northern demonstration area was in deeper water near the northern CTD cast. The original intent was to stay in open water at the edge of the Marginal Ice Zone (MIZ). When it was determined that the required small boat operations could not occur because the environment was outside of the safety parameters established by the ship, a location further into the ice with limited swell, but open water, was found and used.

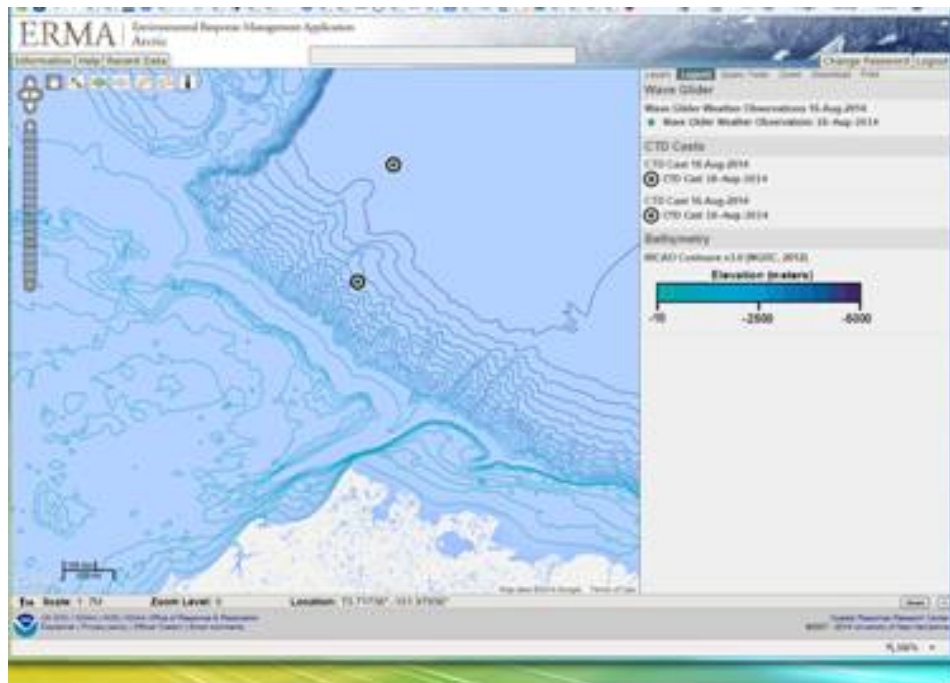


Figure 1. Location of CTD casts.

2 DESIGN OF TEST

The test utilized the capabilities of the various sensors to track the oil surrogates and provide a description of the location. The tracking technologies included an aerostat, a small unmanned aerial system (sUAS), an unmanned underwater vehicle (UUV), an unmanned surface vehicle (USV), a surface wave instrument float with tracking (SWIFT), and two remotely operated vehicles (ROV). Simultaneously, the sensors also tracked the ice to determine how it was moving with respect to the oil. When possible, multiple sensors obtained data simultaneously to help confirm the data. The original planned layout is shown in Figure 2. The plan was for the USCGC Healy to lay alongside the ice, if the ice was stable enough. If the ice was not stable, the plan was to anchor (if shallow enough) or position within sight of the oil surrogates. A location was chosen that had a relatively well defined ice edge with open water and waves. It would have been preferable for the wind and current to both be blowing towards the ice; but any direction within 45 degrees of the ice edge was considered acceptable. The test was scheduled for about 48 hours in duration, so short-term deployments of technologies were expected.

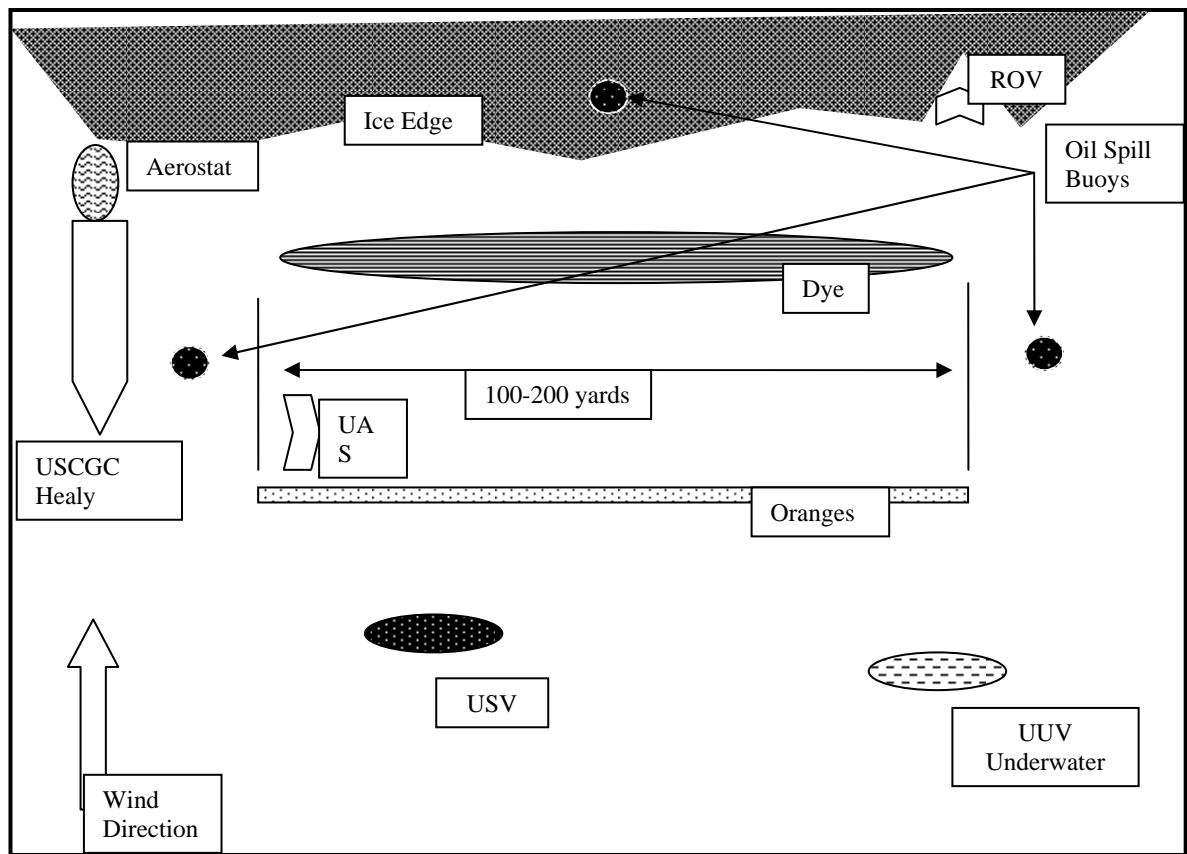


Figure 2. Planned layout of oil-in-ice exercise.

3 SENSOR TECHNOLOGIES

All of the operationally available technologies were used during this evaluation. The exact timing was dependent upon the support needed for each piece of equipment.

3.1 Aerostat – AEROSTAT-IC

The AEROSTAT-IC system is a self-contained, compact aerostat platform and payload/sensor deployment unit which incorporates all the necessary components required to safely inflate, deploy and operate the lighter-than-air surveillance platform. It is designed to minimize the amount of time and resources required for the deployment and operation of the aerostat platform. This lighter-than-air platform is able to carry a diverse number of sensors or payloads of up to 40 pounds, ranging from cameras, communication relays, and atmospheric testing sensors amongst others to an altitude of up to 1,000 feet. The aerostat was deployed from the USCGC Healy flight deck

The system utilizes a launch and retrieval system (LRS) that is comprised of small electrical winches located throughout the unit and controlled by a hand held controller. The LRS is used to take the place of additional operators during the launch and recovery phases by handling the three launch and recovery lines attached to the aerostat. The system also utilizes a main tether line which anchors the aerostat to the main base at all times and brings electrical power to the camera and down-link units and thus eliminating the need for heavy batteries. The aerostat (balloon) is a kite-like semi-sphere aerostat with a volume of 1,400 cubic feet (ft³) and an outer shell which protects it from the elements. Six helium bottles of 300 ft³ each are housed within the unit and provide for inflation and servicing. Additional bottles were provided for cold weather.



Figure 3. Aerostat and LRS (left) and aerostat deployed (right).

3.2 Autonomous Underwater Vehicle (UAV) – GAVIA

The GAVIA from Cambridge, UK is a man-portable autonomous underwater vehicle (UAV) (Figures 4 and 6). The data collected were used to confirm potential use of sonar to find oil on the underside of the ice; and to map the ice configuration beneath ice ridges. This system had to be hung in the water off the side of a small boat, in order to communicate instructions from a separate command transducer. The system was then programmed to run upside-down in order for the sonar to point up into the ice. For insurance purposes, a small Kevlar tag line was attached to ensure the vehicle could be retrieved safely. The extra work needed to program the system and the use of the tether increased deployment times and complicated the effort by keeping personnel exposed in a small boat for up to 4 hours. The locations where ice ridges are formed would be the most interesting to evaluate using this system. Unfortunately, no usable data were provided to the RDC to directly support the oil-in-ice demonstration so this technology is not discussed in the results section of this report. The data collected was not in close proximity to the surrogate deployment locations.

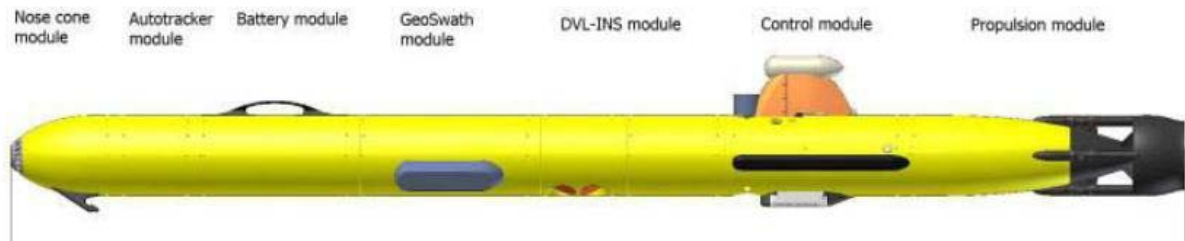


Figure 4. GAVIA AUV.

Physical specs

Length: 2.7m (typical, depends on configuration)

Weight in air: 70 - 80kg (typical, depends on configuration)

Diameter: 200mm

Depth rating: 500m or 1000m

Battery module: 1.2 kW lithium ion rechargeable cells per module

Max speed: > 5.5 knots

Endurance: Dependent on speed and exact configuration. Typically 4 – 5 hours at 3 knots per rechargeable battery module with all sensors (including swath bathymetry).

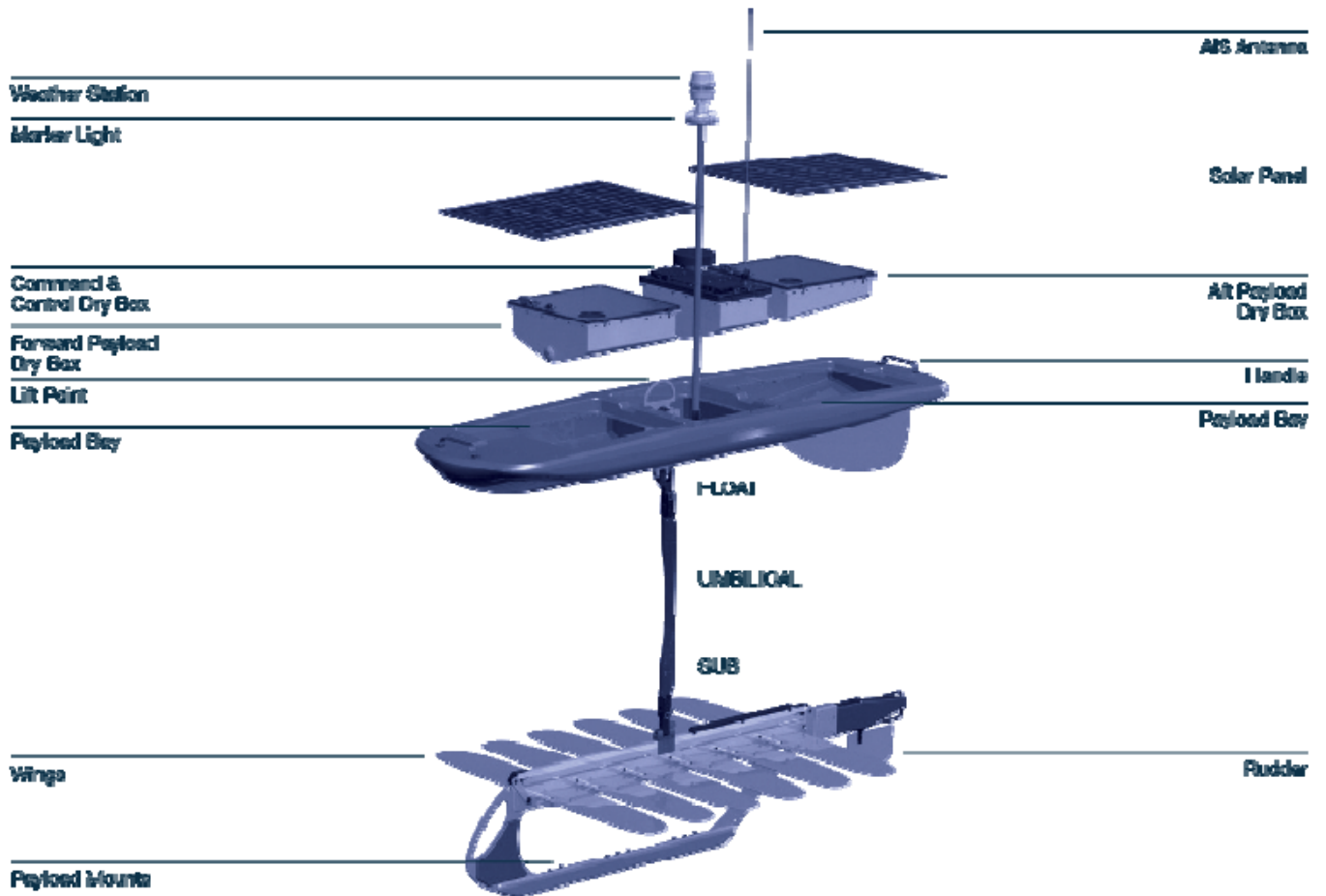
Communication

Wireless LAN: IEEE 802.11g compliant

Satellite communications: Full global coverage via Iridium link

3.3 Unmanned Surface Vehicle (USV) – Wave Glider®TM

The Wave Glider® SV Series are unmanned autonomous marine robots with the ability to stay out at sea for long durations through all weather conditions; and communicate real-time data from the surface of the ocean. The model used in Arctic Shield 2014 was 82 inches long and 24 inches wide at the surface with a 20-foot tether to the wings below (Figures 5 and 6). It was outfitted with CTD, weather, and velocity profiler sensors.



<http://liquidr.com/technology/architecture.html>

Figure 5. Wave Glider® (from Liquid Robotics Web Site).



Figure 6. Wave Glider® (USV) and GAVIA (AUV) on deck.



3.4 Small Unmanned Aerial System (sUAS) – Puma AE

The AeroVironment Puma All Environment (AE) is a small hand-launched UAS designed for maritime use. It has a wingspan of 7.6 feet and is 3.8 feet long. It weighs 13.5 pounds with a standard visual and IR camera package. Test results showed that in cold weather, a two-hour flight endurance is achievable. It is hand launched (Figure 7); and can be landed in the water or on the ice at the end of the sortie. This system was provided by NOAA.



Figure 7. Puma AE sUAS.

3.5 Environmental Buoys

3.5.1 iSPHERE

The iSPHERE is an expendable buoy designed to track and monitor oil spills. It is 15.5 inches in diameter, weighs 24 pounds, and is constructed of high impact plastic (Figure 8). It provides GPS and sea temperature data at 20 second intervals, that is uploaded to a satellite every 30 minutes through an Iridium transceiver. The data collected were post-processed. The buoys were funded by the Oil Spill Research Institute of Cordova, AK.



Figure 8. iSPHERE from MetOcean.

3.5.2 Consolidated Surface Wave Instrument Float with Tracking (SWIFT)

The SWIFT Buoy (Figure 9) is designed and built by the Applied Physics Laboratory at the University of Washington. It is designed to measure turbulence near the ocean surface. It was used in this test to study wave-ice interaction and associated mixing and dispersion.



Figure 9. SWIFT buoy.

3.6 Remotely Operated Vehicles (ROV)

Two small remotely operated vehicles (ROV) were available for use. A small VideoRay from San Francisco (see Figure 10) and a slightly larger SeaBotex (see Figure 11) were utilized. Limited useful data were collected by them, as the deployments of the oranges and dye were too far away from the ship for the ROVs to detect.



Figure 10. VideoRay.



Figure 11. SeaBotex.

3.7 Ice Navigation Radar

The Coast Guard relies on radar to achieve multiple vital missions. In the Arctic, this sensor becomes crucial in times of limited visibility, especially when a vessel is transiting in ice-covered waters. In addition, the identification of open water where oil will collect during an accidental spill is important. In order to determine requirements, the RDC mounted a Rutter SIGMA S6 radar processor on the USCGC Hollyhock in the Great Lakes, in February 2013, in a configuration very similar to the one mounted on the USCGC Healy. The data collected indicated the extra processing in the ice navigation radar enabled the crew to identify different types of ice and its thickness as well. An additional evaluation was done on the USCGC Healy in 2014 to determine if the same performance parameters applied in the Arctic.



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The radar installations on the USCGC Hollyhock and the USCGC Healy were both temporary. A letter of permission was provided for the USCGC Hollyhock installation dated 15 February 2013 by CG Surface Forces Logistics Center and confirmed for the USCGC Healy via email 2 December 2013.

The key to this processor is that it processes a full dynamic range of data (12-bit video) versus the 2-4 bit intensity in standard navigation radar that are more than adequate to identify other vessels, buoys and points of land. This processor then is able to produce a higher-quality image for better ice definition. The processor uses the standard X-band out (Analog) usually set on a short pulse for better resolution. Other high intensity targets are not removed from the display (see Figure 12). Figure 13 shows the processor and monitor set in the navigation area of the USCGC Healy.



Figure 12. Rutter radar display with radar turned on.





Figure 13. Rutter radar processor setup on the USCGC Healy.

4 TIMELINE

4.1 General Description

The USCGC Healy approached the ice on August 15. On August 16, a conductivity, temperature, and depth (CTD) cast was made at location 73 0.79N and 156.24W using the vessel's equipment. Data were collected down to 200 meters. An attempt was made to begin the experiment and several iSPHEREs were placed on or near the ice and dye/oranges were deployed. Unfortunately, the wind was too high to deploy the aerostat and Puma AE, the visibility deteriorated, and all equipment was retrieved. The ship moved further into the Marginal Ice Zone (August 18) and found a location with sufficient fetch to create some waves and turbulence; and all of the equipment was launched. A second CTD was performed at 73 59.8N and 155 20.2W. The visibility was still limited but the aerostat and Puma AE were able to provide some pictures. The next day, August 19, the weather was optimal and additional dye and oranges were deployed; and photographs taken from the aerostat and Puma AE. All of the previously deployed equipment was recovered. The detailed collection of data to provide to modelers was not able to be accomplished. The focus changed to documenting the capabilities of the equipment and how the data can be formatted for use in ERMA.

4.1.1 Specific Details

16 Aug 2014 – Ship arrived at ice edge and performed a CTD cast and deployed the Wave Glider® (Figure 14).

17 Aug 2014 – Ship transited farther into ice to find appropriate testing location. The SWIFT Buoy 09 was deployed. The GAVIA was deployed on one occasion.



Figure 14. Wave Glider® ready to deploy.

18 Aug 2014 – A location was found away from the large ocean swells but with enough fetch that choppy waves were being created near the ice edge. A location for the tracking demonstration was chosen about one-half mile off the bow of the Healy (Figure 15). Two of the iSPHERE buoys were deployed on ice floes using the cutter’s Arctic Survey Boat (ASB). Before any oranges or dye could be placed, a sUAS was launched; but could not hold position due to the high winds of over 25 knots at 300-400 feet, so it was brought down. The buoys were retrieved and the experiment postponed. Data on a nearby ice floe was recorded by the AUV. The ship had drifted at least one mile from the starting position but less than that with respect to the buoys.

In the afternoon, at approximately 1500, the USCGC Healy moved further into the ice to conduct a second attempt. A location again about one-half mile from the USCGC Healy was identified. The aerostat was launched although with limited visibility. The ASB was launched and deployed four iSPHERE buoys, a SWIFT buoy, three buckets of dye solution, and five cases of oranges (Figures 16, 17 and 18). The dye was partially mixed with warm fresh water and then dispersed through a fire hose using an eductor similar to what is used with firefighting foam. The dye patch sank quicker than anticipated and was not observable within 2 hours of release. The resulting mixture may have caused the dye to sink quickly.

The ASB could see the ship but the aerostat was not visible through the fog, even when lowered to about 100 feet which resulted in the EO/IR package being at the same level as the ALOFTCON, which is an alternative conning station located up the ship’s mast. Data were collected by the AUV. An attempt was made later in the evening to launch a sUAS, but the fog rolled in. As the USCGC Healy drifted several miles downwind, researchers received confirmation that data were being received from the four iSPHERE buoys and the SWIFT buoy.





Figure 15. Site on morning of 18 August.



Figure 16. Oranges being deployed.



Figure 17. iSPHERE buoy on ice.



Figure 18. SWIFT buoy deployed.

19 Aug 2014 – The USCGC Healy was repositioned to within about one mile of the iSPHEREs’ reported position and the aerostat and sUAS were launched. It appears that the USCGC Healy drifted so quickly out of range that neither system had sufficient resolution to find buoys or oranges. The ship again repositioned using the reported locations of the iSPHEREs and lookouts spotted two of the buoys. The ASB was directed to the area; and found and recovered a third buoy and the SWIFT buoy. The position of the last buoy was apart from the others; the USCGC Healy was successful in finding it when directed to the latest position. The ASB was directed to and successfully recovered the last buoy. The UUV was deployed twice during this day to record underwater ice ridge data. Additional oranges and dye were deployed in the afternoon and the aerostat and sUAS recorded the movement for a brief period of time lasting about one hour (Figure 19).



Figure 19. Deploying oranges and dye on August 19.



5 RESULTS

The results are discussed below in terms of how successful the demonstration was in collecting multiple sets of data that correlate with each other. Environmental data including air and water temperature, wind speed and direction, and buoy drift were collected by several sensors as well as by the ship. The results are divided into two groups of data to be analyzed. The Wave Glider®, the USCGC Healy, and SWIFT buoys recorded data near the first CTD locations on or about August 16. The second group of data were collected August 18-20 during the oil-in-ice demonstration.

5.1 Oceanography and Weather on August 16-18

Casts were done at the edge of the Marginal Ice Zone (MIZ) on August 16 that still had ocean swells moving through the ice at about 0830 local time. The day was slightly overcast in the morning and the seas were calm (see Figure 20). CTD data were collected only for the first 200 meters of the water column. The CTD data shown in Figure 21 indicates a quick reduction in the radiance as a function of depth given as density; which would be expected and will be used to compare with data collected from the alternate location. Figure 22 shows a typical increase in salinity with depth, a decrease of oxygen with depth and, ignoring the data fluctuations, a general reduction in temperature with depth.

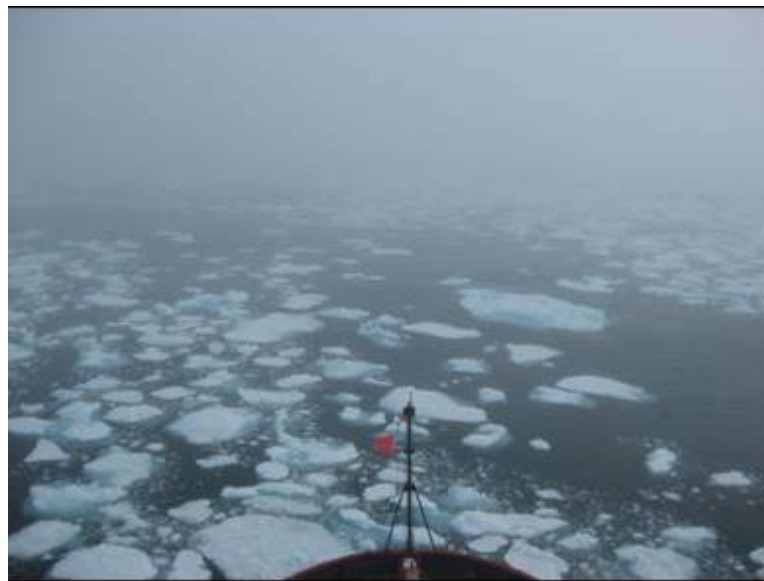


Figure 20. Conditions off USCGC Healy bow on August 16.

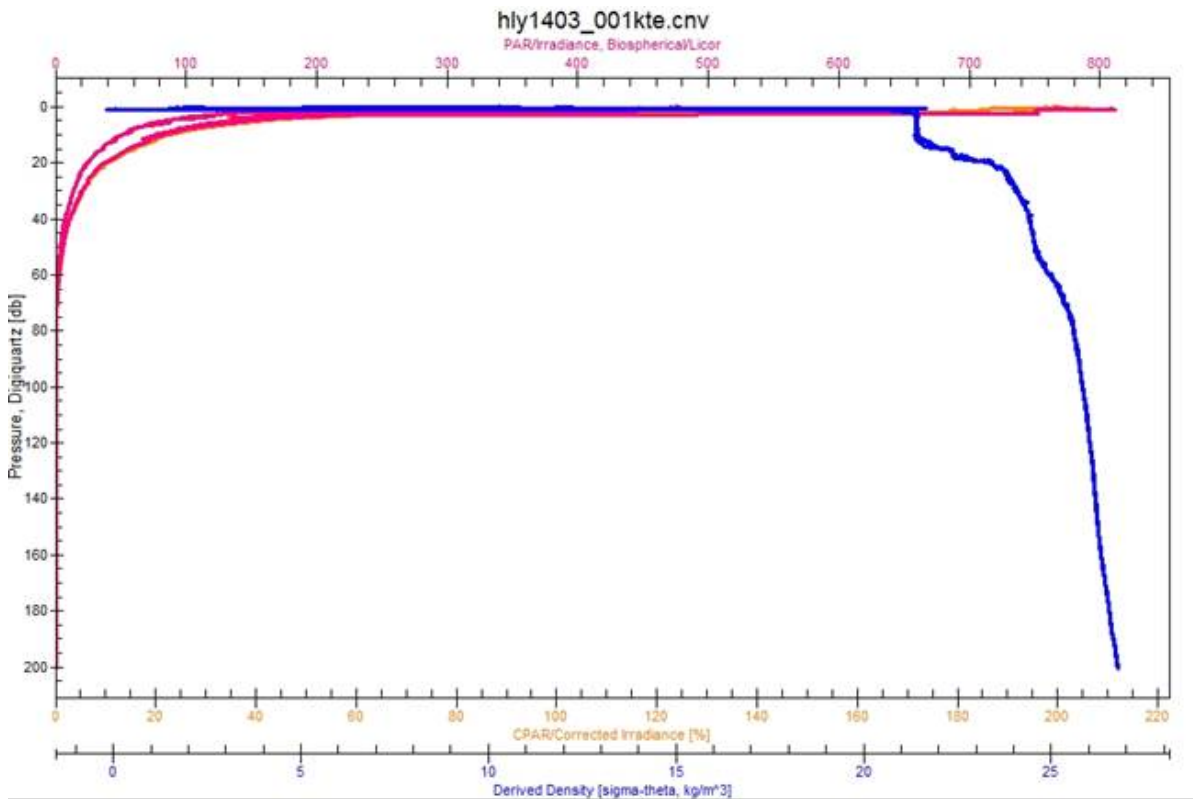


Figure 21. PAR radiance for August 16 CTD.

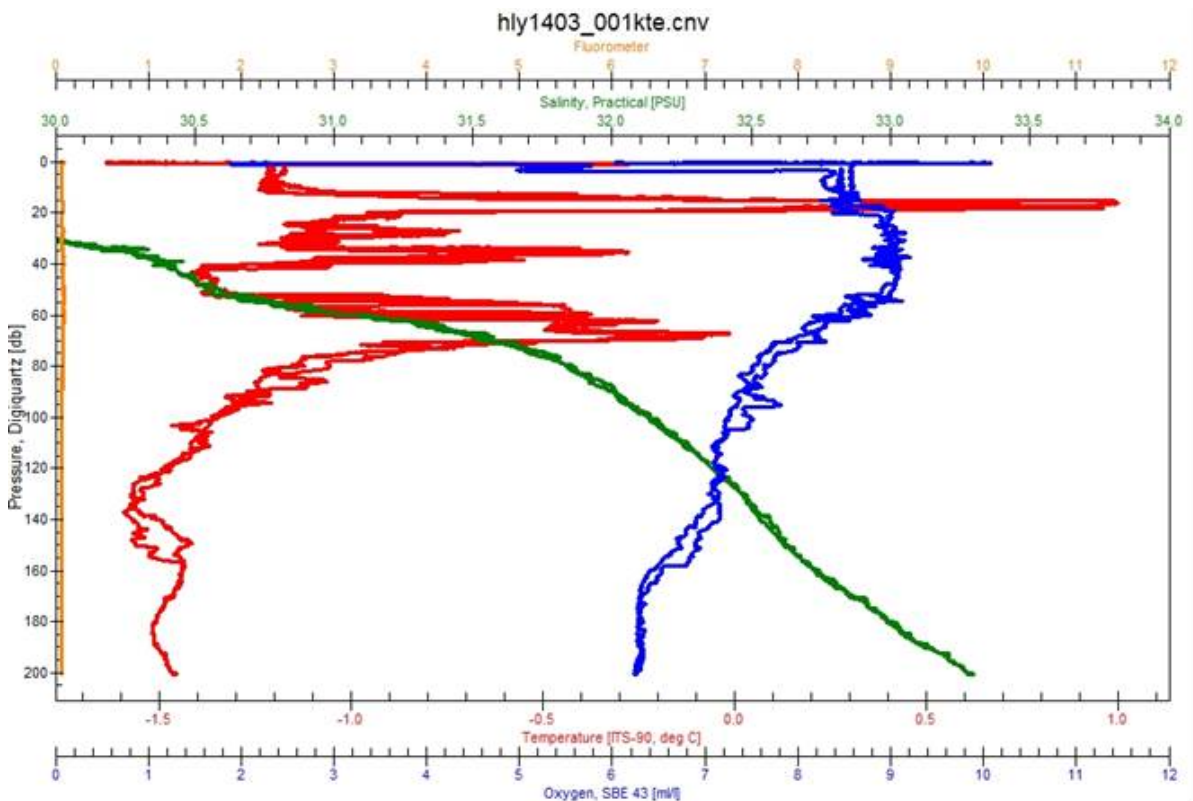


Figure 22. Data from August 16 CTD.



5.1.1 Other Environmental Data

The intent was to deploy several of the unmanned systems and simultaneously collect identical data. For instance, the Wave Glider® and SWIFT data could be compared to the ship data. After the first CTD cast, the Wave Glider® and SWIFT Buoy were deployed in locations about 20 miles apart (see Figures 23 and 24).

The data from SWIFT are shown in Figure 25. The Wave Rider quickly depleted its power and was not able to collect much besides its position and some wind data as seen in Figure 26. USCGC Healy wind data is shown in Figures 27-28.

When comparing wind speed, all of the data sets do not overlap temporally or spatially. The data from the USCGC Healy and SWIFT both show the wind coming out of the east and blowing about 6-8 meters per second. The Wave Glider® data show easterly wind during the early part of the 16th but then coming in from the north. The fluctuations of the wind between 350 degrees and 010 results in a plotting issue between 0808 and 0828. It is not clear what caused this difference, but one possibility is that the Wave Glider® was in some type of ice condition that caused a change in the wind direction near the surface, or it was in a different wind field away from the ice. No other data were collected during this time to use for comparison.

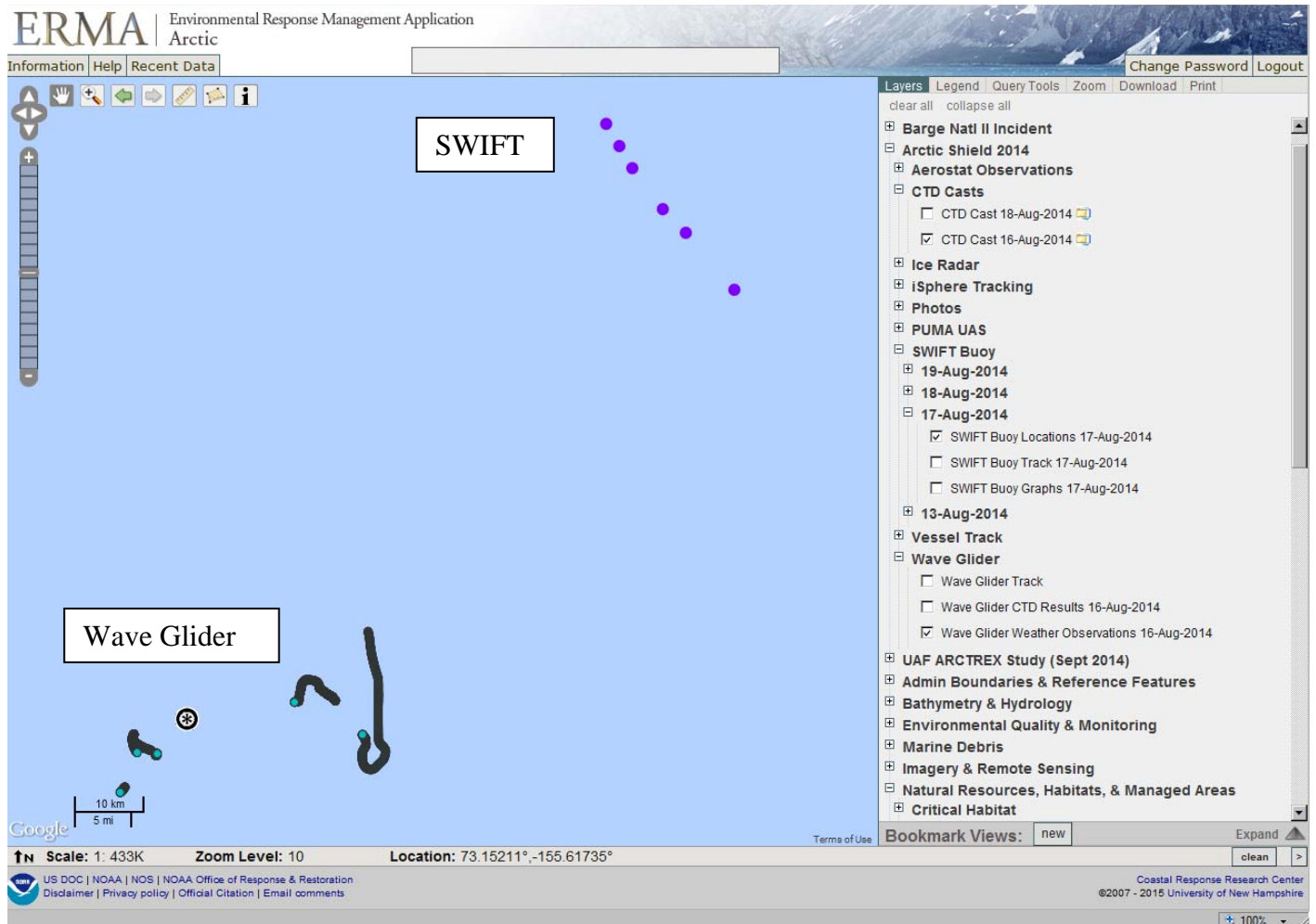


Figure 23. Location of CTD cast, Wave Glider® Positions, and SWIFT August 16-17.



Figure 24. Wave Glider® after launch.

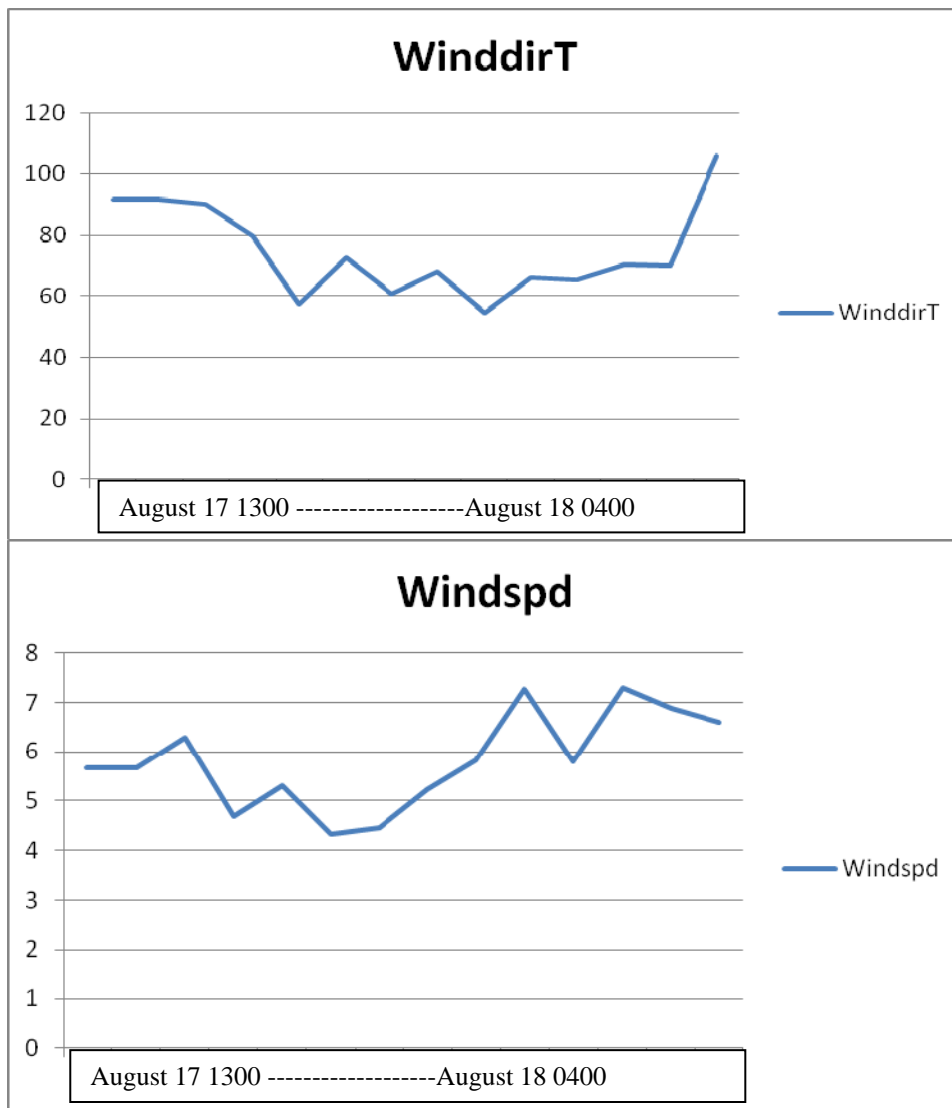


Figure 25. SWIFT08 Data: Wind direction (top) wind speed (bottom).



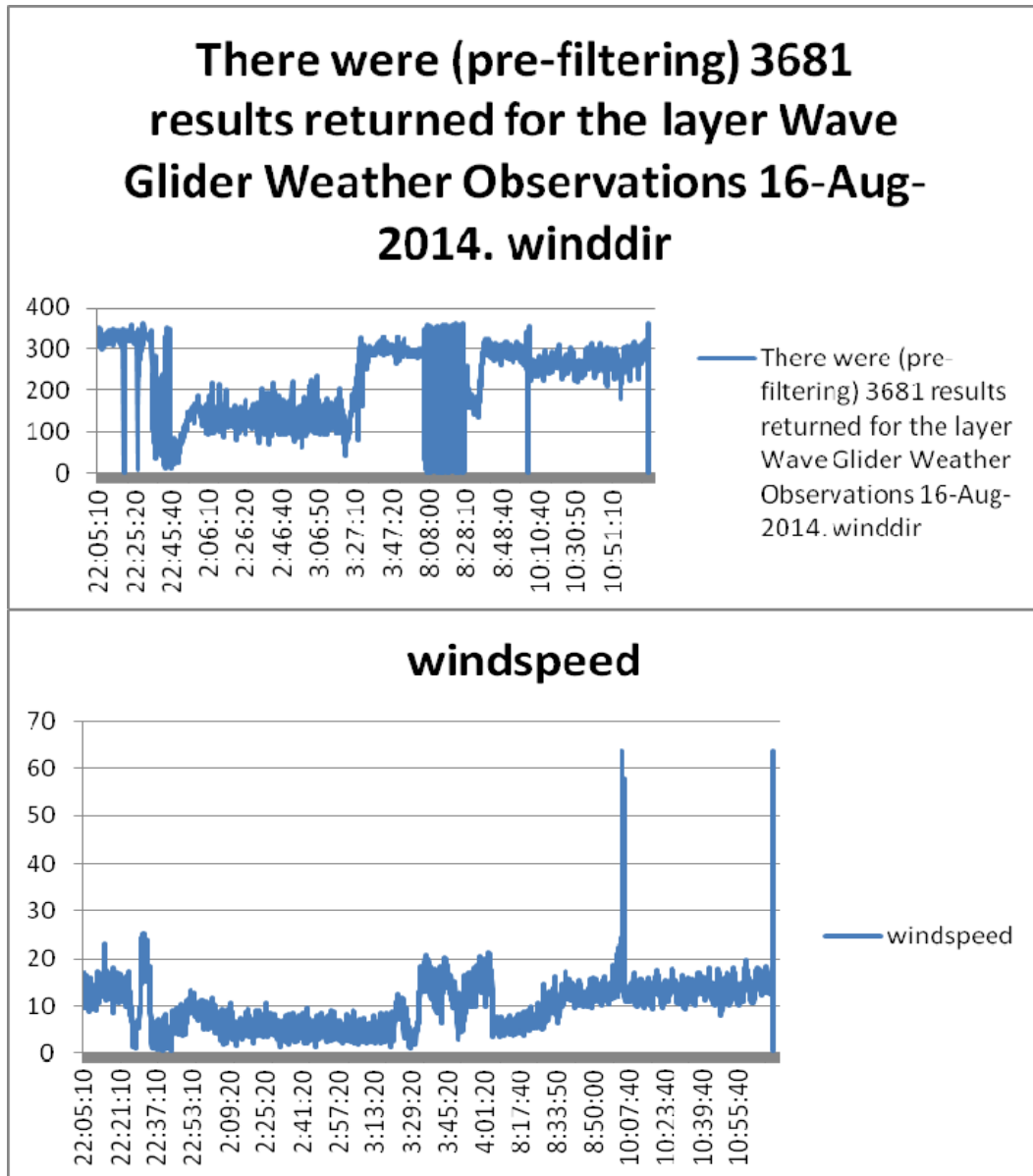


Figure 26. Wind data from Wave Glider®.



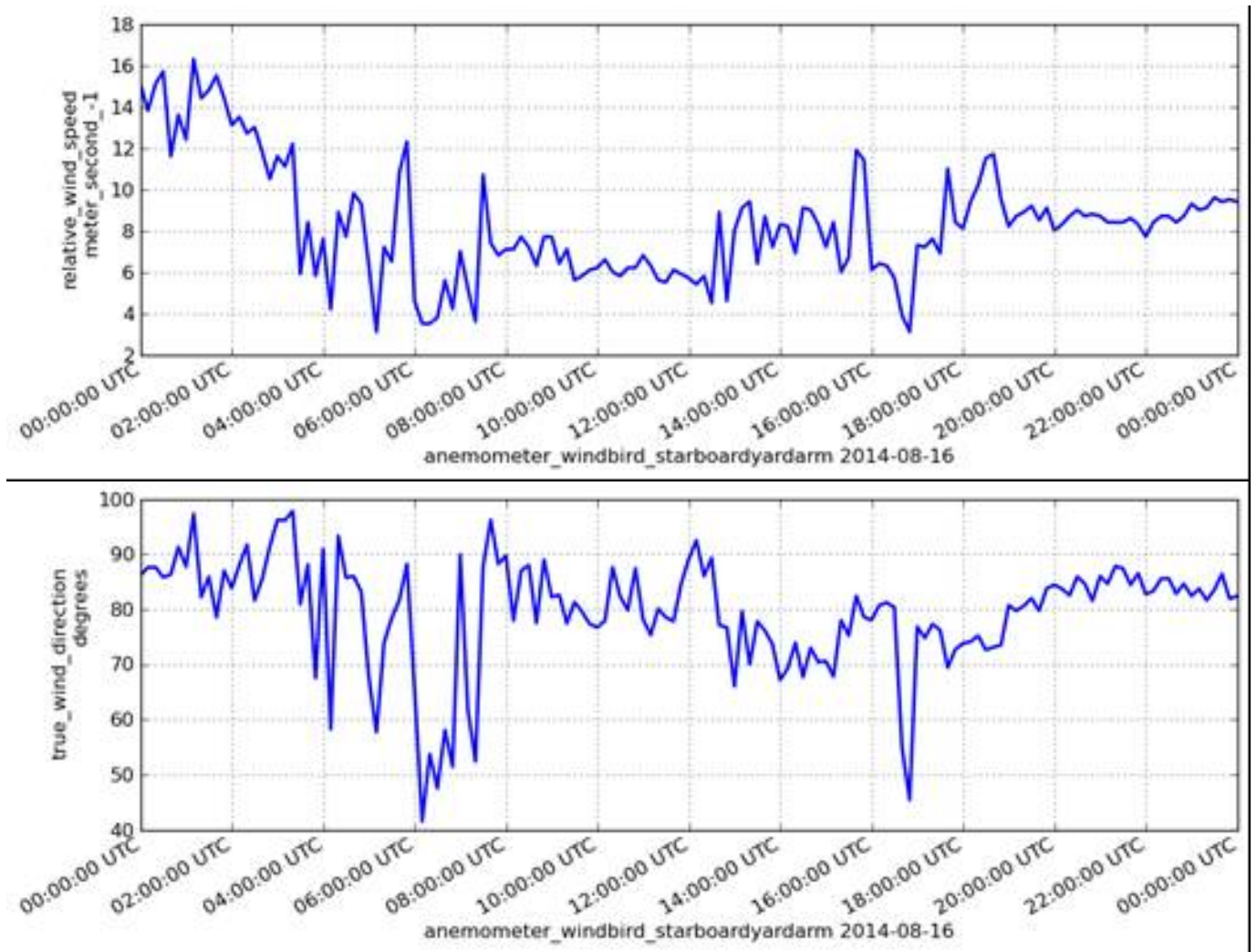


Figure 27. USCGC Healy on August 16: Wind speed (top), wind direction (bottom).

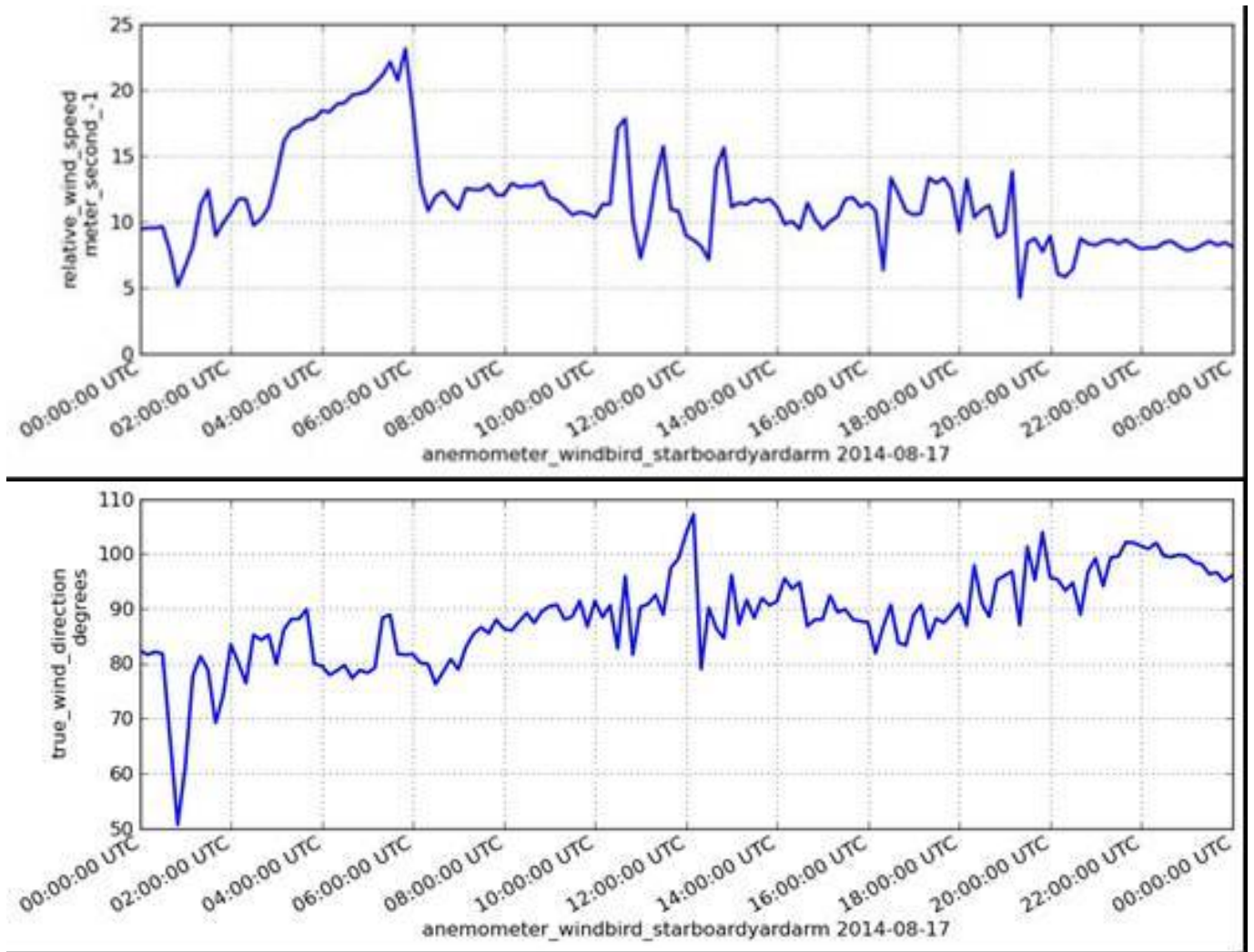


Figure 28. USCGC Healy on August 17: Wind speed (top), wind direction (bottom).

5.2 Oceanography and Weather on August 18-19

Next, a location was sought to deploy the dye, oranges, and drifting buoys (iSPHEREs and another SWIFT) to conduct the oil-in-ice demonstration. As described in Section 4, weather postponed the test at the first location, but the deployment finally occurred on August 18. The varying conditions can be seen in Figures 29 and 30. Some of these changes occurred within a few hours as weather fronts moved through the area.

5.2.1 Weather



Figure 29. Conditions on August 18, morning and afternoon.

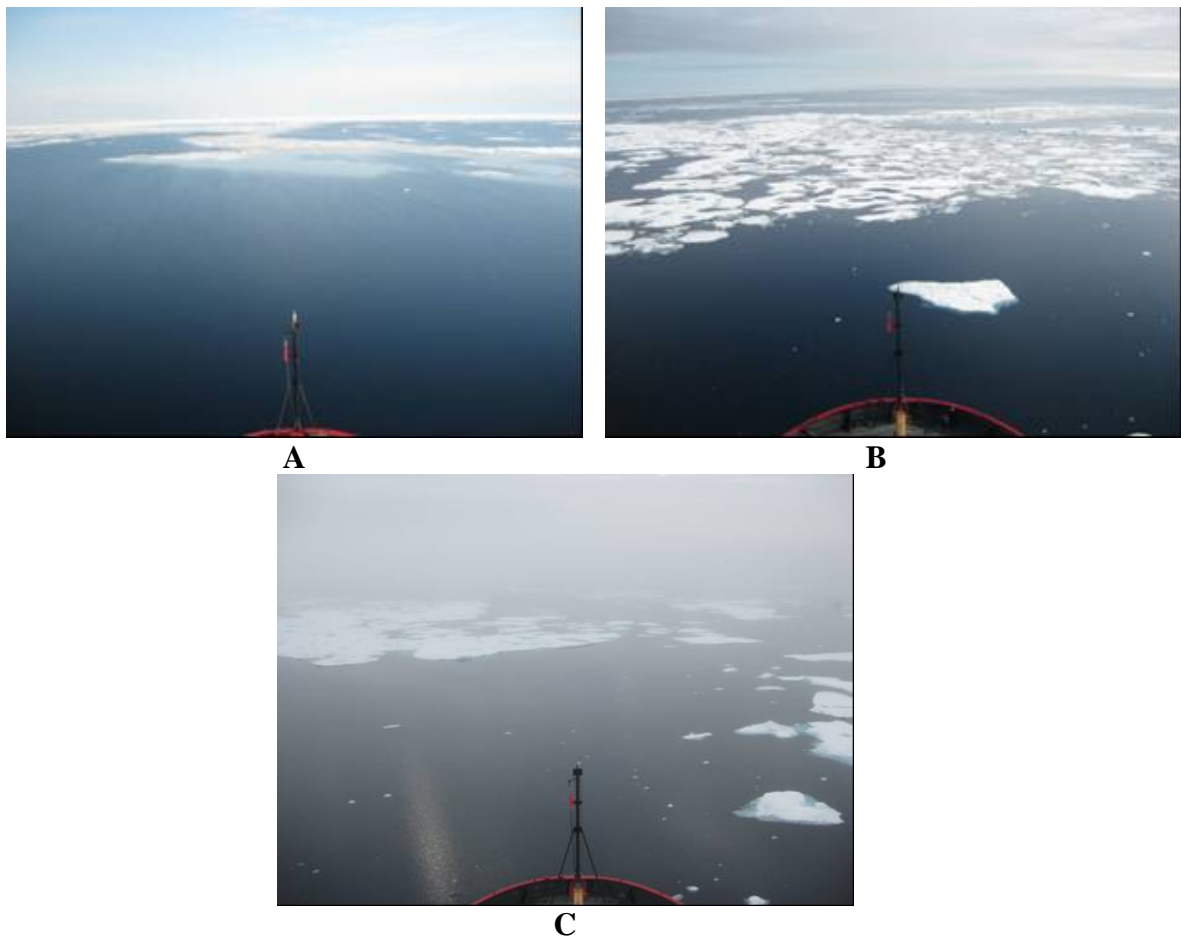


Figure 30. August 19: Morning (A), mid day (B) and afternoon (C).

5.2.2 CTD

The data collected on August 18 in the ice pack far from the ice edge shows lower radiance (Figure 31) than the previous site (Figure 20) and about the same density. In Figure 32, the temperature data are cleaner but colder, the density is cleaner when compared to the previous location (Figure 22), the salinity a little higher, and the oxygen about the same. It appears that the mixed depth is lower as the mixing energy is reduced, as indicated by the SWIFT buoy data.

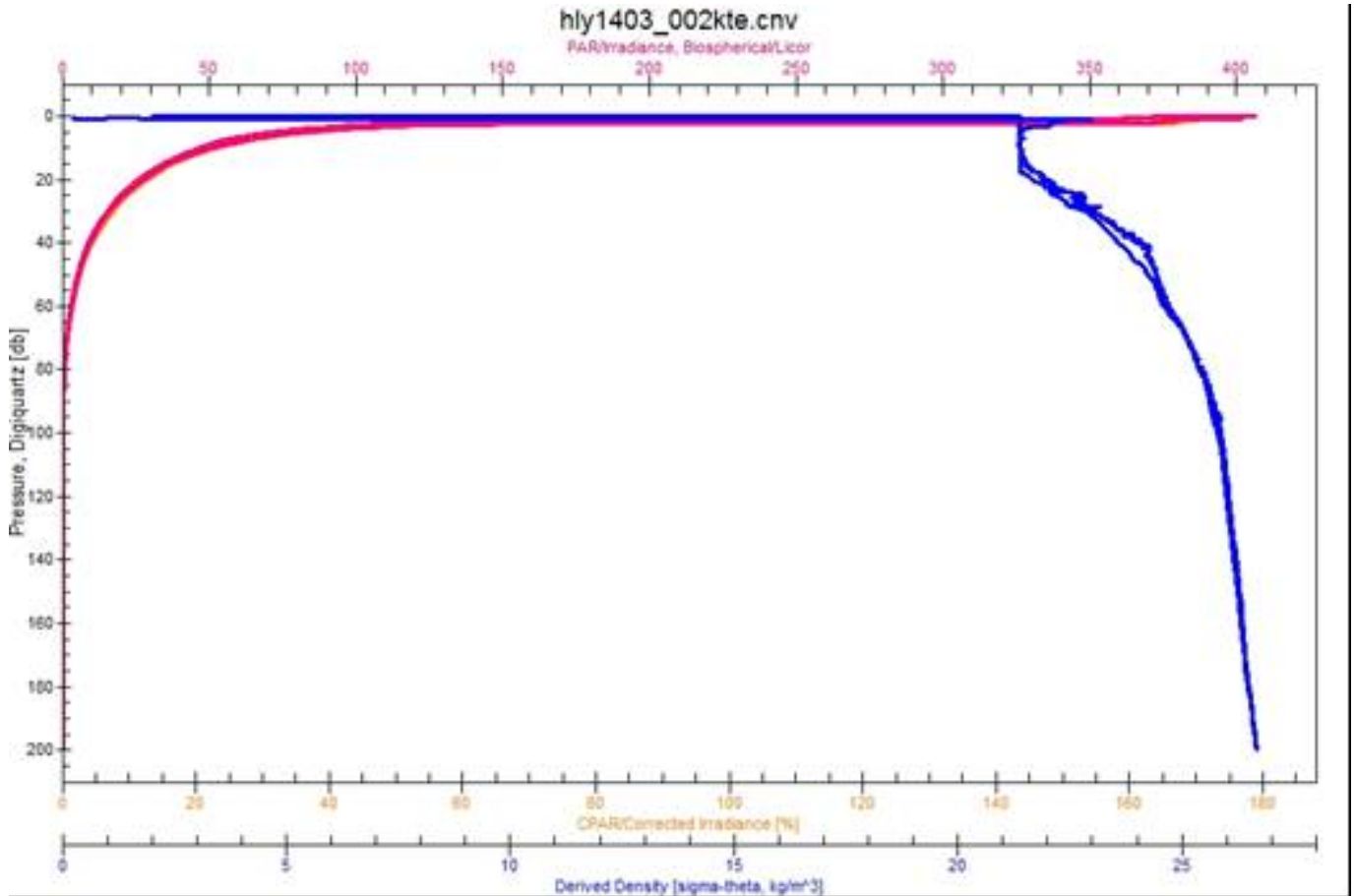


Figure 31. Data from CTD August 18.



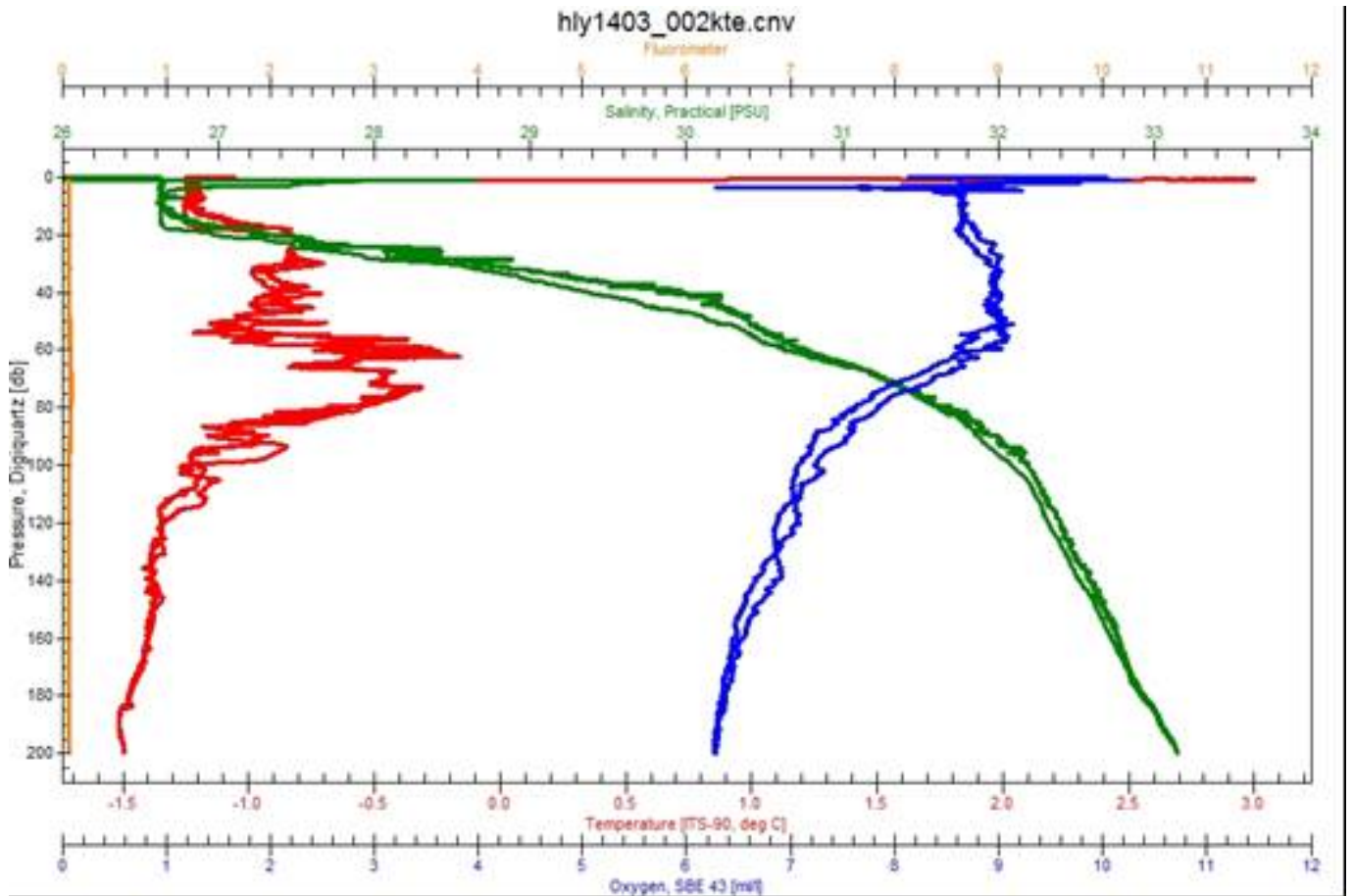


Figure 32. Data from August 18 CTD cast.

5.2.3 SWIFT Data

Several SWIFT buoys were deployed in the Arctic during this time period by other researchers as part of an Office of Naval Research (ONR), the Marginal Ice Zone (MIZ) Program, in nearby waters (<http://www.apl.washington.edu/project/project.php?id=miz>). The advantage of a SWIFT buoy is that it shows, in near-real time, what mixing and turbulence is occurring. Three distinct areas of open water, mixed ice, and more concentrated ice are seen in Figure 33 with data from SWIFT 10 and is compared to SWIFT 11, which remained in open water about 200 miles away. A drastic reduction in energy is seen, especially in the location selected that was well away from the open ocean and not exposed to any swell. The data collected and shown in Figure 34 indicate a variability of temperatures, wind speed, salinity, and drift during the short 30-hour period. Long term data from the MIZ should be evaluated to determine trends during the period when the ice is retreating. Additional data are needed for the ice build season. Another method of comparing mixing energy is to measure the wave heights and convert this to Wave Spectra as seen in Figure 35. This data shows the higher energy levels in the open ocean with the higher frequency waves (shorter wavelengths) that tend to be damped out further into the ice field.

The wind data from both of the SWIFT buoys (Figure 36) and the USCGC Healy data in the next section (Figures 37 and 38) generally agree. The wind started out of the east and backed around to coming from the south and also slowed down to less than 5 meters/second.

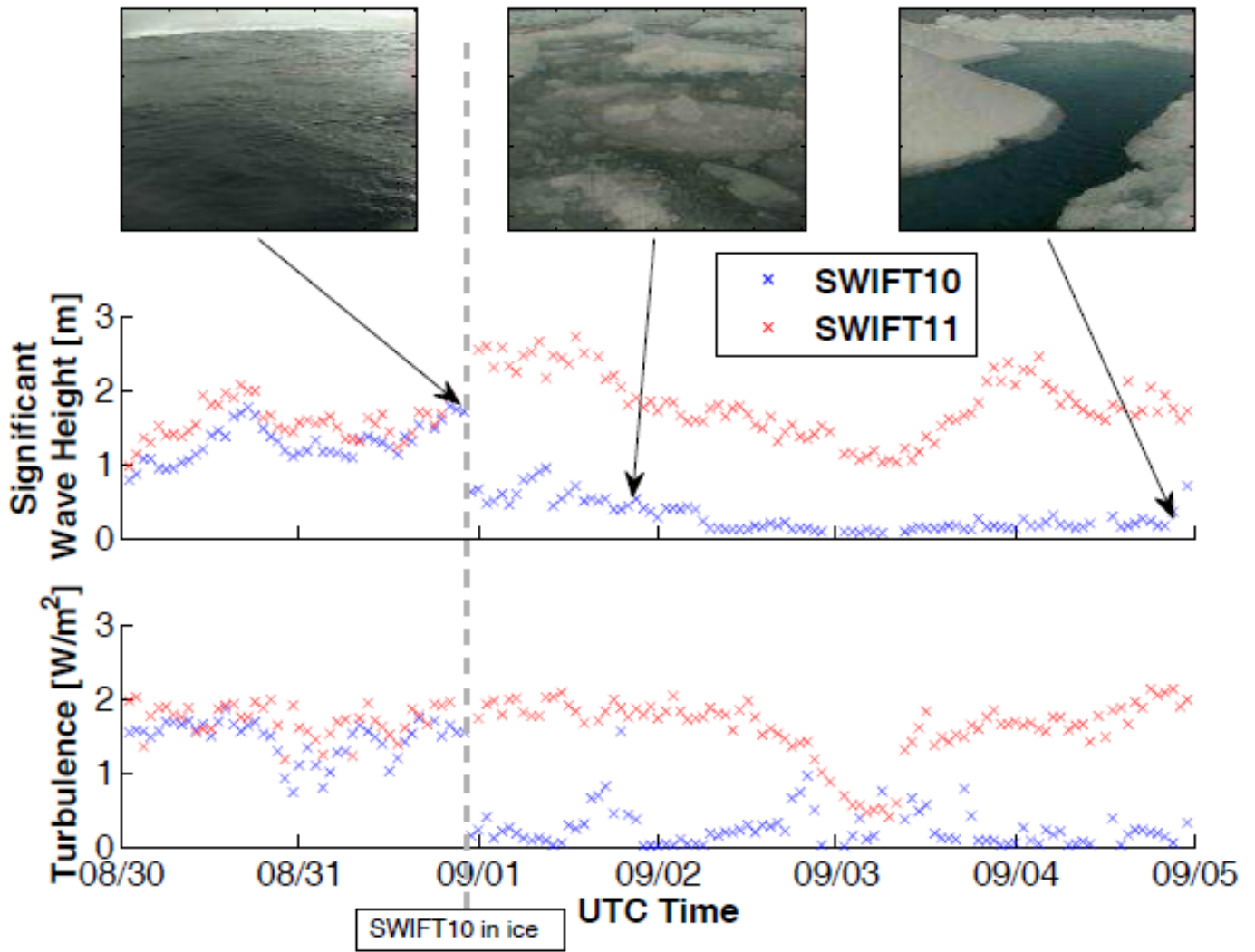


Figure 33. Turbulence and wave height from SWIFT10 and 11.

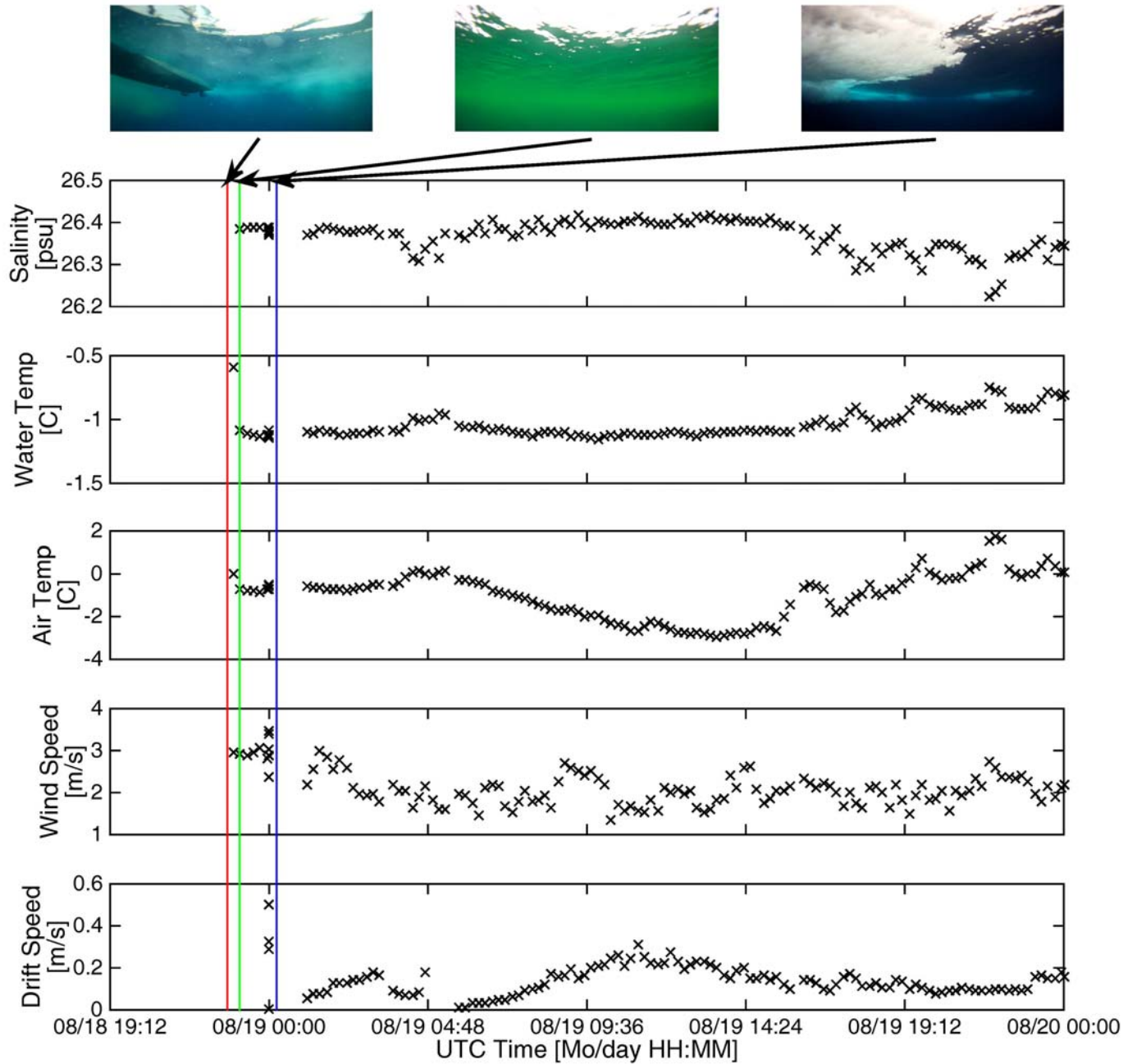


Figure 34. Data and Underwater GoPro from SWIFT 09.

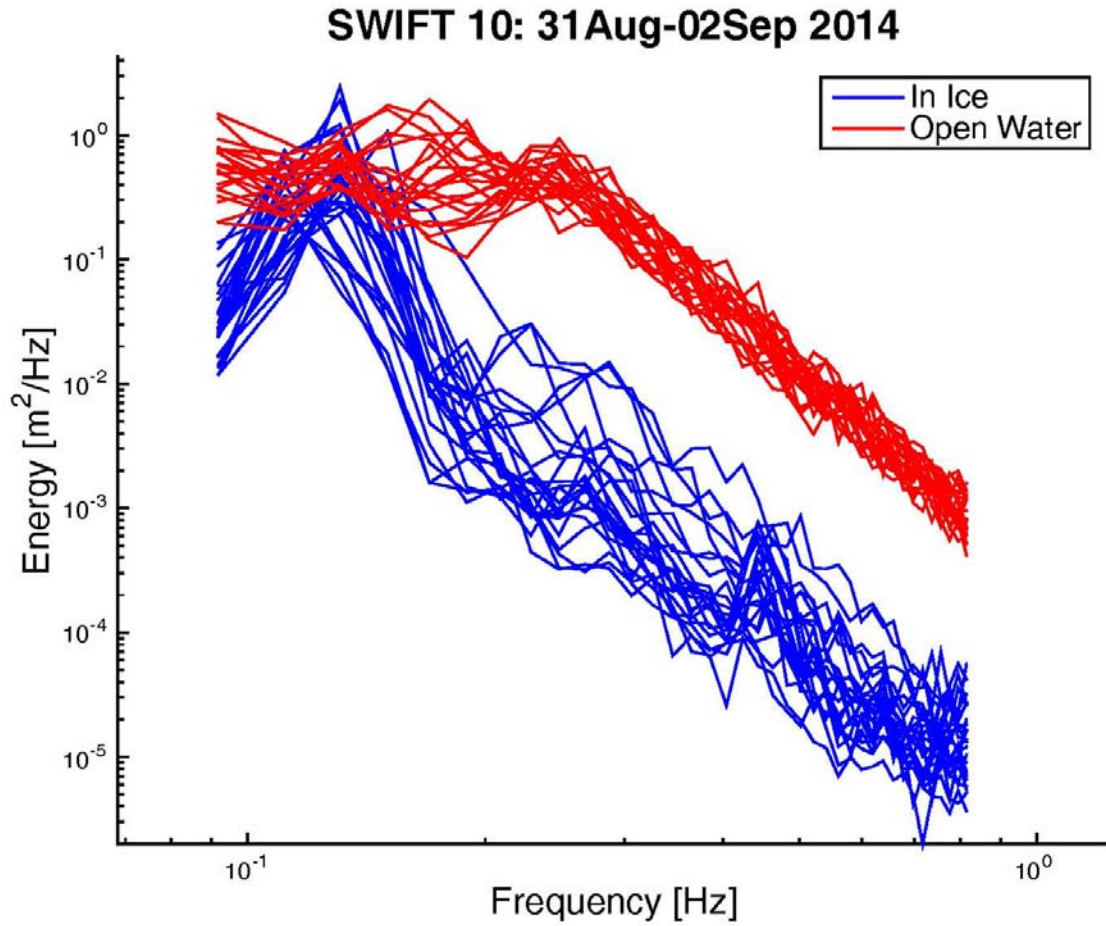


Figure 35. Wave energy data from SWIFT 10.



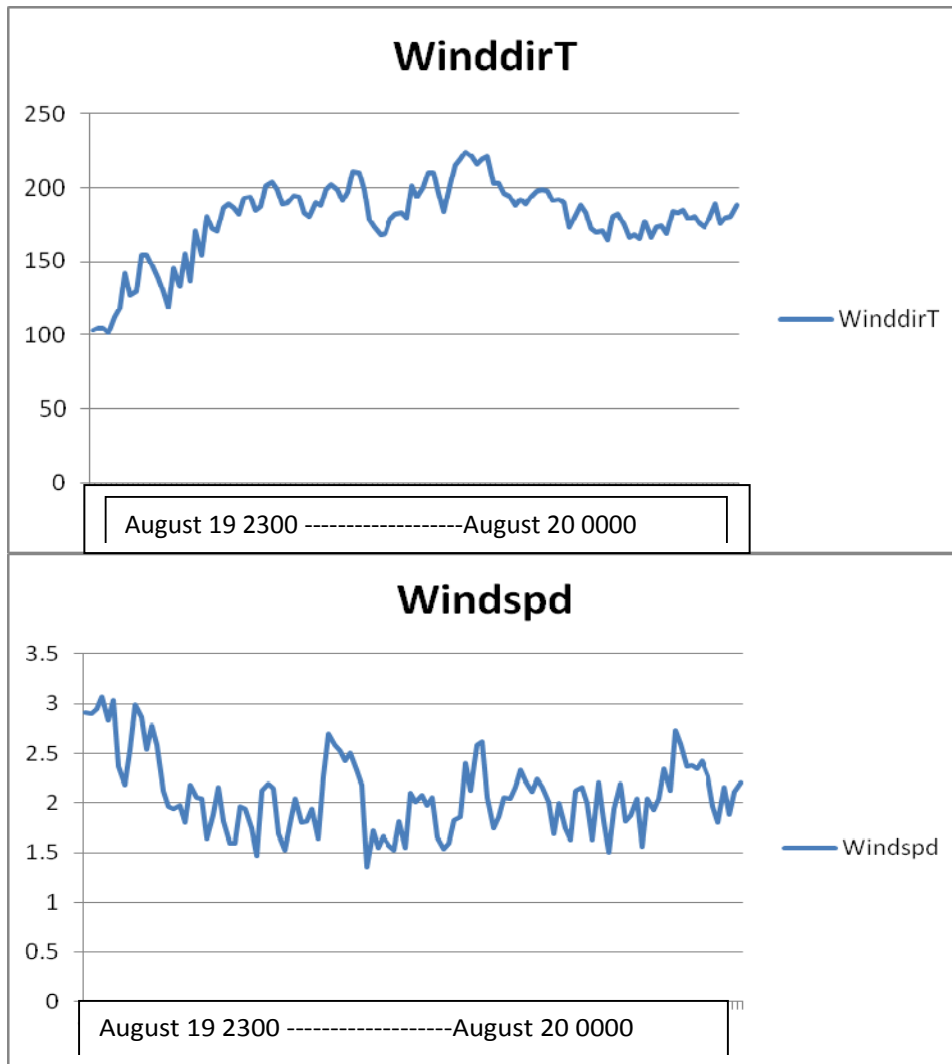


Figure 36. SWIFT 09: Wind direction (top) wind speed (bottom).



5.2.4 Ship Data

The data recorded from the starboard yardarm is shown in the figures below. The USCGC Healy deployed with the Port side to the ice and the starboard side into the wind when selecting a position that was stable during the demonstration. The anemometer on the starboard yardarm was then the cleanest data taken about 100 feet above sea level.

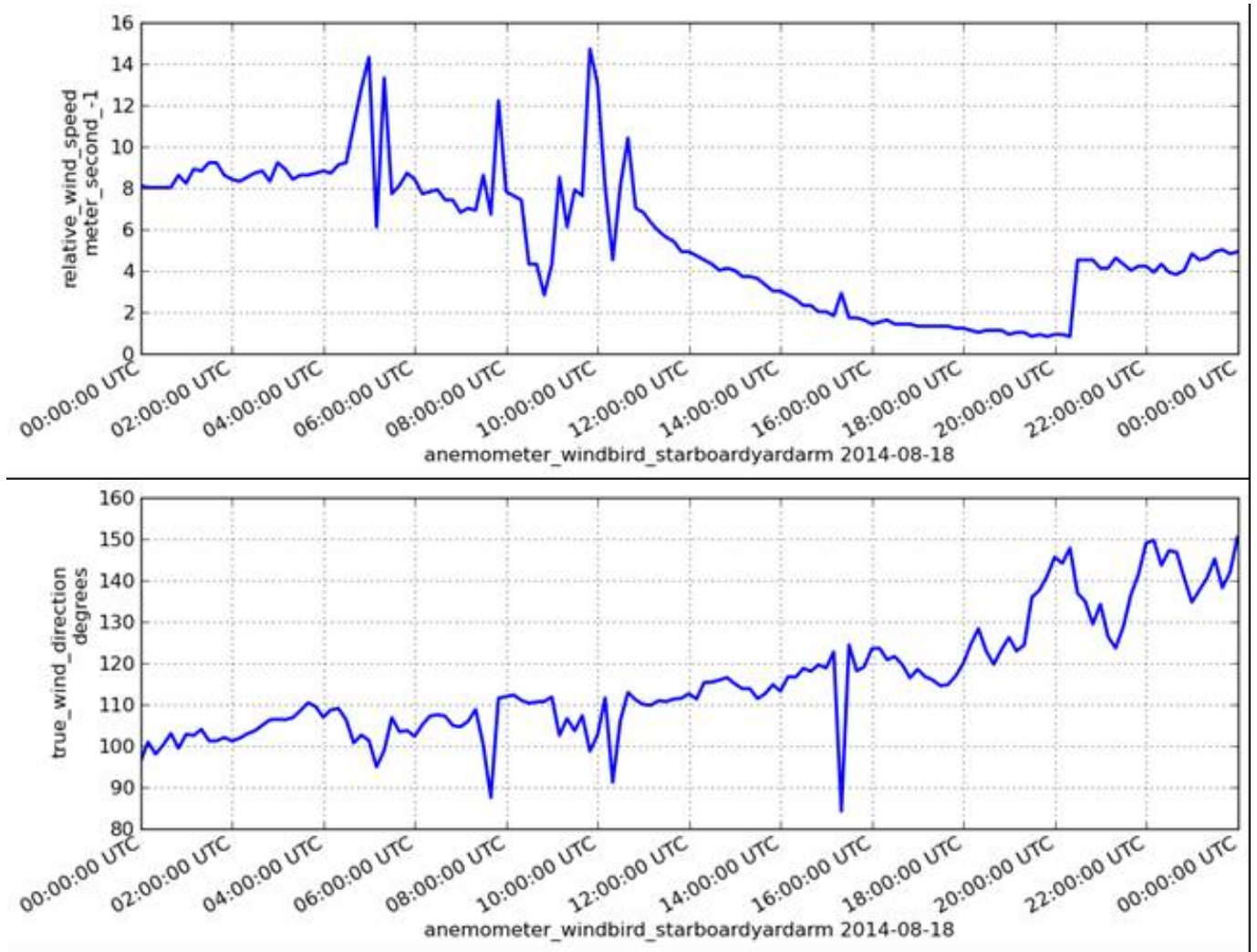


Figure 37. August 18: Wind speed (top) wind direction (bottom).



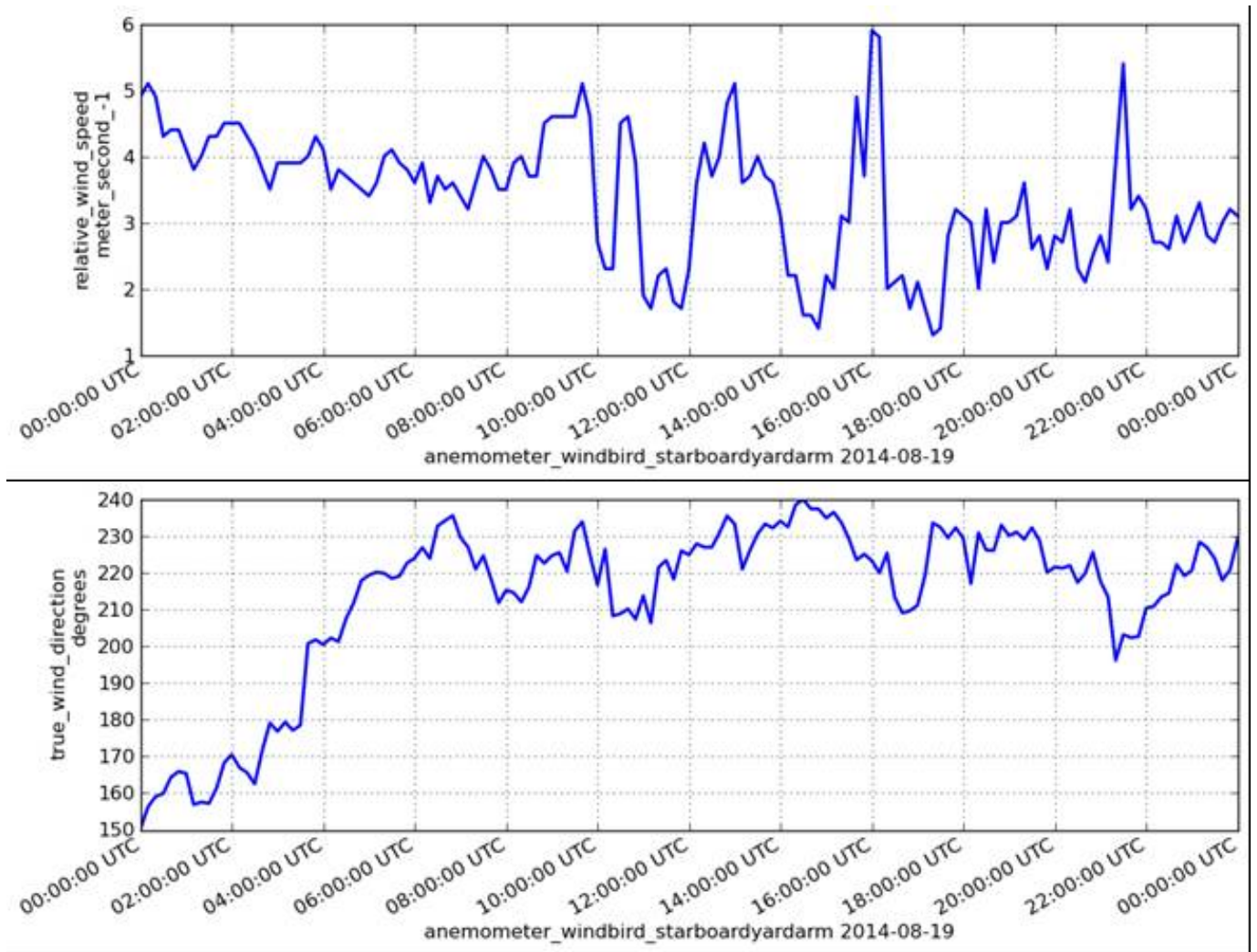


Figure 38. August 19: Wind speed (top) wind direction (bottom).

5.2.6 Drift Data

All of the data were gathered to determine how oil might move and drift in and around ice. A total of 4 iSPHEREs were deployed in the water and on ice floes on the 18th and recovered on the 19th. The drift is shown in Figure 41. Even though the winds were generally from the east and south, all buoys drifted southeast, almost directly into the wind. All were caught up in ice after only a few hours; and it appears that the ice movement restricted the drift. The movement was about 30 kilometers (about 18 miles) during this period. Looking at wind data for the previous several days, it appears to be generally out of the north and northwest. It may be that the ice movement was started by those winds and the water was still moving south. More research is needed that is outside the scope of this project. The key is that the local wind may not necessarily be driving the oil and ice movements.

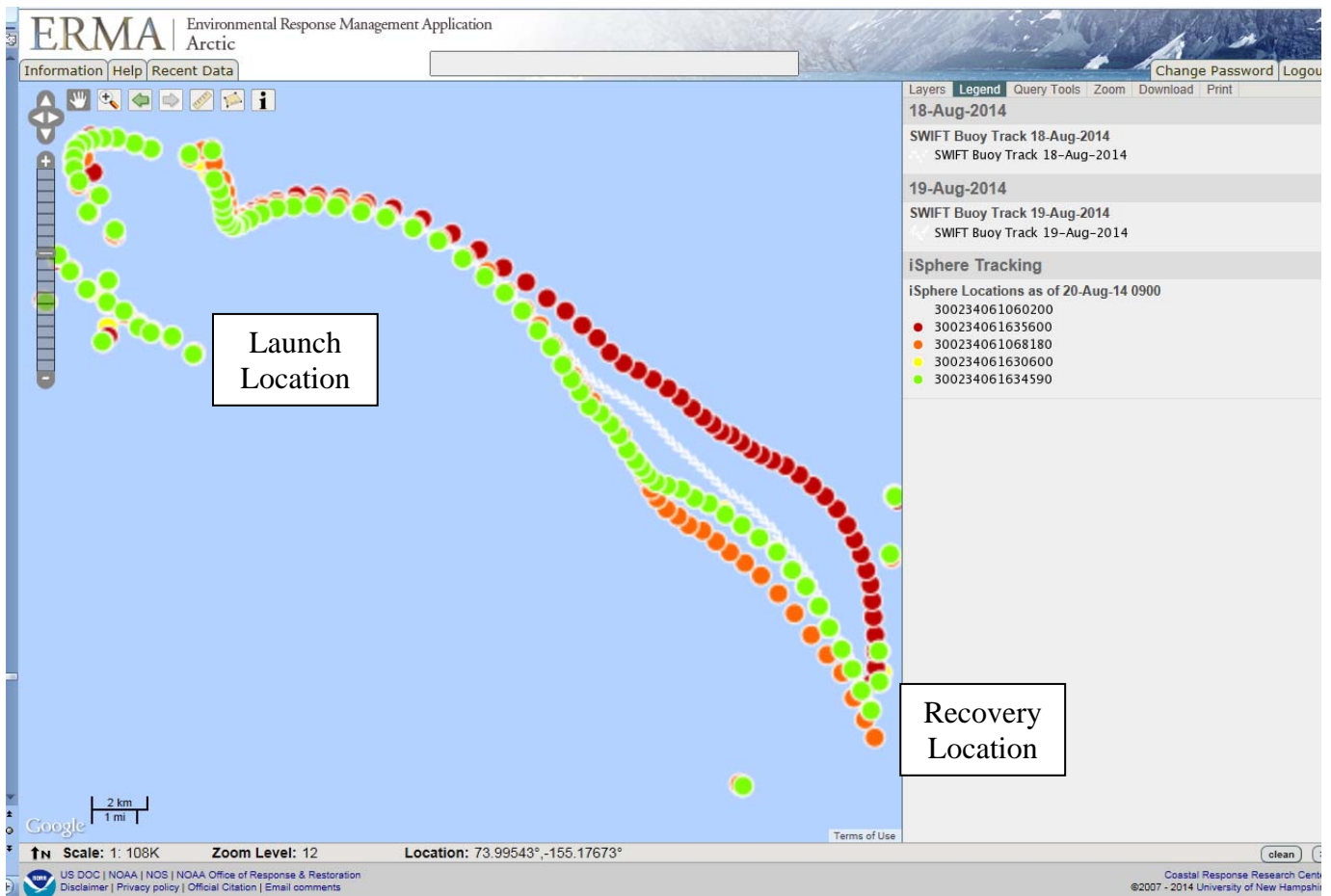


Figure 41. iSPHEREs and SWIFT buoy drift.

5.2.7 Dye Tracking

One of the objectives of this demonstration was to determine a process to obtain data from unmanned vehicles; and get it into a format that decision-makers can use. As discussed earlier, NOAA's Emergency Response Management Application (ERMA) is the software used to provide a common operating picture to responders. A picture of the dye patch (Figure 42), from the aerostat, was sent to the ERMA operators who drew the red line around the patch and plotted it as seen in Figure 43 (green area). This method is an approximation, as the exact camera angles are not known; so some assumptions are made for slant ranges, etc. and the known size of the ASB in the picture. Almost simultaneously, the Puma AE sUAS collected photographs from locations shown in Figure 43. Sample photographs are shown in Figure 44 and the resulting patch plot is shown in Figure 45. Some of the correction information was lost during the processing, so the shape mapped in Figure 45 cannot be specifically mapped to ERMA.

The results are within about 2,000-3,000 meters of each other, which may be useful for strategic decisions but not for any tactical decisions. Extra work would be needed to back-calculate the locations, but the required information from the photographs is not available.

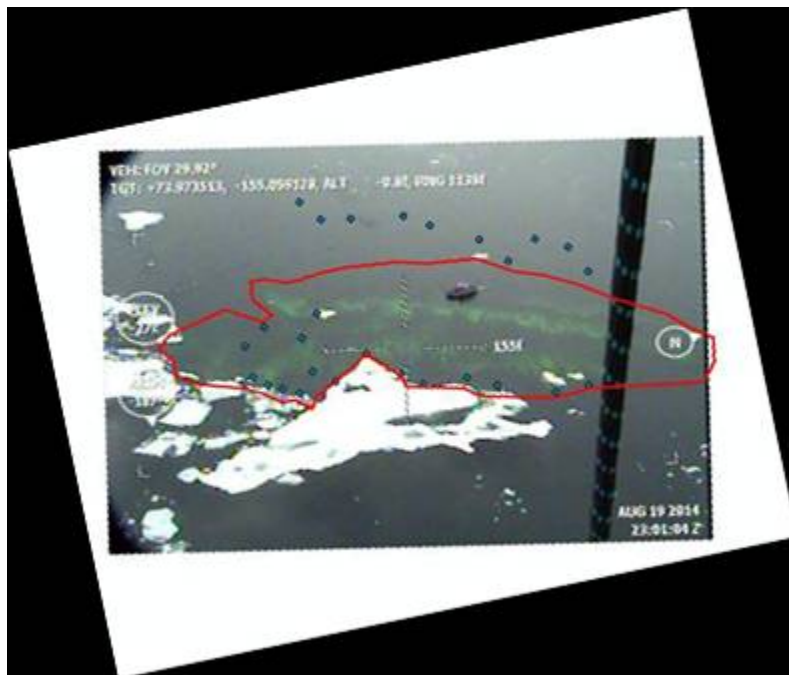


Figure 42. Aerostat photo, August 19 at 2301.

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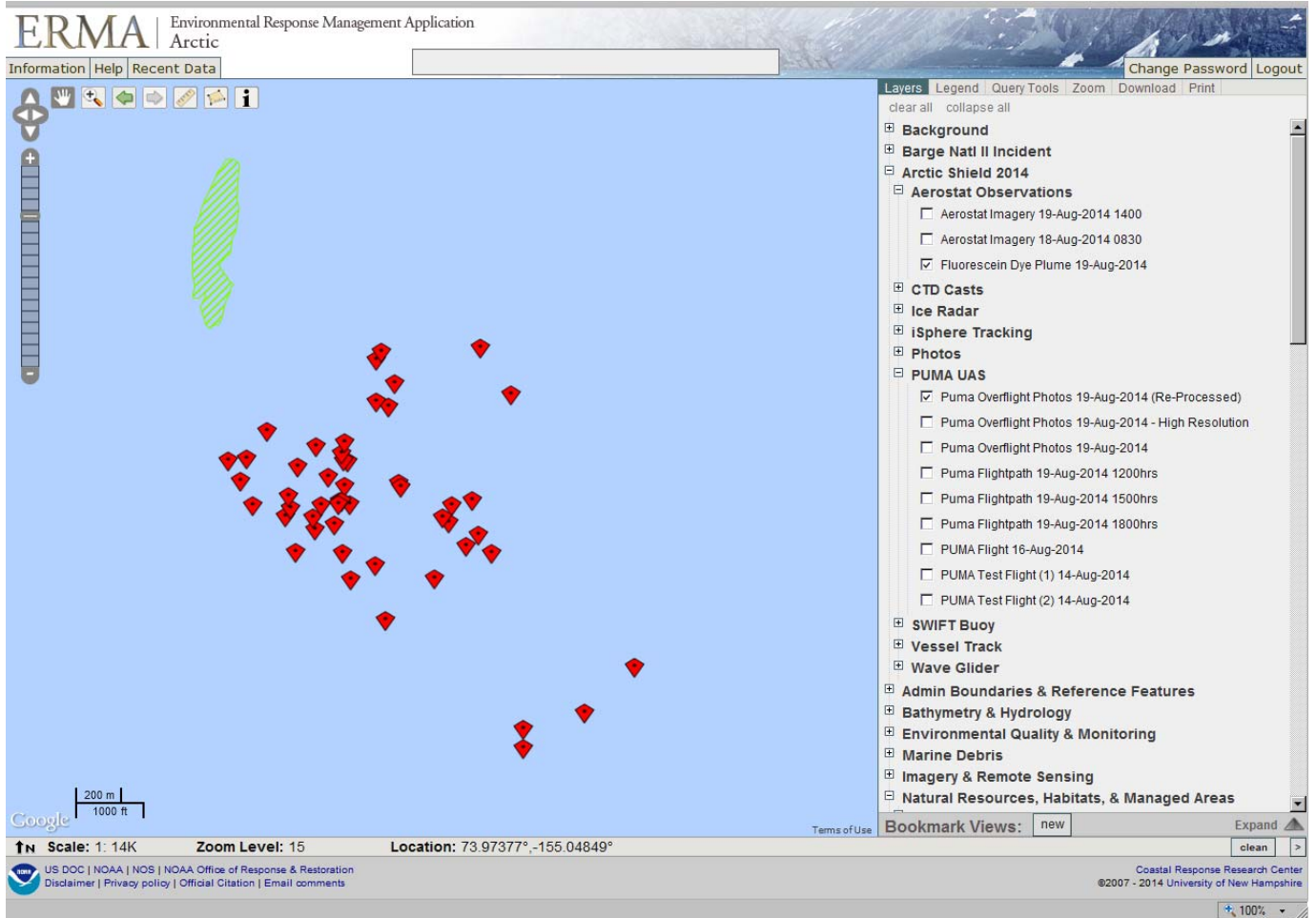


Figure 43. Dye patch and location of Puma AE photos plotted in ERMA.



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Figure 44. Dye patch from Puma AE.

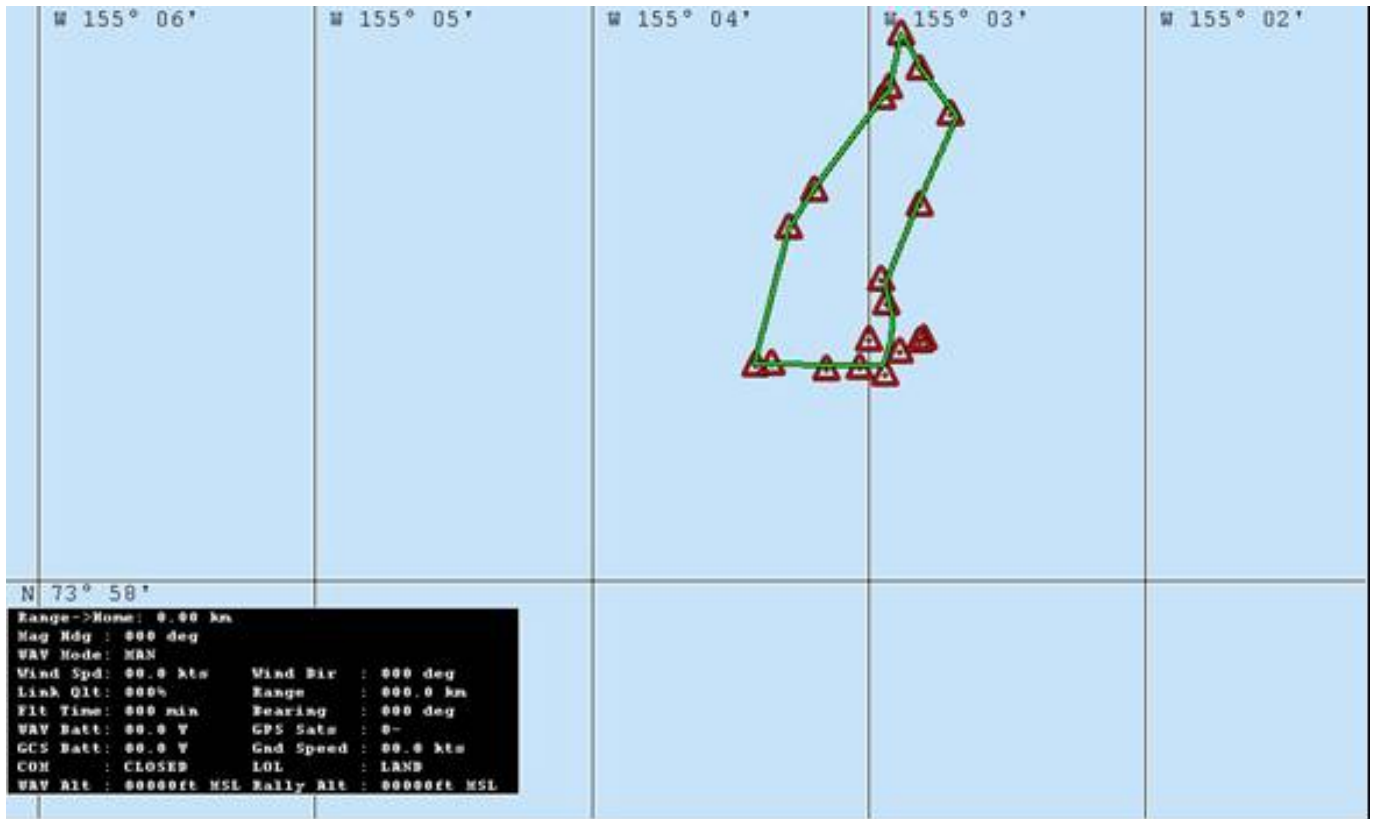


Figure 45. Dye patch plotted by Puma AE.



5.3 Lessons Learned

1. The iSPHERE buoys and SWIFT worked and collected good data. Both would be useful during an actual event, if there are difficulties in keeping the oil in sight. Some ice conditions may preclude use of the SWIFT to ensure that the system is not damaged.
2. As expected, weather will play a major role for any surveillance. Many times, visibility is clear but the winds are high. If the winds are low, the fog has a better chance of settling in. While the use of the aerostat and sUAS should be safer because a human pilot is not put at risk, they may not provide a full picture. More robust systems are needed; so that during windy weather, surveillance can still be performed. Even when windy, the ice reduces the waves; so mitigation may still be able to be performed.
3. Although this is already a known factor, the drift of a vessel can result in the loss of visibility of the oil. If this had been an actual spill, an attempt would have been made to keep the vessel in the same relative position to the oil instead of drifting alongside an ice patch/floe. This may require multiple UAS and/or aerostat systems and teams to be able to track the oil through the night. While the oil-tracking buoys can help a vessel get back to the same location the next day, the time spent may be time-consuming and has the potential of disturbing the ice.
4. The surrogates used for this demonstration provided better targets than the last time, but a larger volume is needed. The oranges stayed very bright and were useful for this exercise. The resolution needed by camera systems to detect a single, or a small group of oranges during an exercise, is different than that needed to identify an oil patch that is large enough to track and mitigate during a spill. A much larger number of oranges would be needed in a future demonstration to evaluate the resolution of potential camera systems. The dye was not able to be seen from the bridge of the USCGC Healy, even though the ship was about 0.75 miles away and the bridge is about 72 feet from the surface. The aerostat at an altitude of 500 feet easily picked up the dye on the visual camera, as well as the Thermal OSCAR on its IR camera.
5. The creation of the dye is crucial. A NOAA representative who had used dye the week before provided some direction; but it still appears to sink too quickly, in less than 1 hour. This is most likely due to the mixing concentration plus the circulation created by the wind. A better mixing method is needed for subsequent tests.
6. Data was passed to ERMA, but further analysis is needed to determine usefulness and quality of the data from all of the sensors. Standard data organization protocols should be developed; so that the data is submitted in the same format from each sensor for any reporting. One example is deciding whether longitude and latitude positions are provided in degrees and minutes or decimals. General images of spilled oil may be interesting; but if no reference data (e.g. specific locations and aerial extent) is provided, it may be useless to a decision-maker. To facilitate efficient information management during an actual response, having a computer programmer available is mandatory to automate data processing methods more efficiently to support data collection during the next operational period.

6 SUMMARY AND RECOMMENDATIONS

1. USV operations may be successful in oil-in-ice scenarios as a relatively open water asset. The propulsion system of the technology tested requires moderate sea-states and minimal ice. The sensor collection and data transmission systems require significant solar flux and robust battery performance.
2. During this assessment, there was one operator and one USV (SPAWAR SHARC) managed from one vessel (USCGC Healy). Observations suggest that this one-to-one-to-one relationship could likely be



improved upon. During an actual oil spill response it seems plausible to have one “local” operator manage a small fleet of USVs, and data analysis could be easily managed remotely.

3. The efficiency of launch/recovery operations for the USV was aided by USCGC Healy’s tall A-Frame crane and contributed to ease of deck force operators managing the SHARC, especially during recovery with two components being connected with a long tether. Having a capability to “collapse” the Float and Glider® prior to recovery out of the water would appear to be a significant improvement, especially during heavy sea-state conditions.
4. Aerostat operations can be successful in the Arctic region. However, challenges will include wind speed, visibility and camera capabilities. The data from the aerostat can be integrated into ERMA and provide the decision makers another data source to direct assets in a spill response.
5. Operating requirements, such as maximum wind speed and distance to targets, have to be clear and specified for all deployed equipment. Resolution on the deployed systems was reasonable for this demonstration, but may not be adequate for future spills.
6. Tracking oil in the Arctic will be difficult, as expected. The iSPHERE and SWIFT buoys provided valuable data, but could still be susceptible to damage or loss. But it may be even more difficult to do the research needed to determine how spilled oil will move. While many other investigators are recording turbulence and mixing at the ice edge, it is dangerous to launch small boats in swells and choppy waves in order to place buoys and/or simulants into the water. Some simulants may be able to be thrown from a deck of a larger vessel and survive, but their placement may not be scattered and dye may be difficult to distribute from the higher freeboard of larger vessels. Others have used a sophisticated spraying system; but a large ship, like the USCGC Healy, will most likely disturb the ice formation and could disrupt the natural processes.
7. More robust surveillance systems will be needed; but that also means larger vessels that are specifically manned for the surveillance system. Smaller aerostats and sUAS could be deployed on skimming vessels; however, under many conditions their usefulness may be limited.
8. Deploying multiple systems on a single vessel, as was done in these tests, is not recommended during an actual spill.

7 NEXT STEPS

1. Assess unmanned surface and underwater vehicle operations in more congested ice fields to determine upper limits of capabilities under such conditions.
2. Assess the capability of smaller sized aerostat packages that can be deployed on smaller response vessels that will be located directly on scene of the simulated spill. Also assess different sensor capabilities and different balloon configurations that could be used in higher wind conditions.
3. Check with other organizations on processes for the use of dye to develop more successful mixing strategies that could result in a longer-lasting dye patch. Identify better simulants for subsurface analysis. Follow up on the project by Bureau of Safety and Environmental Enforcement for oil surrogates.
4. Identify more robust systems that can be deployed in harsher weather. This includes all of the unmanned systems: aerial, surface and subsurface that do not need small boats for deployment or retrieval.
5. Conduct multi-vessel demonstrations, combined with response, to determine how much capability is needed for a successful response outcome. These demonstrations should be conducted near the edge of the Marginal Ice Zone, where waves and swells are a major consideration. Consider the use of USCGC Healy, or other icebreakers, as a “motel” ship to support extra crew on a separate response vessel; while also doing surveillance and conducting ice management operations around the other vessel.



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