Knorr 2014 Research Clearance "FINAL" Report F2014-017

Overview

This cruise report documents the initial infrastructure deployment for the Irminger Global Scale Node of the National Science Foundation's (NSF) Ocean Observatories Initiative (OOI) Coastal and Global Scale Nodes (CGSN) (http:///www.oceanobservatories.org). The Irminger Array will include a Global Surface Mooring, a Global Hybrid Profiler Mooring, two Mesoscale Flanking Moorings, and Open Ocean Gliders. It is one of four global arrays expanding the oceanographic communities capabilities by deploying and maintaining platforms with multidisciplinary sensor suites at high latitude sites.

The Irminger 1 deployment cruise accomplished five main objectives: 1) Deploy the Global Irminger Surface Mooring, 2) Deploy the Global Irminger Hybrid Profiler Mooring, 3) Deploy the Global Irminger Mesoscale Flanking Moorings, A and B, 4) Deploy and test three Open Ocean Gliders, 5) Collect bottom surveys of the planned year 1 and alternate year anchor sites for the four Global Irminger Moorings, and 5) carry out validation studies of the deployed Global Irminger platforms.

Ancillary activities were carried out on a not to interfere basis. Multibeam bathymetry was collected in international waters. Six profiling Argo floats were deployed. The Dutch (Royal Netherlands Institute of Oceanography or NIOZ) LOCO2 mooring was deployed just south of the Irminger Sea Array.

The cruise was conducted on the *RV Knorr*, departing Reykjavik, Iceland on 9/7/2014 and returning to Woods Hole on 9/28/2104. A twenty-person science party from the Woods Hole Oceanographic Institution (WHOI), Scripps Institution of Oceanography (SIO) and NIOZ, plus two technicians from the WHOI Shipboard Scientific Services Group (SSSG) and an intern, were on board.

The report includes brief description of pre-cruise preparation activities, a chronology of the cruise, a description of the platforms and deployments, a summary of platform and instrumentation configurations, descriptions of supporting and ancillary activities, and a discussion of selected issues which arose during the cruise.

1 Introduction

1.1 Background and purpose

This cruise is the first cruise to the Irminger Sea Array of the National Science Foundation's (NSF's) Ocean Observatories Initiative (OOI; http://www.oceanobservatories.org). The Irminger Sea Array includes four moorings (Figure 1-1) and a combination of patrol and profiling gliders deployed off the southeast tip of Greenland, close to 39°W, 60°N (Figure 1-2). The location is one characterized by strong air-sea interaction and wintertime water mass formation. It is also an important location of the large-scale global thermohaline circulation where freshening of the water column has been observed, and the data from the array will contribute to improved understanding of the impact of climate variability and change on the physics, chemistry, and

biology of the ocean. The combination of the moored array and the gliders will enable investigation of the role of processes at mesoscale and sub-mesoscale horizontal length scales. At the same time the moored array and gliders will sample the full water column, from the sea floor to the sea surface and the surface mooring will provide unique new observations of surface meteorology and air-sea fluxes.

The Irminger Sea Array deployment cruise (Irminger-1) has the following primary objectives: mapping the seafloor bathymetry and establishing the sites for the initial deployment on this cruise of the moorings as well as establishing the sites for the deployment of the replacement moorings one year later, deployment of the Surface Mooring (GI01SUMO), deployment of the Hybrid Profiler Mooring (GI02HYPM), deployment of the two Flanking Moorings (GI03FLMA, GI03FLMB), initial deployment of the Irminger Sea mobile assets (GI05MOAS) with the deployment of gliders tasked to patrol within and around the moored array, and CTD casts with water sampling at both for instrument calibration and to further characterize the region of the mooring sites.

The intent one year from now is to deploy some or all of the second set of moorings before recovering the first set in order to obtain overlapping data sets invaluable to the process of intercalibrating the moored instrumentation. Because of this and because the intent is to have future mooring operations to be conducted in close proximity to moorings in the water, the site locations for both the first and second deployments will be identified during the bathymetric survey on this cruise.

Secondary objectives for the cruise are to: deploy the Dutch LOCO2 taut subsurface mooring, to deploy Argo floats along the track to Woods Hole for a German investigator, and to collect multibeam data along the track to Woods Hole for investigators at Lamont-Doherty Earth Observatory.

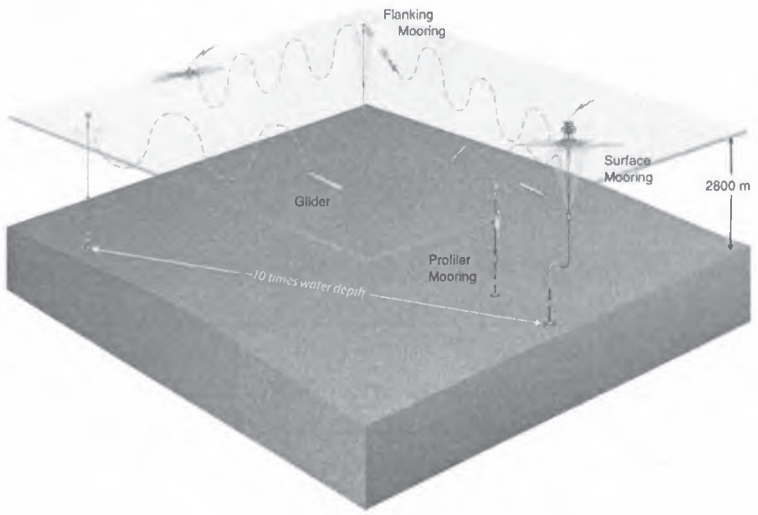

Figure 1-1 Schematic drawing of the Irminger Sea Array. For this deployment, the Global Profiling Gliders shown in the vicinity of the Profiler Mooring will not be deployed.

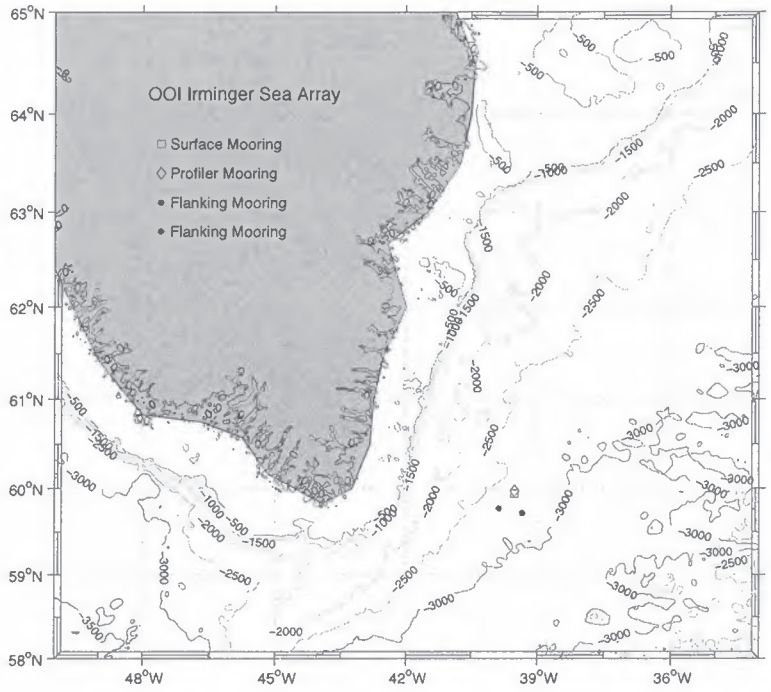

Figure 1-2 Global Irminger Sea Array mooring site locations.

1.2 Cruise Chronology

August 26-September 3, 2014

The first group of WHOI personnel flew to Reykjavik August 25, arriving August 26. Unpacking of gear began on the 26th. They were joined by a second group from WHOI on August 27. The workspace was a warehouse near the container port in Reykjavik, and the agent provided a forklift, crane upon request, and other support services. The WHOI effort focused on getting the surface buoy up and running. SIO personnel arrived August 28 and 29. Work proceeded in the warehouse until the *RV Knorr* entered Reykjavik on September 3.

September 3-6, 2014

Containers and other gear were moved to the downtown port location where *RV Knorr* berthed beginning September 3. Most of the gear was shifted by September 5. The assembled surface buoy and an anchor were left at the warehouse. On September 6 *RV Knorr* went over to the container port and loaded the buoy and anchor; *RV Knorr* then returned to the downtown berth. On September 6 a science meeting was held including a safety briefing about hydrogen gas safety protocols as applied to the battery and charging systems of the surface buoy.

September 7, 2014

RV Knorr sailed from Reykjavik at 0900 local, underway to the Irminger Array site.

September 8, 2014

At 0815 local, in 2,268 m of water, we stopped to do CTD casts. The first, to 1,500 m tested the CTD, the water sampling bottles, WHOI acoustic releases and SIO acoustic releases. A bad dissolved oxygen sensor was found on the CTD and exchanged for the spare sensor. A 1,000 m CTD followed to calibrate SIO instrumentation. After moving further along the track into deeper water a 2,500 m CTD cast was done to calibrate additional SIO instruments and the NIOZ microcats. After dark a 500 m CTD was done.

September 9, 2014

Weather slowed the speed of the ship, but the sites of the planned surface mooring and hybrid profiles were reached and a bathymetric survey of the two sites carried out.

September 10, 2014

Starting 0400 local, preparations began for the surface mooring deployment. The buoy went over the side about 1030 local; anchor over 1650 local (1850 UTC). A visual inspection of the surface buoy was made including a close look to assess the waterline depth (45 to 50 cm down from the foam top) of the buoy. After that, the ship headed south to do a bathymetric survey for Flanking Moorings A and B. This was motivated by the finding that we had found the water depths 50 to 100 m shallower than anticipated at the surface and profiler moorings, and SIO wanted to know as soon as possible if the same would be found at the flanking mooring sites, which would lead them to modify the mooring designs.

September 11, 2014

The deployment of the profiler mooring began in the morning with 20 to 25 knot winds. As the deployment proceeded a cold front passed through and winds gusted as high as 45 knots with a period of sustained 40-knot winds. With the releases and balls attached as we moved toward the anchor site, a stopper line parted and the mooring went off the stern. The glass ball string was hooked into and the mooring end recovered. The deployment then proceeded. After the deployment anchor surveys were conducted for the surface mooring and for the profiler mooring. A 1,500 m CTD was also done at the surface mooring.

September 12, 2014

In the early morning a CTD cast was made at the profiler mooring to coincide with the time when the moored profiler would run. Data were downloaded via acoustic link. Flanking Mooring A was deployed, with anchor drop at about 2011 UTC. An acoustic anchor survey followed as well as acoustic communication with the mooring. A strong storm was approaching and winds of 60 knots with seas in excess of 10 m were predicted for the Irminger Array site. On the evening of September 12 *RV Knorr* moved approximately 100 miles north and close (~30 mile off) the coast of Greenland to seek shelter.

September 13-14, 2014

RV Knorr sheltered close to the coast of Greenland, north of the OOI Irminger Array site.

September 15, 2014

On the morning of September 15, *RV Knorr* transited south back to the array, arriving at the surface mooring about 1315 local. A CTD to 1,500m was made. The ship stayed close to the surface mooring to allow collection of coincident ship and buoy data for validation of the buoy instrumentation.

September 16, 2014

Light winds and calm seas prevailed. At about 0600 local the deployment of Flanking Mooring B began, and the anchor was dropped about 1200 local. *RV Knorr* transited south the

site of the LOCO2 mooring deployment. Deployment of this mooring was finished by 1715 local. A full depth CTD and an anchor survey were carried out at LOCO2. The ship then returned to Flanking Mooring B for an anchor survey. The ship went to the profiler mooring for a data download.

September 17, 2014

A CTD was made near the two gliders. The ship then went to stand by the surface mooring to collect a second ship-buoy comparison.

September 18, 2014

The ship-buoy comparison went to the early evening. We were asked to recover glider 469, which was located to the south between the two flanking moorings. After that we went to Flanking Mooring A for a data download. With another storm approaching, the decision was made to begin the transit back to WHOI.

September 19-28, 2014

Transit back to WHOI. Four Argo floats deployed. Seabeam run until reaching Canadian waters.

1.3 Weather and Operating Conditions

The cruise was scheduled late in the season. July had been requested, but September was assigned. The probability of storm events was thus of concern, and a number of such events were observed. The *RV Knorr* wind speed record (Figure 1-3) shows the variability encountered:

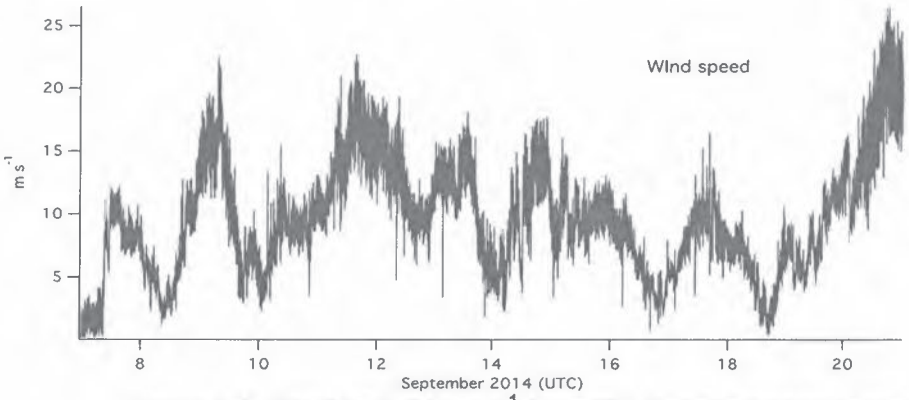

Figure 1-3 Wind speed in m s^{-1} from *RV Knorr* meteorological mast.

On September 11 during a mooring deployment, the wind gusted to 45 knots. As we left the site at the end of the cruise winds in excess of 50 knots were encountered. Winds in excess of 60 knots and wave greater than 30 ft were forecast for the array area as shown in Figure 1-4. Wave forecasts pointed to waves at the site being in excess of 30 ft (Figure 1-5). As a result, *RV Knorr* stopped work and moved about 100 nm north to shelter about 30 nm off the coast of Greenland. She left Friday the 12th and returned Monday the 15th.

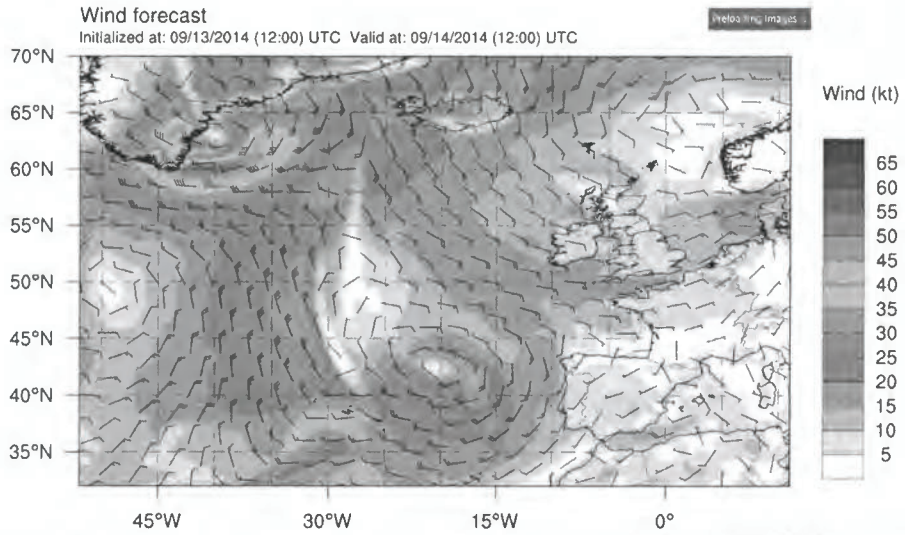

Figure 1-4 Surface forecast for September 14, 2014 showing wind speeds. Forecast from http://globalsailingweather.com/.

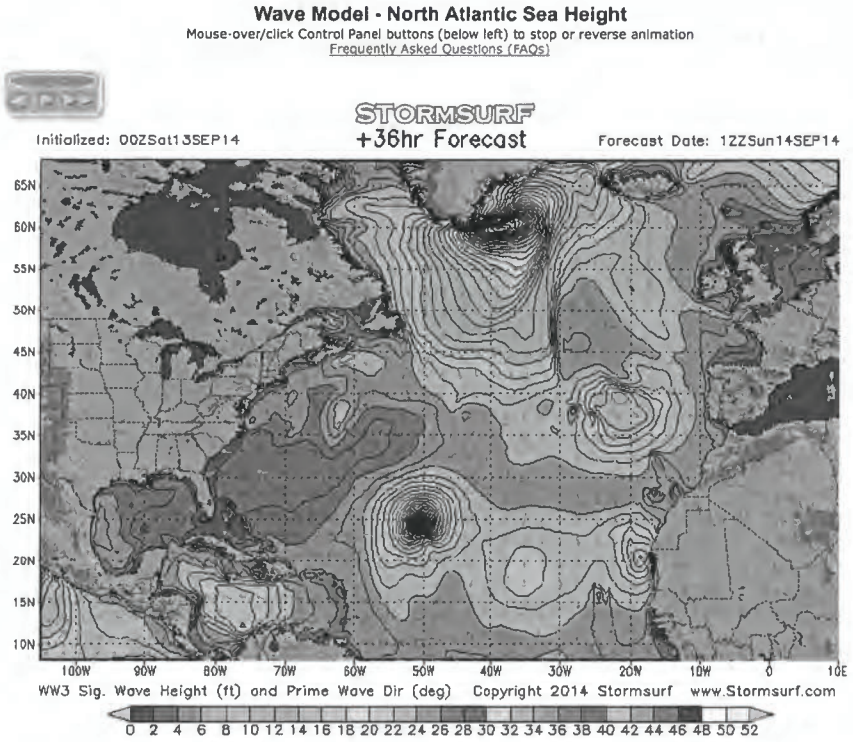

Figure 1-5 Surface wave forecast for 1200 UTC September 14, showing a prediction of waves in excess of 30 ft at the Global Irminger Array site.

This turned out to have been a sound decisions as the FDCHP package on the surface buoy registered significant wave heights approaching 9 m (Figure 1-6)

Weather forecasts were watched closely, and mooring operations were planned for the best weather windows.

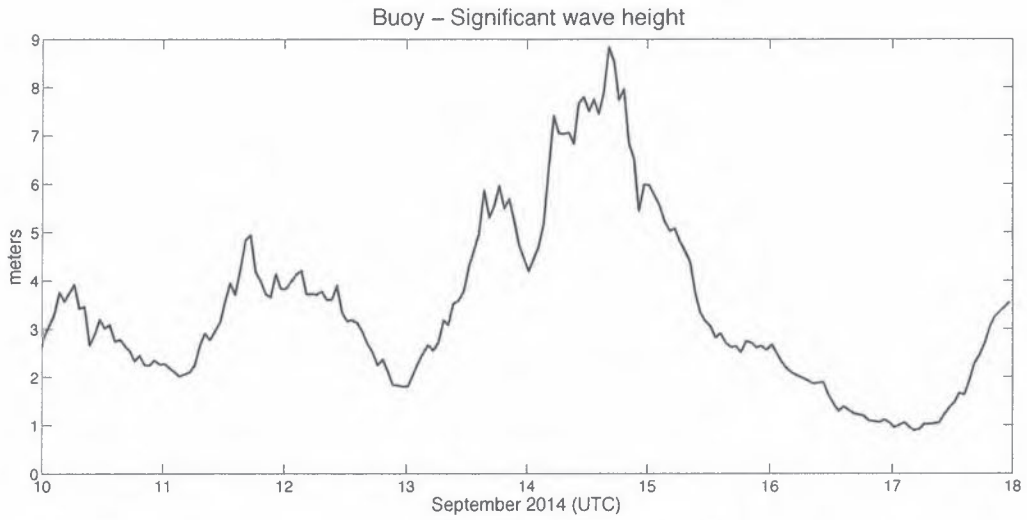

Figure 1-6 Significant wave height in meters from the Global Irminger Surface Mooring FDCHP. Note surface wave heights approaching 9 m on the 14th when *RV Knorr* had moved north to shelter close to the coast of Greenland.

It was not always possible to avoid weather. During the deployment of the Hybrid Profiler Mooring, work started with winds at about 20 kts. Midday a front passed over and wind gusted to 45 knots with sustained winds of 40 knots for an hour or more. This made mooring operations that day challenging.

OOI Irminger Mooring Locations – Anchor Positions from Acoustic Survey

Mooring	Deployment Date/Time (UTC)	Latitude	Longitude	Depth (m)
GI01SUMO	9/10/2014 18:50	59° 56.024' N	39° 28.430' W	2685
GI02HYPM	9/11/2014 17:10	59° 58.52' N	39° 28.91' W	2678
GI03FLMA	9/12/2014 20:11	59° 46.01' N	39° 50.55' W	2700
GI03FLMB	9/16/2014 13:24	59° 42.768' N	39° 19.224' W	2830
LOCO2	9/16/2014 17:10	59° 12.048' N	39° 30.241' W	3030

Note: 1488 m s^{-1} used for mean sound speed.

2 Supporting Data Collection

2.1 Bathymetric Surveys

A Sea Beam 2100 multibeam sonar was used to map the bathymetry near the OOI mooring locations in the Irminger Sea (Figure 2-1). A single-beam Knudsen 320B/R echosounder with two transducers (12 and 3.5 kHz) served to spot-check mooring depths. Previous planning had

entailed using an online gridded system to resolve mooring location depths. According to the multibeam sonar, the flanking mooring depths were as expected from the online gridded product, but the surface mooring depth was shallower than previously supposed. The Sea Beam 2100 data will be further processed on shore, with accurate sound speeds.

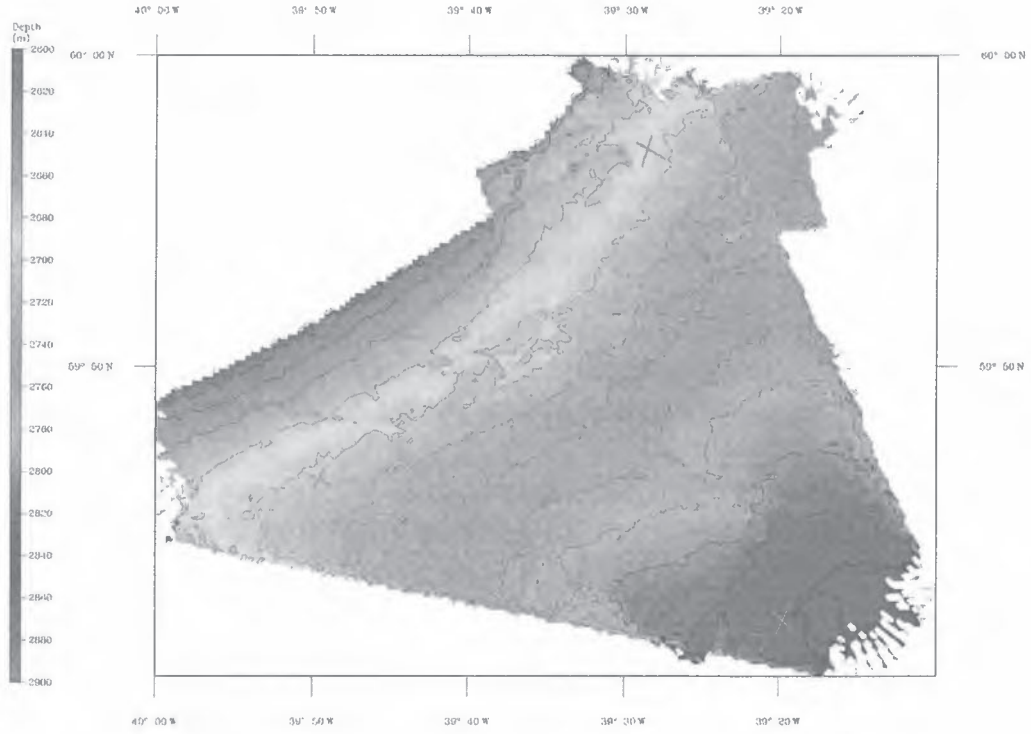

Figure 2-1 Contour plot of the bathymetry at the Global OOI Irminger Node site.

2.2 CTD, Sampling and Hydrographical Measurements

The R/V *Knorr* CTD is outfitted with a Niskin bottle rosette and instrumentation to measure the following parameters.

- Conductivity, Temperature and Pressure (SeaBird SBE 911; Temp S/N: 4360; Cond S/N: 3042; Digiquartz Pressure S/N: 0462)
- Dissolved Oxygen (SeaBird SBE 43; S/N: 1646)
- Fluorescence (WET Labs ECO-AFL/FL; S/N: FLNTURTD-304)
- Turbidity (WET Labs ECO-NTU; S/N: FLNTURTD-304)
- Transmissometer (WET Labs C-Star; S/N: CST-1117DR)
- PAR (Biospherical QSP2300; S/N: 70171)

CTD casts and water sampling were conducted to provide ancillary data for evaluation of instrumentation on the deployed moorings and gliders.

Water samples and analyses included the following:

- Dissolved Oxygen – Measured on-board the ship
- DIC/TA and pH – collected in glass bottles for analysis on-shore
- Salts – Measured on-board the ship
- Nutrients – collected in plastic vials for analysis on-shore
- Chlorophyll – water filtered on-board the ship for analysis on-shore

A total of 9 CTD casts were performed on this cruise, KN221 leg 4. Water samples were taken at various depths from 10 liter OTE Niskin bottles on 7 of these casts. Chemical parameters such as Total Dissolved Inorganic Carbon, pH, Alkalinity, Nutrients, and Chlorophyll were prepared and then stored for later analysis back at WHOI, while salinity and dissolved oxygen samples were analyzed during the cruise.

Table 2-1 – CTD casts

Cast #	Date	Latitude	Longitude	Bottom depth (m) As per Knudsen	CTD cast depth (m)	Quantity of water samples
1	9/8/14	62° 06.42′ N	31° 22.90′ W	2,401	1,490	Bottles fired for test purposes only
2	9/8/14	61° 59.72′ N	31° 52.35′ W	2,698	995	12
3	9/8/14	61° 53.17′ N	32° 18.33′ W	2,698	2,483	12
4	9/8/14	61° 39.45′ N	33° 04.60′ W	2,976	499	12
5	9/11/14	59° 55.45′ N	39° 30.56′ W	2,715	1,484	12
6	912/14	59° 57.97′ N	39° 28.24′ W	2,706	2,481	12
7	9/15/14	59° 55.13′ N	39° 25.73′ W	2,737	1,490	12
8	9/16/14	59° 14.19′ N	39° 30.13′ W	3,030	2,986	None
9	9/17/14	59° 46.27′ N	39° 38.47′ W	2,758	994	12

Example plots (from cast 7):

UKN22104007.CNV: 59 ° 55.13 S 039 ° 25.73 W Sep 15 2014 15:50:13 gmt

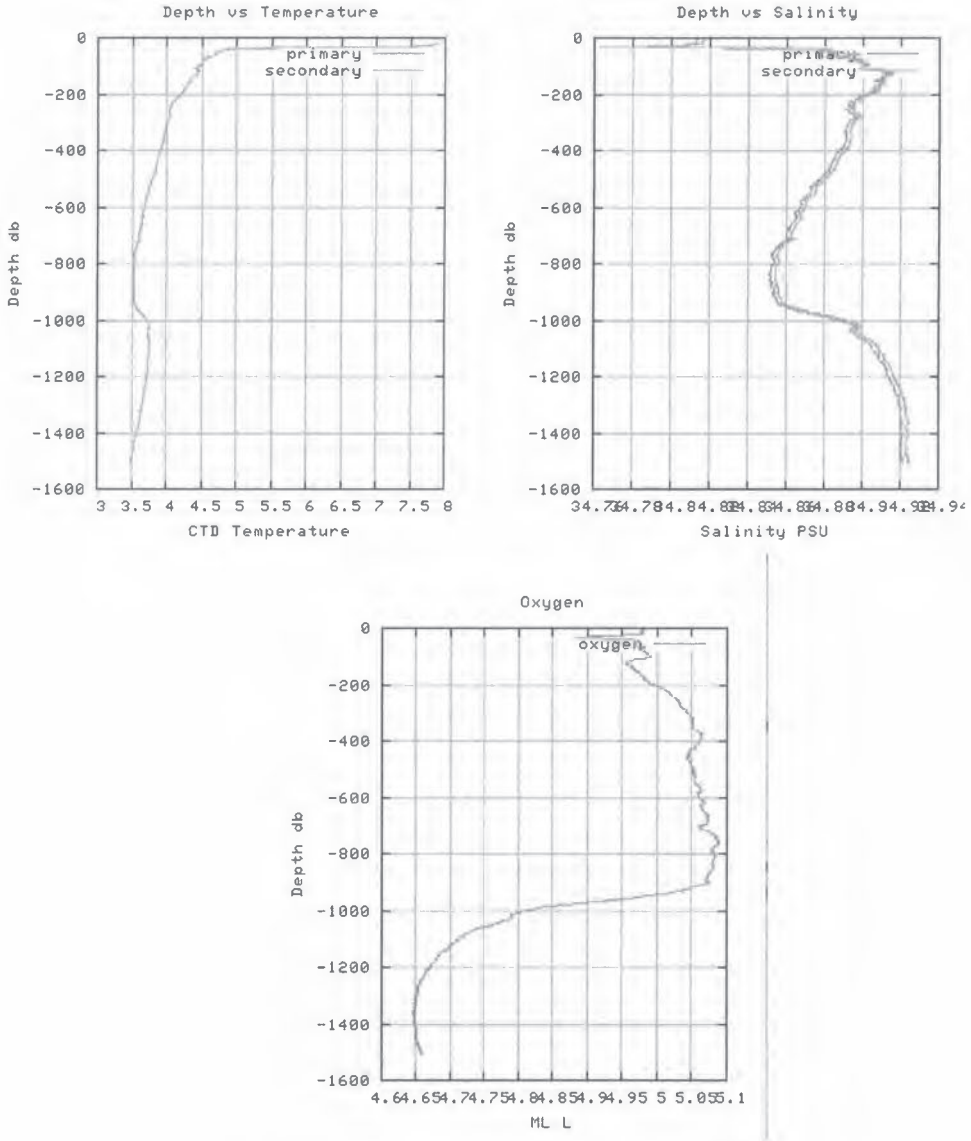

Figure 2-2 Examples plots from cast 7.

Salinity measurements were performed on this cruise using a Guildline Autosal model 8400B salinometer. Salinity samples were collected from the CTD rosette in 250ml sample bottles and were allowed to reach a room temperature at, or slightly below, the Autosal's set bath temperature of 24 degrees Celsius to achieve optimal accuracy. The manufacturer, (Guildline Instruments of Canada), claims an accuracy of +/- 0.003 psu and a resolution of 0.0002 at 35 psu. IAPSO standard seawater (current batch, P-156) was used to standardize the Autosal daily before runs.

Dissolved oxygen measurements were made using a modified Winkler technique similar to that described by Strickland and Parsons (1972) and using a Metrohm Model 888 Titrando dosing

device. Each seawater sample was collected in a 150 ml brown glass Tincture bottle. When reagents were added to the sample, iodine was liberated which is proportional to the dissolved oxygen in the sample. A carefully measured 50-ml aliquot was collected from the prepared oxygen sample and titrated for total iodine content. Titration was automated using a PC controller and the Metrohm Model 888's dosing buret. The titration endpoint was determined amperometrically, with a resolution better than 0.001 ml. Accuracy was about 0.02 ml/l, with a standard deviation of replicate samples of 0.005. This technique is described more thoroughly by Knapp et al (1990).

2.3 Ship's Acoustic Doppler Velocity Profiler

The R/V *Knorr* was outfitted with three ADCP data streams to provide water-column velocity estimates of varying vertical extent and depth resolution.

- RD Instruments Ocean Surveyor – NarrowBand Mode (OS75NB, 75 kHz operating frequency, configured with bottom track on, a sampling interval of 300 s, and 60 depth bins of 16 m each).
- RD Instruments Ocean Surveyor – BroadBand Mode (OS75BB, 75 kHz operating frequency, configured with bottom track on, a sampling interval of 300 s, and 80 depth bins of 8 m each).
- RD Instruments Workhorse (WH300, 300 kHz operating frequency, configured with bottom track on, a sampling interval of 120 s, and 70 depth bins of 2 m each). The velocity profile data can be used to evaluate current meters on the moorings. The OS75NB and BB are configured for deep water operation. The WH300 is configured for shallow water operation, and will profile from a minimum depth of 10 m (BB) to 25 m (NB) to a maximum depth of about 140 m.

The RV *Knorr* is equipped with a 75kHz RDI Teledyne Ocean Surveyor and a 300 kHz RDI Teledyne Workhorse ADCP. Both instruments continuously collected data during the cruise with an hourly resolution, recording position (lat/lon) and the Northward and Eastward velocities at various depths. The two instruments differ in their range and bin size, with the 75kHz ADCP sampling in 31 bins between 20 and 750m, and the 300kHz ADCP sampling in 6 bins between 10 and 120m.

The 75kHz ADCP was used to validate preliminary data from the two flanking moorings by comparing data from the shipboard, downward-looking instrument with the upward looking ADCPs at approximately 500m depth on the moorings for periods during which the ship was close (< 2 nm) to the respective mooring positions.

2.4 Ship's Underway Oceanographic Measurements

The R/V Knorr was outfitted with system and sensors to measure the following near surface parameters:

- Near-Surface Temperature (Sea-Bird Electronics SBE-48 hull-mounted temperature sensor, located on the forward port bulkhead at approximately 5 m depth near the salt water intake).
- Near-Surface Salinity (Sea-Bird Electronics SBE-45 MicroTSG, located at the aft end of the main lab and sampling water from the salt water intake located in the forward transducer well – approximately 5 m depth on the port side).
- Near-Surface Fluorescence (WET Labs WETStar Chlorophyll sensor, located at the aft end of

the main lab and sampling water from the salt water intake located in the forward transducer well – approximately 5 m depth on the port side).
The near-surface data collected from the area of the Pioneer Array mooring sites can be used to evaluate the data from near-surface instruments on the Moorings.

2.5 Ship's Meteorological Measurements

The R/V Knorr was outfitted to measure the following meteorological parameters:

- Air temperature, Barometric Pressure, Humidity, Wind Velocity, Precipitation (Vaisala WXT520; S/N: D0220001 & C3620001; MET mast port & starboard side, 15.5 m above waterline)
- Short Wave Radiation (Eppley Precision Spectral Pyranometer; S/N: LS#1; MET mast, 15.5 m above waterline)
- Long Wave Radiation (Eppley Precision Infrared Radiometer; S/N: LS#1; MET mast, 15.5 m above waterline)
- Photosynthetically Available Radiation (Biospherical Surface PAR QSR2200; S/N: 20313; 02 Deck port side)

The met mast is shown is Figure 2-3.

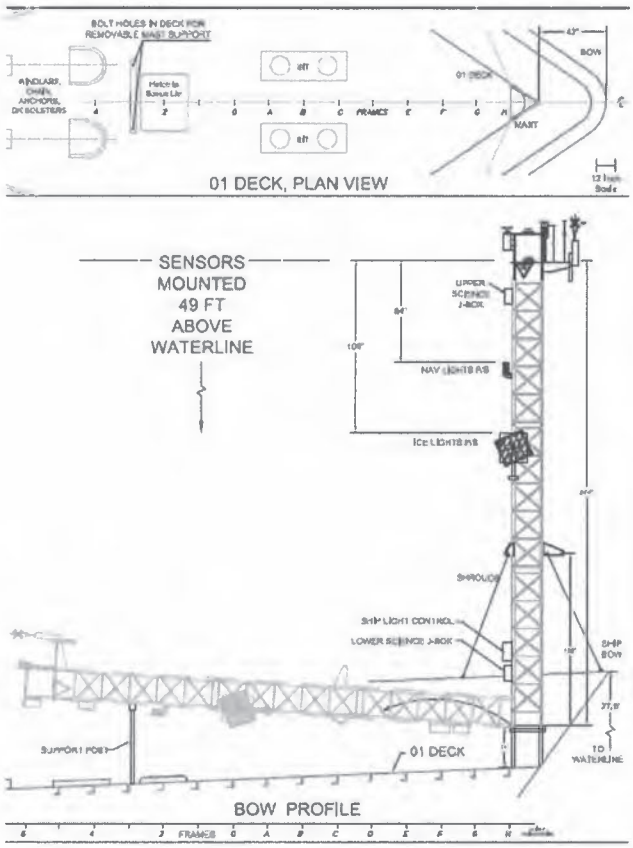

Figure 2-3 RV Knorr meteorological mast.

A plot of the RV *Knorr* meteorology from Reykjavik until the day after she left the Irminger Array is shown below (Figure 2-4):

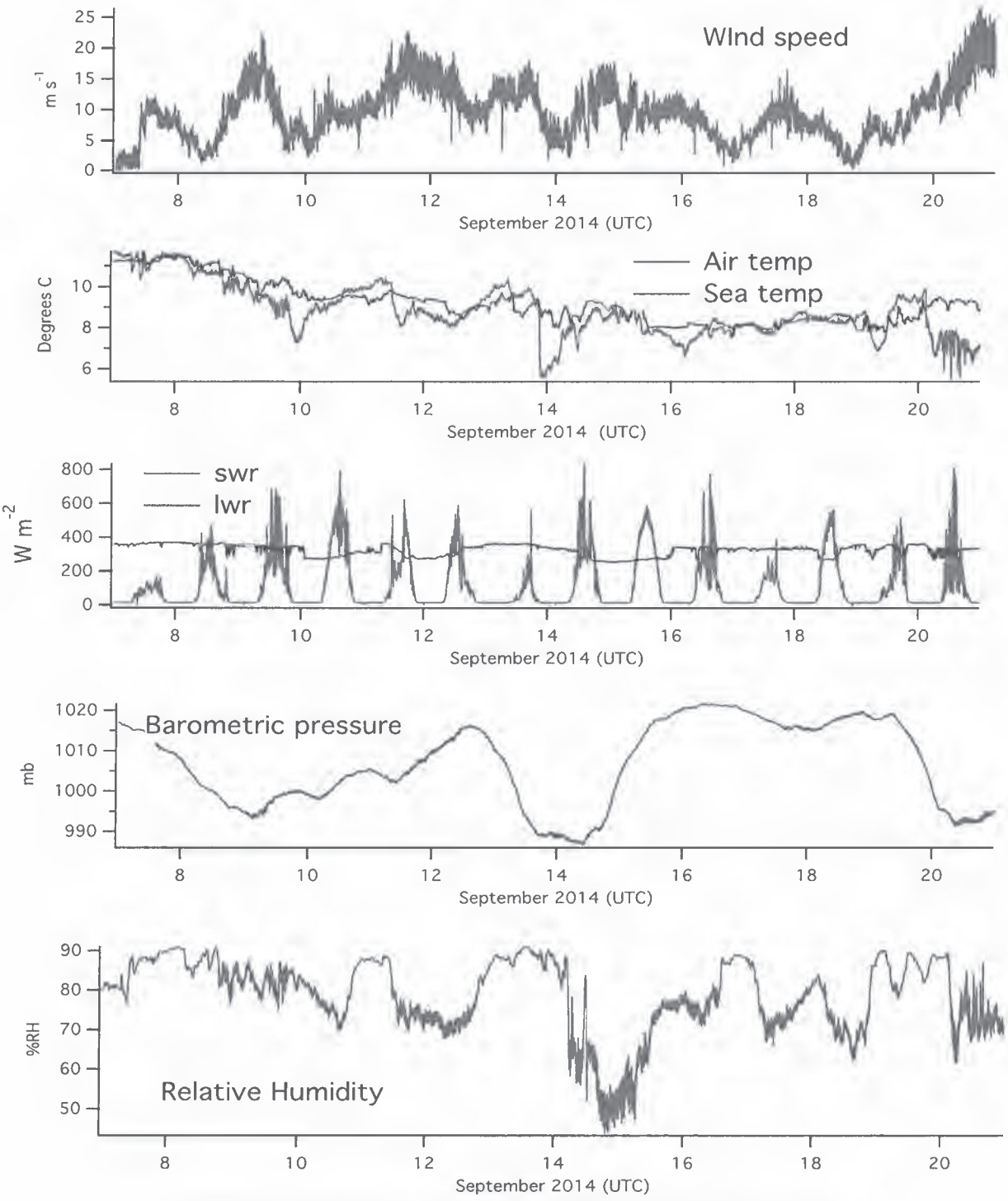

Figure 2-4 Time series of surface meteorology from RV Knorr.

3 Ancillary Activities

3.1 Argo float deployments

Seven MetOcean Argo floats were deployed for Dr. Birgit Klein, Bundesamt fuer Seeschifffahrt und Hydrographie (BSH). Two floats were deployed on the leg from Reykjavik to the Irminger OOI site. After deployment they were found to be in test mode, not diving, and the manufacturer reprogrammed them via Iridium. The manufacturer asked for the remaining five floats to be turned on (magnet off) and placed on deck so that they could be reprogrammed prior to deployment on the leg home from the Irminger site to Woods Hole. One float was found during this reprogramming to have a vacuum leak, and we were asked to not deploy that float.

Float ID	Date	Time (UTC)	Latitude	Longitude	Note
23186	9/8/2014	14:01	62° 02.93'N	31° 39.79' W	
23089	9/9/2104	11:31	61° 09.08'N	34° 53.76' W	
24090	9/20/2104	05:16	56° 27.34' N	46° 48.53' W	
23097	9/20/2014	12:50	55° 56.41' N	47° 41.75' W	
23087	9/21/2014	09:29	55° 19.54' N	49° 04.03' W	
16481	9/21/2014	14:38	54° 58.13' N	50° 02.25' W	
23028					Not deployed

3.2 Deployment of LOCO2 mooring

LOCO2 is a long term mooring project of the Netherlands Institute for Sea Research (NIOZ). With the exception of 1 year NIOZ deployed continuously at this spot a mooring containing 2 Long Ranger ADCP's, 2 SBE37 and a McLane Moored Profiler with an FSI-CTD. The mooring is 'refreshed' yearly, usually in autumn. The mooring itself consists of buoyancy in the top (2 elliptical-shaped floats, the upper one containing the upper ADCP), cable covered with nylon, a pair of Oceano releases and a block of steel as anchor. In order to facilitate recovery rings made of steel and small pieces of chain were incorporated. The design remained unchanged over the years. One small addition is made this year: a DO-sensor (brand Rinko) just above the lower SBE37, a few meter above the ocean-floor. Beside of this the measuring frequency of the SBE37 is changed from 1 measurement per 5 minutes into 1 measurement per 15 minutes. For details of the mooring design please have a look at the figure.

LOCO2-10 was recovered during an earlier cruise. The 2 SBE37 CTD's were calibrated against the Seabird CTD-sensors during an inter-calibration cast. The SBE37's were tied to the CTD-frame and the rosette-stops were much longer than normal to give the (slower) SBE37-sensors the time to accommodate. Both the SBE37's showed very small differences in temperature, conductivity and pressure compared with the sensors of the CTD and very well within acceptable tolerances.

The deployment of the mooring went flawless due to the professionalism of the crew of the RV *Knorr* and the mooring technicians of WHOI and the University of San Diego. After the mooring action a triangulation was carried out and therefore we know that the anchor landed on the ocean floor very near to the intended spot and the depth was only 10 m off the target-depth. To put the anchor on the right depth-line was challenge for the colleagues on the bridge, because the 12 kHz echo-sounder went down 20 minutes before we reached the intended anchor-location.

After the triangulation (Figure 3-1, Figure 3-1) a CTD-cast to the bottom on a mile distance from the mooring was carried out to obtain the hydrographic status of the ocean on that moment.

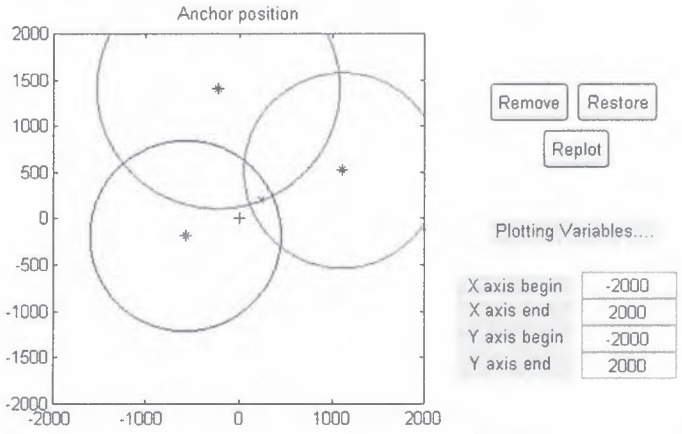

Figure 3-1 Triangulation during acoustic survey of LOCO2 anchor site.

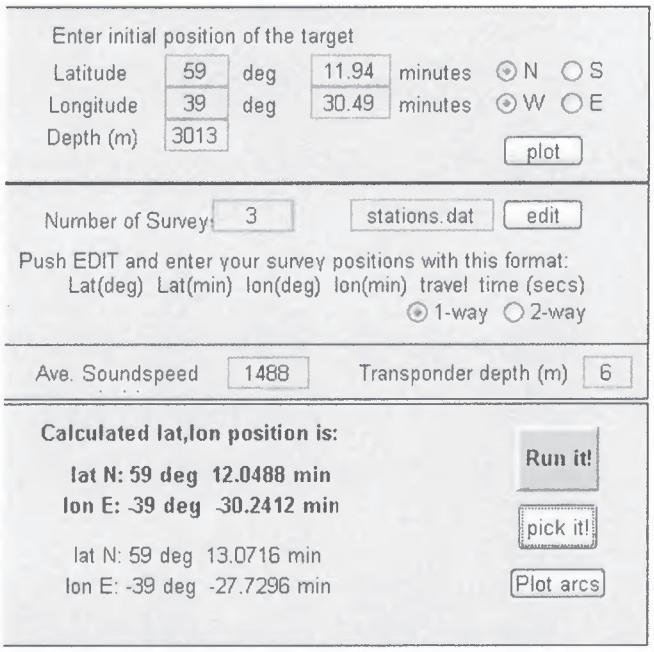

Figure 3-2 Determination of anchor position for LOCO2.