U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SERVICE

DATA ACQUISITION & PROCESSING REPORT

Type of Survey: Hydrographic Survey

Project Number: OPR-K354-KR-18

Time Frame: May - September 2018

LOCALITY

State: Louisiana

General Locality: Gulf of Mexico

Sub-locality: Louisiana Coast

2018

CHIEF OF PARTY

George G. Reynolds

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Date:

NOAA FORM 77-28 (11-72) U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION	REGISTRY NUMBERS:
HYDROGRAPHIC TITLE SHEET	H13100, H13101 H13102, H13103, H13200

State:	**Louisiana**
General Locality:	**Gulf of Mexico**
Sub-Locality:	**Louisiana Coast**
Scale:	**1:40,000**
Date of Survey:	**May 28 to September 24, 2018**
Instructions Dated:	**Initial: March 23, 2018, Expanded Area: August 6, 2018**
Project No.:	**OPR-K354-KR-18**
Vessels:	**R/V Ocean Explorer- Official Number 905425**
Chief of Party:	**George G. Reynolds**
Surveyed By:	**Ocean Surveys, Inc.**
Soundings by:	**Multibeam Echosounder**
Imagery by:	**Side Scan Sonar, Multibeam Echosounder Backscatter**
Verification by:	**Atlantic Hydrographic Branch**
Soundings Acquired in:	**Meters at MLLW**
H-Cell Compilation Units:	

Remarks: The purpose of this project is to provide contemporary surveys to update National Ocean Service (NOS) nautical charting products. All times are recorded in UTC. Data recorded and presented relative to UTM Zone 15 North.

Contractor: Ocean Surveys, Inc.
129 Mill Rock Rd E
Old Saybrook, CT 06475

TABLE OF CONTENTS

Page

APPENDICES

A. EQUIPMENT

A.1 Survey Vessel: *R/V Ocean Explorer*

All survey operations were conducted from the *R/V Ocean Explorer* (Figure 1). *R/V Ocean Explorer,* O.N. 905425, is an 18-meter aluminum vessel, with a 5.1-meter beam and nominally 2-meter draft. *R/V Ocean Explorer* is powered by two 1,000 HP Iveco diesel engines.

Figure 1. *R/V Ocean Explorer* configured for hydrographic survey operations.

The *R/V Ocean Explorer* was modified to support hydrographic survey operations by Ocean Surveys, Inc. (OSI). The following summarizes the major adaptations and/or custom survey support hardware installed on the *R/V Ocean Explorer*:

1. Survey system control modules (processors) and computer systems were installed at purpose-built work stations in the main cabin of the vessel.
2. A measured and indexed Inertial Measurement Unit (IMU) mounting plate was installed on the vessel's fore-aft (roll) centerline at the approximate pitch center of rotation. The POS MV IMU was installed on this plate which resides approximately 0.5 meters below the plane of the vessel waterline.
3. A retractable multibeam transducer pole, constructed of thick-wall aluminum pipe, was attached to the starboard side of the vessel at the approximate pitch centerline. The pole was attached at two points: a substantial, positive locking swivel near the deck of the vessel and a "receiver plate" at the chine of the vessel. The transducer pole is forced, by means of a block and tackle system using non-stretch rope and a hand-crank winch, into the V-notch receiver plate, thereby eliminating pole movement. The transducer pole was fitted with fairings on the trailing edge to minimize cavitation. The

bottom of the transducer pole was fitted with a termination flange configured with a small copper orifice. This configuration allowed the transducer pole to be used as a stilling well.
4. To support fixed-mount side scan sonar (SSS) operations a custom SSS mounting bracket was affixed to the forward side of the multibeam transducer pole. The fixed-mount SSS bracket was installed approximately 0.4 meters above the multibeam transducer. Due to relatively shallow water depths on this project, no towed SSS imagery was acquired.
5. A moving vessel profiler (MVP) was installed on the port quarter of the vessel.

A full survey of the *R/V Ocean Explorer* was conducted on May 6, 2015 by OSI in order to establish permanent shipboard benchmarks and define a fixed vessel reference frame, vessel reference point (RP), draft measurement locations and sensor mounting locations. The points were surveyed using a precision total station while the vessel was hauled and blocked on land. Offsets measured from the 2015 total station survey were confirmed for the 2018 vessel mobilization employing a steel tape measure.

The multibeam transducer pole is capable of variable draft settings. During the 2018 vessel mobilization, the initial transducer phase center-to-RP value was established relative to shipboard benchmarks employing a steel tape measure. The relative distance between transducer phase center and vessel RP did not change during the survey. Survey offsets and estimated measurement accuracies were incorporated into the CARIS vessel configuration file.

Major data acquisition system components that were employed on the *R/V Ocean Explorer* during the project are summarized in Table 1 below. A brief description of the equipment is also included after the table.

Table 1
***R/V Ocean Explorer* Acquisition Equipment**

System	Data	Manufacturer	Model/ Version No.	Firmware/Software Ver.	Serial Number (s)
Side Scan Sonar Towfish (fixed-mount)	Imagery/Contacts	EdgeTech	4125	N/A	46118
Side Scan Sonar Processor	Imagery/Contacts	EdgeTech	4125P	4125D V. 36.0.1.120	46921
Multibeam Echosounder Processor	Soundings	Reson	7125 SV2	SV2 SP4 7K 6,0,0,6	18342213063
Multibeam Echosounder Transducer	Soundings	Reson	7125 SV2	N/A	Proj. 4712049 Rec. 4514295
Surface Sound Speed	Sound Speed	AML	Micro-X w/ SV- Exchange	N/A	MicroX 10315 SV-X 203524
Moving Vessel Profiler (MVP)	Sound Speed	ODIM	MVP30	MVP Controller 2.43	10646
MVP Sound Speed Profile Sensor	Sound Speed	AML Oceanographic	Micro SVPT SV-Xchange & Pressure/Temp Sensor	N/A	SV-X-203516 PT-7786 SV-X-201521 PT-7777
Sound Speed Profiler	QC Comparison Sound Speed	AML Oceanographic	Base-X SV-Xchange P-Xchange	4.15	Base X-25028 SV-X 203108 P-X 304351
Navigation, Vessel Attitude & Heading	Position, Attitude, Heading	Applanix/ Trimble	POS MV 320 V.5 using Marinestar Correctors	HW 1.2-10 SW 07.92	TPU 6415 IMU 861
Navigation	Position (comparison)	Trimble	MS750	1.58	220330606
U.S.C.G. Differential Beacon Receivers	DGPS correctors for Position Comparison GPS	Trimble	ProBeacon	3	0220096149
Base Station GPS	RTK GPS Base Station used for IAPPK processing	Trimble	NetR9 with Zephyr 3 Geodedic	HW 3.2 FW 5.33	5811R52419 6122223813
Water Level Gauge	Static Draft	GE/Druck	PDCR-830	N/A	363764
Lead Line	Bar Check	OSI	Lead Disk	N/A	2010B
Steel Tape Measure	Static Draft	BMI	Ergoline 100	N/A	N/A
Autopilot	Vessel Steering	Simrad	AP50	V1R4	20212221 DA1711

A.2 Echo Sounding Equipment

A.2.1 Side Scan Sonar System

A.2.1.1 EdgeTech 4125

The fixed-mount or SSS system used on the *R/V Ocean Explorer* was an EdgeTech 4125 dual-frequency CHIRP system operating at a nominal frequency of 600 kHz. The second frequency, 1,600 kHz, was not enabled during this survey. This sonar was operated at the 50 m range scale exclusively. The system consists of a portable Topside Processing Unit (TPU) and sonar towfish. The towfish was equipped with an optional telemetry package that allowed for towfish-TPU communication via a coaxial cable connection. The towfish was equipped with standard sensors for pitch, roll, heading, and depth (pressure). However, given that the respective systems were fixed-mounted, none of these sensor data were used during data processing. The TPU was connected to the SSS acquisition computer through a dedicated Ethernet cable. A 4125 SSS positioning verification test was performed in the vicinity of the vessel's home port in Connecticut on May 10, 2018 (DN 130). The test results are documented in the DAPR Appendix II: Echosounder Reports. SSS positioning accuracy was verified regularly during the course of the survey by observing adjacent and/or reciprocal data. Due to relatively shallow water depths no towed SSS imagery was acquired.

Figure 2. Fix-mount EdgeTech 4125 SSS transducer as configured on the *R/V Ocean Explorer* for Project OPR-K354-KR-18. Note that the SSS transducer module (pointing down in this photo) is separated from the electronics module which is secured parallel to the forward side of the transducer pole. A Reson 7125 transducer is mounted to the bottom of the pole in this photo.

A.2.2 Multibeam Echosounder

A.2.2.1 Reson SeaBat 7125 SV2

The SeaBat 7125 SV2 is a dual-frequency Multibeam Echosounder (MBES) System with operational frequencies of 200 kHz or 400 kHz. For Project OPR-K354-KR-18, the echosounder was set to 400 kHz. For this project the swath width was maintained at the system maximum, 140°. At the frequency and beam spacing chosen for this project, the 7125 system is able to illuminate a swath of the seafloor that is 140º across track by 1º along track with a maximum ping rate of 50 Hz. The system can be configured with numerous beam density and swath angle combinations. The 512-equidistant beam configuration was used for Project OPR-K354-KR-18. The manufacturer's stated depth resolution is 6 mm. This sonar system, as employed, is designed to comply with International Hydrographic Organization (IHO) standards to measure seafloor depths to a maximum range of 175 meters. Digital data were output through the Ethernet data port and displayed in real time on a high-resolution color monitor.

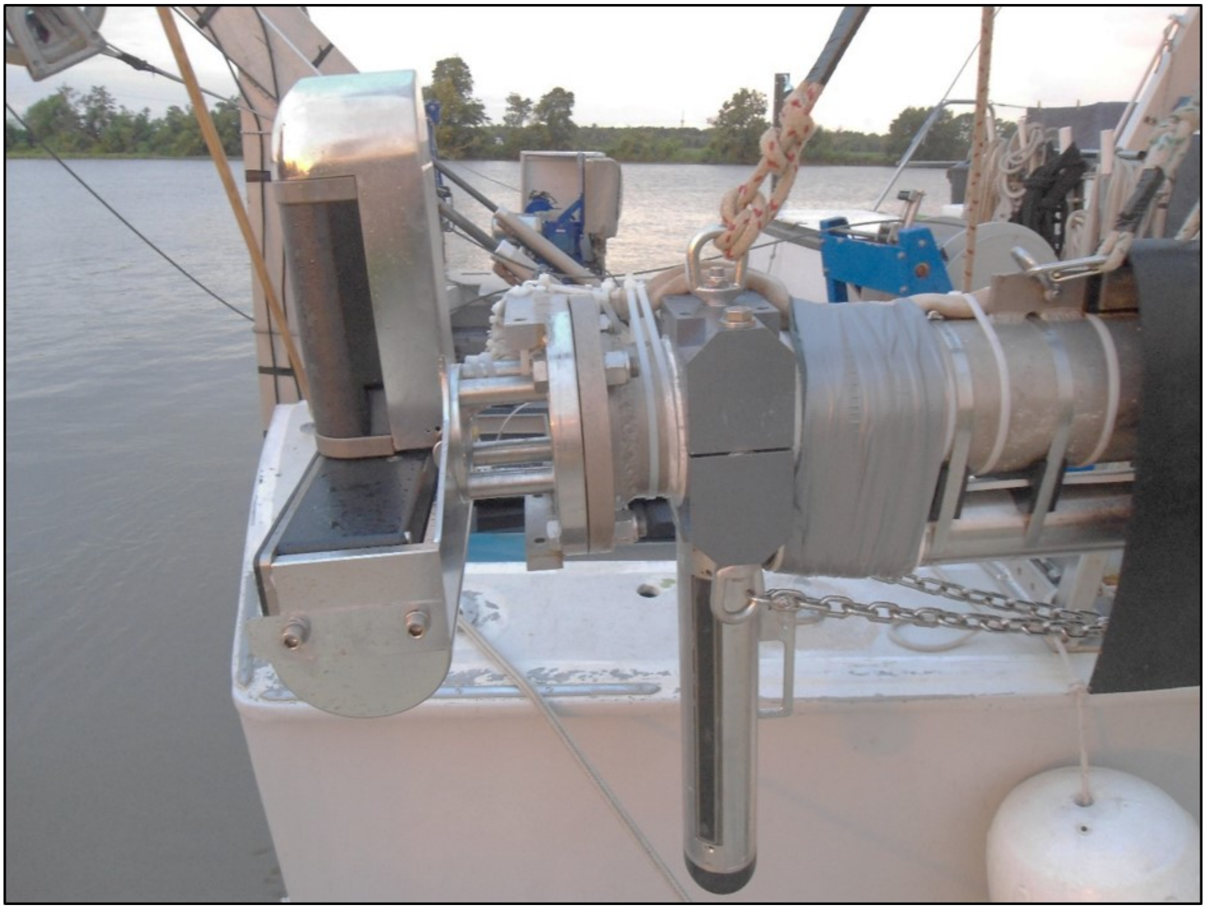


Figure 3. Pole-mounted Reson 7125 transducer as configured on the *R/V Ocean Explorer* for Project OPR-K354-KR-18.

The transducer X, Y, Z position and angular offsets, were referenced to values derived during the 2015 total station survey. XYZ offsets were confirmed during the 2018 mobilization; angular offsets were finalized by patch test.

A.3 Manual Sounding Equipment

A.3.1 Lead Line

The lead line was constructed by OSI utilizing a 9 kilogram, 0.3-meter round lead disk attached to stainless steel cable with permanent index markers established at 1-meter intervals.

The lead line was calibrated prior to survey operations using a steel tape measure to verify index mark accuracy. The lead line calibration was accomplished on April 27, 2018 (DN 117) (see DAPR Appendix II for results).

A.4 Positioning and Attitude Equipment

A.4.1 Applanix POS MV

An Applanix POS MV 320 V.5 system was installed on the *R/V Ocean Explorer* to provide position and attitude data. The POS MV (Position and Orientation System for Marine Vessels) consists of a rack mountable POS Computer System (PCS), a separate Inertial Measurement Unit (IMU) and two GPS receivers.

The POS MV combines the IMU and GPS sensor data into an integrated and blended navigation solution. Per manufacturer's literature there are two navigation algorithms incorporated into the system, namely a tightly coupled and a loosely coupled inertial/GPS integration. Tightly coupled inertial/GPS integration involves the processing of GPS pseudo range, phase and doppler observables. In this case, the GPS receiver is strictly a sensor of the GPS observables and the navigation functions in the GPS receiver are not used. With loosely coupled inertial/GPS integration, the GPS position and velocity solution are processed to aid the inertial navigator.

The POS MV generates attitude data in three axes (roll, pitch, and heading). Roll and pitch measurements are made within an accuracy of 0.02°. Heave measurements supplied by the POS MV maintain an accuracy of 5-centimeters or 5% of the measured vertical displacement for movements that have a period of up to 20 seconds.

The GPS Azimuth Measurement Subsystem (GAMS) allows the POS MV system to achieve high-accuracy heading measurement. The GAMS subsystem uses two GPS receivers and antennas to determine a GPS-enhanced heading that is accurate to 0.02° or better (using an antenna baseline ≥ 2 meters) when blended with the inertial navigation solution. The system uses this heading information together with the position, velocity and raw observations supplied by the primary GPS receiver. GAMS heading was employed for all survey data acquisition, and GAMS status was monitored continuously during survey operations using the MV-POSView controller software.

IMU and antenna offsets, relative to the vessel frame and vessel RP, were measured during the 2015 total station survey (values were confirmed prior to the 2018 survey). An Applanix-specified GAMS calibration procedure was conducted during mobilization and prior to acquisition of any of the calibration data of record. The GAMS calibration was conducted on May 4, 2018 (DN 124).

A.4.2 DGNSS-DGPS

The POS MV was supplied with real-time correctors from Fugro's Marinestar GNSS corrector service or Differential GNSS (DGNSS). Marinestar correctors are referenced to the 2008 realization of the International Terrestrial Reference Frame (ITRF 2008). In order to operate in real-time within the local reference frame, UTM 15N, NAD83, the time variable transformation function was utilized in the HYPACK acquisition software.

Marinestar correctors were employed with the initial intention of utilizing Marinestar-corrected ERS tide data as acquired in real-time. However, Marinestar-derived ERS tide data (including Marinestar data processed using POSPac MMS) was found to be consistently inferior to Inertially Aided Post Processed Kinematic (IAPPK) ERS tide data. With the approval of the COR in an e-mail dated June 28, 2018, 100% of the real-time position and attitude data was substituted with IAPPK Smoothed Best Estimate of Trajectory (SBET) solutions. This subject is covered in detail in Section B.2.4.

The secondary positioning GPS, described below, was supplied with Differential GPS (DGPS) correctors from the local U.S. Coast Guard (USCG) DGPS beacon, English Turn, LA.

Refer to the Vertical and Horizontal Control Report for additional details of DGNSS/DGPS position correctors.

A.4.3 Secondary "QA" Positioning: Trimble MS750

Onboard the *R/V Ocean Explorer,* a secondary GPS was setup in parallel to the POS MV and was used to trigger "position integrity alarms" within HYPACK as necessary. The secondary GPS system consists of an integrated GPS and DGPS receiver and operated in DGPS mode.

A.5 Sound Speed Equipment

Onboard the *R/V Ocean Explorer,* the surface sound speed sensor (affixed to the multibeam transducer), the sound speed "comparison" profiler, and the moving vessel profiler (ODIM MVP), were all fitted with AML Oceanographic sensors which were manufacturer calibrated prior to survey data acquisition. Copies of the calibration sheets are included in DAPR Appendix IV.

A.5.1 Sound Speed Profiles

A.5.1.1 Sound Speed Profiler: ODIM MVP30

The MVP30 was the primary sound speed profiler employed on the *R/V Ocean Explorer* during this survey. The ODIM MVP30 Moving Vessel Profiler allows sound speed profiles to be collected while the vessel is underway. The ODIM MVP consists of towfish-mounted sensors (AML sound speed, temperature, and depth "micro SVPT"), an electro-mechanical conducting cable, and an electric winch. The MVP may be deployed manually using the winch controls or remotely using the ODIM MVP Controller Software. When operated in "FreeWheel" mode while underway, the MVP falls near-vertically to a preset depth off the bottom, collecting sound speed and temperature/depth measurements at a frequency of 10 Hz. During data acquisition on the *R/V Ocean Explorer,* MVP casts were performed at approximately 15-minute intervals.

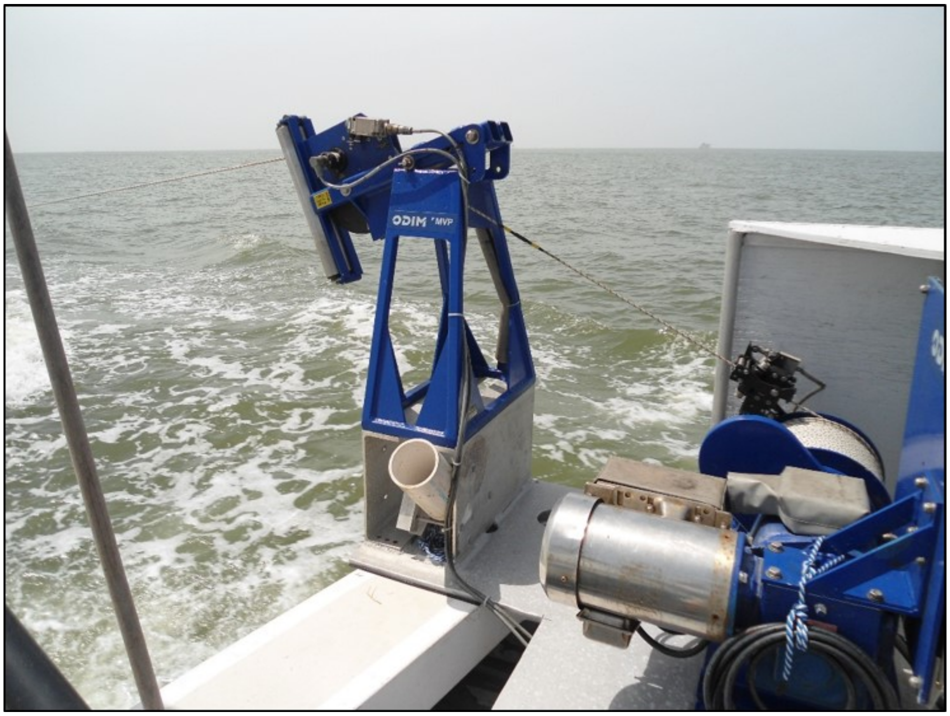


Figure 4. ODIM MVP30 as mounted on the port quarter of the *R/V Ocean Explorer*.

A.5.2 Surface Sound Speed: AML Micro-X

The AML Micro-X is a high-accuracy sound speed sensor capable of measuring and transmitting sound speed data directly to the MBES via a manufacturer-supplied data cable. The Micro-X, mounted within the forward faring of the MBES transducer, transmitted real-time surface sound speed data to the Reson 7125 multibeam system and the HYPACK acquisition computer via the Reson interface. The Micro-X, like the AML SVPT and Base-X sensors discussed above, uses a sound speed “exchange” sensor.

A.5.3 Sound Speed Comparison: AML Base X

Sound speed comparison profiles were acquired using an AML Oceanographic Base-X logging profiler. This instrument collects high-precision direct sound speed and pressure measurements. The instrument was configured to take measurements at a rate of 5 Hz. These data were stored internally and downloaded via a serial connection using the field logging computer.

A.6 Horizontal and Vertical Control Equipment

A.6.1 GNSS Base Station: Trimble NetR9

To supplement IAPPK SBET processing, OSI installed a temporary GNSS station at the U.S. Army Corps of Engineers Freshwater Bayou Canal Lock, which is the closest improved location (having power, structure, and security) near to the survey area. Specifically, a Trimble NetR9 GNSS receiver was installed on the roof of the lock house located at the southeastern corner of the lock (Figure 5). The NetR9 was configured to record GNSS observables continuously throughout the period of the survey and parse data observables into daily files for each 24-hour period. With two exceptions (described below), there were no outages of the base station record during survey operations. The exceptions include base station outages which occurred on September 2-3, 2018 and September 24, 2018 (DNs 245-246 and DN 268 respectively). The unexplained DNs 245-246 outage lasted from 16:02 (DN 245) to 08:09 (DN 246) UTC and coincided with a weather delay period and therefore did not impact data acquisition. The DN 268 "outage" was not really an outage. Rather, the field team recovered the base station at the end of operations (after all survey data and post-survey calibration data were acquired) which resulted in a daily file with less than 24 hours of observables data.

The configuration of the NetR9 was based on UNAVCO standard configuration settings for this device. GNSS observables were recorded on removable media as well as on the NetR9's internal storage. Data were delivered to OSI's home office processing center via regular automated FTP and e-mail "pushes." Pushes were transmitted over a network connection that was established at the Freshwater Bayou Canal Lock for this purpose. The Trimble NetR9 was included in IAPPK processing and designated as Ocean Surveys Freshwater Lock or "OSFL." The antenna reference point (ARP) is located at the following OPUS-averaged position (Table 2).

Table 2
121-Day OPUS-Averaged Position of OSFL

Latitude (NAD83-2011)	Longitude (NAD83-2011)	Ellipsoid Height (GRS80)
29° 33' 09.22889" N	092° 18' 17.04326 W	-17.223

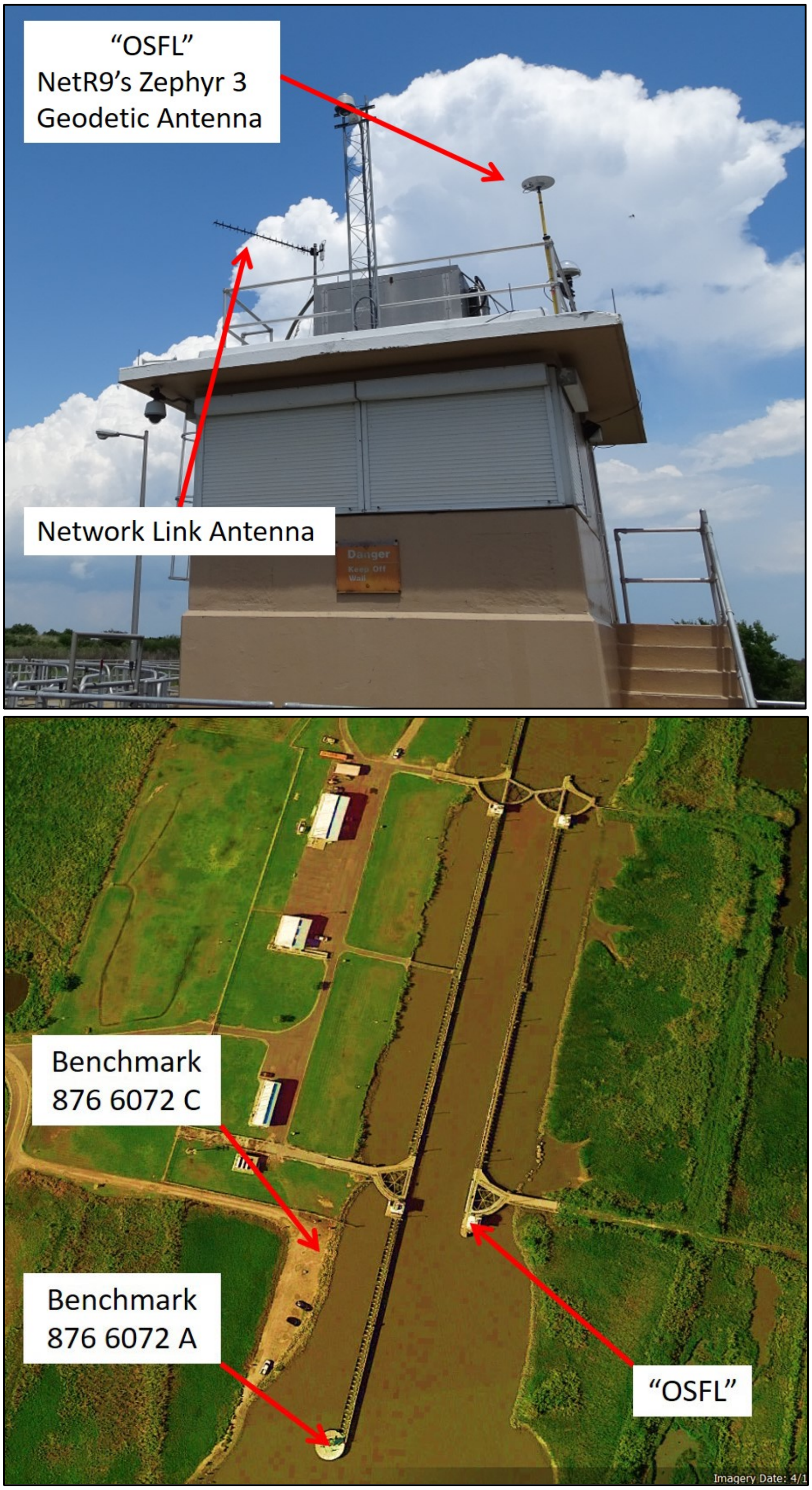


Figure 5. The local setting of OSI's temporary GNSS base station "OSFL."

A.6.2 NOAA Tide Gauge 876-6072

Water levels from NOAA tide gauge 876-6072 were employed in QA/QC analysis of ERS tide data. Details of NOAA gauge tide data use are detailed in Section B.2.4.2.

A.6.3 Pressure Gauge: GE/Druck Water Level Gauge

Onboard the *R/V Ocean Explorer,* data from a GE/Druck pressure sensor were used to calculate vessel static draft values while the vessel was offshore. The water level system consists of a vented pressure transducer connected to a top-side voltage converter. The system transmits a serial "depth" string to the HYPACK logging computer. The pressure transducer was installed well below the waterline at a fixed elevation within the multibeam transducer pole. As mentioned earlier, the otherwise sealed base of the multibeam pole was configured with a small copper orifice, in effect making the transducer pole a stilling well. The physical offset between the sensor "depth" and vessel draft was established dockside during a series of physical draft measurements versus sensor value observations (static dockside calibration).

During offshore operations on the *R/V Ocean Explorer*, sensor data were logged once a day (when practical) when the vessel was at full stop. The system was configured to record a water level at a rate of 20 Hz. Water level readings were logged to a HYPACK .RAW file for 5-10 minutes while the vessel was at a full stop. The average sensor value for the term of the observation was used for each offshore static draft calculation. Sensor readings were adjusted based on the derived fixed offset value established during the static dockside calibration procedure. This approach allowed the field team to accurately track vessel static draft despite offshore conditions.

A.6.4 Steel Tape Measure

A plastic-coated steel tape measure was employed throughout the survey for various tasks requiring physical measurements including: offset confirmations and manual static draft measurements. Static draft measurements were made relative to permanent shipboard benchmarks which were related to the vessel RP during the full vessel survey of 2015.

A.7 Additional Acquisition Equipment

A.7.1 Bottom Sampler

A sediment sampler was employed to obtain seafloor sediment samples within the survey area. A hydraulic pot hauler and davit aboard the *R/V Ocean Explorer* were used to recover the sampler.

A.7.2 Auto Pilot

A Simrad AP50 Marine Autopilot was installed on the *R/V Ocean Explorer* and interfaced with HYPACK to steer the vessel during concurrent MBES and SSS data acquisition. When activated, the Autopilot controlled the rudder adjustments to keep the vessel on line.

A.8 Computer Hardware and Software

A.8.1 Computer Hardware

Table 3
Computer Hardware

Use	Manufacturer	Model	Operating System
MBES/POSView/SSS Acquisition and Log-Keeping	OSI Custom Build	OSI Custom	Windows 10 64-bit
MVP Acquisition	Hewlett Packard	HP 530	Windows XP
Onboard Data QA/QC	OSI Custom Build	OSI Custom	Windows 10 64-bit
AML Base-X Comparison Cast Download	Dell	D830	Windows XP

Onboard the *R/V Ocean Explorer* concurrent MBES, POSView functions, and SSS acquisition was accomplished using custom-built computers running HYPACK SURVEY/HYSWEEP SURVEY, Applanix POSView, and EdgeTech Discover software. MS EXCEL was for the acquisition log. Each computer build was a Windows 10 64-bit computer having a MSI Military Class 4 Motherboard, a 3.2 GHz Intel Core i7 quad core processor, redundant 250 gigabyte (GB) solid-state program drives, redundant 1 terabyte (TB) solid-state data drives, redundant 4 TB data backup drives, three gigabit network adapters, 16 GB of RAM, dedicated graphics, multiple display monitors, 9 serial ports and multiple USB-3 ports.

An additional computer machine was used for onboard data review and as the onboard data backup hub. In practice, data were synced across the network after the completion of each trackline and then synced to an external 2-GB or 4-GB removable USB-3 drive.

Data processing was completed at the home office using multiple Windows 10 64-bit computers with the following typical hardware specifications: 3.60 GHz Intel Core i9-9900K processor (8-core/16-thread), 120 GB primary PCle-based SSD, 2 TB RAID 0 (high-performance) SSD data drive, two 2 TB hard drives in RAID 1 (redundant) configuration, 16 GB of RAM, dual graphics cards, and four high-definition displays. Data processing was completed using large format 4K monitors. The multiple computers shared data over a 10 gigabit local area network.

Several Windows Server computers were used to store the raw and processed data at the office. The HIPS processed MB, SIPS processed SSS, field sheets, and other support files were stored on an 8-terabyte redundant Solid State Drive Array on a server with 4 10-gigabit network ports. Multiple copies of raw and processed data were stored on other servers both on and off site.

A.8.2 Computer Software

Computer software utilized during this survey is itemized in the table below.

Table 4
Computer Software

Manufacturer	Application	Version	Version Date
HYPACK	HYPACK SURVEY	17.1.3.0	Jan. 26, 2017
HYPACK	HYSWEEP SURVEY	17.1.11.0	Jan. 25, 2017
EdgeTech	Discover 4125D 9.0	37.0.1.108	March 22, 2017
Teledyne CARIS	HIPS/SIPS	10.4.3	April 16, 2018
Teledyne CARIS	HIPS/SIPS	10.4.8	Nov. 5, 2018
Teledyne CARIS	Notebook	3.1.1	SP1 2011
HYPACK	MBMax64 SBMax64	17.1.9 17.1.6	June 9, 2017 May 22, 2017
Chesapeake Technology	Sonar Wiz 5	7.1	April 27, 2018
UNH-CCOM/NOAA	Sound Speed Manager	2018.1.15	March 29, 2018
AML Oceanographic	SeaCast	4.2.5	April 12, 2016
Microsoft	Office (Word, Excel) 2016	16.0.6965.2058	June 3, 2016
MathWorks	MATLAB	R2018b (9.5.0.944444)	August 28, 2018
ODIM Brooke Ocean	MVP Controller	2.430	Jan. 20, 2010
Applanix	MV POS View	7.92	April 9, 2014
Applanix	POSPac MMS	8.3 SP1	August 2018
Global Mapper Software LLC	Global Mapper	19.1	Feb. 13, 2018
AutoDesk Inc.	AutoCAD Map 3D	2019	March 29, 2018
Trimble	Pro Beacon (DOS)	N/A	Sept 12, 1994
Trimble	MS Controller	1.1.0.0	July 2013
National Geodetic Survey	OPUS	2.5.2	August 23, 2018
UNH-CCOM/NOAA	HydrOffice QC Tools 2	2.6.7	October 5, 2018
NOAA HSTP	XMLDR	18.4 (9090)	Nov 19, 2018

A.8.2.1 HYPACK SURVEY

Survey vessel trackline control and positioning were accomplished with the HYPACK SURVEY data-logging and navigation software package. Real-time vessel position data were output from the POS MV at 20 Hz and transmitted to the navigation computer system, which processed these data in real-time to the desired mapping coordinate system (UTM Zone 15 North, NAD 83). Raw and processed position data were continuously logged onto the computer hard drive, sent to the autopilot, and displayed on a video monitor, enabling the vessel's helmsman or autopilot to guide the survey vessel accurately along pre-selected tracklines. Tracklines and survey features were displayed on the helm monitor with geo-referenced data that included current NOS nautical charts and other pertinent survey reference files.

Motion and predicted tide-corrected sounding data were displayed as HYPACK gridded depth models and coverage matrices. HYPACK "targets" were also recorded to mark the location and time of significant observations during data acquisition, such as MVP positions, bottom sample locations, and side scan targets of interest. Raw, geographic position data (NAD83 latitude and longitude) were time tagged with UTC time by the POS MV and recorded by HYPACK SURVEY in .RAW format line files. MBES nadir depths and vessel attitude and heading were recorded in HYPACK SURVEY "RAW" format files.

The HYPACK computer was also used for sensor monitoring and data quality review while data were acquired. Utilities in the acquisition module of HYPACK notify the operator with a visual alert in the event of a sensor malfunction or, in some cases, when a sensor parameter drifts out of operator-set limits (e.g. position comparison or surface sound speed change).

HYPACK SURVEY was used to generate real-time SSS positioning at a rate of 10 Hz which was transmitted to and recorded by the Discover SSS software. For fix-mounted 4125 SSS, HYPACK's "Genoffset.dll" was used to calculate SSS fish position. This process is described in more detail in Section C.1.4. Towfish position was recorded in the HYPACK RAW data, and the real-time position was sent to Discover to serve as primary (interim) positioning for the SSS system.

The acquisition computer's HYPACK SURVEY program was configured to use GPS UTC time (Group 7 from the POS MV) to continuously sync the computer time.

During post-acquisition data processing, all position and attitude data were replaced with 20 Hz IAPPK position and attitude SBET data.

A.8.2.2 HYSWEEP SURVEY

Multibeam data were logged with HYPACK HYSWEEP software which was run simultaneously with HYPACK SURVEY. Multibeam raw beam ranges, intensities, and quality flags were time tagged with UTC time by the Reson 71P and recorded by HYSWEEP in HSX format line files.

Motion and attitude data (heave, pitch, roll, and heading) were time tagged with UTC time by the POS MV and recorded by HYSWEEP in HSX format line files.

Multibeam backscatter data were recorded via HYSWEEP SURVEY in HYPACK .7K format.

Over certain features, multibeam water column data were recorded via HYSWEEP SURVEY in HYPACK _WC.7K format. These data were simultaneously acquired on the Reson multibeam computer in Reson .s7k format. A review of recorded water column data did not result in an enhanced view of the features investigated. Therefore, water column data are not included in the project deliverables.

HYSWEEP SURVEY was also configured to display and record a network-streamed instance of the EdgeTech SSS signal. This SSS imagery waterfall, viewed in a HYSWEEP SURVEY window, was monitored along with the imagery waterfall viewed using the primary SSS acquisition software, EdgeTech's Discover.

The HYSWEEP SSS functionality, though redundant, was a useful field tool with a number of benefits. First, the HYSWEEP/SSS interface enabled coincident starts of both HYPACK/HYSWEEP MBES/SSSfiles and Edgtech Discover SSS files with a single key stroke. The Discover-recorded file, logged in a separate directory on the acquisition computer, was named by HYPACK with the identical name of the corresponding HYPACK file except with a different file extension. Specifically, the Discover-recorded file is given a .JSF extension. This functionality was not only a convenience, but also helped to eliminate transcription errors in file naming and made file correlation easier during processing.

The second benefit, as mentioned above, is the ability to view a second instance of the SSS waterfall. The HYSWEEP SSS waterfall was often setup with a different color palate and gain setting than the Discover waterfall. This afforded the field teams an alternate view of a given feature which is sometimes helpful in interpreting the character of the feature.

Finally, HYPACK's standard "double click" targeting functionality also works in the HYSWEEP SSS waterfall. Features viewed in the HYSWEEP SSS waterfall could be "targeted" and displayed on the HYPACK SURVEY map window for future consideration or avoidance.

The HYSWEEP-recorded SSS data were not intended to be a project deliverable. Therefore, the HYSWEEP-recorded SSS data were stripped from the .HSX files (using HYPACK's HSX Utilities module) prior to compilation of the project deliverables.

A.8.2.3 EdgeTech Discover 4125D

Discover is a side scan sonar control and acquisition software that interfaces directly with the EdgeTech SSS systems via a dedicated Ethernet connection. The software was installed and operated on computers which also ran HYPACK, Applanix POSView, and EXCEL. The majority of the SSS settings are controlled within the Edgetech Discover software; these include the specific sensor inputs/outputs, SSS range settings, display gains, color palettes, real-time bottom tracking parameters, file recording characteristics, pressure sensor zero depth calibration (not applicable in this case), altitude alarms, and navigation offsets (not applicable in this case).

Discover received fish position information from the HYPACK SURVEY program via a looped serial connection (HYPACK-out to Discover-in on the same computer). HYPACK SURVEY calculated and transmitted fish position based upon the fixed physical offsets of the EdgeTech 4125 SSS relative to the vessel RP. Given that HYPACK was providing position information to Discover, navigation offset settings within Discover were set to zero.

In addition to receiving position, Discover was configured to accept ancillary time and heading inputs. NMEA ZDA and a NMEA HTD messages were generated by the POS MV and delivered to Discover over serial connections. The software used the timing message to sync its time and the EdgeTech 4125 TPU time to UTC. The NMEA HDT message was used by Discover in lieu of the onboard compass for sonar heading determination.

All SSS scrolling waterfall data displays (Discover and HYSWEEP) were configured to display uncorrected side scan sonar imagery. Scrolling imagery was continuously reviewed during collection for data quality, feature detection, and to identify water column noise and/or interference (e.g. fish, boat wakes, refraction, etc.). System and user alarms were monitored to ensure continuous system functionality.

Discover compiled system specific side scan sonar image data along with position records and stored these data in EdgeTech .JSF format. Based on past project experience, OSI has determined that JSF files produce superior imagery in CARIS. Therefore, XTF data were not recorded for this project.

A.8.2.4 CARIS HIPS and SIPS

HIPS and SIPS, Version 10.4.3 was used during all phases of data processing up until December, 2018 when data processing computers were upgraded to Version 10.4.8.

All multibeam echosounder data were converted from raw HYPACK format data files to HDCS format and processed using CARIS HIPS software.

All SSS data were converted from raw JSF format line files to HDCS format and processed using CARIS SIPS software.

HIPS/SIPS was also utilized to process MBES and SSS calibration data, which included MBES patch and performance tests, and SSS position confidence tests.

The Feature Editing Module within CARIS HIPS/SIPS 10.4.3 was used during home office processing to track and organize side scan sonar targets of interest, i.e. significant targets and targets requiring further investigation. Danger to Navigation (DtoN) submittals were compiled and exported in S-57.000 format using the Feature Editing Module. Field investigation assignments were tracked and conveyed to the field team using, among other tools, HOB files created in the Feature Editing Module.

A.8.2.5 CARIS Notebook

CARIS Notebook, a predecessor to CARIS' Feature Editing Module was used during manual SSS feature correlation. Functionality within Notebook, not available in CARIS HIPS/SIPS, allows the user to easily change the visual character of HOB symbols. This functionality was employed as an accounting tool. During feature correlation, a HOB file was created with non-fish contacts, i.e. features eligible for correlation. These features were symbolized and viewed using an OSI-customized S-52 presentation. In practice, as common features were correlated, their respective HOB symbol "primary key ID" was assigned a group number. For example, if a monopile "satellite" platform was imaged on four separate SSS runs then each of the four detections were given the same primary key ID. By populating this attribute field, the respective text on the Notebook main display changed color from red to black. Once all of the HOB layers' text on the main display screen had been converted to black, the operator could be confident that all eligible features had been reviewed and, if appropriate, correlated.

A.8.2.6 HYPACK MBMax and SBMax

MBMax64 was used for various shipboard and home office support functions such as confirmation patch test and performance test processing and general day-to-day shipboard and home office data QA/QC review. MBMax64 patch and performance test processing were used as a QA/QC measure and to validate the CARIS-derived values.

A.8.2.7 Chesapeake Technologies, Inc. (CTI) SonarWiz 5

CTI's SonarWiz was used frequently aboard the survey vessel for various SSS QA/QC functions such as image quality review, feature review, and positioning accuracy confirmation.

A.8.2.8 UNH-CCOM/NOAA's HydrOffice Sound Speed Manager

Sound Speed Manager was used to convert the MVP sound speed cast data into CARIS SVP format. Sound Speed Manager was also used to document daily surface-to-surface sound speed comparisons of the MVP and the AML Micro X (which was located on the multibeam transducer). Periodically throughout the survey, full water column sound speed comparisons were made between simultaneous profiles of the MVP and the AML Base X. Again, Sound Speed Manager was employed to document the comparisons. In all cases, both daily and periodic, comparisons "passed" the Sound Speed Manager tests. Comparison results are summarized in Sound Speed Manager "DQA" text files.

DQA results are presented in DR Separate II, Sound Speed Data Summary.

A.8.2.9 AML Oceanographic SeaCast

As noted above, comparison sound speed cast data were acquired using an AML Oceanographic Base-X. AML's SeaCast software was used to interface with the Base-X. This software was used to configure the instrument for deployment and to download the raw cast data into .CSV format which is readable by Sound Speed Manager.

A.8.2.10 Microsoft Office Word and Excel

MS Word was used for report generation. MS Excel was used for log keeping (acquisition and processing), organization and preparation of field and office tasks, report figure production, QA/QC tide smoothing and analysis, and internal or reportable data QA/QC tasks.

A.8.2.11 MathWorks MATLAB

MATLAB was used during project-wide ERS tide smoothing. Smoothed ERS tides were ultimately used in reducing soundings to MLLW. ERS tide smoothing steps are detailed in Section B.2.4.3

A.8.2.12 ODIM Brooke Ocean MVP Controller

Onboard the *R/V Ocean Explorer* a dedicated laptop computer was used to operate the ODIM MVP30 Controller Software. The System Configuration Window was used to interface the MVP towfish, MVP winch and the HYPACK inputs. Position, depth, and vessel speed data were received from HYPACK and sound speed profiles were exported to HYSWEEP to be used for real-time correction of the multibeam waterfall display.

The deployment configuration, alarm settings, and data logging options were set in the Configuration Window, including profile depth limit, max cable out, and docked cable out. Sound speed profiles (SV Files) were saved to the MVP laptop in .CALC format. CALC files were post processed and converted to CARIS .SVP files using Sound Speed Manager. During manual casts, completed periodically during sound speed comparisons, the MVP fish was allowed to reach near full water depth.

The Main Operator Window was used to remotely "cast" the towfish and to monitor the towfish parameters and alarms. Graphical tabs in the Main Operator Window were used to monitor towfish depth and surface sound speed. The manual logging option was toggled on during the acquisition of stationary, comparison, MVP casts.

A.8.2.13 Applanix MV POSView

The MV POSView controller software was used to configure and monitor the POS MV position and attitude subsystems. IMU parameters (heave, pitch, roll), navigation, and GAMS status were monitored continuously at the acquisition station. Visual alarms were configured to alert the operator in the event that attitude, position, velocity, heading or heave accuracy was degraded.

MV POSView was also used to start and end logging of daily POSPac-group files which contain True Heave data and were used to create daily SBET files.

POSView-recorded data were acquired continuously during survey operations. The TrueHeave component of the raw POSView-recorded data was applied to the MBES data in CARIS HIPS.

A.8.2.14 Applanix POSPac MMS Post-Processing Data

POSPac MMS is a post-processing software module, which, given acceptable distance and geometry between the survey vessel and nearby Continuously Operating Reference Stations (CORS) stations, significantly increases the efficiency, accuracy, and robustness of mapping and surveying using GPS data. Using POSPac MMS in post processing, reliable decimeter level or better accuracy can be obtained from existing reference station networks.

POSPac MMS figured prominently in this survey. IAPPK SBET position and attitude were substituted for real-time position and attitude in all submitted MBES data. IAPPK SBET position and heading were substituted for real-time position and heading in all submitted SSS data. The IAPPK-derived vertical solution was used as the basis for creating daily mean lower low water (MLLW) tide files.

The POSPac MMS "Smart Base" function was employed in creating SBET files. The Smart Base process was configured to employ local CORS stations as well as OSI's GNSS base station "OSFL." Inclusion of OSFL was found to improve the vertical component of the SBET solution.

A.8.2.15 Global Mapper

This 3-D visualization software and geographic information system was used to produce detailed sun-illuminated Digital Terrain Model (DTM) images, display vector geographic data and convert file formats. These data were used for QC checks and presentation purposes.

A.8.2.16 AutoCAD 2004

AutoCAD drafting and geographic information system was employed for pre-survey planning, line file construction, hydrographic data QC and the production of presentation graphics.

A.8.2.17 Trimble ProBeacon

The Trimble ProBeacon PC interface program was installed on a utility laptop computer onboard the *R/V Ocean Explorer* and used to configure the Trimble ProBeacon to receive DGPS correctors from the selected USCG station. The PC Interface Program was run through a DOS command window to enter the receiver frequency, check the receiver status and monitor the RTCM messages.

A.8.2.18 Trimble MS Controller

The Trimble MS Controller program was installed on the data acquisition computer and used to program and monitor (as necessary) the Trimble MS750 GPS. This GPS was used for input to the positioning integrity alarm function in HYPACK SURVEY.

A.8.2.19 NGS OPUS

Prior to the start of survey operations during OSI's 2017 survey (OPR-K354-KR-17), a navigation checkpoint was established at the vessel's Louisiana base of operations. OSI employed the same base of operations during the 2018 survey (OPR-K354-KR-18). In 2017, dual-frequency GPS observations were recorded at the navigation performance checkpoint location known as "SMIC-01." The dual-frequency GPS observables were submitted to the National Geodetic Survey's (NGS) Online Positioning User Service (OPUS) and processed to determine the position of the temporary control point. NGS provided an OPUS Report which included both ITRF and NAD83 coordinates along with position accuracy information. The 2017 OPUS report is provided with the digital Horizontal and Vertical Control Report (HVCR) deliverables.

As noted earlier, OSI deployed a non-CORS base station, "OSFL," to support the contemporary survey. According to Section 3.4 of the 2017 HSSD, "*The hydrographer shall conduct a certification on non-CORS to ensure that no multipath or other site specific problems exist. The reference position of non-CORS antenna installations shall be verified at least once per week while the site is utilized for survey operations. Verification may be achieved by repeated OPUS sessions to demonstrate that the difference between adopted and check positions are within the error budget allotted per THU*". Section B.2.4.4 of this report presents the results of OPUS-derived antenna installation verification and a discussion of station certification. The OPUS reports contributing to the "position verification" results are provided with the digital Horizontal and Vertical Control Report (HVCR) deliverables.

A.8.2.20 HydrOffice QC Tools 2 v.2.6.7

UNH-CCOM/NOAA's HydrOffice QC Tools 2 was used for various surface QC tasks including the following:

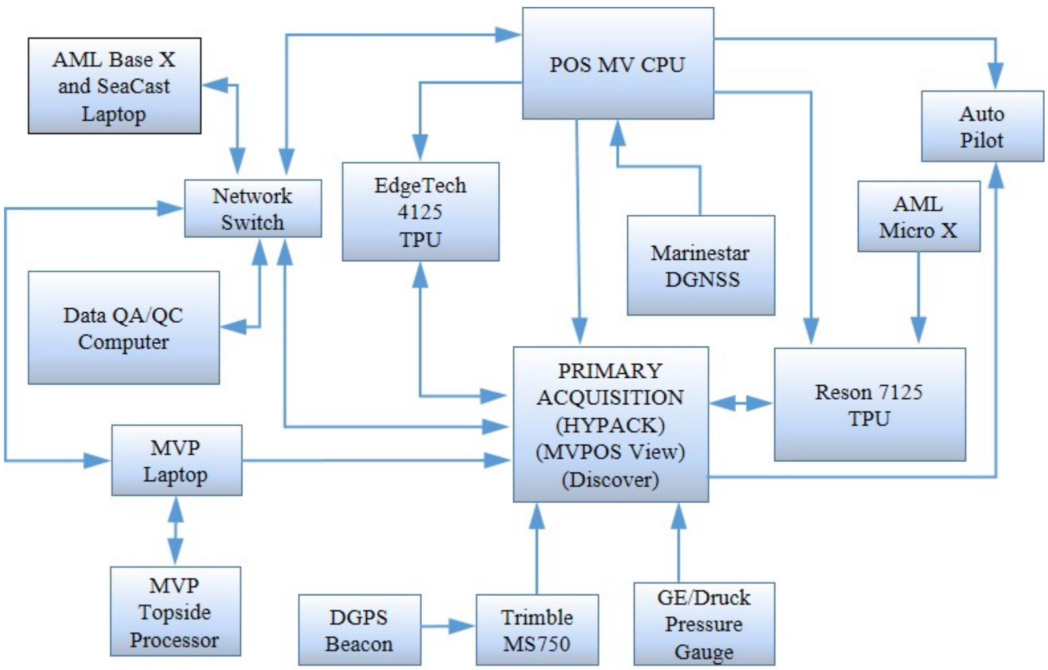
- Flier Finder v6 - Scan grids for anomalous grid data "fliers."
- Holiday Finder v4 - Scan grids for empty grid nodes that meet NOAA NOS Hydrographic Survey Specifications and Deliverables (HSSD) definitions of "holidays."
- Grid QA v5 - Compute basic grid statistics to ensure compliance to uncertainty and density requirements.
- Designated Scan v2 - Scan grids to ensure the eligibility of soundings designated.
- Feature Scan v8 - Scan features to ensure proper attribution.
- VALSOU Check v7 - Ensure surveyed features are properly accounted for in the gridded bathymetry.
- Submission Checks v3 - Ensures the required directory structure and completeness of survey deliverables.

Given that the 2017 HSSD was specified in the Project Instructions, the delivered Data Directory Structure adhered to Appendix J in the 2017 HSSD. As such the "2017" option was chosen in the Submission Checks test.

A.8.2.21 NOAA HSTP XmlDR

Used in compilation and printing (to PDF) of project Descriptive Reports.

A.8.2.21 Acquisition System Block Diagram – *R/V Ocean Explorer*



B. QUALITY CONTROL

B.1 Data Acquisition

All data acquisition and processing were performed under the supervision of an experienced team including the Chief of Party, Lead Hydrographer, Senior Hydrographer and Sheet Manager, each with over ten years of experience conducting hydrographic surveys and/or processing the acquired data. The Chief of Party and Lead and Senior Hydrographers are ACSM/NSPS/THSOA "Certified Hydrographers."

Prior to the survey, a review of the current charted data was conducted to identify critical features and areas including platforms, obstructions and wrecks. The Composite Source File (CSF) and Project Reference File (PRF) supplied by NOAA were included in this review.

The Hydrographic Survey Project Instructions called for "Complete Coverage" of the entire survey area. In consideration of the Project Instructions, where appropriate, line plans were created to achieve 100% SSS coverage with concurrent MBES. The Project Instructions included a "Towfish Operation Waiver" which permitted SSS towfish height above the bottom of 6-20% of SSS range (as opposed to the 8-20% specified in the HSSD). The fixed-mount SSS was operated only at the 50-meter range scale. For most Complete Coverage areas, 100% SSS coverage lines were planned as follows:

- 80-meter line spacing (in anticipated and/or preliminary water depths ≥ 5 meters) resulting in 20 meters of outer range overlap; SSS nadir coverage provided by the MBES

- 40-meter (or less) line spacing (in anticipated and/or preliminary water depths ≤ 5 meters). The 40 meter line plan, resulted in substantial yet variable outer range overlap depending on conditions. As in the case above, SSS nadir coverage was provided by the MBES.

Certain relatively deep reaches of the assigned survey areas were covered with Complete Coverage MBES in lieu of 100% SSS. In these areas SSS was in fact acquired but was not used to meet Complete Coverage.

Data acquisition quality control procedures were established and performed to ensure survey data met requirements specified in the Project Instructions, SOW, and HSSD.

B.1.1 Bathymetry: Multibeam Echosounder (MBES)

Transducer offsets for the Reson 7125 were measured relative to permanent shipboard benchmarks and to the vessel reference point (RP) using a steel tape measure. The shipboard benchmarks were established during the full static survey which was completed using standard optical survey equipment and techniques in 2015.

The initial rotation angle (yaw) of the multibeam transducer was physically set relative to the vessel's fore-aft centerline and POS MV IMU with the aid of a portable, survey grade, gyroscopic compass mounted on a square plate. The multibeam transducer orientation was established as follows: soon after the 2015 fixed static survey, once the vessel was launched, the vessel was secured to a fixed dock on a calm day with engines slow ahead pulling the dock lines taut. The transducer pole was then rotated until the heading (mounting angle) of the transducer matched the physical heading of the POS MV IMU (via gyrocompass observations). The gyrocompass was passed back and forth multiple times to confirm that the orientation of the IMU matched the orientation of the transducer. At that time index marks were permanently scribed into both the transducer pole and vessel attachment point so that the initial transducer orientation could be reliably repeated if it was necessary to move the transducer pole, e.g. to accommodate a draft change or, in this case, remobilization for a new field season. These permanently scribed index marks were used to make the initial alignment during the 2018 mobilization.

A patch test was then used to determine minor residual misalignments between the transducer and the POS MV IMU. Apart from retracting the pole for transit, once the draft and alignment were set during mobilization, no changes were made for the period of the survey. Frequent (nearly daily) "roll check" patch test results indicated that the multibeam pole was stable for the period of the survey (with one exception detailed later in this section).

The POS MV IMU reference point, or "bullseye," located on the top of the IMU served as the vessel RP on the *R/V Ocean Explorer*. The IMU mounting plate and key components of the transducer pole mounting apparatus are permanently installed hardware components of the vessel. For detailed information regarding system offsets refer to *Section C* Correction to Echo Soundings.

The Reson 7125 processor was interfaced with the POS MV such that UTC date and time information from the POS MV were used to accurately time stamp the Reson output data string. The Reson 7125 processor received a pulse-per-second (PPS) signal and a serial $ZDA NMEA timing string from the POS MV. The POS MV also supplied a "TSS1" message to the Reson TPU for real-time roll stabilization. Surface sound speed, measured at the transducer head with the AML Micro-X, was output to the Reson 7125 processor for beam-forming. The 7125's "Normal" filter was used for sound speed filtering. Raw sounding data were output directly from the Reson 7125 TPU to the HYPACK acquisition computer via an Ethernet connection.

The POS MV received DGNSS correctors from an integrated Marinestar receiver. POS MV position, heading and attitude data strings were output to the HYPACK acquisition computer via an Ethernet connection.

HYPACK SURVEY and HYSWEEP SURVEY were configured to record position, heading, attitude and depth to RAW and HSX data files. For the real-time display, system offsets for the IMU and for the transducer phase center were entered into the HYPACK configuration files. These offsets were subsequently incorporated into the CARIS data processing routine.

Prior to the start of data collection, the vessel's static draft was measured and the transducer draft was confirmed by means of a bar check while alongside a dock. The bar check procedure consists of lowering the "bar" (a lead disk in this case) to various known depths (calibration points) directly below the multibeam transducer and comparing the nadir depth value output from the multibeam echosounder to bar depth; they should match. A "spot check" was also completed which consisted of sounding the seafloor directly below the multibeam transducer with the lead line while simultaneously observing the multibeam nadir depth. Bar checks and spot checks were completed periodically throughout the course of the survey. All bar checks and spot checks demonstrated that the multibeam system performed within expected accuracy limits. Bar check results are presented in DAPR Appendix II.

The determination of residual transducer alignment offsets (patch test) and multibeam system performance test were completed on May 10, 2018 (DN 130). The May 10, 2018 patch test is the patch test of record for this field season. The calibration to establish the dynamic draft correction table (squat test) was performed on May 11, 2018 (DN 131).

The tests described above were performed with the POS MV in RTK GPS mode with a land based RTK GPS base station which was temporarily established for this purpose. These data were collected near the vessel's home port once the vessel was mobilized and physical offsets confirmed. Ultimately however *all* calibration data and final offset values were processed with IAPPK SBET positioning.

After the vessel transited to the project area, a second set of patch test and performance test data were acquired. Specifically, a confirmation patch test was performed adjacent to the survey area (south of the Freshwater Bayou Canal Lock) on May 28, 2018 (DN 148). None of the *R/V Ocean Explorer's* survey system components were removed during transit to the project area; therefore, as mentioned above, the May 10, 2018 patch test is considered the patch test of record. The initial performance test of record was performed south of the Freshwater Bayou Canal Lock on May 28, 2018 (DN 148). Verification or "close out" patch and performance testing for the *R/V Ocean Explorer* were performed at the completion of the project on September 24, 2018 (DN 267). Close out test results were in keeping with the pre-survey results. The patch test and performance test results of record are presented in DAPR Appendix II.

Given that the multibeam transducer was deployed on a retractable pole, daily "roll" patch tests were performed throughout the course of the survey in order to maintain confidence that the deployed pole was stable. In practice, reciprocal multibeam data were collected on a short set of lines at a convenient time each day and processed onboard to confirm system stability. In cases where the pole was deployed after transit, e.g. upon returning to the survey area after a port call, a roll test was conducted immediately prior to data acquisition. In only one case did interim testing indicate a slight roll change. On this day, September 23, 2018 (DN 266), a roll offset change of ~0.1° was detected. Upon investigating the change, it was discovered that a large clump of weeds had lodged on the multibeam pole's forward guy. It is suspected that shaking of the forward guy due to the weed mass contributed to the roll change. The situation was remedied by clearing the weeds and reseating the multibeam pole. Roll testing performed immediately following this action showed that the roll offset was back to the typical value. All other interim roll testing (100 tests total) demonstrated the stability of the multibeam transducer installation. The small, one day change in the roll offset is reflected in the HVF.

The SeaBat display and user interface of the Reson 7125 TPU were used to configure MBES settings, to monitor sounding acquisition, and to adjust system parameters in real time.

The Reson 7125 was operated in equidistant mode using 512 return beams and a swath width of 140°. The roll stabilization feature was activated throughout the term of the project.

The 7125's "absolute" depth gates were conservatively employed to reject fliers during mainscheme and crossline data acquisition. Depth gate filters were used sparingly or completely disabled during item investigations.

The Reson sounding profile "wedge" was monitored in real time. The multibeam was operated at full power for the period of the survey. System gain, pulse length, and "ocean" settings (absorption and spreading) were adjusted to optimize bottom detection with most of these adjustments occurring during calibration and system acceptance. Range settings were monitored and adjusted to observed depths to maximize the ping rate.

Bathymetry, position, motion and heading data were logged in HYPACK SURVEY and HYSWEEP SURVEY.

During operations, the HYSWEEP real-time MBES sounding wedge and digital terrain model (DTM) waterfall displays were monitored. The sounding wedge, DTM waterfall, and plan view coverage displays were corrected for draft, motion, predicted tides and sound speed. Survey coverage was tracked in the HYPACK SURVEY display window with a matrix file updated in real time. MBES survey line names were composed of the year, vessel, day number, UTC time and line number, for example: 2018OE1650133_2163.HSX/RAW where "OE" stands for Ocean Explorer.

The POSView software was used to monitor position, heading and motion accuracy status indicators. Applanix "TrueHeave" data (included in the POSView-recorded data) were acquired and recorded during survey operations. The TrueHeave algorithm uses a delayed filtering technique to increase heave measurement accuracy, reducing error caused by IMU drift induced by long-period ocean swell. In most cases POSView-logged data were recorded at least 5 minutes prior to and after MBES acquisition. POSView-recorded TrueHeave file names include the project number, "POS" to indicate a POS MV file, year, day number, and month/day (ex: 18ES010_POS_2018_212_0731.000). POSView-logged files were saved in individual day folders. Once the file size reached 64 MB, a new file was created; therefore, each day of survey has multiple TrueHeave files.

The POS MV heave bandwidth filter was configured with a dampening ratio of 0.707. The cutoff period of the high-pass filter was determined by estimating the swell period encountered during the project. A heave bandwidth filter of 10 seconds was employed for Project OPR-K354-KR-18 data collection.

The *R/V Ocean Explorer* was operated on a 24-hour/day schedule. Data acquisition was halted each day before midnight (UTC) during which a number of mandatory and/or elective QA/QC functions were performed. During this period, the vessel was brought to a full stop. On a typical day the following functions were performed either during or immediately before/after the stoppage:

- A transducer pole stilling well pressure series was acquired and processed into a static draft value (conditions permitting).
- The in-progress Applanix POSView-recorded/Trueheave day file was ended (before midnight) and a new day file was started (after midnight).
- File naming was updated to reflect the new day.
- Interim roll check data were acquired and processed.
- A surface-to-surface sound speed comparison DQA test was documented (comparing MVP surface speed to multibeam sensor surface speed).

Periodically throughout the course of the survey a bar check was performed to verify echosounder draft offsets and system sounding accuracy and a full water column sound speed profile comparison cast was performed to ensure the primary sound speed profiler (MVP) compared favorably to an independent, recently calibrated sound speed profiler (AML Base X). In all cases, the results of the bar checks and sound speed comparisons indicated that the respective systems were functioning properly.

Data were copied via network connection onto a shipboard data backup computer which also served as the data QA/QC platform. Data were copied from this computer to removable media, 2-TB or 4-TB USB drives, frequently throughout each survey day. These data were periodically transferred to OSI's home office via express courier.

B.1.2 Imagery: Side Scan Sonar

Fixed-mount SSS was the only deployment method employed during this survey. The horizontal position of the SSS was measured in relation to the vessel RP. These values were ultimately used in creating the CARIS vessel file (discussed later). However, horizontal offsets entered into the HYPACK SURVEY data acquisition program, used to calculate fixed-mount fish position for real-time positioning, were referenced to the survey vessel "steering point" origin which was accurately related to the vessel RP.

As discussed previously, EdgeTech Discover acquisition software was used to log the SSS imagery and position information in JSF file format. Discover received towfish position from HYPACK SURVEY and ship heading directly from the POS MV. SSS survey line names are identical to their simultaneously recorded HYPACK counterpart, the only difference being the .JSF file extension. For example: 2018OE1650133_2163.JSF where "OE" stands for Ocean Explorer.

Over much of the study area over one hundred percent (100%) SSS coverage was attained employing line spacing described in Section B.1. However, as mentioned above, certain relatively deep sections of the study area were surveyed with Complete Coverage multibeam.

Vessel speed was maintained such that any 1 m^3 objects would be ensonified more than three times per pass at the operating range scale. Approximate vessel speed for SSS acquisition on the *R/V Ocean Explorer* was 6-9 knots.

Due to the fixed-mount configuration, the 4125 SSS towfish altitude varied based on water depth. For any towfish height below 6 percent of the 50-meter range scale (3-meters), the effective scanning range is defined to equal 16.7 times the towfish height. 40-meter "split" lines were run in the shallow reaches of the study area. Splitting 80-meter lines in shallow areas, ensured that the 100% SSS coverage requirement was met or surpassed even when effective range was reduced due to shallow water.

Confidence checks observed across the full SSS range (e.g. scour marks and bottom type changes) were recorded frequently throughout each survey day to verify system operation and object detection capability, particularly in the outer range. Confidence checks were recorded with line names, observation times, and comments in the daily acquisition log.

B.1.3 Imagery: MBES Backscatter

Backscatter data were logged in HYSWEEP SURVEY simultaneously with MBES soundings. Backscatter file names were composed of the year, vessel, day number, UTC time and line number, for example: 2018OE1650133_2163.7K where "OE" stands for Ocean Explorer. MBES system settings such as power, gain, and pulse length were optimized for acquisition of MBES sounding data. Figure 7 shows the acquisition setting used in HYSWEEP SURVEY.

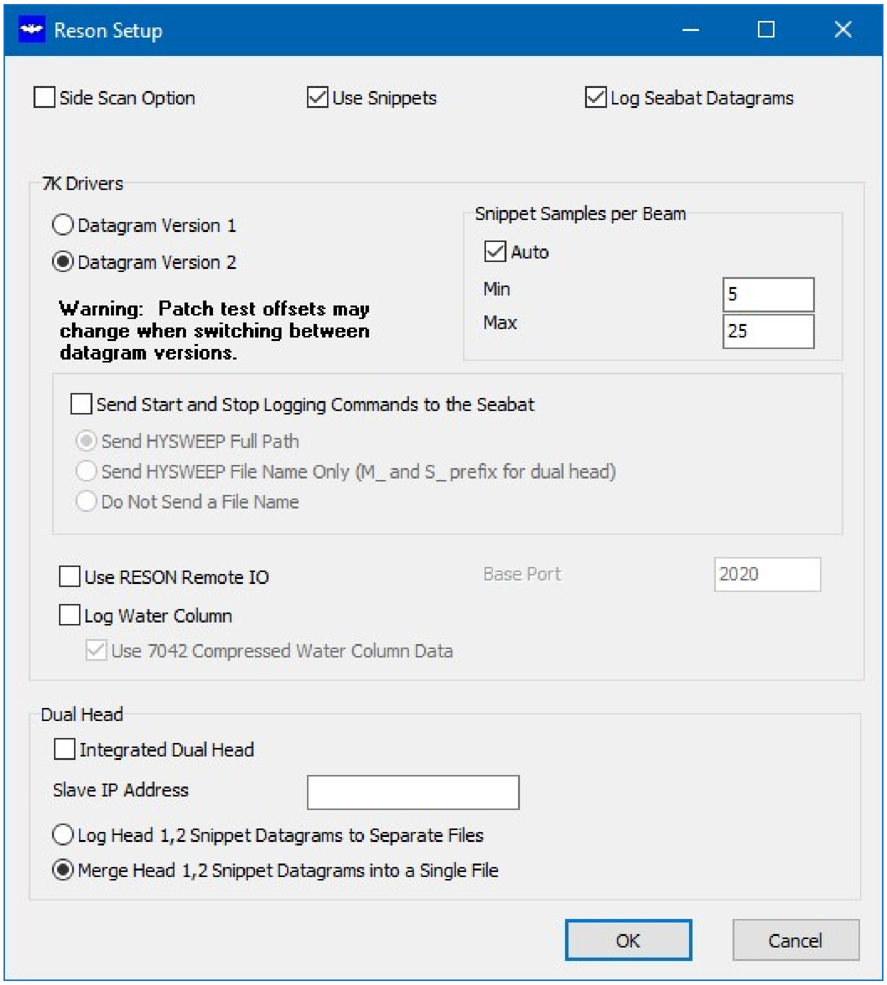


Figure 7. HYSWEEP SURVEY settings used for backscatter acquisition.

B.1.4 Sound Speed

B.1.4.1 Sound Speed Profiles

On the *R/V Ocean Explorer,* sound speed profile data were acquired with the ODIM MVP30 approximately every 15 minutes, except when this time interval occurred while the vessel was turning between survey lines. A utility in HYSWEEP SURVEY allows for real-time comparison of the surface sound speed at the multibeam transducer to the surface sound speed recorded in the most recently acquired MVP profile. The hydrographers acquired more frequent profiles if high variability was noted in the surface sound speed, or when the surface sound speed comparison threshold was exceeded (> 2 meters/second change). Profiles were acquired to a depth approximately 0.8 meters off the bottom when operating in freewheel mode. All casts were acquired inside the bounds of the survey area or within 250 meters of the boundary. Profiles acquired outside the survey area (within 250 meters) were typically acquired on the lead-in to a given survey line.

The ODIM MVP Controller software was configured to receive navigation data from HYPACK via the MVP.dll. HYSWEEP SURVEY was configured to receive MVP casts in real time to correct the real time waterfall and profile displays with the most recent sound speed profile. MVP cast position, sound speed and depth data were recorded in .CALC file format and saved to the designated MVP laptop computer. Profiles were named for day number and cast number, for example: MVP_DN181_0007.calc.

B.1.4.2 Surface Sound Speed

An AML Micro-X sound speed sensor was installed on the multibeam transducer essentially at the draft of the transducer phase center. Real-time surface sound speed values were transmitted to the Reson 7125 topside unit and subsequently recorded with multibeam echosounder data in the raw HYPACK .HSX data files. Sound speed data were also utilized by HYSWEEP SURVEY which was configured to display a visual alarm if the surface sound speed changed +/- 2 m/s. Variations in surface sound speed were monitored and evaluated as an indicator of surface water temperature/salinity fluctuation and potential water column variation which would necessitate additional sound speed profile measurements.

B.1.5 Horizontal and Vertical Control

B.1.5.1 Horizontal Control

The vessel’s primary positioning device, a POS MV, was supplied with Fugro’s Marinestar DGNSS corrector service during data acquisition. However, the Marinestar solution was replaced during post processing with Applanix SmartBase (ASB)-derived SBET positioning and attitude. Final SBET positioning is referenced to NAD83. Correctors from the USCG DGPS station in English Turn, LA were applied to the secondary “position integrity alarm” GPS.

Positioning system confidence checks of the POS MV were accomplished at the start of survey and during provisioning stops in Intracoastal City, LA. In practice, the distance between the vessel’s reference point (RP) and the dockside horizontal control point “SMIC-01,” as computed by the navigation system, was compared to the tape-measured distance between the vessel RP and the horizontal control point. In all cases, dockside navigation system accuracy testing demonstrated that the POS MV, employing Marinestar correctors and subject to real-time datum transformation (see Section A.4.2), had an accuracy of better than 1.0 meter. A tabulation of navigation system performance checks is included in DAPR Appendix III.

Position information from the vessel’s primary and secondary GPS receivers (POS MV w/Marinestar and Trimble DGPS) were continuously compared in HYPACK SURVEY and status indicators were monitored in real time. By means of a “positioning integrity” utility in the HYPACK SURVEY program, a position disparity between the primary and secondary positioning systems that exceeded two (2) meters would be reported by a visual alarm on the data acquisition screen. In one case, August 30, 2018 (DN 242) @ ~21:56 the position integrity alarm detected an unexplained, substantial POS MV positioning (and heading) fault. The fault was remedied by rebooting the POS MV. In this case the affected survey line was abandoned and re-surveyed. As a conservative measure, the preceding survey line was also abandoned and re-surveyed.

During data acquisition, the MV-POSView controller software was used to monitor real-time position accuracy, with the accuracy alarm set at 1.0 meter.

B.1.5.2 Vertical Control

Per the Project Instructions, the contemporary survey is controlled vertically employing ERS tides relative to MLLW.

OSI's proposal for this survey suggested surveying to the ellipsoid using Fugro's Marinestar GNSS corrector service integrated with an Applanix POS MV. With the exception of certain calibrations, all field data were recorded utilizing Marinestar correctors. The manufacturer's stated horizontal and vertical accuracy using Marinestar correctors with an Applanix POS MV is 10 centimeters (95%) and 15 centimeters (95%) respectively. However, Marinestar-derived ellipsoid data (including Marinestar data processed using POSPac MMS) were found to be consistently inferior to Inertially Aided Post Processed Kinematic (IAPPK) ellipsoid data. Consequently, Applanix SmartBase (ASB)-derived ellipsoid records were used as the basis for the development of MLLW tides. This change in approach, i.e. using ASB Smoothed Best Estimate of Trajectory (SBET) solutions instead of Marinestar-derived X, Y, Z data, was approved by the COR in an e-mail dated June 28, 2018.

Section B.2.4 details vertical control issues and the solutions used to remedy the issues.

During transits to/from the local shore base, the survey vessel stopped near NOAA's Freshwater Bayou Canal Lock tide gauge (876-4227) to perform "boat floats" which involved drifting, as vessel traffic allowed, for a period of three NOAA tide gauge readings, i.e. just over 18 minutes coinciding with the 6-minute tide observations. Applanix POSView-logged data were recorded during this period. The resultant ERS data were regularly compared to NOAA tide gauge values and found to be consistently in line with the NOAA station-recorded values (after a bias adjustment described in Section B.2.4). The processing approach and the results of the boat float/NOAA tide gauge comparisons are covered in more detail in Section B.2.4.

B.1.6 Feature Verification

When necessary, additional MBES-only lines were run over significant contacts and features observed in the MBES and SSS records in order to investigate or develop those features and to determine a least depth in accordance with Complete Coverage specification in the HSSD (Section 5.2.2.3). During home office processing, once an item was deemed significant, nearly significant, or simply required more data to make a determination, the contact or outstanding sounding position was conveyed to the field team in various formats including:

- An EXCEL tracking table that was added to the acquisition log
- a HYPACK target file of point items
- an AutoCAD-compatible .DXF file for area features
- a HYPACK line file (.LNW) for SSS or MBES fill in areas

The field team then ran a series of short MBES lines to develop the object from various angles with high sounding density.

In some cases, single SSS coverage was not sufficient for data analysts to confidently describe the nature of a particular feature. Furthermore, the shadowing effect of items such as oil platform legs, dense fish schools, etc. occasionally resulted in small coverage gaps. These data gaps were identified during home office data processing and conveyed to the field team via the various methods bulleted above. All such data gaps were eventually filled with additional SSS coverage or Complete MBES coverage while the field team was still mobilized.

B.1.7 Bottom Sampling

Bottom samples were acquired in close proximity to all recommended bottom sample positions included in the PRF provided with the OPR-K354-KR-18 Project Instructions. Four additional stations were sampled based on unusual bottom conditions encountered during the survey. In this case, apparent rocky mounds were detected in Survey H13103. Large areas of rocky bottom are unusual in coastal Louisiana. Due to their relatively large areal extent, it is unclear if the apparent rock mounds, especially the two primary mounds, are man-made or of natural origin. OSI acquired a sample from each of the two primary rock mounds and two samples from the apparent flat bottom areas between mounds.

Bottom sample locations were logged to a HYPACK SURVEY target file. Each sample was photographed and classified based on the criteria outlined in Appendix H, Bottom Classification, in the HSSD.

B.1.8 Other

B.1.8.1 Autopilot

Onboard the *R/V Ocean Explorer* the Simrad AP50 Autopilot was configured to receive heading from the POS MV, and speed, position and the Autopilot (APB) message from HYPACK. Once in control, the Autopilot maintained the vessel steering point within approximately 2 meters of the selected trackline.

B.1.8.2 Digital Acquisition Logs

Onboard the *R/V Ocean Explorer* an acquisition log was maintained in Microsoft Excel to record all pertinent information related to acquisition, such as:

- Daily operations and locations
- Weather and sea state observations
- MBES/SSS survey line ID and start time
- Date and time of "boat floats"
- Date and Time of MVP (or AML) and POSView-logged TrueHeave files
- Navigation System Performance Checks, Bar Check Table, Vessel Water Level Tabulation and Sound Speed Comparison Table
- Systematic changes (i.e. equipment repairs, changes, or adjustments)
- SSS Confidence Checks
- Significant SSS contacts or Bathy features
- Excessive Noise in the SSS/MBES records due to fish, vessel traffic, or surface noise
- Deviations from planned tracklines or Data Gaps
- System "crashes" or Position Outages
- Line Miles and Survey Statistics
- Item investigations

B.2 Data Processing

B.2.1 Bathymetry

I. Data Conversion and Preliminary Sounding Correction

QA/QC level processing was completed onboard the survey vessel; however, all formal data processing occurred at OSI's home office. In practice, data disks were shipped via express courier to the home office processing center during convenient in-ports. Using this approach, the lag between acquisition and data check-in at the home office was about one week. In addition to courier delivery, especially near the end of the field program, some data were transmitted via FTP during in-ports.

Upon receipt of a data disk (or FTP download), information contained in the daily acquisition log was compared to the data package to ensure that no files were lost or omitted. Prior to data processing, the acquisition log was consulted to verify line names and file size and to remove any aborted lines from the preprocess folder before converting the data in CARIS HIPS. All accepted MBES & SSS line data, POS MV TrueHeave files, and sound speed profile data were entered into the survey processing log, which was subsequently used to track the processing progress of each line and to record all notes pertinent to individual lines or days.

Vessel configuration files (.HVFs) were created in CARIS HIPS Vessel Editor prior to data conversion. The HVF files contained transducer offsets relative to the RP, alignment offsets derived from the calibration testing, as well as the waterline height and standard deviation values for all surveyed parameters (used to model sounding uncertainty). Duplicate HVFs were created for the MBES system to convert lines into HDCS folders according to classification, i.e. mainscheme lines, crosslines, and investigation lines. Waterline correctors were updated in the HVF files as new values became available. See *Section C* Corrections to Echo Soundings for additional information regarding vessel configuration files.

During past NOAA-contract surveys, OSI experienced infrequent interruptions to the recorded POS MV POSView-recorded data stream. It was suspected that network collisions were responsible for the faults. For this reason, during the contemporary survey, OSI simultaneously logged a second instance of POSPac-group data each day. The second copy was logged directly to removable USB media which negated the chance of network collision interruptions. As it turns out, the network-logged POSPac-group data recorded flawlessly during the contemporary survey. This is likely due to an improvement in network addressing and hardware. That said, there were three instances when the POSView-recorded stream was interrupted for other reasons. In these cases, July 5, 2018 (DN 186), July 11, 2018 (DN 192), and July 12, 2018 (DN 193), USB-logged POSPac-group data (and SBET data) are included with the deliverables in lieu of the network-logged files. A full day of network-logged files, as recorded using OSI's preferred configuration, results in approximately 45 files per day with individual files of 65 MB. In contrast, a full day of USB-logged files results in approximately 236 files per day with individual files of 12 MB. For efficiency and to contribute to the tide smoothing process, by-day "TrueHeave-only" files were created from the full set of POSPac-logged files. These files have the naming convention of YYYY-DOY-MMDD-OE-TH.000.

Multibeam sonar data conversion and the application of sounding correctors were completed using routines developed in CARIS' Process Designer. The Process Designer (model) runs a user-defined script which accomplished the following standard tasks in succession:

1. Convert the HSX and RAW data to the HDCS data format, establish UTM grid.
2. Enable all multibeam beams.
3. Load daily TrueHeave files.
4. Load and apply concatenated sound speed profile data. Sound speed profiles were loaded with the CARIS *nearest in distance within time* correction method. A time basis of 1 hour was used. During CARIS SVP Correction, the following correctors were applied: sound speed, heave, pitch, roll and waterline.
5. Run "Compute GPS Tides" employing an updated VDatum ellipsoid separation model (SEP).
6. Merge data to apply vessel offsets/alignment, position, gyro, tide, and dynamic draft correctors to bathymetry. HIPS/SIPS computes the fully corrected depth and position of each sounding during the Merge process.
7. Compute Total Propagated Uncertainty (TPU). TPU is calculated in CARIS HIPS from contributing uncertainties in the echosounder, positioning and motion sensor measurements as well as uncertainties associated with sound speed and water level correction. The standard CARIS devicemodel.xml was used to create the HVF.

Tide uncertainty for each sounding was calculated by summing 1) the fixed value SEP uncertainty of 17.166 centimeters, and 2) the near-instantaneous uncertainty (from 20Hz data) of the vertical component of SBETs resulting from Applanix SmartBase processing. As detailed in Section B.2.4.3 of this report, OSI smoothed high frequency "noise" from each day's SBET ellipsoid record. Although the smoothed ellipsoid records (merged with the SEP) contribute to what is considered to be a more accurate representation of the actual tide curve, OSI did not attempt to estimate uncertainty of the smoothed SBET vertical. Rather, OSI conservatively used the ASB-reported uncertainty.

Sound speed TPU values were estimated from manufacturer-stated accuracy of the ODIM MVP30 and from guidance in the OCS Field Procedures Manual (FPM) Appendix 4 under CARIS HVF Uncertainty Values. Since MVP casts were collected at 15-minute intervals, a sound speed profile uncertainty value of 1 m/s was chosen. A conservative value of 2 m/s was chosen for the surface sound speed uncertainty despite the fact that the surface and near surface sound speed profile gradient was relatively uniform throughout the period of the survey.

II. Preliminary BASE Surfaces

Preliminary field sheets and Bathymetry Associated with Statistical Error (BASE) surfaces were created for reviewing and cleaning full-density soundings using the Combined Uncertainty and Bathymetry Estimator (CUBE) process. Daily data review and cleaning were performed using 1-meter resolution CUBE surfaces as a guide for directed editing. Due to water depth and in consideration of coverage requirements defined in the Project Instructions, the survey was completed employing two types of "Complete Coverage." Specifically, Complete Coverage was accomplished for the majority of the survey according to HSSD Section 5.2.2.3 Option B. Complete Coverage for deeper reaches of each sheet was accomplished according to HSSD Section 5.2.2.3 Option A.

After the lines were run through the Process Designer, they were added to 1-meter Cleaning/Coverage surfaces. Depth, Standard Deviation and Shoal surface models were viewed with sun illumination and/or vertical exaggeration to highlight areas that would require immediate investigation. Standard deviation surfaces were reviewed to evaluate data for consistency between overlapping coverage and crosslines, and to detect any systematic position, motion, tide, or sound velocity errors. The highest standard deviation values were observed over obstruction features, seafloor depressions, and in the vicinity of offshore platforms.

Coverage surfaces were reviewed for any data gaps meeting the criteria described in HSSD Section 5.2.2.3. All surfaces were reviewed to ensure that Complete Multibeam Coverage was obtained over significant shoals and features. Density layers were reviewed to verify that at least 95% of all nodes in the Complete Coverage surfaces were populated with at least 5 soundings.

III. Data Cleaning and Processing

Line attitude and navigation data were reviewed in their respective CARIS editors to ensure that there were no problems with the correctors, such as gaps in attitude data or navigation jumps.

CARIS surface filters were employed to clean the majority of fish, noise, multipath returns, and gross fliers. To avoid poor surface filter performance where survey lines intersect, 2-meter surfaces (with 4-meter CUBE parameters) were created such that no survey line overlapped another survey line. Due to the abundance of fish, shrimp, and other water column returns, surface filters were commonly run multiple times.

Swath Editor was used to review the surface filter results and further clean fliers or reaccept over-filtered soundings. Soundings were colored by depth and reviewed in multi-directional profile and plan view displays. Tracklines and swath boundaries were viewed in the CARIS Map window in reference to BASE surfaces, charted data (RNC/ENC), SSS contacts and field annotations (HYPACK target files).

The CARIS Subset Editor was used to clean fully-corrected, geo-referenced soundings in 2-D and 3-D displays. Soundings were colored by line to verify the validity of bathy features or SSS contacts recorded by multiple MBES passes and to reject fish or water column noise recorded in one MBES pass and disproved by overlapping coverage from a different MBES line. Areas with multiple sounding coverages from adjacent survey lines were evaluated to increase confidence in outer beams and over significant features. Subset boundaries were viewed in the CARIS Map window in reference to BASE surfaces, charted data (RNC/ENC), and SSS contacts.

Full-density soundings were reviewed for each SSS contact in the CARIS Subset Editor and a sounding was designated for the representative least depth of significant contacts.

“Outstanding” sounding flags were temporarily assigned to soundings on features, or possible features, which required further review. Occasionally, a request would be sent to the field crew for additional coverage on a feature for clarification. Before finalizing the survey, all Outstanding soundings were reviewed and resolved, then either marked as “Accepted” or “Designated” as appropriate. No soundings were left with an “Outstanding” flag.

The “Designated” flag was used to identify the least depth of a significant feature and ensure that the least depth would be represented in the finalized CUBE surfaces. When a designated sounding was assigned to a feature, it indicated that no further investigation was required. OSI followed Section 5.2.1.2.3 of the HSSD guidance on the criteria for choosing designated soundings. Near nadir soundings were designated as least depths on features in lieu of outer beam soundings whenever possible. In the instance that soundings from multiple MBES lines suggested different least depths, the contact heights measured in side scan editor were reviewed to assist with least depth designation and near nadir soundings were favored over outer beam soundings.

Once the surface deliverables were finalized, chart comparisons were completed with the surveyed depths and charted depths on the assigned Electronic Nautical Charts (ENCs). The final chart comparison was completed using charts downloaded from the OCS website, nauticalcharts.noaa.gov, with an issue date of December 12, 2018, and updates applied through December 20, 2018. CARIS HIPS & SIPS was utilized to complete chart comparisons with the appropriate ENCs. This was accomplished by overlaying surveyed depths in the form of finalized surface layers, sounding layers, and S-57 features over the ENCs. Surveyed data were compared to all charted depths, contours and features, with agreements, discrepancies and disprovals addressed in each survey's descriptive report and final feature file.

B.2.1.1 Methods Used to Maintain Data Integrity

All project raw data files were copied onto the onboard QA/QC processing computer. The hard drives on the onboard processing computer retained both the raw and QA/QC-processed data. Raw data on the QA/QC processing computer were backed up to a removable, 2 TB or 4 TB, USB-3 hard drive numerous times each day. During each port call, the removable hard drive was shipped to OSI's home office. The removable drive was packaged for shipping only after a redundant, fully populated backup had been placed in service onboard the vessel.

B.2.1.2 Methods Used to Generate Bathymetric Grids

After MBES sounding editing was complete, final BASE surfaces were created using the CUBE algorithm in CARIS HIPS and SIPS. The CUBE algorithm generates surface models from multiple hypotheses. Hypotheses with lower combined Total Propagated Uncertainty (TPU) are given higher significance for incorporation into the final surfaces. Also, soundings closest to a grid node have a greater weight on the node depth value than soundings that are further away.

The following options were selected when final CUBE surfaces were created:

- Surface Type – CUBE
- IHO (International Hydrographic Organization) S-44 Order 1a
- Include Status – Accepted
- Additional Attributes – Shoal and Deep
- Disambiguation Method – Density & Locale

The CUBE parameters Capture Distance Scale and Capture Distance Minimum were set according to grid resolution to meet the requirement that the maximum propagation distance for a node shall be no more than the grid resolution divided by the $\sqrt{2}$.

The Capture Distance Scale (CDS) defines a radial distance from the node which is based upon a percentage of water depth. All soundings within this radius are included in the Density value and propagated to the node.

The Capture Distance Minimum (CDM) defines a fixed radial distance in meters from the node in which all soundings are included in the Density value and propagated to the node.

During CUBE surface creation, the maximum value of the two capture distance parameters is used to set the actual capture distance. To ensure that the CDM was the determining factor for the radius of influence for each node, a CDS value of 0.50 % was used for the creation of submitted surfaces.

Example: for a 1-meter BASE surface in depths less than 20 meters,

CDS = 0.005
CDM = 1 / ($\sqrt{2}$) = 0.707

The CDS radius maximum value (0.005 * 20 = 0.1 meters) will not exceed the CDM value (0.707 meters) for the maximum depth, and therefore the Density Attribute Layer will represent those soundings that lie within a fixed radial distance (0.707 meters) for all nodes.

Table 5 displays the CDS and CDM values entered for the submitted grid resolution.

Table 5
CUBE Parameters Applied in Surface Generation

Grid Resolution (m)	Capture Distance Scale (%)	Capture Distance Minimum (m)
1.0	0.5	0.71

Sounding density and coverage are based on requirements specified in the Project Instructions. The Project Instructions' coverage requirements are shown below.

Table 6
Project Instruction Coverage Requirements

Coverage Water Depth	Coverage Required

All waters in survey area	Complete Coverage (refer to HSSD Section 5.2.2.3). LNM no less than 10,592 LNM. Acquire backscatter data during all multibeam data acquisition (HSSD Section 6.2). Report significant shoaling via weekly progress report. COR may adjust survey prioritization based on observed shoaling.

All significant features were developed with MBES to meet Complete Multibeam Coverage standards. Feature investigations are integrated with their associated 1-meter complete coverage surfaces, i.e. there are no stand-alone investigation surfaces.

The attributes associated with each grid node are as follows:

- Depth Value
- Uncertainty
- Standard Deviation
- Mean, Deep and Shoal Depths
- Sounding Density
- CUBE Surfaces: Hypothesis Count, Hypothesis Strength & User Nominated

B.2.1.3 Methods Used to Derive Final Depths

The Complete Coverage grids were "finalized" as 1-meter surfaces for each survey. Per the CARIS HIPS & SIPS 10 Users Guide, a finalized surface "is a finished version of the surface that is ready for export." Designated soundings were incorporated into the finalized BASE surfaces making certain that the least depth sounding was honored in the grid. Given that the maximum project depth is < 20 meters, the Complete Coverage MBES surfaces were finalized at 1-meter resolution.

B.2.2 Imagery

Preliminary QA/QC of the SSS data occurred simultaneously with data acquisition. However, all formal data processing occurred at OSI's home office. SSS data backup and shipment methodology were identical to the treatment of MBES data as described earlier. Once these data were received by the home office, the backup disk's files and acquisition log were reviewed to verify line names and file size and to remove any aborted lines from the preprocess folder prior to converting the data in CARIS HIPS. All lines copied from the acquisition computer were entered into the survey processing log, which was used to track the processing progress of each line and to record all notes pertinent to individual lines or days.

CARIS HVFs were created to convert EdgeTech JSF data files. All Preprocess EdgeTech JSF data were converted to the HDCS data format in the CARIS' Conversion Wizard.

Since the SSS towfish was mounted rigidly in relation to the vessel frame, the vessel heading from the POS MV (via SBETs) was applied during SSS processing instead of using heading from the SSS compass sensor or deriving it from course over ground averaging. The real-time fixed-mount SSS imagery was acquired using 10 Hz position and heading input directly from HYPACK SURVEY and the POS MV respectively. However, during post processing, 20 Hz SBET position and heading data were substituted for the field-recorded data. The 20 Hz heading data were smoothed prior to application to the SSS imagery in order to improve the appearance of the mosaics.

The CARIS SIPS bottom tracking routine was used to 1) bottom track the imagery and 2) populate the altitude field as required in the HSSD. Although the CARIS SIPS bottom tracking routine was ultimately used to accomplish (and fine tune) the bottom tracking solution, the bulk of the bottom tracking effort was accomplished as follows. Line-by-line coincidental multibeam nadir depths were exported, corrected for the difference in draft between the MBES and the fixed-mount SSS, and imported to the fixed-mount SSS dataset with the CARIS Generic Data Parser. The CARIS SIPS bottom tracking routine was then employed to format and review the imported bottom tracking solution and make the relatively few minor corrections/edits that were needed.

The fixed-mount SSS vessel file is not a “zero” configuration. During fixed-mount SSS acquisition and subsequent onboard QA/QC data processing, HYPACK SURVEY-derived SSS positioning data were utilized. The fixed-mount SSS vessel file includes forward and starboard towpoint offsets which allowed the fish position to be recomputed using IAPPK SBETs in CARIS SIPS. The fixed-mount configuration did not have a variable “cable out” field; therefore, this value is always shown as zero.

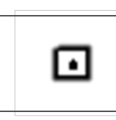
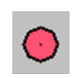
Navigation time stamp irregularities were edited, and navigation data were reviewed in the CARIS Navigation Editor. Each side scan line was reviewed in CARIS Attitude Editor to ensure that the towfish attitude was properly represented and that there were no gaps or problems with this parameter.

The CARIS Side Scan Editor was used to bottom track, slant range correct, and apply image enhancement correction to the data. Processing was completed as follows:

1. Review the raw side scan data in Side Scan Editor. Parse-in MBES-derived bottom tracking then use automated bottom detection algorithms where necessary and correct any automated or parsed bottom tracking errors by manually re-digitizing the bottom trace.
2. Lines were Beam Pattern corrected to normalize angular response across the swath.
3. Average sound speed from each respective day was applied during mosaicking. The sound speed used in mosaicking each day’s imagery is noted in the processing log.

During pre-survey planning, the CARIS HIPS/SIPS *.hips database files were modified by OSI to include additional Contact Feature types with which to classify contacts in Side Scan Editor. The additional contact types are included in Table 7 below, along with their graphical display in CARIS HIPS and a brief description of the conditions under which the contact type is selected.

Table 7
Modified OSI Contact Types Selected in Side Scan Editor

Unknown Contact **UNKCNT** Feature whose nature cannot be determined.	
Obstruction, height 0.7m+ **SIGCNT** Feature that has a SSS measured height > 0.7 meters or has significant size or features, i.e. submerged platform ruins, loose fish net, subm piling, etc.	
Feature with insignificant height **INSCNT** Feature that has a SSS measured height between 0.25m and 0.7m.	
Fish contact **FSHCNT** Fish	
Wreck **WRECK** Boat, ship, sailboat, barge, etc., any feature that might be a wreck.	
Platform **OFSPLF** Oil production platform. High water, not submerged.	
Navigational Aids (charted) **NAVAID** Navigation Aids that can be verified against raster chart, ENC, or CSF.	
Exposed pipe and gas leak marker **QAQC** Use as a point feature marker for digitized linear pipes & cables, and possible gas seep locations.	
Cable **NPCA** Linear features that are not pipelines.	
Pipeline **NPPL** Pipeline only	

Once image processing was completed, contacts were selected in the Side Scan Editor waterfall. Objects were identified by the presence of sonar shadows. Shadow lengths were measured and converted to heights. Contacts with significant heights or horizontal dimensions were positioned and created at the top (closest to nadir) of the shadow, and attributed with the following information: feature type (obstruction, platform, unknown, wreck), height, width &

length (if significant), and processor remarks. Heights were measured with the shadow tool and lengths and widths were measured with the distance tool.

SSS lines were reviewed a minimum of two times by more than one data analyst to make certain that all significant contacts were selected that may require investigation. The contacts selected in Side Scan Editor were visible in the HIPS and SIPS Display window. Contacts were reviewed in CARIS Subset Editor using full sounding density while toggling views between visible and hidden rejected soundings.

In order to ensure sufficient coverage, individual line mosaics were created with a resolution of 0.15 meter. The line mosaics were then merged and saved as 0.25-meter resolution sheet mosaics for the 100 and 200 percent side scan coverages.

During initial home office processing, the 100 and 200 percent coverage mosaics were reviewed for coverage gaps and poor-quality imagery that required SSS fill-in lines. Fill-in lines were assigned to the field team, as necessary, to supplement the existing coverage. After the completion of survey and processing operations, the final 100 and 200 percent coverage mosaics were exported from CARIS HIPS and SIPS to individual GeoTiffs.

B.2.2.1 Methods Used to Maintain Data Integrity

See Section B.2.1.1.

B.2.2.2 Methods Used to Achieve SSS Coverage and Accuracy Requirements

As noted earlier, only one type of SSS system was employed on this project.

For fixed-mount SSS operations utilizing the Edge Tech 4125, a traditional high resolution "single pulse" SSS, the system was operated only at the 50-meter range scale. At this range scale, the system's pulse repetition interval was sufficiently fast to accommodate vessel survey speeds.

B.2.2.3 Methods Used to Verify Swath Coverage

During home office data review the 100 percent side scan coverage mosaic was updated frequently and reviewed for gaps or poor-quality data that required fill-in lines or re-runs of the mainscheme line. The review process occurred while the field team was still mobilized onsite.

Line spacing was planned so that there was ample overlap between adjacent lines for the single, 100% coverage. All SSS lines were planned with the intention of achieving outer beam overlapping coverage of at least 20 meters. MBES near-nadir data provided secondary SSS nadir coverage which was useful in assessing near-nadir SSS contacts. Gaps in side scan coverage that occurred when the vessel steered off line to avoid oil platforms were subsequently filled with side scan development lines and/or Complete Coverage MBES to the extent that safety of the vessel and platforms allowed. SSS shadows created by platforms even if the vessel did not have to steer offline were also filled with either additional SSS or Complete Multibeam which were acquired from a different perspective. In many cases large fish balls caused gaps in the 100% SSS coverage mosaic. These gaps were also filled with either additional SSS or Complete Coverage MBES.

B.2.2.4 Criteria Used for Contact Selection

The criteria used to select contacts was based on the guidance provided in the HSSD Section 6.1.3.2 Side Scan Sonar Contacts, which defines a contact as significant based on its shadow height in different depth ranges. The HSSD significant contact specifications are summarized in Table 8.

Table 8
Significant Contact Selection Criteria

Surrounding Depth or Area	Significant Contact Height
≤ 20 meters	1 meter
> 20 meters	5% of surrounding depth

No portion of the assigned survey area was found to be over 20 meters deep. Therefore, only the ≤ 20 meter significant contact height criteria was considered. OSI used a more conservative approach than required when selecting contacts to make certain that significant features would not be overlooked for further investigation or correlation in the MBES record. All contacts with a minimum height, based on shadow length, of 0.7 meters were selected. Features smaller than 0.7 meters were sometimes chosen if they appeared navigationally "significant" in relation to the charted depth.

At times there was an abundance of fish encountered within the project area, represented in the side scan record as individual fish and as schools. Fish contacts were created when the fish schools, singular swimmers or dolphins created detectable shadows in the side scan record. Singular fish presented themselves in the record most often as hard returns with long detached shadows. Sometimes the fish and dolphin reflections were evident in the water column, which also created shadows in the SSS record.

Individual fish contacts having a well-defined, characteristic detached shadow were not investigated further. When available, coincidental SSS and/or MBES data were consulted to bolster the decision not to investigate. Conversely, there were many cases where the character of an interpreted individual fish shadow was *not* convincing, i.e. further investigation was warranted. In these instances, additional data were acquired to disprove the questionable fish feature.

The presence of fish contact symbols in the HIPS display window was also helpful during editing of bathymetry as an indicator to the hydrographer to anticipate noisy data. Fish contacts were not assigned heights.

Most side scan contacts were symbolized as point features; however, sections of exposed pipeline were digitized as linear contacts. At times, contacts without a shadow were selected if there was a noteworthy shape or size to the item, despite its insubstantial relief.

B.2.3 Sound Speed

B.2.3.1 Sound Speed Profiles

As mentioned earlier an ODIM MVP was used as the primary sound speed profiling device on the *R/V Ocean Explorer.* All automated and manual comparison casts were reviewed in the field as they were acquired.

MVP profiles were plotted on the HYPACK SURVEY screen along with a recent history of preceding casts. In practice, as MVP casts are performed, they are plotted in profile in HYPACK SURVEY displayed as a red line. As subsequent profiles are performed the previously acquired profile changes to blue and the newly acquired profile is plotted in red. This process is repeated each time an MVP cast is acquired with the older profiles turning a lighter shade of blue each time a new profile is written in red.

Sound speed profile data were continually assessed in the field by the following means:

- their shape in relation to previously acquired profiles
- their effect on the real time sounding wedge as displayed in HYSWEEP SURVEY
- the profile surface speed in comparison to the real time surface speed output by the MBES-mounted AML Micro-X sound speed sensor.

As these data were received at OSI's home office, the delivery disk's file listing was compared to the acquisition log to verify file names and size and to remove any aborted casts from the preprocess folder prior to converting the data to the respective vessel's SVP file.

For the automated MVP-derived cast data, the ASCII CALC files logged with each cast were converted using Sound Speed Manager. The MVP-to-CARIS processing route was used to convert one or more CALC files and append them to a CARIS HIPS SVP file. All individual MVP casts, attributed with position, date and time of cast, were concatenated to a survey-specific SVP file (ex: H13103.svp) for use in sound speed correction of raw MBES soundings using CARIS HIPS.

During the Load SVP step in the HIPS Batch Editor, the Survey-specific SVP file was chosen, and the Edit option was selected to open the CARIS SVP Editor. All new casts that had been appended to the SVP file were reviewed upon inclusion.

The CARIS Profile selection method used to apply sound speed correction was the "Nearest in distance within time" option. A time increment of one (1) hour was chosen. Prior to the final application of sound speed correctors, the master SVP file for each survey was opened as a Background File in CARIS HIPS to verify that the cast positions all fell within the area surveyed.

Occasional AML Base-X-to-MVP comparison casts were acquired during the *R/V Ocean Explorer*'s "UTC midnight" changeover. Comparisons were documented using Sound Speed Manager. The comparison casts were not appended to the CARIS SVP file used for sounding correction. A listing of DQA results is included in DR Separate II.

B.2.3.2 Surface Sound Speed

Frequent comparisons were also made between the MVP profiler-derived surface sound speed and values from the multibeam transducer-mounted surface sound speed device. The comparison, observed visually by the onboard hydrographers and monitored using the HYSWEEP SURVEY utility, was occasionally documented employing Sound Speed Manager. A listing of DQA results is included in DR Separate II.

B.2.4 Horizontal and Vertical Control

B.2.4.1 Horizontal Control

RTK GPS positioning and water level determination were employed during initial MBES patch testing, side scan sonar positioning verification, and settlement and squat testing offshore Noank, CT in Fishers Island Sound. However, all calibrations were ultimately positioned employing SBET data.

Once the calibration values (derived using SBET positioning) were known, the vessel was repositioned to the Gulf of Mexico survey area and certain processes were repeated using Marinestar-aided real-time positioning. Examples of post site arrival tests include patch and performance testing. For home office "onsite test" processing, Marinestar positioning was replaced with SBET positioning and ERS tide.

B.2.4.2 Vertical Control

The Project Instructions specified that the survey be controlled vertically using ERS techniques.

A SEP with a vertical uncertainty of 17.166 centimeters was provided by NOAA with the original project files. However, the original SEP was superseded on July 22, 2018 with an updated SEP as a result of events described below. The updated SEP was ultimately used in creating MLLW ERS tides. Per wording in the July 22, 2018 e-mail transmitting the updated SEP it was stated that "*MLLW SEP uncertainty in the OPR-K354-KR-2018 project area* *remains the same [as] previously indicated: 17.2 cm."* OSI used the unrounded original value of 17.166 centimeters moving forward.

The updated SEP was provided after a bias in the original SEP was detected and brought to the attention of the COR for subsequent discussion during initial data processing.

The updated SEP contained 3 important changes:

1) GEOID 2012B was replaced with xGEOID17B in VDatum.
2) A 10.2 cm scalar was applied to account for a residual error in VDatum TSS (topography of the sea surface) which remained after the change in GEOID model.
3) SEP coverage was extended to include NWLON gauges 876-6072 and 876-4227 (Freshwater Canal Lock), the entire OPR-K354-KR-18 project area, and 2 BMPG sites from Project OPR-K354-KR-16.

The following discussion provides background information which instigated the request for an updated SEP.

Applanix Smart Base processing of the first few weeks of field data revealed a geographically variable offset between ERS-derived tides and a QA/QC tide dataset derived using alternate methods. The QA/QC tides dataset included local NOAA tides from Station 876-6072 and zoned tides using the data from NOAA tide Station 876-4227 and the .ZDF file provided with OSI's 2017 Project OPR-K354-KR-17.

Graphical comparison of the three tide sources showed that the ERS MLLW tide curve (using the original SEP) was consistently lower than the gauge-derived data with differences on the order of 0.2-0.3 meters offshore at the project site. The magnitude of the difference was less when the vessel was closer to land and greater at the offshore survey extent.

VDatum version (3.6.1), used in creating the original SEP, used Geoid 2012B to calculate TSS. Use of Geoid 2012B appeared to be the primary factor contributing to the detected bias in the original SEP once a comparison was made using xGEOID2017B. This issue was brought to the attention of the COR with a recommendation to shift to xGEOID2017B.

During correspondence on this subject, OSI and NOAA personnel also considered a tide dataset derived during a nearby survey performed by OSI in 2016 (see OPR-K354-KR-16 - HVCR). Specifically, NOAA requested the ellipsoid-MLLW SEP and position values from two bottom mounted pressure gauges (BMPG) deployed to support the 2016 survey. The 2016 Tidal Computation Report (included in the 2016 HVCR) revealed a similar bias, i.e. a total magnitude of 0.23 meters, when using VDatum and GEOID 2012B to correct ERS "boat float" data to MLLW.

The replacement of the GEOID removed most of the observed bias, but not all. A residual bias remained both offshore and inshore which was on the order of 0.1 m. As described earlier, during transits to/from the vessel's local shore base, the survey vessel stopped near NOAA's

Freshwater Bayou Canal Lock tide gauge (876-4227) to perform "boat floats" for a period of three NOAA tide gauge readings.

It should be noted that the current, local VDatum model (and the original SEP) did not extend northward all the way to the Freshwater Bayou Canal Lock. The model stopped approximately 1 km south of the lock. The absolute difference between MLLW and NAVD88 at the VDatum (3.6.1) node closest to the lock is 0.28 meters. For the boat float/tide gauge QA/QC comparisons, OSI initially chose to use the VDatum node value of 0.28 meters when adjusting ERS tides to MLLW. However, numerous comparisons indicated a bias of approximately 0.1 meters between the boat float ERS MLLW water levels and the tide gauge MLLW water levels when using the 0.28 meter corrector.

The respective NOAA and NGS benchmark descriptions for the primary benchmark at the Freshwater Bayou Lock station (876-6072-A) suggest a difference of 0.38 meters between MLLW and NAVD88. In investigating the bias described above, OSI acquired physical measurements of the water surface relative to the primary benchmark (NAVD88) and compared these data to preliminary NOAA tide gauge data for the same period (relative to MLLW). In this case a difference of approximately 0.38 meters was derived which is in keeping with the NOAA/NGS-published difference. When OSI shifted to using a corrector of 0.38 meters instead of 0.28 meters to convert NAVD88 ERS water levels to MLLW ERS water levels the boat float comparison data compared favorably to NOAA tide gauge-recorded values. This information and the GEOID comparisons contributed to the discussion which resulted in the updated SEP.

B.2.4.3 ERS Tide Smoothing

ASB processing and the relative improvement in SBET ellipsoid heights as (compared to Applanix Single Base or Marinestar results) yielded ASB SBET ellipsoid records which were still too "noisy" in the opinion of OSI data analysts. Consequently, final ERS MLLW tides were smoothed prior to inclusion in the data reduction process. ERS tide smoothing was approved by the COR in a July 5, 2015 e-mail.

I. ERS Tide Smoothing Steps:

1) Create and export ASB SBETs.
2) Smooth SBETs using MATLAB,
    - Convert SBET altitude to a MLLW tide by removing the following components of the SBET altitude:
        - Static draft based on time
        - Dynamic draft based on speed
        - Delayed heave based on time
        - SEP based on position
    - Smooth MLLW tide with a 4th order low pass filter.
    - Export smoothed SBETs after re-applying the above components.

3) Import smoothed SBETs in CARIS HIPS.
4) Run CARIS HIPS “Compute GPS Tides” with the updated SEP.

II. ERS Smoothed Tide Curve QA/QC:

Graphical analysis was the primary QA/QC tool during the development phase of the ERS smoothing routine described above. MATLAB graphs were generated for all conversion and correction steps to identify erroneous source data or MATLAB program code.

III. Choice of Smoothing Parameters:

Daily SBETs were grouped by vessel trip, starting and ending with passage through Freshwater Lock. Combined SBETs were smoothed with a 4th order Butterworth low pass filter using MATLAB’s “filtfilt” function which runs the filter in forward and reverse resulting in a zero-lag solution.

When choosing the “best” smoothing filter settings for this project OSI considered a number of filtering approaches including: 1) those used by OSI on a prior NOAA contract survey, 2) those used by JOA Surveys (on behalf of OSI for a prior NOAA contract survey), 3) those suggested by third party sources, and 4) new approaches developed by OSI data analysts.

Based on the above information the following candidate smoothing parameters were compared:

- 1, 5, and 10, minute averages
- 0.5, 1, 2, 3, 4, 5, and 6, hour low pass filters

Both quantitative and qualitative comparative analyses were performed. Statistical assessments were made with EXCEL histograms of crossline and mainscheme difference data generated by CARIS HIPS. Data from all 5 survey sheets composed of all the crosslines and a subset of mainscheme lines equal to the crossline spacing were used. The qualitative analysis consisted of observation of the CARIS HIPS standard deviation surface (at intersections) using each version of the smoothed ERS MLLW tides.

As a result of the comparative analysis, a 4th order Butterworth low pass filter with a 3-hour cutoff frequency (i.e. 8-cycles per day) was chosen. The cutoff frequency of 5 hours was the statistical winner; however, the 3, 4, and 5, hour cutoff frequencies’ statistics were nearly equal, therefore, the 3-hour cutoff frequency was chosen to better model any shorter period tide undulations.

B.2.4.4 GNSS Base Station “OSFL”

OSI installed a GNSS base station at the Freshwater Bayou Canal Lock. The Freshwater Bayou Canal Lock was an ideal location for the GNSS station as the lock is also the site of NOAA tide gauge 876-6072 and associated tidal benchmarks. This proximity allowed for an optical leveling tie between the GNSS antenna and the tide station's primary benchmark, 876-6072-A, as well as benchmark 876-6072-C. Leveling results served as a QA/QC check of the ellipsoid value ultimately assigned to the OSFL base station during ASB processing. OSI submitted 121 individual days of dual frequency GNSS observables to OPUS and OPUS returned 121 reports based on "precise" ephemerides. OSFL's 121-day OPUS average of ellipsoid height (and latitude/longitude) was assigned to OSFL for ASB processing. Leveling results are included in the Project Horizontal and Vertical Control Report (HVCR).

OSFL was incorporated into ASB processing for all survey days. Due to its proximity to the survey area as well as observed data quality, OSFL was manually selected as the "primary network control" for all days. OSFL was the station against which all other CORS stations utilized in the process were assessed. In fact, after the necessary Z3G antenna ARP adjustments and DEV1 XYZ position adjustments were instituted (discussed in detail below), none of the NGS-CORS stations considered in the SmartBase process required adjustment when using OSFL as control. In other words, the SmartBase process retained the original coordinates of the NGS-CORS stations because the delta between their published and calculated horizontal and vertical coordinates (using OSFL as a reference) were consistently below the threshold necessitating an adjustment.

Station OSFL is considered "certified" in consideration of the information contained in the foregoing paragraph as well as the results of the numerous position verifications discussed below.

To satisfy the HSSD requirement that "*The reference position of non-CORS antenna installations shall be verified at least once per week while the site is utilized for survey operations*", OSI submitted OSFL RINEX files to OPUS for each of the 121 days that OSFL was in operation. Figure 7 is fashioned after individual NGS-CORS station "Time Series (short term)" statistics display. Specifically, Figure 7 exhibits the horizontal and vertical variability or distance from the accepted position (red line) of the OPUS-derived 3-D position results. The error bars on each point indicate the 1-sigma OPUS-reported peak-to-peak root mean square (RMS) error estimate of the 3-D position components, namely east, north, and ellipsoid height.

According to NGS' "OPUS-Best Practices" presentation,
(https://www.ngs.noaa.gov/web/science_edu/presentations_archive/files/weston-soler-opusbestpractices.pdf)
"the relationship between peak-to-peak and RMS (1σ) is peak-to-peak = 1.6929 x σ."
Individual OSFL OPUS reports are included in the HVCR digital deliverables.

B.2.4.5 NGS-CORS Station DEV1 Adjustment

During SBET processing it was discovered that one of the ASB-selected NGS-CORS network stations "DEV1" has an unusually large 3-D position error (accepted position vs. daily observed positions). The resultant ASB processing, as viewed in time series graphs, i.e. as "tide curves," demonstrated to OSI's satisfaction that use of the as-published, uncorrected 3-

D position data for DEV1 resulted in degraded SBET ellipsoid height solutions. For this reason, OSI "forced" DEV1 coordinates during the ASB process. The 3-D coordinates employed by OSI for DEV1 during ASB processing are an average of DEV1 OPUS results for the period of the survey, i.e. 121 days of DEV1 dual frequency GNSS observables were submitted to OPUS. Individual DEV1 OPUS reports are included in the HVCR digital deliverables. Figure 8 provides an example of the aforementioned DEV1 3-D position error for the period of the survey.

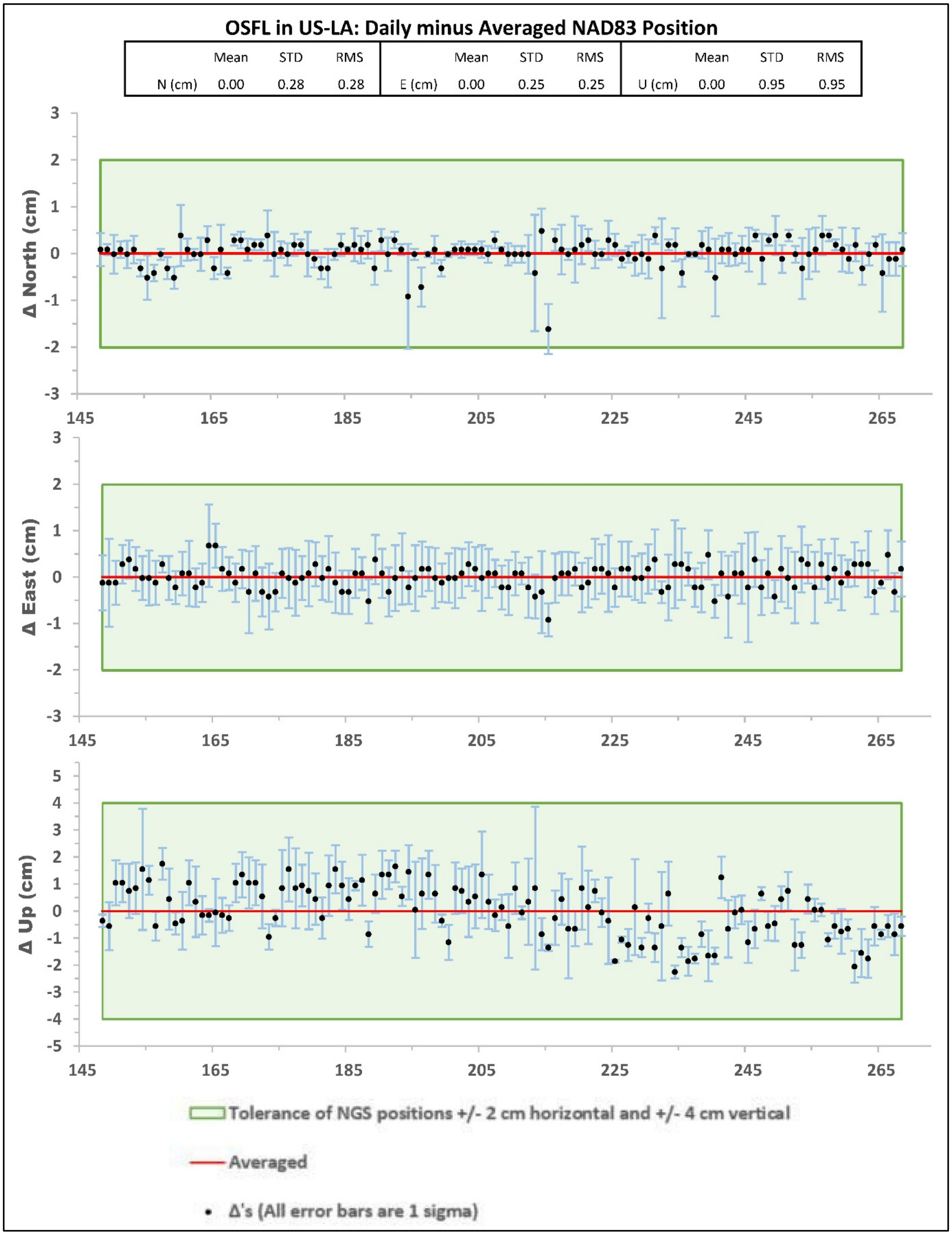


Figure 7. Station OSFL position verification statistics (fashioned after the NGS-CORS default presentation).

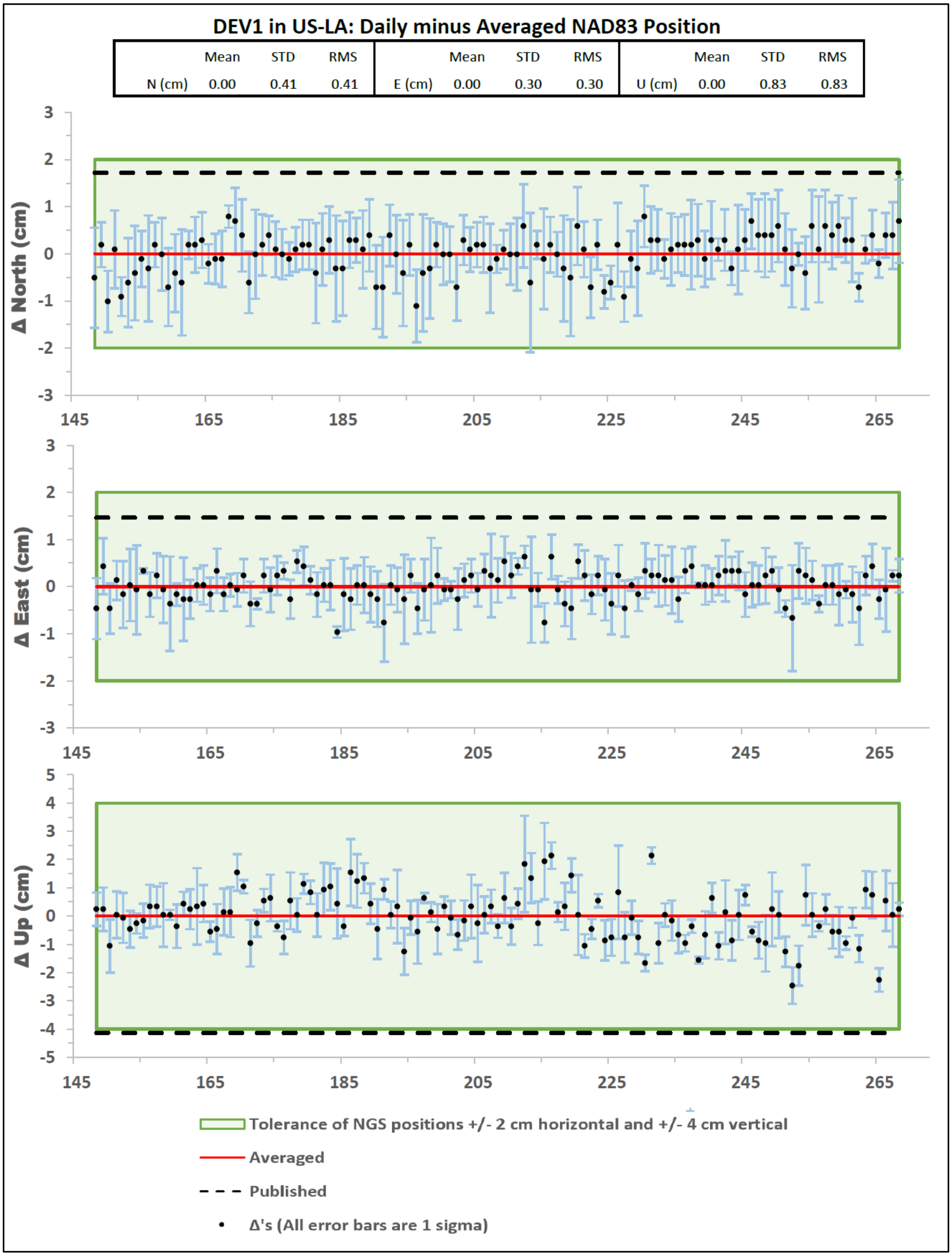


Figure 8. CORS Station DEV1 position error statistics calculated using NGS-CORS-published data and fashioned after the NGS-CORS default presentation.

The CORS-reported and OSI-forced (121 day OPUS-averaged) coordinates of DEV1 are shown in Table 9.

Table 9
Pre- and Post-Adjustment Coordinates used for DEV1

Source	Latitude (N)	Longitude (W)	Ellipsoid Hgt (m)
NGS-CORS Reported NAD83 (2011)	28 10 39.74267	091 43 57.51032	10.546
OSI ASB-Forced (121 day OPUS Averaged) NAD83 (2011)	28 10 39.74323	091 43 57.50977	10.505

In many circumstances it is acceptable to omit a "flawed" CORS station from ASB processing assuming that other local CORS stations allowed for suitable network geometry. In the case of the contemporary survey area, as seen in Figure 9, it was necessary to include DEV1 in ASB processing, otherwise the survey area would not fall within the convex hull of a CORS network. For this reason, OSI forced the 3-D coordinates shown in the table above.

Figure 9 illustrates the placement of ASB-contributing CORS Stations (including OSI's base station OSFL) in relation to the survey area. CORS stations TONY, FSHS, DEV1, CALC, and AMER along with OSI's OSFL were employed in *all* ASB SBET solutions. CORS Stations HOUM and LMCN were included in just a few ASB SBET solutions.

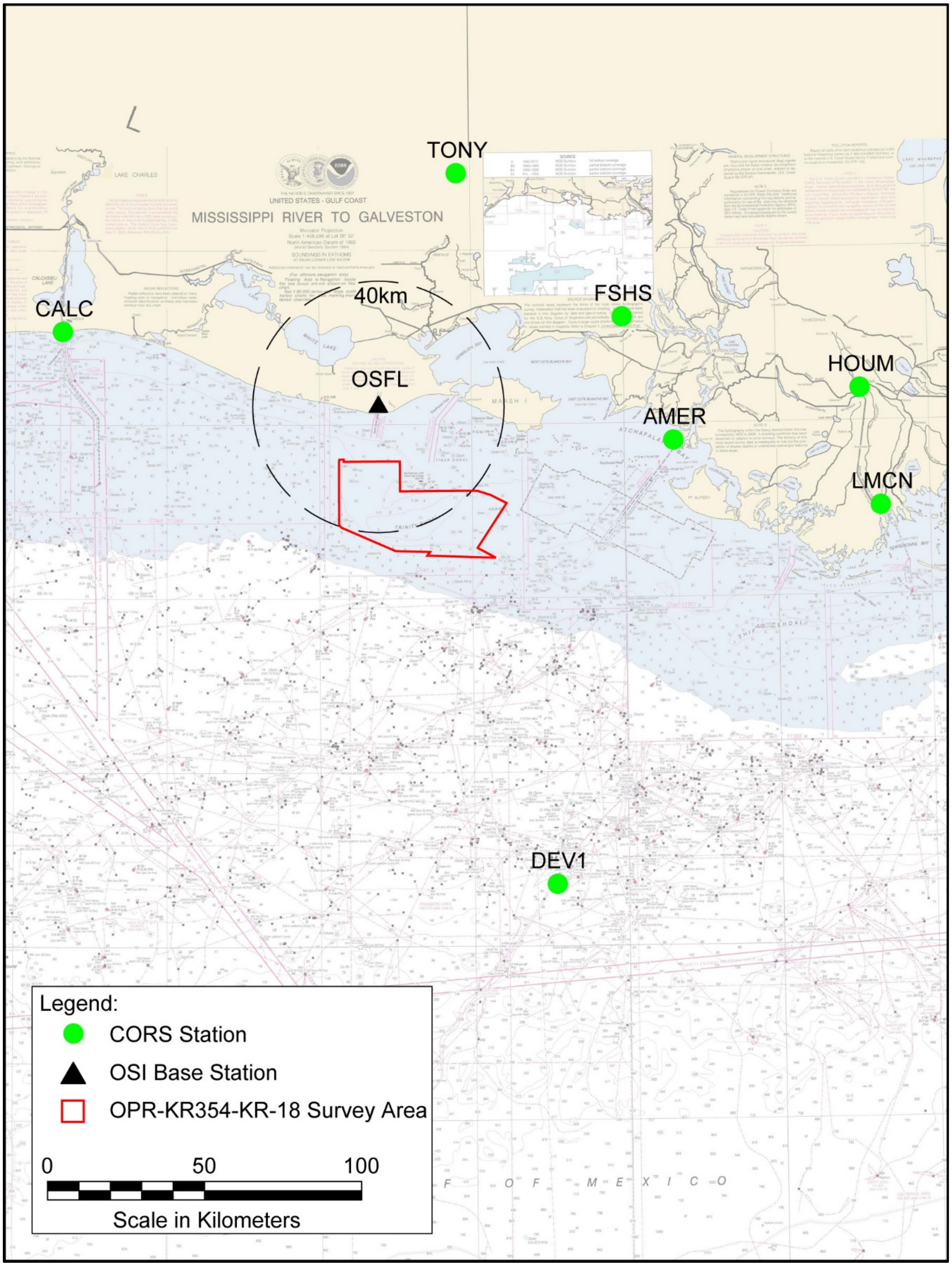


Figure 9. CORS stations (along with OSFL) used in ASB SBET solutions supporting Project OPR-K354-KR-18.

B.2.4.6 OSFL and NGS-CORS Antenna Adjustments

OSI used the current version of POSPac MMS, v. 8.3 w/ SP1, for all ASB processing. During ASB processing it was discovered that the program does not handle the antenna reference point (ARP) to antenna phase center (APC) offset calculation correctly for the newer type of antenna used on OSI's GNSS base station OSFL. The new antenna type is a Trimble Zephyr 3 Geodetic (Z3G) which has an antenna code of "TRM115000.00 NONE". The ARP is 0.065 meters below the APC on a Trimble Z3G antenna. It was also discovered that three of the NGS-CORS base stations used in ASB processing (Figure 9 above) changed to the new antenna type during the period of the survey.

The POSPac MMS processing issue appears to be a misapplication of the ARP-APC offset. Essentially the software behaves as if the ARP of the Z3G is located at the APC. The software issue was raised with Applanix before v.8.3 w/ SP1 was issued. Unfortunately, the offset error has not been corrected in the software (as of the completion of project ASB processing).

OSI determined the start date of antenna changes at NGS-CORS stations contributing to the ASB SBETs from their respective NGS-CORS "Site Logs."

In order to fix the incorrect application of the Z3G antenna offset in POSPac MMS, OSI forced the ellipsoid height for the affected NGS-CORS stations as well as OSI's OSFL.

The affected stations, the date on which the respective antennas were changed to a Z3G, and the pre-/post-change ellipsoid heights are shown in Table 10.

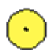
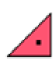
Table 10
SBET-Contributing Stations with Trimble Zephyr 3 Geodetic Antennas

Station	Antenna Type @ Start of Survey	Date Changed to Zephyr 3 Geodetic TRM115000.00 NONE	Published ARP Ellipsoid Height	OSI-Forced ARP Ellipsoid Height
OSFL	TRM115000.00 NONE	N/A	-17.223 (From 121 Day OPUS Average)	-17.158
FSHS	TRM57971.00 NONE	2018-08-24T15:18Z	-14.505	-14.440
TONY	TRM57971.00 NONE	2018-08-13T18:27Z	-5.557	-5.492
LMCN	TRM57971.00 NONE	2018-08-22T17:45Z	-14.743	-14.678

B.2.5 Feature Verification

During home office processing contacts were exported (daily) from HIPS and SIPS to an ASCII text file, which was reformatted and imported into a CARIS edit layer (.HOB file). Senior processing personnel would identify the contacts that required additional investigation from the contact HOB file. An item investigation HOB layer was then created which included the positions of all side scan contacts and outstanding soundings to be developed with additional MBES coverage. The Investigation HOB layer was exported to an S-57 (.000) file which could be opened as a background layer in HYPACK SURVEY during acquisition of development lines. Several S-57 feature symbols were chosen and re-defined for OSI tracking purposes; the in-house descriptions of the tracking objects are included in Table 11.

Table 11
Description of Investigation Tracking HOB Layer

S-57 Symbol		Description	Parameters
	BOYISD	Indicates Survey Data Issues	SSS: Incorrect contact, Incomplete contact, Additional contact description needed MB: Fish still in data, Tide Issue, Heave Issue acqsts = Investigate
	BOYSPP	Indicates Items as Examined	Any Ftr that is not significant should be marked examined. Downgrade any investigation item that is found to be insignificant.
	BOYLAT (green)	Indicates Resolved Survey Task Items	Item Investigations Shoal Areas Photos acqsts = Resolved
	BOYLAT (red)	Indicates Unresolved Survey Investigations	
 	Cartographic Lines and Areas	Indicates Lines and Areas that require additional survey data	Item Investigations Shoal Areas Photos acqsts = Investigate

Following the field team's completion of investigation and development tasks, feature verification and sonar coverage confirmation were accomplished through intensive review employing various data sources and software. Prior to the conclusion of survey operations, the home office project manager reviewed the data to ensure the following:

- Complete Coverage MBES was obtained over significant SSS contacts.
- Charted soundings were verified or disproved with MBES coverage per guidance included in HSSD Section 5.2.2.1. Bathymetric Splits.
- CSF "assigned" items were adequately addressed.
- Photos were obtained of high-water features, e.g. platforms.

The item investigation and development lines were converted and processed in CARIS HIPS following the bathymetry processing procedures outlined above. CUBE surfaces with a grid resolution of 1-meter were created over the investigated significant features. The density layers were reviewed to verify that the Complete Multibeam Coverage requirement of 5 soundings per node was met.

Contacts were evaluated with correlating SSS, BASE surfaces, charted information, and designated soundings. Significant contacts were evaluated in full density sounding subsets to ensure that there was adequate MBES coverage.

Contacts, contact images, and designated soundings were exported from CARIS HIPS and SIPS. All contacts were imported into a HOB file which was the foundation of the S-57 SSS Contact File included with the project deliverables. The designated soundings were imported into a HOB file, as well, and were utilized in the production of the S-57 Final Feature File (FFF).

Shoal soundings, designated soundings and contacts were compared to the largest scale charts in the survey area to identify Dangers to Navigation (DtoNs). All DtoNs were submitted to AHB as attributed S-57 .000 files per the specifications laid out for Contractors in the HSSD. All features submitted as DtoNs are included in the FFF.

I. SSS Contact File

It was discovered during data processing that, even with high-performance computers, the CARIS 10.4.3 Contacts Database file became unstable/unusable when the number of contacts approached 3,000. The project-wide SSS imagery contains many thousands of fish contacts. For example, Survey H13100 contains over 13,000 fish contacts. Given that fish contacts had to be considered during contact feature analysis and correlation, an alternate method was devised to manage fish and fish-like contacts.

Initially, all SSS imagery was reviewed in the CARIS SSS View window. Due to the limitations of the CARIS Contact Database the *only* contacts chosen in the traditional manner, i.e. within the SSS View waterfall, were those contacts presenting themselves as “obvious” seafloor-prone features and features with a questionable character. Those items interpreted to clearly be fish or other nondescript water column targets (due to their character, e.g. detached shadow) were intentionally *not* chosen as a traditional contact in the SSS View waterfall.

Upon choosing all traditional contacts a new feature layer, i.e. a .HOB layer, was created for each coverage percentage, i.e. 100% mainscheme, 200% mainscheme, 100% investigation and, 200% investigation coverage layers. Each survey generated the four (4) fish feature .HOB layers. The .HOB layer names included the sheet name and a color designation. The color designation was used in a later step during feature correlation.

In practice each 15 cm line mosaic was loaded into CARIS HIPS/SIPS and reviewed as a stand-alone layer in concert with the SIPS traditional contacts layer, the appropriate ENC chart background, and a CSF-assigned features layer. All layers were toggled on and off throughout the process to ensure each mosaic was viewed in the context of all available supporting information. As a given mosaic was reviewed (at a scale appropriate for target identification on a 49-inch 4k monitor) individual fish targets were chosen with the mouse cursor (on the plan view mosaic) and appended the appropriate coverage percentage .HOB file. The operator used the SIPS contact layer overlay to help make informed fish target picking decisions and to help avoid placing fish targets on top of previously chosen SIPS traditional targets. A column entitled “fish positioned” was added to the data processing log to ensure each SSS line file was reviewed in the manner described above.

Once all fish targets were chosen the .HOB files were loaded into the CARIS HIPS/SIPS main operator window and the display properties of each fish feature layer adjusted such that the displayed fish symbols were colored according to their associated file name color designation. The end result was a CARIS operator window displaying thousands of fish targets colored according to their source file, e.g. red, green, blue, cyan. The intent of this approach was to allow for the opportunity to discern any actual features from the visual background noise created by thousands of fish contacts.

During contact review and correlation, the four-color fish symbols were viewed in relation to one another *and* the SIPS contact layer. Fish contacts, regardless of color, were dismissed if there was not a correlating fish contact (of a different color) in close proximity. In instances when two or more fish contact symbols (of different colors) were found in close proximity to one another then further investigation was undertaken. Individual fish contact. HOB layers were concatenated (per Survey) and are included with the project deliverables in the Ancillary Data directory.

All SIPS traditional SSS contacts, point and linear features, were exported from HIPS and SIPS to an ASCII file and imported into a .HOB File. Individual contacts were correlated manually with respect to available overlapping SSS coverage, fish contact .HOBs, BASE surfaces, charted information, field photos and observations, and designated soundings. Correlation was accomplished by selecting all contacts found to represent the same independent feature in the Display Window and assigning each group a unique correlation number in the Primary Key ID (prkyid) attribute field. All contacts with the same prkyid are a correlating contact group. Singular contacts were not assigned a correlation number.

Each feature in the S-57 SSS Contact File includes the required NOAA Extended Attributes as specified in the table from Section 6.1.3.3 of the HSSD. The contact number is composed of the SSS line number and the number assigned in the HDCS line Contact file, for example: 2018OE1661036_2199146.

The contact image from SIPS Side Scan Editor is embedded in the S-57 contact file in the Image (images) attribute field.

II. Final Feature File

A Final Feature File (FFF) in S-57 .000 format was created in CARIS HIPS/SIPS per the guidance in HSSD 2017 Section 7.3. The feature file includes all source features assigned for investigation in the OCS-provided Composite Source File (CSF) and new navigationally significant objects discovered during the survey that required additional description beyond inclusion in the submitted bathymetric surfaces. The FFF includes new survey features, and updated and disproved charted features. Per Section 2.2. of the HSSD the FFF is submitted in the WGS84 datum, unlike all other project deliverables which are submitted in the NAD83 datum.

Regarding the OCS-provided CSF, it should be noted that the areal extent of the survey assignment changed two times during the period of the survey. As survey area expansions were assigned, NOAA issued new CSF.000 and PRF.000 files. The initial CSFs/PRFs of record were transmitted to OSI on April 4, 2018 (files dated March 22, 2018) and the last CSFs/PRFs of record were transmitted to OSI on September 12, 2018 (with same file date). The September 12, 2018 CSFs/PRFs were used exclusively during final home office feature development and chart comparisons.

All CSF-"assigned" features falling within the bounds of the as-surveyed areas were investigated. A number of CSF-"assigned" features fall outside the southern as-surveyed boundary of Survey H13200. These features were not investigated per wording in the Project Instructions, "*As LNM are completed the KR will square off the acquired area and ensure the full investigation of any features within the surveyed extent.*"

For clarity, the CSF "assigned" and "unassigned" features that fall completely outside the bounds of the as-surveyed areas are not included in the FFFs. Line features such as pipelines that fall inside/outside the as-surveyed limits were retained at their CSF-defined lengths, i.e. the CSF pipelines were not trimmed at the per-sheet survey limits.

OSI followed the feature attribution guidance in Section 7.5, S-57 Feature Attribution, in the 2017 HSSD, while building the FFF. In particular, the determination of a charted feature as an "Update" or a "New/Delete" item was based on the guidance that an Update is a modification to "attribution, geometry, and/or feature object class." Further guidance on this subject was offered by the COR during OSI's 2017 Project OPR-K354-KR-17 in an e-mail dated November 17, 2017 (see DR Appendix II). The guidance on positioning wellheads and platforms follows, "Include both the significant wellheads and platform features in the FFF, and reposition any platform that deviates greater than 10 meter from the center point of the corresponding charted feature, based on the page 97 of the HSSD. These are all delete/add for the charted platforms."

New or Updated point features' depths (VALSOU – value of sounding) and positions were imported from Designated soundings selected in CARIS HIPS and SIPS.

High-water features such as platforms were digitized into the FFF with the position determined from the MBES data or from the 25-centimeter SSS mosaic.

Descriptive information pertinent to each feature was entered in the IHO S-57 attribute fields and the NOAA extended attribute fields as specified in Section 7.5 and Appendix F of the HSSD.

The following attributes were updated for each item in the FFF:

- SORDAT (Source Date) – Final day of survey. New or verified features only.
- SORIND (Source Indicator) – Survey registry number, ex: US,US,graph,H12905. New, updated or verified features only.
- descrp (Description) – New, Update, Delete, Retain
- remrks (Remarks) – Processing remarks including survey techniques, feature classification (i.e. obstruction, rock, platform).
- recomd (Recommendations) – Hydrographer's charting recommendations.
- sftype (Special Feature Type) – Only updated for ATON and/or DTON items.
- images (Images) – Contact images, CARIS screen grabs or shoreline photographs included in the multimedia folder. Not Applicable for "Delete" features.

The mandatory S-57 attribution for each S-57 object class was updated as specified in Section 7.5 of the HSSD. The required attributes vary with S-57 object class (i.e. OBSTRN, OFSPLF, SBDARE).

B.2.6 Bottom Samples

Bottom sample positions were imported into CARIS from the HYPACK target file then included in the FFF. The bottom samples were classified as SBDARE (Seabed area) objects and attributed as instructed in Section 7.5 of the HSSD. The full bottom sample description was entered into the Remarks attribute field. The photo names for each bottom sample were entered into the Images attribute field.

B.3 Quality Management

For each of the originally assigned sheet limits a full crossline sounding data set was acquired prior to collection of mainscheme coverage. This was accomplished on a sheet-by-sheet basis. The original-assignment crosslines were oriented nominally perpendicular to mainscheme lines. However, as sheet limits were expanded (via contract modification) circumstances and efficiency dictated that some of the expansion areas crosslines no longer met the mainscheme lines in a nominally perpendicular fashion.

Soundings from mainscheme lines and crosslines were compared periodically throughout survey operations using preliminary CUBE surfaces and using CARIS HIPS Subset Editor. Crossline comparisons provided confirmation that the system offsets and biases were entered correctly and verified the accuracy of sounding correctors (i.e. tide, sound speed, TrueHeave).

As required in the HSSD, the planned crossline mileage was > 4% of mainscheme mileage for Complete Multibeam Coverage areas.

Statistical quality control information was generated periodically during data acquisition by comparing the beams of each crossline to CUBE Surfaces generated from mainscheme data using the CARIS QC Report Utility. At the completion of MBES data processing for each survey, difference surfaces were generated between a surface compiled from mainscheme/investigation MBES data and a surface compiled only from crossline MBES data. The results from the difference surface creation and the statistical analyses are discussed in the descriptive reports for each survey.

Detailed line queries were utilized periodically throughout data processing to be certain all necessary processes were completed and the right corrector files were applied to all the lines. The line queries were also used to calculate line mileage and were compared to processing logs to verify line names and be certain that no aborted lines were included in the final data products.

The standard deviation, depth and uncertainty layers were reviewed to identify possible systematic errors related to sound speed, tide, and TrueHeave correction or to detect errors in system alignment.

Sound speed profiles were plotted by day to visualize the variation over time and space (Figure 10). Relatively rapid increases or decreases in sound speed in the top few meters of the water column generally correlated with higher error in the sounding position, as evidenced by a "smile" or "frown" effect across the MBES swath. Surface sound speed logged in the raw HYPACK files was extracted and plotted for every line. Relative higher deviation and more rapid changes in the surface sound speed over a line were also an indicator of increased sound speed error in sounding correction which was most severe in the outer beams (Figure 11). Given the relatively shallow water depths in this project area, overall, the effect of the sound speed profile shape/severity was less pronounced than it may have been for a deep water survey. On this project, sound speed was simply not a substantial negative factor for overall data quality. Even so, lines that exhibited high variability in the surface sound speed were reviewed in the CUBE surface layers and in Subset Editor for excessive sound speed error.

Junction comparisons between current and prior hydrographic surveys were accomplished using the CARIS HIPS difference surface function.

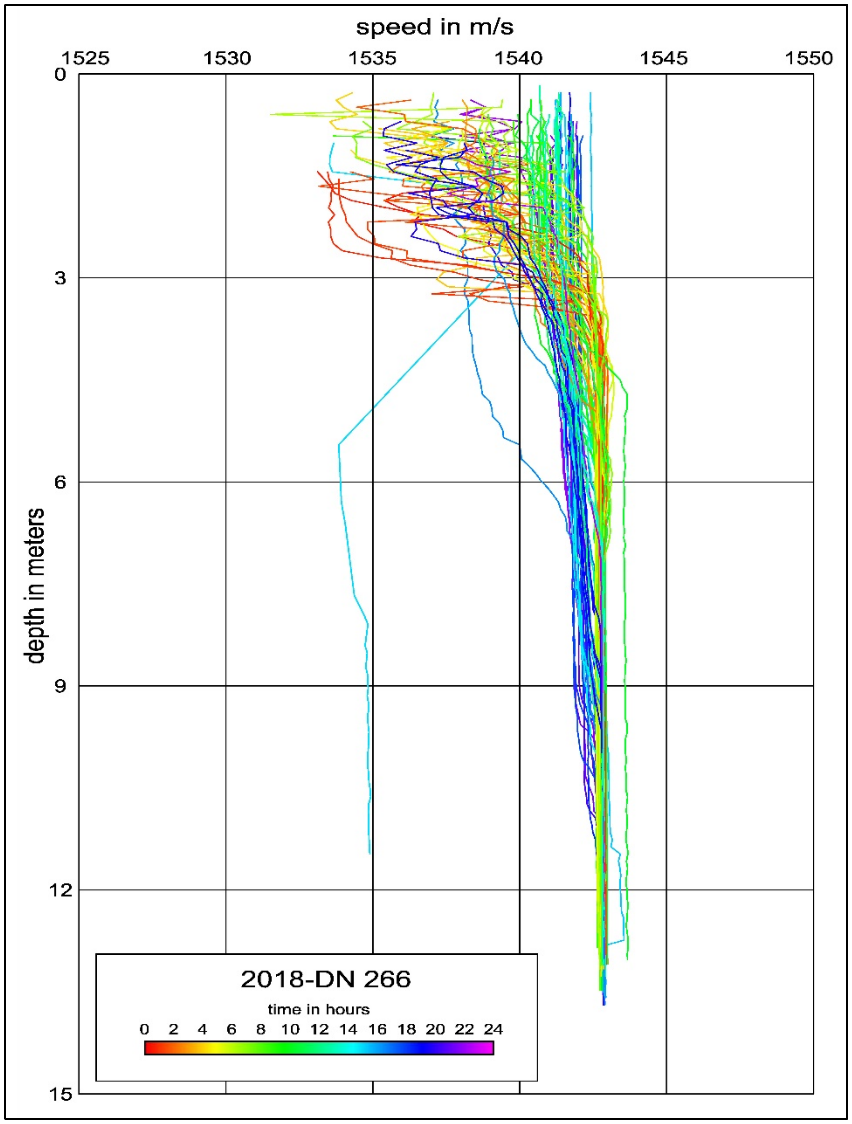


Figure 10. Plot of sound speed casts from the *R/V Ocean Explorer*, September 23, 2018 (DN 266). Substantial near surface sound speed variability was observed for part of the day.

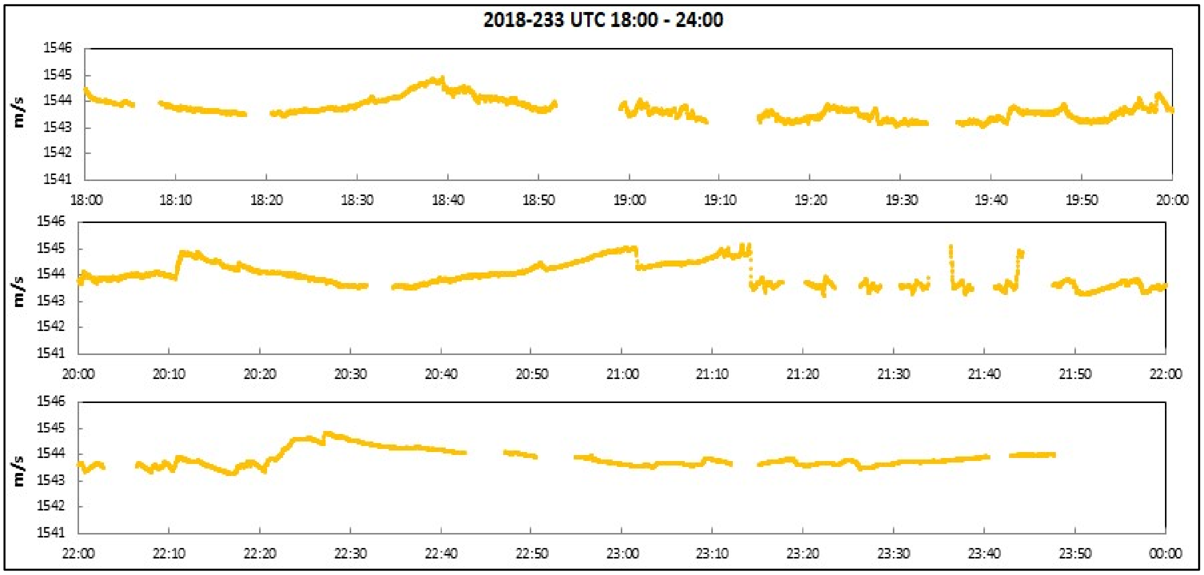


Figure 11. *R/V Ocean Explore*r surface sound speed plot by survey line for August 21, 2018 (DN 233) spanning 18:00 to 24:00 UTC.

B.4 Uncertainty and Error Management

Estimates for the uncertainty of all measurements associated with sounding collection were gathered from either reported manufacturer system accuracy or from statistics calculated from multiple measurements of the value in question.

Error is defined as the difference between a measured value and the true, or accepted, value. Since the true sounding value is not known ahead of time, an accurate error value cannot be reported with confidence. Uncertainty, not error, is the chosen parameter to quantify sounding accuracy such that it can be reported in terms of an interval of confidence around the measured value. The uncertainty associated with a measurement is reported as the standard deviation (σ) of the value from the mean.

The combined uncertainty value per sounding, or the Total Propagated Uncertainty (TPU), was calculated using CARIS HIPS. Standard deviation values for vessel offsets, motion, draft and alignment measurements were entered into the HVF "TPU values" section at the 1-sigma level. The HVF uncertainty values along with uncertainties associated with tide and sound speed were used in combination with the sonar model in the DeviceModels.xml file to assign a total horizontal uncertainty (THU) and total vertical uncertainty (TVU) for every sounding.

B.4.1 Total Propagated Uncertainty (TPU)

Table 12 lists the standard deviation and uncertainty estimates used for all measurements incorporated into the TPU estimates for the Reson 7125 echo soundings (used during early stage processing). It is important to note, however, that a number of the values shown in the table below are superseded by real-time RMS error values contained in the final SBETs ultimately employed to provide 3-D positioning, attitude, and heading for the MBES soundings.

Table 12
***R/V Ocean Explorer* Reson 7125 Uncertainty Estimates**

Uncertainty Values Included in CARIS HVF Files & Compute TPU Fields			
Heading Measurement σ (deg)	0.02*	XYZ Offset Measurement σ (m)	0.015
Heave % Amplitude	5.00	Vessel Speed Measurement σ (m/s)	0.530
Heave Measurement σ (m)	0.05*	Loading Measurement σ (m)	0.030
Roll Measurement σ (deg)	0.02*	Draft Measurement σ (m)	0.030
Pitch Measurement σ (deg)	0.02*	Delta Draft Measurement σ (m)	0.030
Navigation Measurement σ (m)	1.00*	MRU Align StdDev Gyro (deg)	0.10
Transducer Timing σ (sec)	0.01	MRU Align StdDev Roll/Pitch (deg)	0.10
Navigation Timing σ (sec)	0.01		
Gyro Timing σ (sec)	0.01	Tide Measurement σ (m)	0.00*
Heave Timing σ (sec)	0.01	Tide Zoning Vertical Uncertainty (m)	17.166
Pitch Timing σ (sec)	0.01	Sound Speed Error Measured (m/s)	1.00
Roll Timing σ (sec)	0.01	Sound Speed Error Surface (m/s)	2.00

* Values later superseded using real-time RMS error values contained in the final SBETs.

The POS MV 320 manufacturer recommended uncertainty values for the heading, heave, roll, pitch and timing measurements were entered in the HVFs.

The standard deviation values for the XYZ Offset and static draft measurements were calculated from distances acquired with the coarsest tool used to verify vessel offsets, the steel tape.

For the *R/V Ocean Explorer*, standard deviation for the loading measurement was calculated from the measure down values acquired on the port and starboard sides as well as pressure gauge-derived static draft values measured during the daily changeover.

The uncertainty for the delta draft was established by calculating the standard deviation of the differences between settlement values of reciprocal runs per each vessel speed tested. The settlement curve is included in DAPR Appendix I.

The MRU Alignment standard deviation values were calculated from the bias values estimated by multiple hydrographers who had individually processed the patch test data.

The Tide Measurement uncertainty is variable and is applied automatically based on the near-instantaneous uncertainty (RMS from 1Hz data) of the vertical component of SBETs resulting from Applanix SmartBase processing. Delayed Heave RMS, Gyro-Pitch-Roll RMS, and Position RMS errors are similarly applied using values contained in the 1Hz SBET data. See Figure 12 for the CARIS HIPS setup resulting in "instantaneous auto-uncertainty" application of certain TPU inputs (noted with * in the table above).

Sound speed TPU values were estimated from manufacturer-stated accuracy of the ODIM MVP30 and from guidance in the OCS Field Procedures Manual (FPM) Appendix 4 under CARIS HVF Uncertainty Values. The *R/V Ocean Explorer*'s MVP was deployed for a cast at a frequency of ≤15 minutes. As such a sound speed profile uncertainty value of 1 m/s was chosen for the measured sound speed of the *R/V Ocean Explorer*. A conservative value of 2 m/s was chosen for the sound speed surface uncertainty despite the fact that the surface and near surface sound speed profile gradient was relatively uniform throughout the period of the survey.

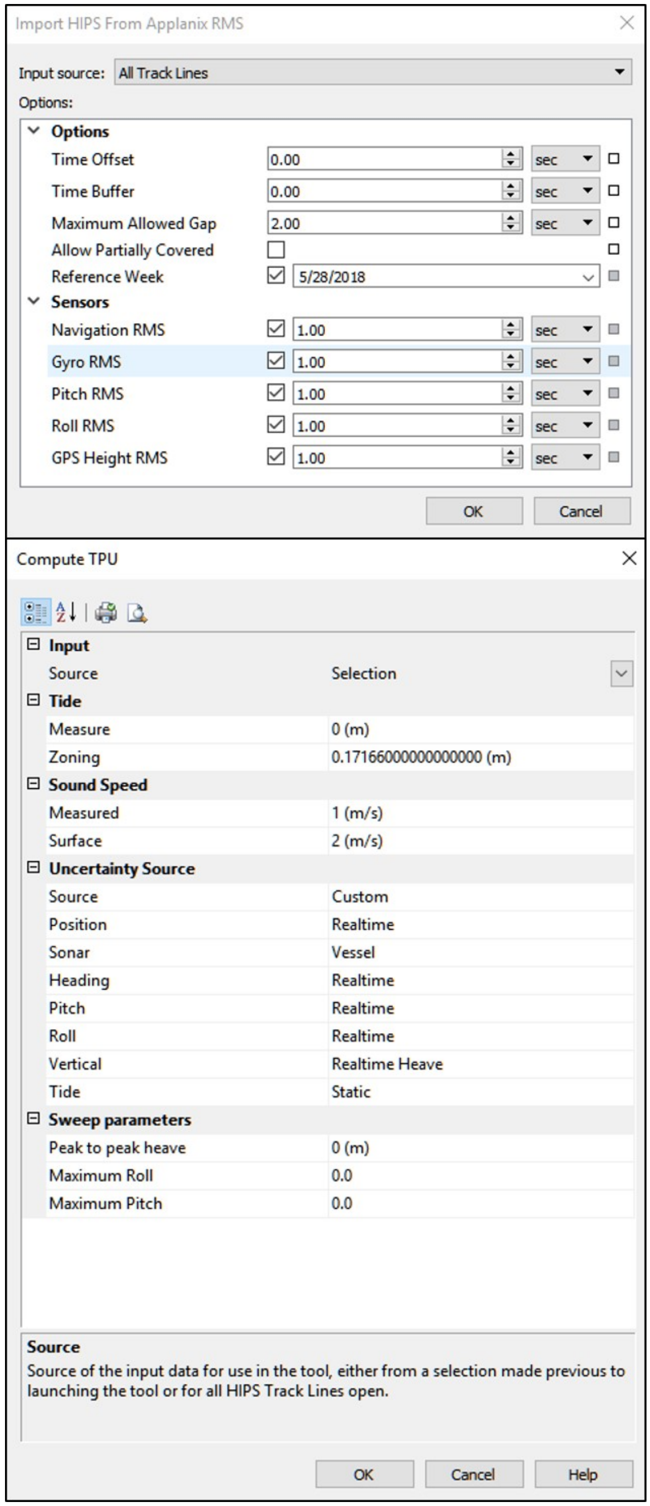


Figure 12. CARIS TPU input setting used to achieve automatic application of near instantaneous tide measurement uncertainty as provided in the form of 1Hz RMS error reported by the POS MV.

C. CORRECTIONS TO ECHO SOUNDINGS

C.1 Vessel Configuration and Offsets

C.1.1 Description of Correctors

Vessel configuration parameters and offsets are measures of the location of the integrated survey systems with respect to a Reference Point (RP) that serves as XYZ point 0, 0, 0 within the vessel's established reference frame. The RP on the *R/V Ocean Explorer* was the phase center or "bullseye" of the POS MV IMU. The measured offsets included the distance between the MBES transducer phase center to the RP, the distances between the GPS antenna phase centers and the RP, and the distance from the fixed-mount SSS to the RP.

C.1.2 Methods and Procedures

As mentioned earlier an optical total station was used to complete a full survey of the *R/V Ocean Explorer* on May 6, 2015 prior to mobilizing Project OPR-J377-KR-15. Since the 2015 total station survey, only one change was made to the physical configuration of the vessel. Near the location of the POS MV antennas the boat was fitted with new spot lights. As a result the POS MV antennas were raised 2.0 feet (0.610 meters) in order to avoid the GPS signal shadowing effects of the new hardware. This year-to-year change is reflected in the table below. However, since the antenna offsets are entered directly into the POS MV controller software the change is not reflected in any HVF.

Onboard the *R/V Ocean Explorer* the POS MV IMU was mounted on a permanent plate close to the vessel's center of rotation (Figure 13). The total station was used to measure the offsets from the IMU bullseye or RP to the POS MV GPS port and starboard antenna mounts, the Trimble DGPS antenna mount, and multiple port/starboard reference points including the draft measurement point(s). When the multibeam/fixed-mount SSS pole-mount was fully deployed, the offsets between the MBES and fixed-mount SSS transducers were related to the vessel's RPs via repeated measurement between the transducers and the starboard side reference points mentioned above. These measurements were made using a steel tape measure. The MBES and fixed-mount SSS transducers are located directly below conveniently situated starboard side reference points allowing for an unobstructed measurement path.

The IMU and transducer mounting hardware were co-aligned using a protable gyrocompass.

C.1.3 Vessel Offset Correctors

Instrument offsets input to the CARIS vessel configuration files are included in Table 13. A systems layout schematic is presented in Figure 13.

Table 13
***R/V Ocean Explorer* Sensor Offsets**

***R/V Ocean Explorer* Offsets via Topcon Total Station Survey or Measured Relative to Permanent Shipboard Benchmarks. Offsets are relative to Reference Point (RP) or Waterline**	**Forward Positive (m)**	**Starboard Positive (m)**	**Up Positive w.r.t RP (m)**	**Up Positive w.r.t. waterline (m)**
RP = IMU Bullseye 0,0,0	0.000	0.000	0.000	-0.480
POS MV GPS Antenna Phase Center Port	4.900	-1.200	6.339	5.859
POS MV GPS Antenna Phase Center Starboard	4.883	1.239	6.333	5.853
Positioning Integrity Comparison GPS Antenna Phase Center	2.713	0.948	7.972	7.492
7125 Transducer Phase Center	0.629	2.870	-1.423	-1.903
Fixed-Mount SSS (EdgeTech 4125)	1.139	2.870	-1.016	-1.496
Starboard Side Draft Measurement Point	-0.325	2.542	1.975	1.495
Port Side Draft Measurement Point	-0.329	-2.494	1.979	1.499

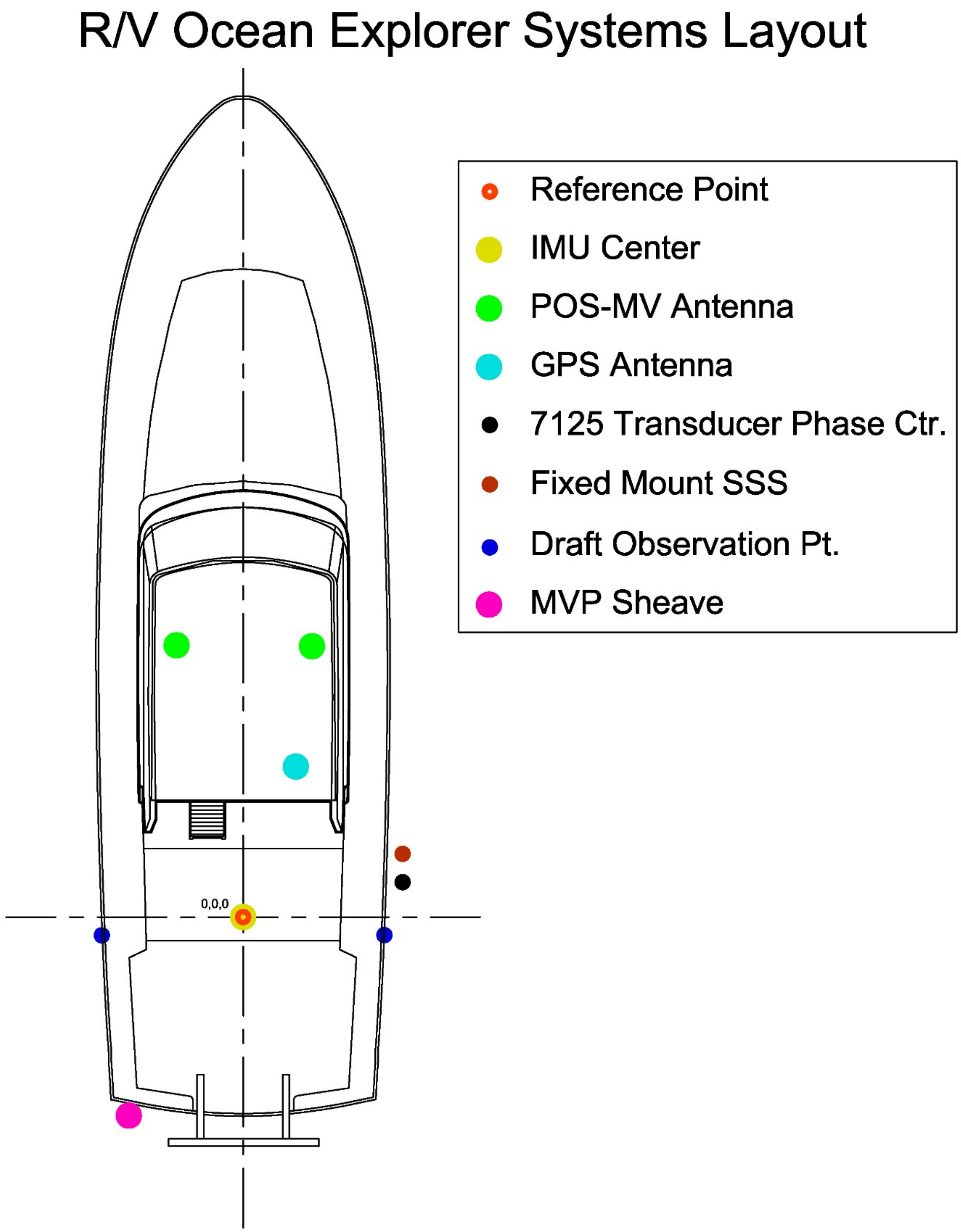


Figure 13. *R/V Ocean Explorer* systems layout.

C.1.4 SSS Positioning

C.1.4.1 Fixed-Mount Configuration

The SSS was operated exclusively in a rigid, fixed-mount configuration, i.e. no towed SSS imagery was collected on this project. Positioning was accomplished in real-time using HYPACK SURVEY configured using the generic offset device (genoffset.dll). HYPACK SURVEY transmitted fish position to the SSS acquisition software package, Discover, based upon the fixed physical offsets of the EdgeTech 4125 SSS relative to the vessel's steering point which is turn was related the vessel's RP. The Discover software also recorded vessel heading (analogous with fish heading) which was supplied to the software via a direct serial connection to the POS MV.

As mentioned earlier, during post processing, 20 Hz SBET position and heading data were substituted for the field-recorded data. Recalculating fish position in CARIS SIPS required that a non-zero vessel file be used, i.e. a vessel file containing the starboard and forward offsets of the fixed-mount towfish relative to the vessel RP.

Positioning accuracy of the fixed-mount system was verified prior to commencing survey operations by comparing the position of a known feature (positioned with MBES data) to the same feature positions as recorded in multiple SSS passes. The multiple SSS passes were collected at varying distances from the feature to confirm overall system accuracy. The SSS was operated only at the 50 meter range scale. Test results are presented in DAPR Appendix II.

C.2 Static and Dynamic Draft

C.2.1 Static Draft

C.2.1.1 Description of Correctors

Static draft is the vertical distance of the echosounder transducer below the water line and is added to the observed soundings during data processing in CARIS HIPS. The vertical offset between the transducer phase center and the RP was entered into the HVF Swath 1, Z-value field. For the *R/V Ocean Explorer* the vertical offset to account for the distance from the RP to the water surface was updated nearly once per day (as offshore conditions allowed). Updates were entered into the Waterline Height field in the HVF. The Z-value and the waterline corrector added together equaled the static draft of the echosounder transducer phase center.

C.2.1.2 Methods and Procedures

Onboard the *R/V Ocean Explorer* static draft measurements were taken during mobilization, prior to the start of the survey (May 4, 2018, DN 124), and periodically throughout the term of the survey. Direct measurements or "measure downs" from the water surface to both the starboard and port draft observation point "benchmarks" were made using a steel tape. The waterline height above the RP was determined by averaging the differences obtained from subtracting the measured distances from the water surface to the benchmarks from the known vertical offsets between the RP and the benchmarks. Minor variations in vessel attitude were negated as the final measured waterline height value is an average of the port and starboard measured values.

For the *R/V Ocean Explorer* a GE/Druck pressure sensor (vented water level gauge) was installed within the transducer pole as an alternate method for monitoring the change in static draft due to changes in vessel loading. The pressure sensor was installed at a fixed elevation within the transducer pole. The transducer mounting flange at the bottom of the transducer pole was fitted with a small diameter copper orifice making the transducer pole, in effect, a stilling well. The pressure sensor depth below the water surface was calibrated prior to the start of survey to determine its vertical offset constant in reference to the RP. When the vessel was at a full stop for the daily "UTC midnight" changeover, the pressure sensor water level data were logged for 5-10 minutes using HYPACK SURVEY. The water level values were extracted from the raw HYPACK file and averaged to obtain the depth of the pressure sensor below the water line. The waterline height was calculated by subtracting the vertical offset between the pressure sensor and the RP from the pressure sensor average depth. Once the measure down-to-pressure sensor corrector constant was established (and subsequently confirmed with later measurements) the pressure sensor gauge water level determination method was used exclusively for static draft measurements offshore as the sea state made measure downs impractical when the vessel was offshore.

Given that the vessel's local operations dock was located well into the Intracoastal Waterway (in fresh water) the dockside measure down values were not included in the HVF for fear that these values would be biased due to the difference in water density between the fresh water dockside location and the salt water environment of both the survey area and the pressure sensor constant determination location. The min/max range of waterline height measurements for the *R/V Ocean Explorer* was less than 19 cm for the period of the survey.

The waterline height measurement was corrected to the vessel reference point and recorded in the acquisition log. Waterline height values calculated from physical measurement, "measure downs," or the pressure sensor gauge data, were time stamped and entered into the CARIS vessel configuration file. In CARIS HIPS, the time stamped waterline height correctors were added to the Z-value vertical offset between the RP and the transducer phase center to obtain the vessel's echosounder static draft.

C.2.2 Dynamic Draft

C.2.2.1 Description of Correctors

Dynamic draft correctors account for the vertical displacement of the transducer when a vessel is underway in relation to its position at rest.

C.2.2.2 Methods and Procedures

Dynamic draft on the *R/V Ocean Explorer* was measured on May 11, 2018 (DN 131) with the vessel at average load and trim and configured for survey operations. The test was conducted in the vicinity of the vessel's home port in Noank, CT which is the location the vessel was mobilized and from where initial calibrations were staged. Calibration test lines were acquired in water with a nominal depth of 6-20 meters; the sea-state was calm during collection. Data were acquired along tracklines nominally 1,000 to 4,000 meters long at regular intervals of speed, beginning with the engines at various "troll" settings and increasing by 100 RPMs until the maximum practical survey speed was surpassed. During testing, reciprocal line pairs were acquired at each RPM setting to average out the effect of any current present. Tidal variations were accounted for by recording a "drift line" with the vessel at rest at the beginning and end of each test line run at speed. Lines, at speed or at rest, were only logged after the vessel speed stabilized to a steady state. The data were collected with the POS MV in RTK mode using a base station approximately three miles away. However, the real time RTK solution was abandoned in favor of a seemingly more stable single base IAPPK solution.

Table 14 summarizes the as-measured settlement test results for the *R/V Ocean Explorer*. In populating the CARIS HVF draft table, the settlement curves generated using the values shown in Table 14 were smoothed and densified using a 4th Order polynomial curve fit in EXCEL. Settlement values entered into the CARIS HVFs were taken from the smooth curve at regular speed intervals. These values are shown in Table 15.

C.2.2.3 Dynamic Draft Correctors *R/V Ocean Explorer*

Table 14
***R/V Ocean Explorer* As-Measured Dynamic Draft Correctors**

RPM Both Engines	Speed		Dynamic Draft Meters
	M/S	Knots	
Static	0	0	0
Troll Setting 2	1.56	3.02	-0.007
Troll Setting 3	2.01	3.90	-0.012
Troll Setting 4	2.56	4.98	-0.027
600	3.60	7.05	-0.049
700	4.09	7.94	-0.070
800	4.60	8.94	-0.090
900	4.91	9.54	-0.134

*Negative value indicates the boat is settling. CARIS correctors are the opposite sign.

Table 15
***R/V Ocean Explorer* - Polynomial Curve Fit Dynamic Draft Correctors**
As entered into CARIS HVFs

Speed M/S	Speed Knots	Dynamic Draft Meters
1.03	2.00	0.008
1.29	2.50	0.010
1.54	3.00	0.011
1.80	3.50	0.013
2.06	4.00	0.015
2.31	4.50	0.018
2.57	5.00	0.022
2.83	5.50	0.027
3.08	6.00	0.033
3.34	6.50	0.041
3.60	7.00	0.050
3.86	7.50	0.062
4.11	8.00	0.075
4.37	8.50	0.091
4.63	9.00	0.109
4.88	9.50	0.129
5.14	10.00	0.153

C.3 System Alignment

C.3.1 Description of Correctors

A multibeam sonar calibration was completed to determine residual navigation timing error and angular biases in roll, pitch, and heading in the echosounder transducer alignment.

C.3.2 Methods and Procedures

Prior to commencement of survey operations, a sensor alignment or patch test was performed. The initial patch test of record for the *R/V Ocean Explorer* was performed in Fishers Island Sound off Noank, CT on May 10, 2018 (DN 130). The Noank, CT area patch test area was chosen given the anticipated paucity of suitable patch test areas within the project area. As mentioned earlier, none of the survey systems were removed from the *R/V Ocean Explorer* between mobilization in Connecticut and the end of data acquisition. Data were acquired in accordance with HSSD April 2017 Section 5.2.4.1.

Throughout the course of the survey the multibeam pole was occasionally recovered (pivoted out of the water for transit and docking). Without exception, if the pole was moved, an abbreviated patch test was performed. Also, despite the unlikely possibility that the multibeam pole would move during 24-hour operations, as a conservative measure, an abbreviated patch test was performed daily whether or not the pole was recovered and redeployed.

For the "interim" or abbreviated daily patch tests, reciprocal multibeam data were collected on a short set of lines at a convenient time each day and processed onboard to confirm system stability. With one minor exception (mentioned earlier in this report) the results of interim roll testing indicated that the multibeam pole was stable.

Full suite, verification patch testing was performed when the vessel arrived at the Louisiana survey area (May 28 2018, DN 148) and at the completion of the project on September 24, 2018 (DN 267). As mentioned above, all test results were in keeping with the pre-survey results. Patch test results of record are presented in DAPR Appendix II.

For the *R/V Ocean Explorer* pre-survey patch test calibrations were initially accomplished employing RTK GPS positioning. All interim patch tests and roll check lines were acquired with the POS MV in Marinestar DGNSS mode. However, as before, all calibration data were ultimately positioned employing SBET data.

For each non-interim patch test, test lines were run multiple times to ensure system repeatability. Patch test biases were determined in the following order: navigation timing error (latency), pitch, roll, and heading. The CARIS HIPS Calibration Tool (Figure 14) was primarily used to determine offset values. All patch test values were verified with the HYPACK HYSWEEP patch test routine (Figure 15).

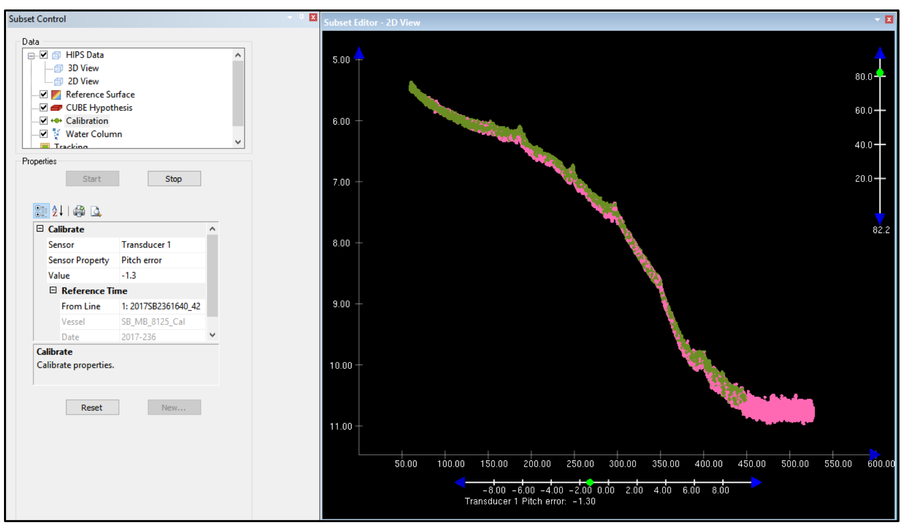


Figure 14. CARIS HIPS Calibration Tool.

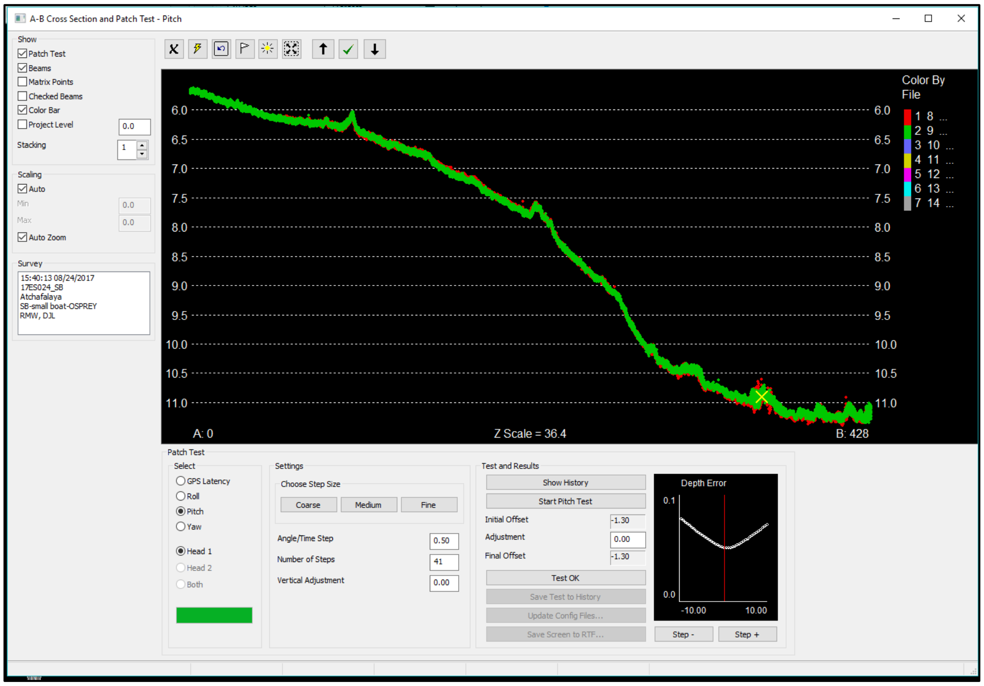


Figure 15. HYPACK HYSWEEP Patch Test Utility.

For each parameter, multiple processing iterations were performed by multiple hydrographers. The final offset values for each vessel file (HVF), e.g. mainscheme, crossline, calibration, investigation, are an average of the CARIS-derived values. The final applied values, entered into the CARIS vessel files, are shown in Table 16. The patch test results were of high quality and repeatability.

The performance test of record on the *R/V Ocean Explorer* was performed south of the Freshwater Bayou Canal Lock, LA on May 28, 2018 (DN 148). Verification performance testing was performed at the completion of the project on September 24, 2018 (DN 267). Close out test results were in keeping with the pre-survey results.

In practice a performance surface was created from a high density, near nadir sounding set collected with the Reson 7125. In creating the surface ten MBES lines were acquired over a relatively flat section of seafloor and processed in CARIS HIPS with the patch test bias values for timing, pitch, roll and yaw entered into the HVF. A port and starboard beam filter of 45 degrees was applied to the performance surface lines and a 1 m x 1 m Uncertainty Surface was generated from the processed soundings. Two performance check lines that were run perpendicular across the center of the surface were processed in CARIS HIPS as well; however, no beam filter was applied. The CARIS HIPS QC Report Utility was used to compare the beams of each performance check line to the performance surface to verify system accuracy. Performance test results of record are presented in DAPR Appendix II.

C.3.3 System Alignment Correctors

Table 16
***R/V Ocean Explorer* MBES Patch Test Alignment Correctors**

CARIS Patch Test Results	
Latency	0.00 sec
Pitch	-0.10°
Roll	-0.22°
Yaw (heading)	1.13°

C.4 Positioning and Attitude

C.4.1 Description of Correctors

DGNSS correctors received from the Marinestar corrector service are used to improve positioning accuracy as compared to operation in stand-alone GPS mode. Attitude corrections measured at the vessel RP are applied to soundings to correct for vessel motion.

C.4.2 Methods and Procedures

An Applanix POS MV 320 V.5 was employed for motion, heading, and position determination on the *R/V Ocean Explorer*. Manufacturer's stated accuracy values, for DGNSS mode operation, are tabulated below.

Table 17
POS MV Specifications

POS MV 320 V.5 Manufacturer's Specifications	
Parameter	**Accuracy**
Roll	0.02°
Pitch	0.02°
Heave	5 cm or 5% of wave height
Heading	0.02°

Prior to calibration of the POS MV, lever arm distances, mounting angles and the separation distance between the port and starboard GPS antennas were entered in the controller software. The heading accuracy threshold was set to 0.5 degrees. A GAMS calibration was run after the heading accuracy had dropped below the 0.5 degrees threshold, keeping a straight course until the calibration was completed. See DAPR Appendix III, Positioning and Attitude System Reports for additional information on the POS MV configuration and calibration.

C.5 Tides and Water Levels

C.5.1 Description of Correctors

ERS tide correctors are applied to reduce the soundings to the Mean Lower Low Water (MLLW) datum.

C.5.2 Methods and Procedures

The QA/QC steps used in assessing ERS tide components and the processes employed in creating ERS tides are detailed in earlier sections of this report. In summary, once a "smoothed" IAPPK ellipsoid record was generated the CARIS "Compute GPS Tides" function was used in conjunction with the NOAA-provided SEP model to develop MLLW tide correctors. Qualitative and quantitative crossline analysis as well as junction analysis indicate that the final ERS correctors employed in reducing soundings to MLLW were adequate for the purpose.

C.6 Sound Speed

Observed depth is a function of the speed of sound in the water column, such that depth is equivalent to the sound speed multiplied by the travel time of the sound pulse from transmit to receive divided by 2. Sound speed is not a constant and varies temporally and spatially, affected by changes in temperature, salinity and depth. Sound speed profiles are acquired to model the speed of sound versus depth within a survey site. Improper sound speed correction can result in inaccurate depth values and sounding positions. The sound speed correctors from the profiles are applied to soundings to override the assumed sound speed value used during acquisition and to calculate the depth using the actual sound speed measured in the survey site for a defined space and time.

C.6.1 Sound Speed Profiles

With exception of one day, the sound speed profiles used to correct the echo soundings were acquired exclusively with an ODIM MVP30 equipped with two sensors: a sensor that measured sound speed directly at a frequency of 10Hz during its descent through the water column and a pressure sensor for profile depth measurement. The exception: due to the temporary loss of communication with the MVP fish, an AML Base X was used for correction of the first onsite verification patch test and the onsite performance test of record. All AML Base X and MVP sensors employed on the project were manufacturer calibrated prior to use on the project (between April 18-20, 2018).

Calibration reports are included in DAPR Appendix IV.

Sound speed profile correctors were applied in CARIS HIPS using the Sound Velocity Correction process, which employs a ray tracing algorithm to simulate refraction. The Nearest in Distance Within Time, 1-hour profile selection method was used to determine which cast was applied to the soundings. This method was selected to limit the effects of spatial and temporal variation in sound speed.

C.6.2 Surface Sound Speed

On the *R/V Ocean Explorer,* surface sound speed correctors were sent directly from the AML Micro-X sensor to the Reson 7125 TPU. The AML Micro-X's SV X-change sensor was manufacturer calibrated on April 18, 2018.

D. APPROVAL SHEET

LETTER OF APPROVAL

REGISTRY NOS.
H13100, H13101, H13102, H13103, AND H13200

This report and the accompanying data are respectfully submitted.

Field operations contributing to the accomplishment of Surveys H131000, H13101, H13102, H13103, and H13200 were conducted under my direct supervision with frequent personal checks of progress and adequacy. This report and associated data have been closely reviewed and are considered complete and adequate as per the Statement of Work.

Approver Name	Approver Title	Approval Date	Signature
George G. Reynolds	Chief of Party	01/25/2019	George G. Reynolds 2019.01.25 16:04:49 -05'00'
John R. Bean	Lead Hydrographer	01/25/2019	John R. Bean 2019.01.25 16:05:09 -05'00'
David T. Somers	Data Processing Manager	01/25/2019	David T. Somers 2019.01.25 16:05:29 -05'00'