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Corpus Christi Ship Channel ADCP and CTD Survey

Final Report

Prepared by

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Chapter 1

Introduction

1.1 Synopsis

This report provides a summary and display of acoustic Doppler current profiler (ADCP) and conductivity, temperature, depth (CTD) profile data collected along the entire Corpus Christi Ship Channel (CCSC) in Texas between September 22 and 26, 2019. ADCP data were collected using a vessel-mounted Nortek Signature 1000 system equipped with 5 acoustic beams. CTD profile data were obtained via a Sontek CastAway CTD probe at select locations along the vessel track with conductivity being used to infer salinity. The data collection effort was conducted in support of U.S. Army Corps of Engineers - Galveston District (SWG) planning and design efforts related to dredge disposal islands and submerged dikes. The data also are a valuable resource for general analysis of the effect of tidal currents on ship navigation and safety.

SWG is responsible for coastal infrastructure and navigation projects along the entire Texas coast, including 700 miles of coastline and 1,000 miles of channels, of which 270 miles are deep-draft. Corpus Christi Bay includes the Corpus Christi Ship Channel (CCSC) and harbor, one of the highest-tonnage ports in the country. Engineering design of a deeper and wider channel requires dredging and placement of several million cubic yards of sediment. As existing placement areas are inadequate to accommodate future volume requirements, various means of placing dredge material need to be investigated. In addition, coastal protection schemes call for innovative solutions that should work with nature to achieve optimal outputs and multi-functionality. Such solutions to wave attack and erosion problems will involve the design and monitoring of sediment-guidance structures, disposal islands, and submerged sandbars. The long-term effects of these solutions are unknown and require detailed information on prevailing hydrodynamics along the CCSC.

Dredge Disposal Islands: Not only will there be permanent continuing need for disposal areas, but the currently available placement areas inside Corpus Christi's bays are nearing their limits. Most bays have no readily available sand sources for construction of traditional stable sand dikes to build enclosures to dredge disposal areas. This calls for the need to investigate the feasibility of using readily available mixed sediment dredge material to construct such dikes. However, this method of protecting placement areas has not been tested extensively in the field.

Submerged Dikes: Several placement areas will be underwater and protected with submarine dikes. The long-term stability of these dikes is unknown. There are currently no reliable methods for predicting their behavior. The subaqueous placement of dredged material has attracted increased attention due to its cost savings potential. However, details on how to best place such submerged dikes in order to optimize erosion protection and stability are not well known. Therefore, analytical and numerical models are necessary to predict sediment transport mechanisms in order to measure effectiveness of the dikes. The hydrodynamic and salinity measurements presented in this report are intended to provide some of the input parameters needed to carry out the proposed sediment transport modeling.

Effects on Ships: The measured current data presented in this report can be used by SWG for analysis of the impact of tidal currents on ship navigation and safety.

1.2 Field Setting and Environmental Conditions

Vessel-borne ADCP scans along the entire 30-mile length of the CCSC and along an additional 5-mile stretch south of already existing dredge placement islands were conducted, passing each segment at least twice at different tidal stages. Figure 1.1 shows an area map of the main Corpus Christi Bay. The yellow line in Figure 1.1 maps the extent of the ADCP scan paths reaching from outside the jetties across Corpus Christi Bay and all the way to the turning basin inside the harbor plus the 5-mile stretch south of the existing in-bay placement sites. Existing tide stations are displayed by red pins. Time series of water level fluctuations and wind velocities during the measuring campaign were obtained from the station marked by a yellow diamond.

Figure 1.2 shows time series of the verified water level fluctuations (blue line in top panel) and wind velocities during the field measurement period from Sept. 21 to Sept. 26, 2019. Local Standard Time (LST) is used to display these data and date axis tick marks indicate 00:00 LST that day. Quality-controlled wind and water level data were obtained from the National Oceanic and Atmospheric Administration Center for Operational Oceanographic Products and Services (NOAA CO-OPS) station Port Aransas,

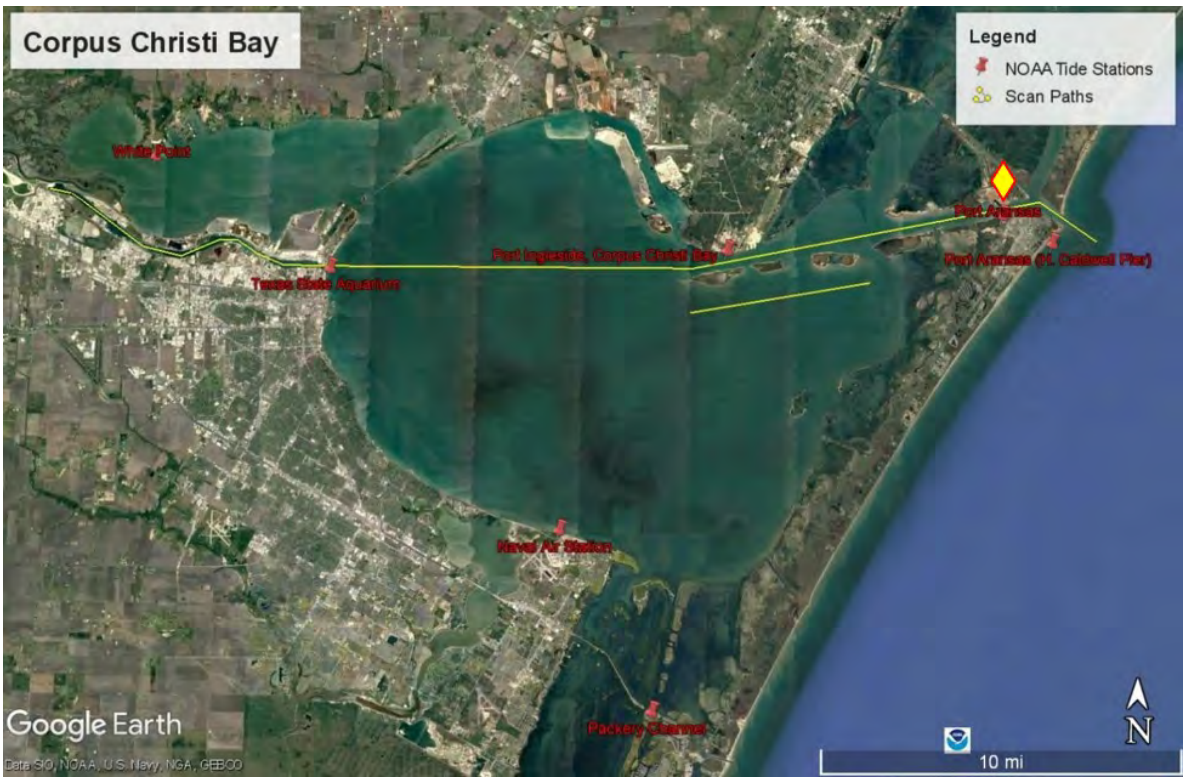

Figure 1.1: Area map of Corpus Christi Bay. Locations of the existing tide stations are shown by red pins. The yellow diamond marks the station used to extract time series of water level fluctuations and wind velocities during the measuring campaign. The extent of the ADCP scan paths is indicated by yellow lines.

TX (ID: 8775237). Station data were accessed on Feb. 12, 2020. Raw data were obtained at 6-minute sampling intervals. The raw wind data were averaged over 30-minute intervals yielding the 30-minute average wind speed W_{30} (m/s) and associated direction in degrees clockwise from true north. Survey segments are shown using shaded vertical bars.

The record indicates diurnal tides with water level changes between $0.3 \sim 0.7$ m above NAVD88 and an average tidal range of 0.3 m. The high (ζ_{high}) and low (ζ_{low}) water levels and respective times (t_{high}, t_{low}) for each day of the measuring campaign in LST are provided in Table 1.2 alongside the corresponding daily averages of wind speed (W_{30}) and direction. Wind direction is given in degrees measured clockwise from true north.

Table 1.1: Characteristic tide and wind values during the field campaign.

Date	t_{high}	t_{low}	ζ_{high}	ζ_{low}	W_{30}	Wind Dir.	
9/21/2019	04:54	15:54	0.55 m	0.32 m	5.1 $\frac{m}{s}$	117°	ESE
9/22/2019	03:54	16:00	0.64 m	0.35 m	3.9 $\frac{m}{s}$	127°	SE
9/23/2019	01:42	18:36	0.69 m	0.34 m	2.9 $\frac{m}{s}$	128°	SE
9/24/2019	04:18	18:12	0.69 m	0.34 m	2.9 $\frac{m}{s}$	143°	SE
9/25/2019	10:30	19:48	0.69 m	0.31 m	2.9 $\frac{m}{s}$	134°	SE
9/26/2019	12:30	19:30	0.64 m	0.34 m	3.5 $\frac{m}{s}$	117°	ESE

Figure 1.3 shows the wind rose based on the wind data shown in Figure 1.2. The prevailing winds were east-southeasterly (ESE) with 3 to 5 m/s speeds throughout the field measurement period.

Next, methods used to measure the presented data are described briefly, followed by detailed illustrations of the results sorted by scanned channel segment and tidal stage. The report closes with a short summary section.

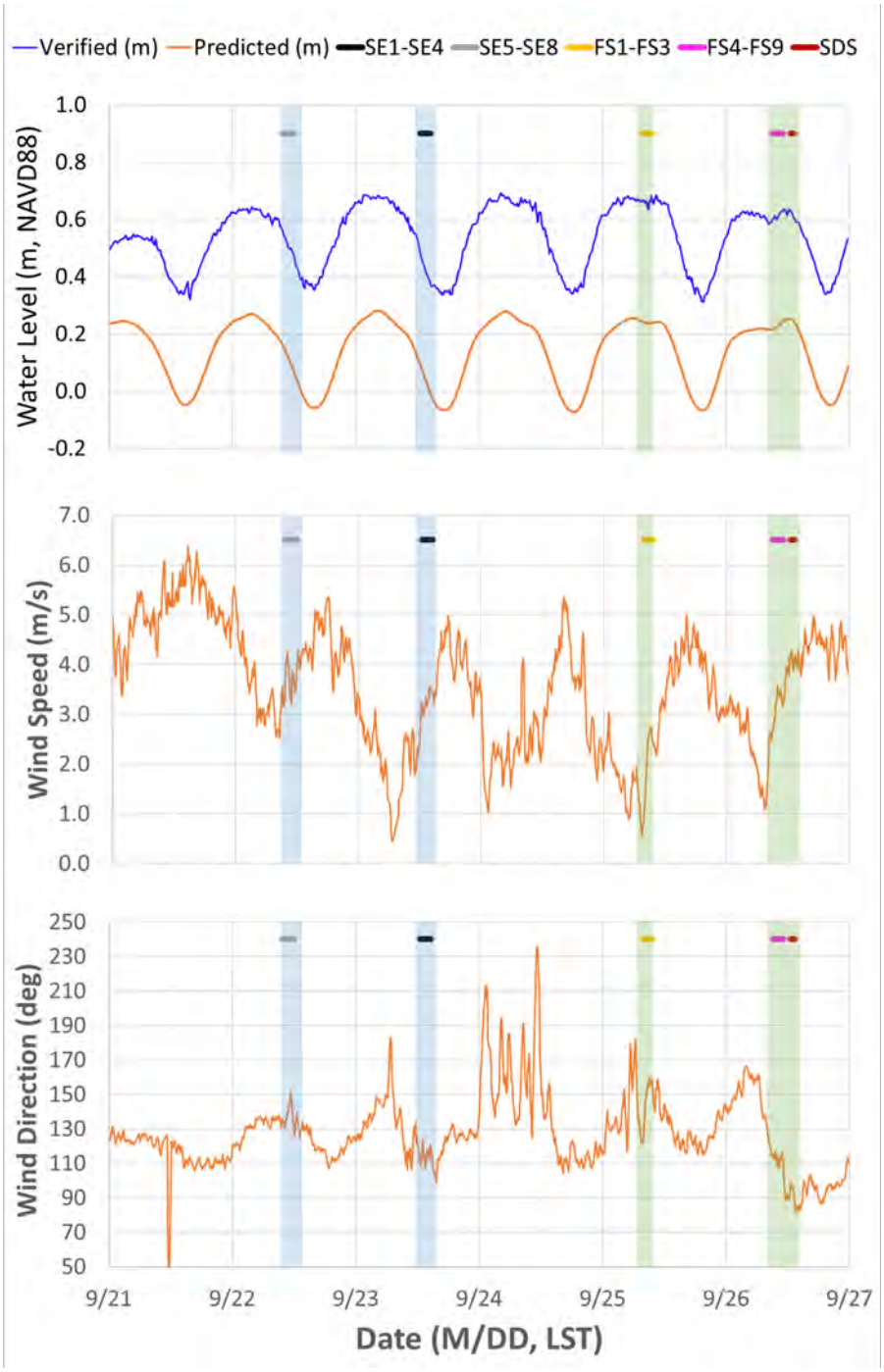

Figure 1.2: Verified (blue) and predicted (orange) water levels, wind speed, and direction from Sept. 21–26, 2019 in LST. Raw data were obtained from NOAA CO-OPS station Port Aransas, TX (ID: 8775237) and averaged over 30-minute intervals.

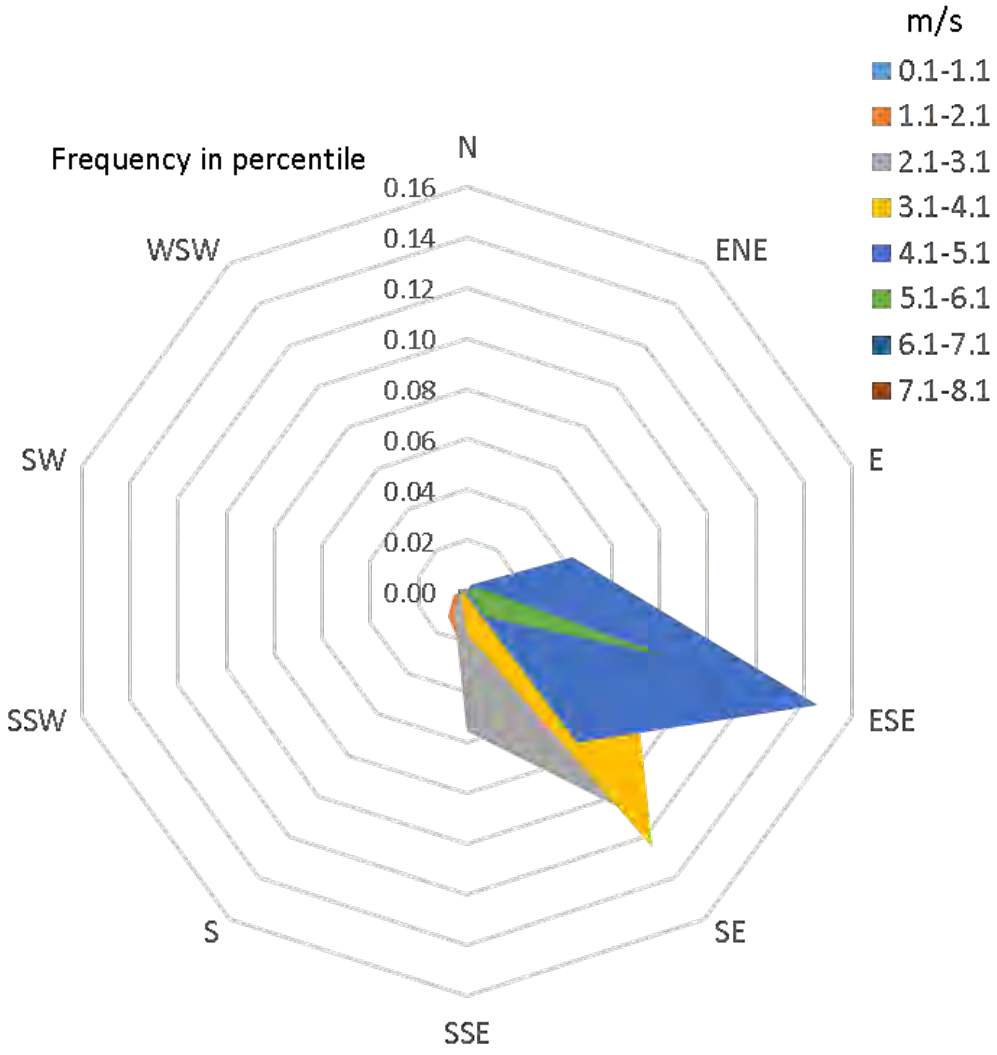

Figure 1.3: Wind rose summarizing winds observed at NOAA CO-OPS station Port Aransas (8775237) from Sept. 21 to Sept. 26, 2019.

Chapter 2

Methods

Field data on currents were measured using a TAMU-owned system consisting of an ADCP (Nortek Signature 1000) and a GNSS heading compass and positioning system mounted on a moon pole attached to a survey vessel as depicted in Figure 2.1. The vessel for the surveys was provided by subcontractor Naismith Marine Services, Inc. The Signature 1000 is a 1000-kHz, low form factor, 5-beam system capable of generating high-resolution 3D velocity profiles throughout the water column and has been upgraded with the VM firmware for vessel-mounted operations. The maximum profiling range is 30 m with a maximum number of cells of 128 (cell size 0.2 – 2 m). Velocity resolution is down to 0.1 cm/s with a minimum accuracy of +/- 0.3 cm/s. The maximum sampling rate is 14 Hz. Depth measurements are collected at a maximum sampling rate of 2 Hz with a vertical resolution of 0.001 m.

Current data were visualized in real time via computer screen onboard the vessel as a first check for quality control. The data were stored on the instrument's data logger and a field computer onboard the survey vessel. At the end of each survey day, all raw data were transferred to an additional backup hard drive and online cloud storage to provide redundancy, prevent data loss, and enable easy access. Post-processing and visualization of 3D current profile and positioning data were accomplished using the Nortek Signature VM Review (v1.9) software.

CTD profile measurements were conducted with a Sontek CastAway probe at various locations along the survey tracks. At each measuring location the probe was cast over the side of the vessel recording data continuously during its descent through the water column. Measuring locations were automatically geo-referenced via the integrated GPS sensor. The CTD data were checked and uploaded to the field laptop after each cast.

The entire field campaign was conducted over the course of 7 days between Sept. 21 and 26, 2019. It included two passes along the entire CCSH within the boundaries

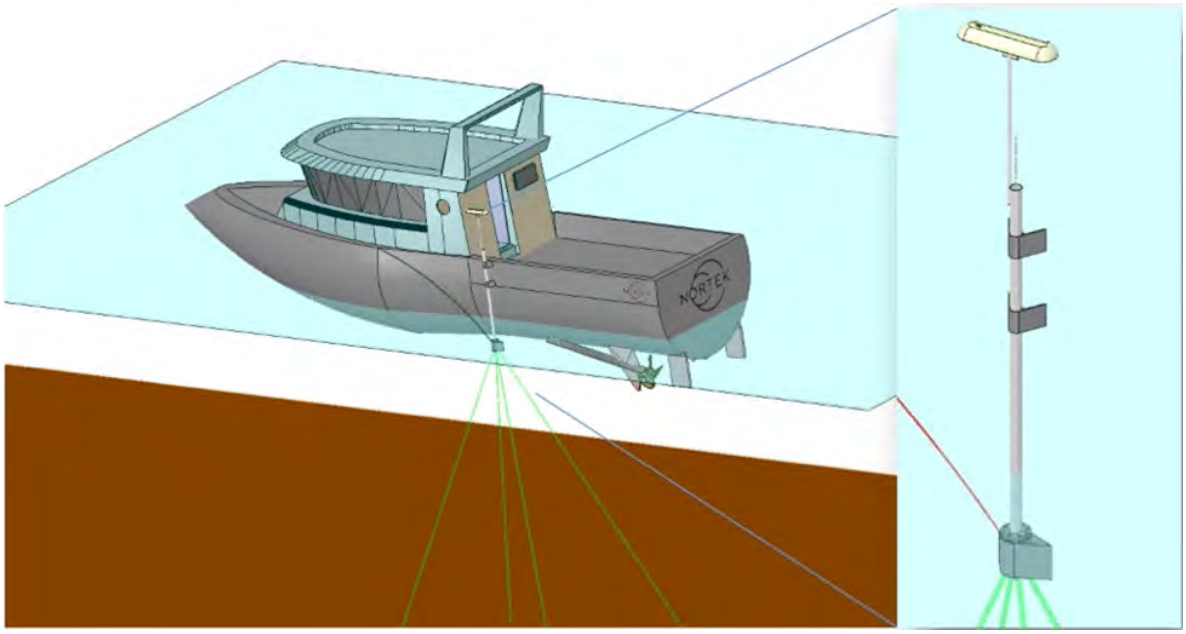

Figure 2.1: Schematic of the Signature 1000 ADCP and heading compass system setup. A moon pole is bracketed to the vessel hull with the ADCP on the bottom end (water) scanning downward and the GNSS heading compass at the top (air).

of the main ship lane. This ensures data collection at each point along the route at two different tide stages. An additional pass south of existing dredge spoil islands was completed as well (Fig. 1.1). Operating vessel speeds were between 3 and 6 knots to guarantee maneuverability while at the same time avoid excessive wake formation and bubble entrainment that could lower the quality of the collected current data. The ADCP scans covered the entire water column pointing downward starting from about 3 – 6 feet below the water surface. To avoid interference from passing vessel wakes, data collection was stopped to allow other vessels to pass and then resumed after residual wake motions from passing vessels had died down. This ensured untainted velocity data collection.

Data were recorded using UTC time stamps and are presented that way throughout the report unless otherwise stated. Some plots are shown using Local Standard Time (LST), i.e., –5 hours compared to UTC. Note that the order in which survey results are presented here follows logical segment patterns and not the chronological sequence of surveys.

Chapter 3

Results

In this chapter example plots and summaries of current profile and CTD measurements are presented. The data are separated into three survey paths, each containing slack to ebb tide or flood to slack tide passes of the survey vessel. The three segments are: (1) Port Ingleside to Aransas Pass, (2) Corpus Christi Inner Harbor, (3) Corpus Christi Inner Harbor to Port Ingleside.

Average speed and direction of currents are represented by U_{95}, defined as the time- and depth-averaged velocity of the measured portion of the water column. U_{95} was computed by first averaging the raw velocity ensembles within 95% of the total depth below the instrument at each sampling time. The ensemble velocities in the bottom 5% of the water column were disregarded in depth averaging to avoid any contamination from measuring errors that can occur close to the bed. The mean current velocities, $\overline{U_{95}}$, were calculated by averaging the depth-averaged velocity ensembles over a 3-second period (i.e., average of 6 depth-averaged velocity ensembles recorded at 2 Hz sampling rate).

3.1 Port Ingleside to Aransas Pass

3.1.1 Slack to Ebb Tide (SE5 – SE8)

During measurements along the survey path between Port Ingleside and Port Aransas, the tidal stage changed from slack to ebb (outgoing tide) between 9:00 and 16:00 on Sept. 22, 2019. The tidal water level reduced from 0.57 to 0.36 m (NAVD88) during the field measurement period and prevailing winds were southeasterly (SE) with directions in the 124° to 152° range (i.e., SE to SSE). The average wind speed varied between 3.2

and 4.4 m/s during the field measurement period (Figure 1.2). Table 3.1 details the individual segments (S1 - S5) making up the survey path and provides a summary of the wind (W_{30}) and water level (WL) conditions. In the following, depth-averaged velocity vectors along the survey path are displayed and statistical distributions of current speed and direction are presented for each individual segment. To visualize the distribution of current velocity throughout the water column and along the survey path, color maps of velocity distributions and select profiles of current speed and direction are given.

Table 3.1: Segment details, wind, and water level conditions for measurements between Port Ingleside and Port Aransas on Sept. 22, 2019

	Date & Time (LST, HH:MM)	Lat (UTM)	Lon (UTM)	Path Length (m) [# of ensembles]	Wind & Tide Avrg. (min - max)
S1 Start	2019-09-22 09:42	27° 48.8843 N	97° 13.2518 W	3784	W_{30min} (m/s | deg)
End	2019-09-22 10:02	27° 49.2256 N	97° 11.1691 W	[2397]	4.0 (3.2 - 4.4)
S2 Start	2019-09-22 10:05	27° 49.2182 N	97° 11.1715 W	2759	134 (124 - 152)
End	2019-09-22 10:22	27° 49.5262 N	97° 09.5136 W	[2046]	SE (SE - SSE)
S3 Start	2019-09-22 10:43	27° 49.5099 N	97° 09.6313 W	11273	WL (m, NAVD88)
End	2019-09-22 11:43	27° 50.3366 N	97° 02.8815 W	[7071]	0.45 (0.36 - 0.57)
S4 Start	2019-09-22 11:54	27° 50.1131 N	97° 02.5603 W	2065	
End	2019-09-22 12:07	27° 49.5643 N	97° 01.5255 W	[1631]	
S5 Start	2019-09-22 14:21	27° 49.8670 N	97° 07.8530 W	8083	
End	2019-09-22 15:04	27° 48.9940 N	97° 12.6467 W	[5185]	

3.1.1.1 East bound: S1 – S4

Figure 3.1 shows velocity vectors U_{95} along the 28,441 m long east bound survey path from Port Ingleside to Port Aransas. A total of 20,902 raw velocity ensembles were obtained from 14:42 to 17:08 (i.e. ∼2.4 hours) at a sampling rate of 2 Hz. Every 25^{th} mean velocity vector (∼ every 12 seconds) is displayed in Figure 3.1. Red boxes indicate the individual segment starting points and numbered yellow triangles show the locations where sample velocity profiles are plotted in subsequent figures.

Figure 3.2 displays the histogram for speed and direction of U_{95} within the survey segment S1, respectively.

Figure 3.3 shows velocity measurements throughout the water column and measured bed level along survey segment S1 in the top panel. Profiles of current speed and direction at the locations marked by white dashed lines are shown in the bottom panels.

Figure 3.1: Depth-averaged current vectors U_{95} for segments S1 – S4 during east bound survey between Port Ingleside and Port Aransas.

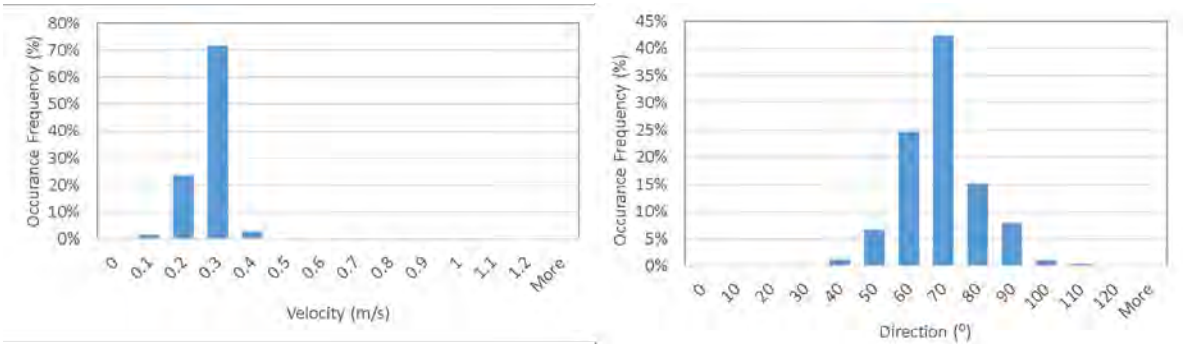

Figure 3.2: Histograms of speed (left panel) and direction (right panel) of U_{95} in survey segment S1 measured on 9/22/2019.

The locations of the white dashed lines correspond to locations of numbered yellow triangles (1-3) in Figure 3.1. These data are time-averaged over 3 seconds. Water depth within segment S1 varied between 16 and 18 m with an average depth of 17 m. The average mean current in this segment was 0.22 m/s and the most prevalent current direction was toward 64° from true north (ENE).

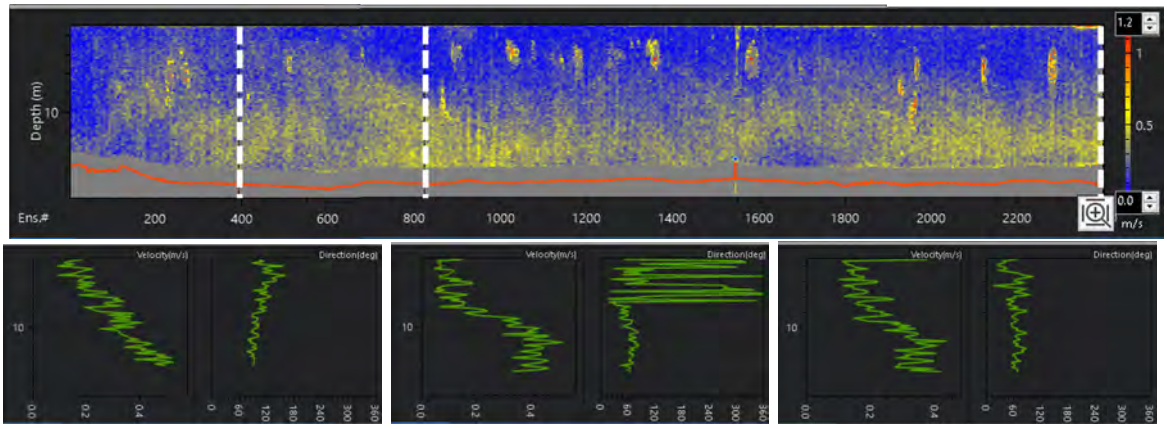

Figure 3.3: 3-second time-averaged velocity throughout the water column along survey segment S1 (top panel) measured on 9/22/2019. The solid (red) line indicates bottom position. Select profiles of current speed and direction at the locations of the white dashed lines are shown in the bottom panels.

The individual current profiles depicted in the bottom panels of Figure 3.3 indicate that the current speed tended to increase relatively uniformly from 0.10 m/s near the surface to 0.50 m/s near the bottom. At the relatively wide entrance near Ingleside Point (e.g., P1), the current speeds continued to increase below 3.0 m of water depth. However, in the relatively confined channel corridor toward Port Aransas (e.g., P2, P3), near surface currents tended to remain at low velocities ($<$ 0.2 m/s) up to a water depth of approximately 8 m beyond which the current speed increased somewhat rapidly between 8 to 10 m water depth. In such a case, the maximum velocity observed near the channel bed was normally no greater than 0.4 m/s. The current directional profiles prominently indicated a current heading within the 60° to 70° range in line with the channel orientation (ENE). However, near surface flow values below 0.2 m/s led to some dispersed current direction values between 0° and 360°, which could be the result of erroneous readings in very low current situations.

Figure 3.4 displays the histogram for speed and direction of U_{95} within the survey segment S2, respectively.

Figure 3.5 shows velocity measurements throughout the water column and measured bed level along survey segment S2 in the top panel. Profiles of current speed and direction at the locations marked by white dashed lines are shown in the bottom panels.

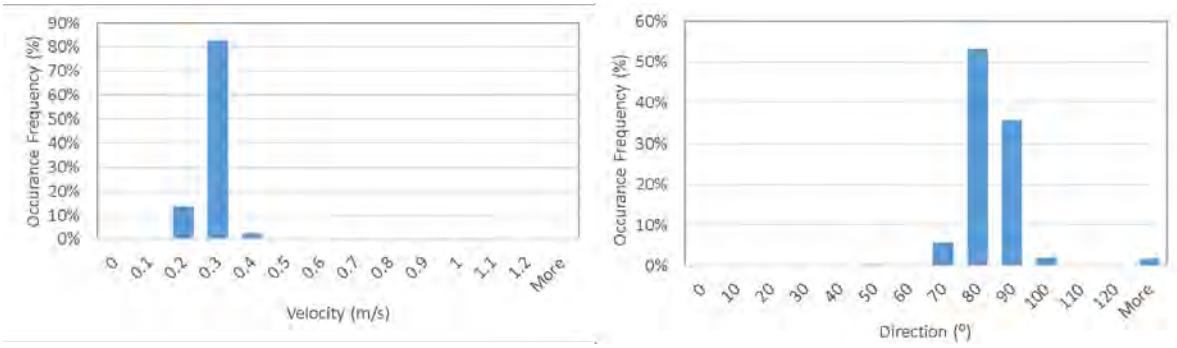

Figure 3.4: Histograms of speed (left panel) and direction (right panel) of U_{95} in survey segment S2 measured on 9/22/2019.

The locations of the white dashed lines correspond to locations of numbered yellow triangles (4-5) in Figure 3.1. These data are time-averaged over 3 seconds. Water depth within segment S2 varied between 16 and 18 m with an average depth of 17 m. The average mean current in this segment was 0.23 m/s and the most prevalent current direction was toward 81° from true north (E).

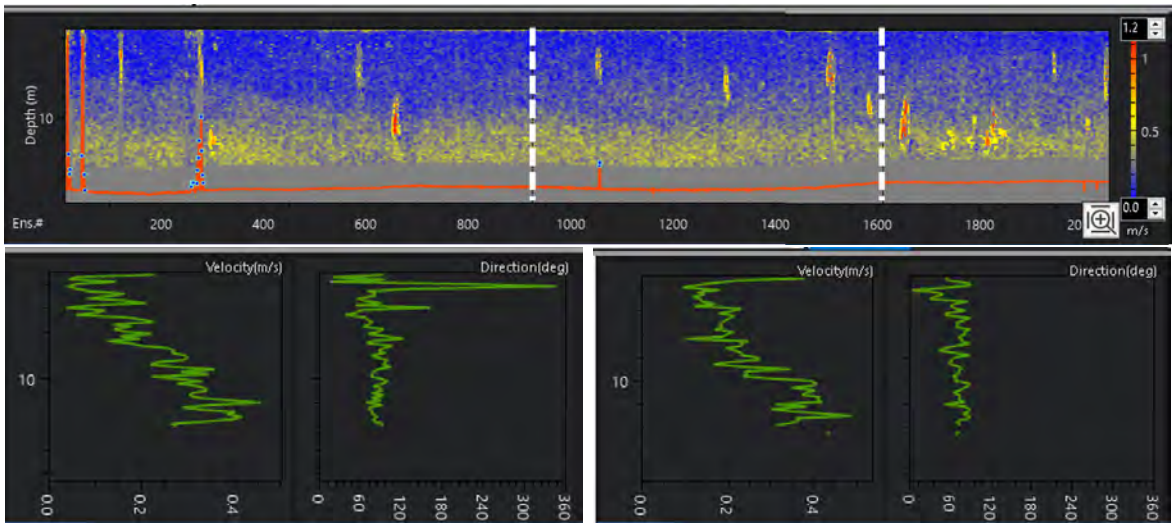

Figure 3.5: 3-second time-averaged velocity throughout the water column along survey segment S2 (top panel) measured on 9/22/2019. The solid (red) line indicates bottom position. Select profiles of current speed and direction at the locations of the white dashed lines are shown in the bottom panels.

The individual current profiles depicted in the bottom panels of Figure 3.5 indicated that the current speed tended to increase moderately, from 0.10 m/s near the surface to 0.40 m/s near the bottom. The current directional profiles indicate mostly 60° to 70°

current headings from true north. The overall velocity profiles observed across segment S2 exhibited similarity to previously observed currents at confined corridor locations (e.g., P2, P3). In addition, the low-velocity flows near the surface (P4, P5) tended to be be easily disturbed in areas near small openings between islands lining the channel.

Figure 3.6 displays the histogram for speed and direction of U_{95} within the survey segment S3, respectively.

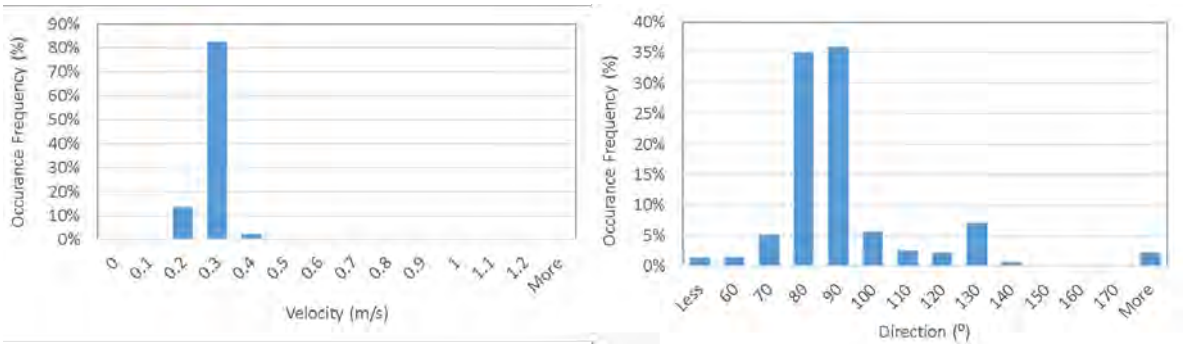

Figure 3.6: Histograms of speed (left panel) and direction (right panel) of U_{95} in survey segment S3 measured on 9/22/2019.

Figure 3.7 shows velocity measurements throughout the water column and measured bed level along survey segment S3 in the top panel. Profiles of current speed and direction at the locations marked by white dashed lines are shown in the bottom panels. The locations of the white dashed lines correspond to locations of numbered yellow triangles (6-8) in Figure 3.1. These data are time-averaged over 3 seconds. Water depth within segment S3 varied between 15 and 24 m with an average depth of 18 m within the main channel. The channel floor deepened sharply to 24 m at the turning point toward the east end of the CCSC inside Port Aransas. The average mean current in this segment was 0.48 m/s and the most prevalent current direction was toward 89° from true north (E).

The individual current profiles depicted in the bottom panels of Figure 3.7 exhibit fairly uniform currents over depth as low as 0.4 m/s at the entrance to Redfish Bay (P6). However, the velocity profiles tended to differ markedly across the confined channel corridor between Port Aransas and Harbor Island (P7) due to increase in near surface velocities. The flow speed within the top 10 m of water column tended to increase to values between 0.8 and 1.0 m/s. The near bed flow remained within the 0.4 to 0.5 m/s range, resulting in decreasing velocity profiles toward the channel floor. The directional profiles indicated prevalent 60° to 70° current headings in line with the channel orientation. At the junction between the CCSC and Aransas channel, the bottom currents increased to form a depth-uniform current with values between 0.6 to

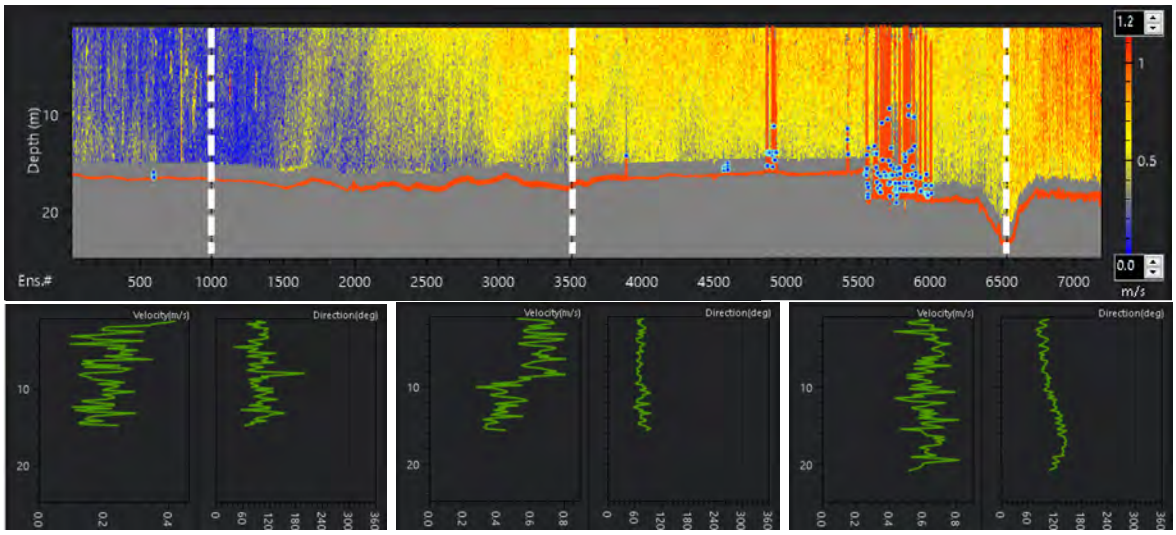

Figure 3.7: 3-second time-averaged velocity throughout the water column along survey segment S3 (top panel) measured on 9/22/2019. The solid (red) line indicates bottom position. Select profiles of current speed and direction at the locations of the white dashed lines are shown in the bottom panels.

0.8 m/s (P8). The current heading was reoriented to about 120° toward the oceanside channel opening.

Figure 3.8 displays the histogram for speed and direction of U_{95} within the survey segment S4, respectively.

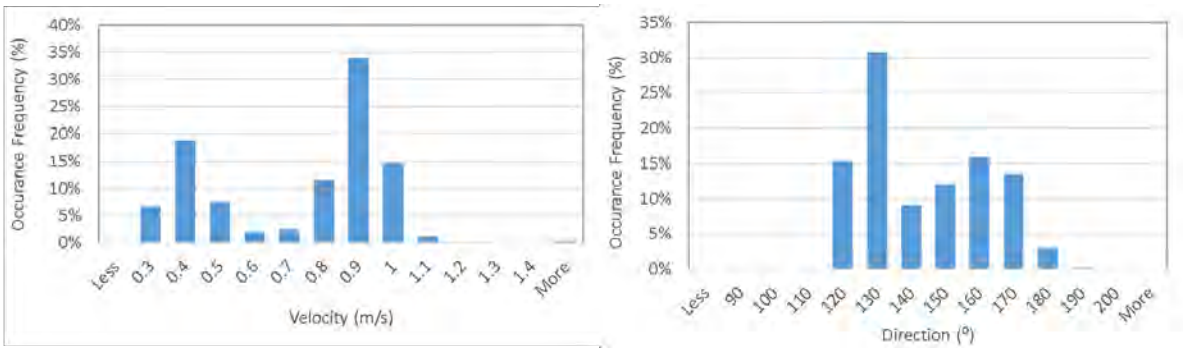

Figure 3.8: Histograms of speed (left panel) and direction (right panel) of U_{95} in survey segment S4 measured on 9/22/2019.

Figure 3.9 shows velocity measurements throughout the water column and measured bed level along survey segment S4 in the top panel. Profiles of current speed and direction at the locations marked by white dashed lines are shown in the bottom panels.

The locations of the white dashed lines correspond to locations of numbered yellow triangles (9-10) in Figure 3.1. These data are time-averaged over 3 seconds. Water depth within segment S4 varied between 15 and 25 m with an average depth of 20 m within the main channel. The channel floor deepened sharply to 24 m at the turning point toward the east end of the CCSC inside Port Aransas. The average mean current in this segment was 0.85 m/s and the most prevalent current direction was toward 129° from true north (SE). At the jetty exit to the Gulf of Mexico, current speeds up to 1.6 m/s were measured. The mean current reduced to values between 0.2 and 0.5 m/s at the southeast end of segment S4 located farther offshore in the Gulf of Mexico.

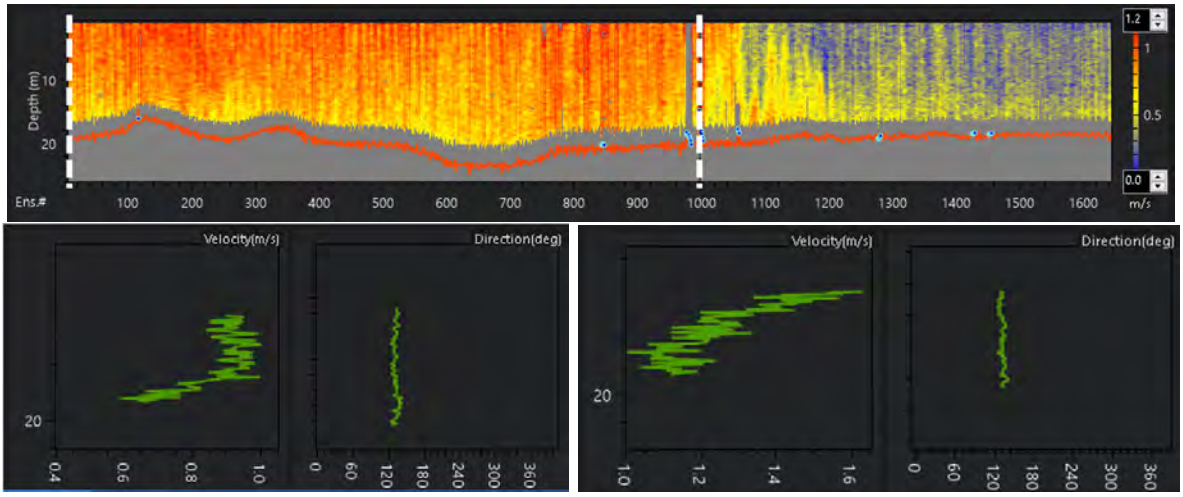

Figure 3.9: 3-second time-averaged velocity throughout the water column along survey segment S4 (top panel) measured on 9/22/2019. The solid (red) line indicates bottom position. Select profiles of current speed and direction at the locations of the white dashed lines are shown in the bottom panels.

3.1.1.2 CTD measurements

Profiles of conductivity and temperature over the entire depth of water were measured at the beginning of segment S1 (in the ship channel near Ingleside) and at the beginning of segment S4 (just inside the jetties) using the Sontek CastAway instrument described in Chapter 2. Profiles of water density and salinity are derived from the measured parameters. The date and time of the measurement was 9/22/2019 at 14:36 in the S1 segment and 9/22/2019 at 17:52 in the S4 segment. Figures 3.10 and 3.11 show depth profile plots of conductivity, density, temperature, and salinity at the respective locations of the field measurements in the top panels. The coordinates of the measurements are displayed in the map making up the bottom panel of each respective figure.

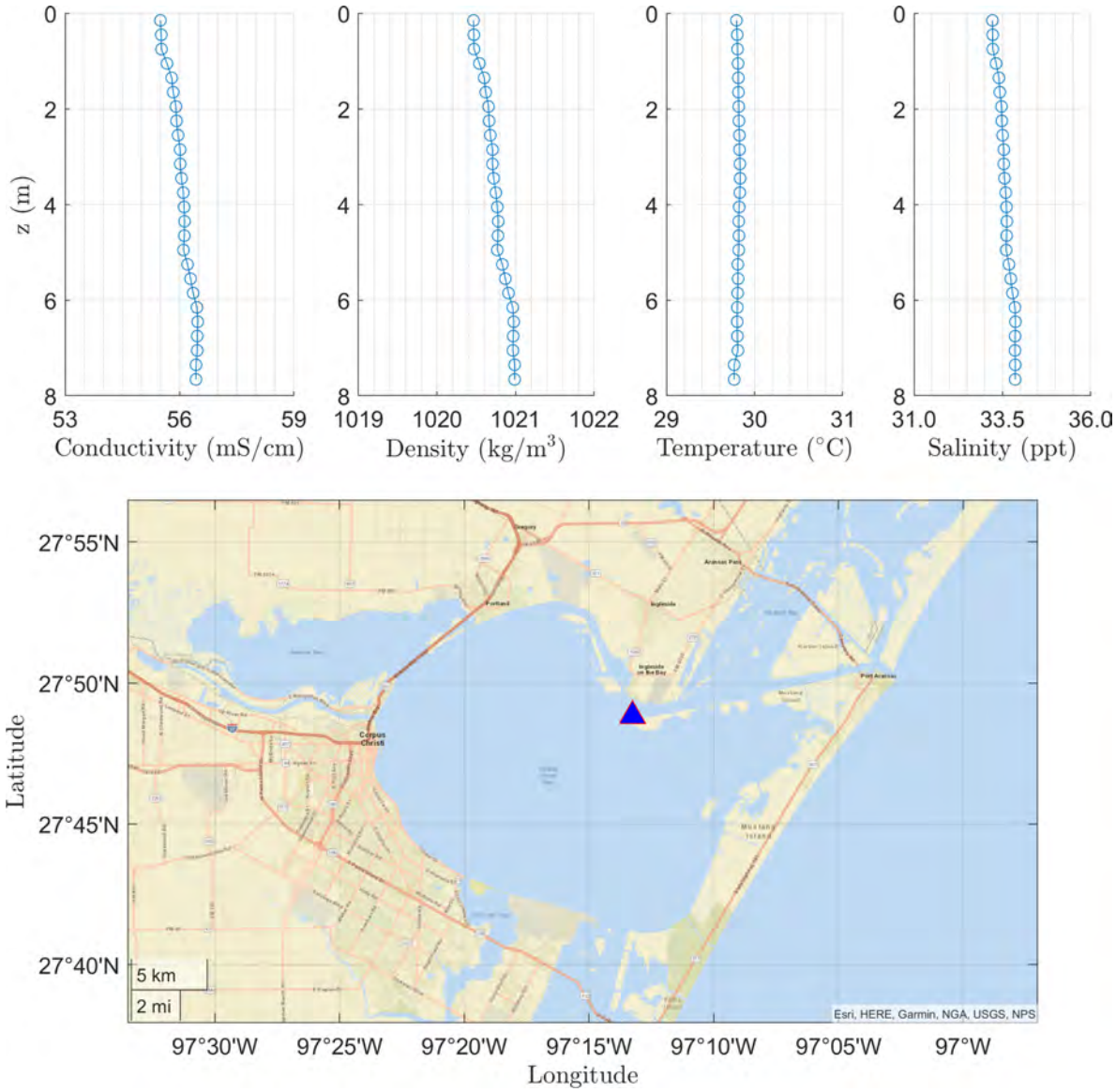

Figure 3.10: Profiles of conductivity, density, temperature, and salinity measured on 9/22/2019 at 14:36 at the beginning of survey segment S1 (top panels). The location of the measurement is indicated by the blue triangle in the map shown in the bottom panel.

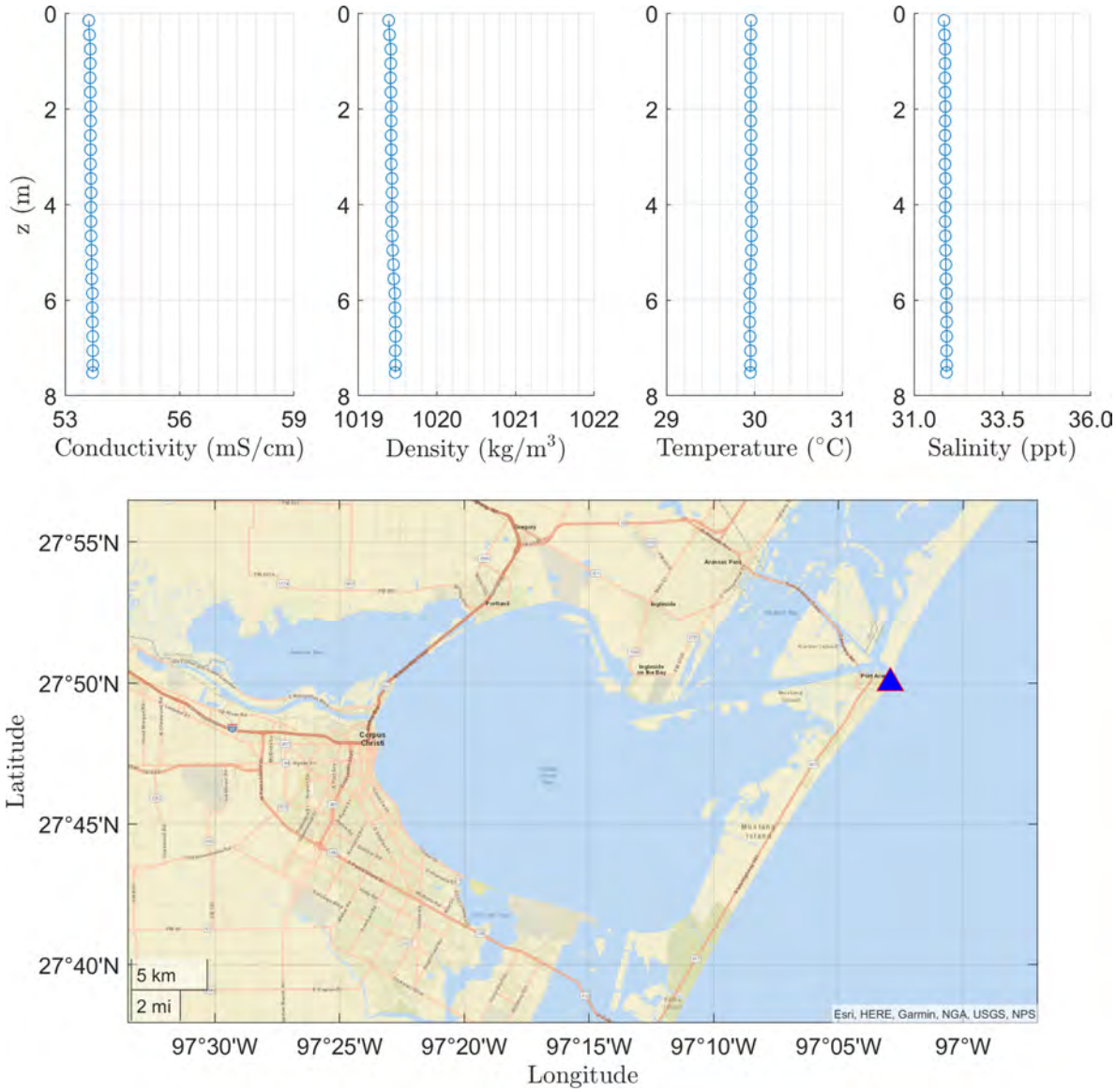

Figure 3.11: Profiles of conductivity, density, temperature, and salinity measured on 9/22/2019 at 17:52 at the beginning of survey segment S4 (top panels). The location of the measurement is indicated by the blue triangle in the map shown in the bottom panel.

3.1.1.3 West bound: S5

Figure 3.12 shows velocity vectors U_{95} along the 1,625 m long west bound survey path from Port Aransas to Port Ingleside. A total of 1,172 raw velocity ensembles were obtained on 2019-09-22 from 19:20 to 20:05 (i.e. $\sim$ 0.7 hours) at a sampling rate of 2 Hz. Every 25^{th} mean velocity vector ($\sim$ every 12 seconds) is displayed in Figure 3.12. The red box indicates the individual segment S5 starting point and numbered yellow triangles show the locations where sample velocity profiles are plotted in subsequent figures.

Figure 3.12: Depth-averaged current vectors U_{95} for segment S5 during west bound survey between Port Aransas and Port Ingleside.

Figure 3.13 displays the histogram for speed and direction of U_{95} within the survey segment S5, respectively.

Figure 3.14 shows velocity measurements throughout the water column and measured bed level along survey segment S5 in the top panel. Profiles of current speed and direction at the locations marked by white dashed lines are shown in the bottom panels. The locations of the white dashed lines correspond to locations of numbered yellow triangles (11-13) in Figure 3.12. These data are time-averaged over 3 seconds. Water depth within segment S5 varied between 14 and 18 m with an average depth of 17 m within the main channel. The average mean current in this segment was 0.51 m/s and the most prevalent current direction was toward 93° from true north (E).

Table 3.2 provides a summary of the conditions measured between Port Ingleside and Port Aransas in segments S1 – S5. The mean currents varied from 0.2 to 2.0 m/s. The average currents were minimal near Ingleside on the Bay and increased at the offshore

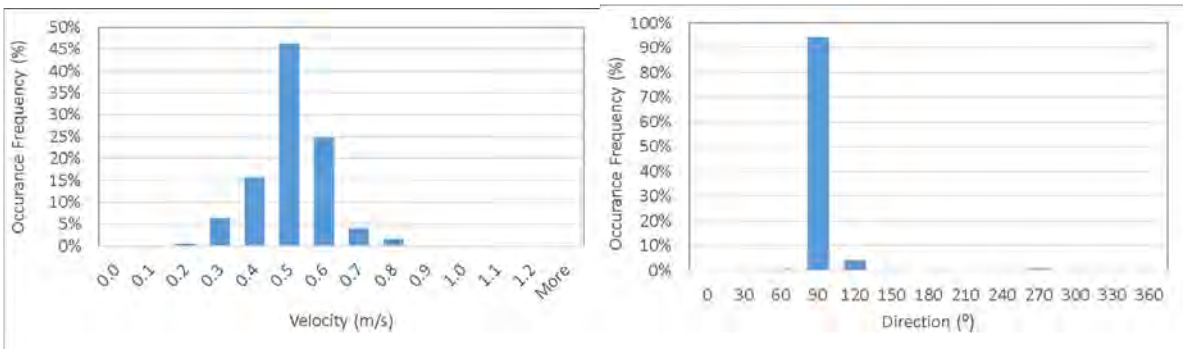

Figure 3.13: Histograms of speed (left panel) and direction (right panel) of U_{95} in survey segment S5 measured on 9/22/2019.

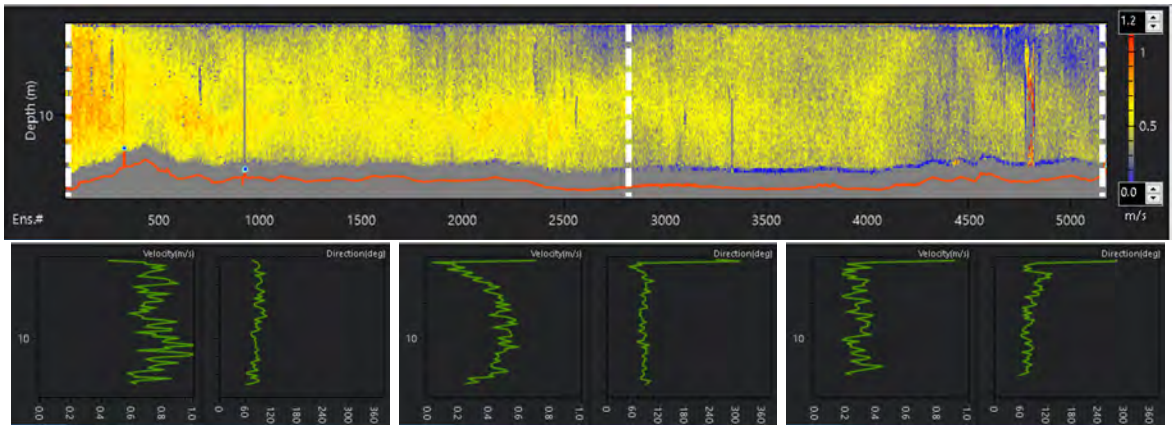

Figure 3.14: 3-second time-averaged velocity throughout the water column along survey segment S5 (top panel) measured on 9/22/2019. The solid (red) line indicates bottom position. Select profiles of current speed and direction at the locations of the white dashed lines are shown in the bottom panels.

end of the jettied Port Aransas inlet. The prevalent current headings were toward east-northeast and east (ENE - E) in line with the orientation of the channel alignment and prominent direction of the receding tidal flows. A southeasterly wind was prevalent in the area during the field measurement period.

Table 3.2: Summary of average water depth and mean currents between Port Ingleside and Port Aransas (S1 – S5) on Sept. 22, 2019 during slack to ebb tide.

	S1	S2	S3	S4	S5
D (m)	17 (16 - 18)	17 (16 - 18)	18 (14 - 24)	20 (15 - 25)	17(14 - 18)
U_{95} (m/s | °)	0.22 (0.07 - 0.40)	0.23 (0.15 - 0.30)	0.48 (0.2 - 0.5)	0.85 (0.5 - 2.0)[1]	0.51 (0.3 - 0.8)
	64 (26 - 112)	81 (60 - 96)	89 (70 - 130)	129 (174 - 110)[1]	93 (90 - 120)
	ENE (NNE - ESE)	E (ENE - E)	E (ENE - SE)	SE (S - ESE)[1]	E (E - ESE)

[1] Based on the current velocities observed on the onshore side of the outlet

3.1.1.4 CTD measurements

Profiles of conductivity and temperature over the entire depth of water were measured at the end of segment S5 (in the ship channel near Ingleside) using the Sontek Cast-Away instrument described in Chapter 2. Profiles of water density and salinity are derived from the measured parameters. The date and time of the measurement was 9/22/2019 at 20:09. Figure 3.15 and shows depth profile plots of conductivity, density, temperature, and salinity at the location of the field measurement in the top panels. The coordinates of the measurements are displayed in the map making up the bottom panel of the figure.

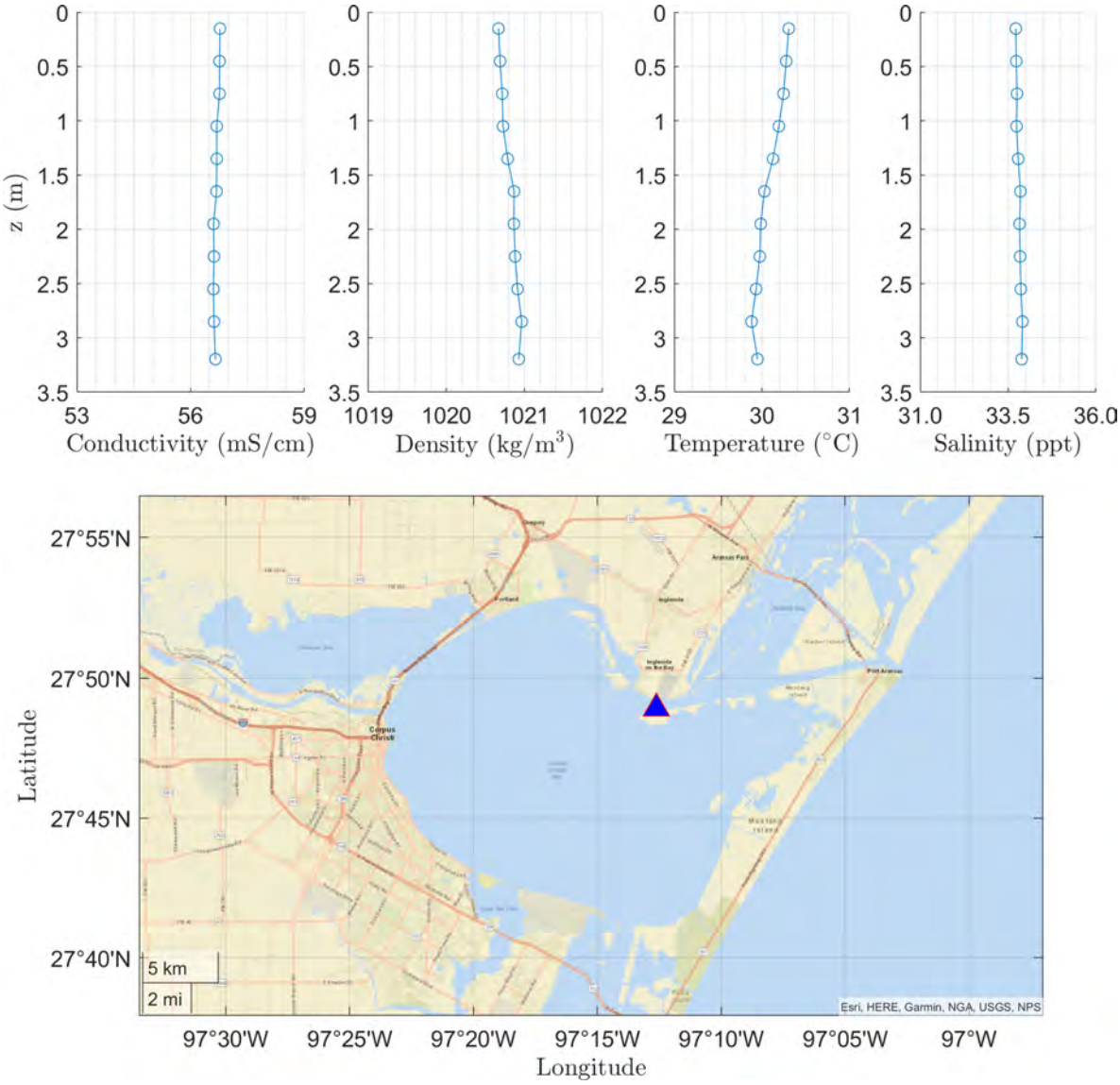

Figure 3.15: Profiles of conductivity, density, temperature, and salinity measured on 9/22/2019 at 20:09 at the end of survey segment S5 (top panels). The location of the measurement is indicated by the blue triangle in the map shown in the bottom panel.

3.1.2 Flood to Slack Tide (FS4 – FS9)

During measurements along the survey path between Port Ingleside and Port Aransas, the tidal stage changed from flood to slack tides between 8:00 and 14:00 on Sept. 26, 2019. The tidal water level reduced from 0.64 to 0.60 m (NAVD88) during the field measurement period and prevailing winds were southeasterly (SE) with directions in the 87° to 118° range (i.e., E to ESE). The average wind speed varied between 2.7 and 4.0 m/s during the field measurement period (Figure 1.2). Table 3.3 details the individual segments (S1 - S5) making up the survey path and provides a summary of the wind (W_{30}) and water level (WL) conditions. An additional segment labelled SDS (south of dredge spoils) is included as well. In the following, depth-averaged velocity vectors along the survey path are displayed and statistical distributions of current speed and direction are presented for each individual segment. To visualize the distribution of current velocity throughout the water column and along the survey path, color maps of velocity distributions and select profiles of current speed and direction are given.

Table 3.3: Segment details, wind, and water level conditions for measurements between Port Ingleside and Port Aransas on Sept. 26, 2019 during flood to slack tide.

		Date & Time (LST, HH:MM)	Lat (UTM)	Lon (UTM)	Path Length (m) [# of ensembles]	Wind & Tide Avrg. (min - max)
S1	Start	2019-09-26 09:06	27° 48.8001 N	97° 13.3841 W	1654	W_{30min} (m/s | deg)
	End	2019-09-26 09:17	27° 48.9927 N	97° 12.3550 W	[1271]	3.5 (2.7 - 4.0)
S2	Start	2019-09-26 09:20	27° 49.0514 N	97° 12.0858 W	1263	103 (87 - 118)
	End	2019-09-26 09:36	27° 49.3149 N	97° 10.6444 W	[1009]	ESE (E - ESE)
S3	Start	2019-09-26 09:46	27° 49.4869 N	97° 09.7304 W	10712	WL (m, NAVD88)
	End	2019-09-26 10:53	27° 50.6431 N	97° 03.3609 W	[8087]	0.62 (0.60 - 0.64)
S4	Start	2019-09-26 11:03	27° 50.6123 N	97° 03.3445 W	1697	
	End	2019-09-26 11:13	27° 50.0943 N	97° 02.4996 W	[1277]	
S5	Start	2019-09-26 11:21	27° 50.1227 N	97° 02.4777 W	1216	
	End	2019-09-26 11:30	27° 49.7465 N	97° 01.8811 W	[1040]	
SDS	Start	2019-09-26 12:39	27° 48.8814 N	97° 08.6504 W	8270	
	End	2019-09-26 13:24	27° 48.3546 N	97° 13.5853 W	[5324]	

3.1.2.1 West bound: S1 – S3

Figure 3.16 shows velocity vectors U_{95} along the 13,629 m long west bound survey path from Port Ingleside to Port Aransas. A total of 10,367 raw velocity ensembles were

obtained on 2019-09-26 from 14:06 to 15:53 (i.e. $\sim$ 1.8 hours) at a sampling rate of 2 Hz. Every 50^{th} mean velocity vector ($\sim$ every 25 seconds) is displayed in Figure 3.16. The red boxes indicate the individual segment starting points (S1 – S3) and numbered yellow triangles show the locations where sample velocity profiles are plotted in subsequent figures (1-6).

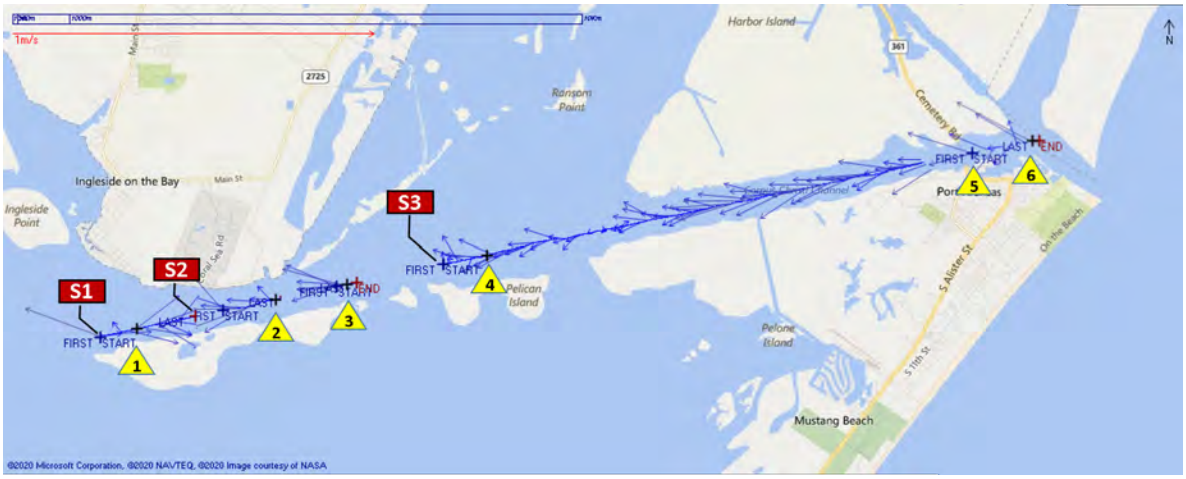

Figure 3.16: Depth-averaged current vectors U_{95} for segments S1 – S3 during west bound survey between Port Ingleside and Port Aransas.

Figure 3.17 displays the histogram for speed and direction of U_{95} within the survey segment S1, respectively.

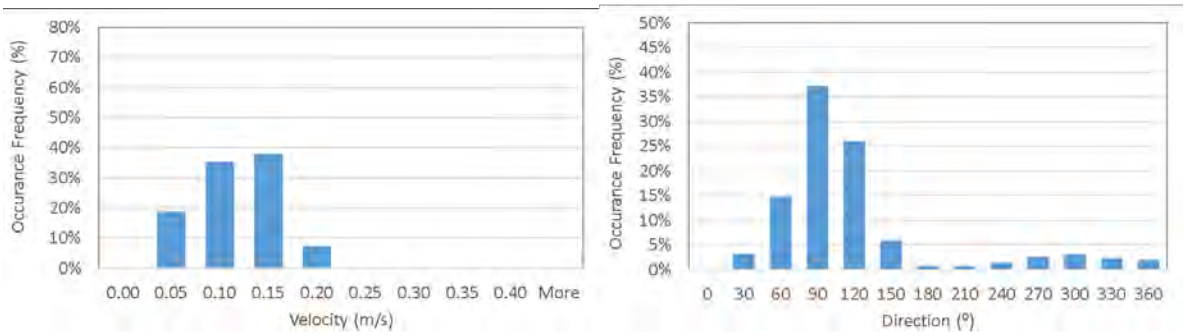

Figure 3.17: Histograms of speed (left panel) and direction (right panel) of U_{95} in survey segment S1 measured on 9/26/2019.

Figure 3.18 shows velocity measurements throughout the water column and measured bed level along survey segment S1 in the top panel. Profiles of current speed and direction at the locations marked by white dashed lines are shown in the bottom panels. The location of the white dashed line corresponds to the location of the numbered yellow

triangle (1) in Figure 3.16. These data are time-averaged over 3 seconds. Water depth within segment S1 varied between 16 and 18 m with an average depth of 17 m. The average mean current in this segment was 0.12 m/s and the most prevalent current direction was toward 106° from true north (i.e., toward ESE).

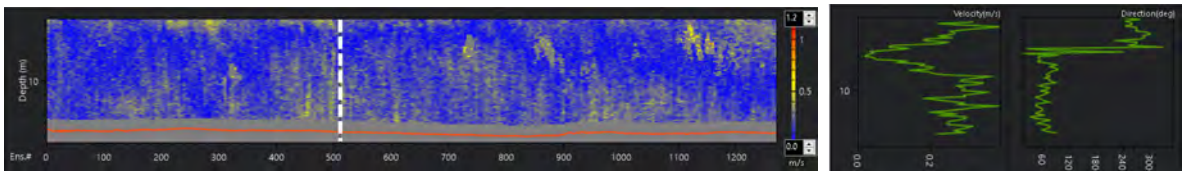

Figure 3.18: 3-second time-averaged velocity throughout the water column along survey segment S1 (left panel) measured on 9/26/2019. The solid (red) line indicates bottom position. Profiles of current speed and direction at the location of the white dashed line are shown in the right panel.

Figure 3.19 displays the histogram for speed and direction of U_{95} within the survey segment S2, respectively.

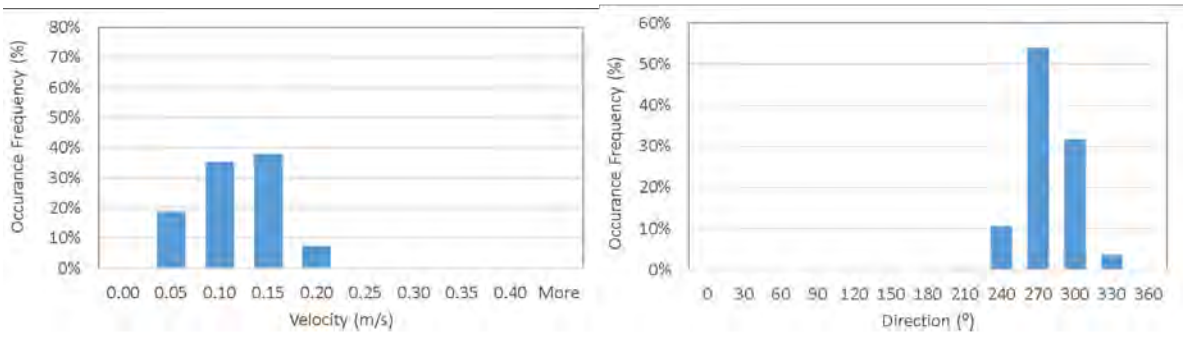

Figure 3.19: Histograms of speed (left panel) and direction (right panel) of U_{95} in survey segment S2 measured on 9/26/2019.

Figure 3.20 shows velocity measurements throughout the water column and measured bed level along survey segment S2 in the top panel. Profiles of current speed and direction at the locations marked by white dashed lines are shown in the bottom panels. The location of the white dashed lines correspond to the locations of the numbered yellow triangles (2-3) in Figure 3.16. These data are time-averaged over 3 seconds. Water depth within segment S2 varied between 14 and 18 m with an average depth of 17 m. The average mean current in this segment was 0.12 m/s and the most prevalent current direction was toward 278° from true north (i.e., toward W).

Figure 3.21 displays the histogram for speed and direction of U_{95} within the survey segment S3, respectively.

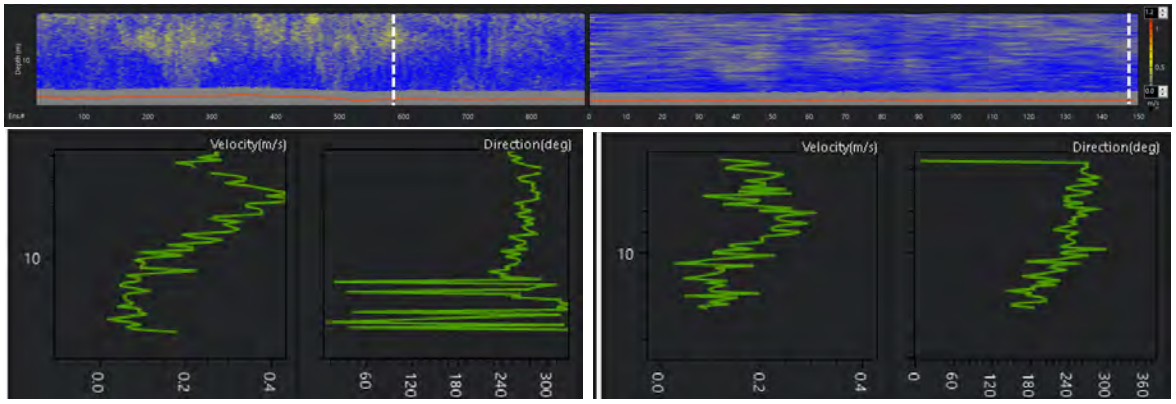

Figure 3.20: 3-second time-averaged velocity throughout the water column along survey segment S2 (top panel) measured on 9/26/2019. The solid (red) line indicates bottom position. Profiles of current speed and direction at the locations of the white dashed lines are shown in the bottom panels.

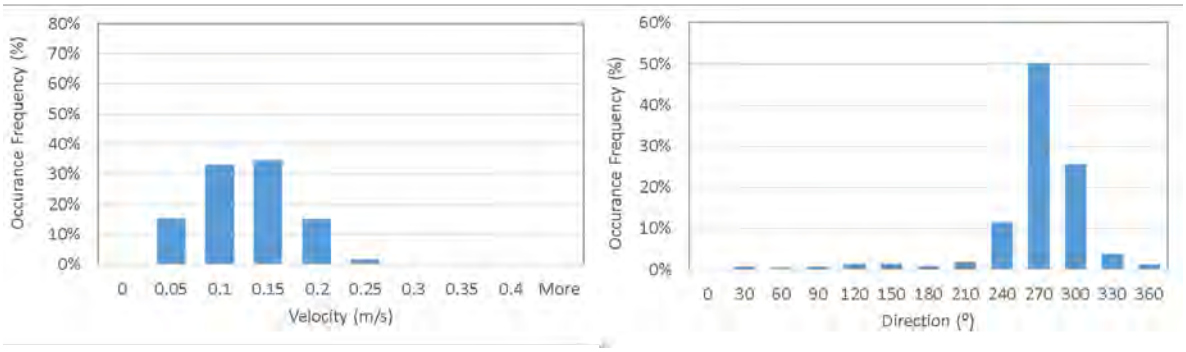

Figure 3.21: Histograms of speed (left panel) and direction (right panel) of U_{95} in survey segment S3 measured on 9/26/2019.

Figure 3.22 shows velocity measurements throughout the water column and measured bed level along survey segment S3 in the top panel. Profiles of current speed and direction at the locations marked by white dashed lines are shown in the bottom panels. The location of the white dashed lines correspond to the locations of the numbered yellow triangles (4-6) in Figure 3.16. These data are time-averaged over 3 seconds. Water depth within segment S3 varied between 15 and 19 m with an average depth of 17 m. The average mean current in this segment was 0.13 m/s and the most prevalent current direction was toward 268° from true north (i.e., toward W).

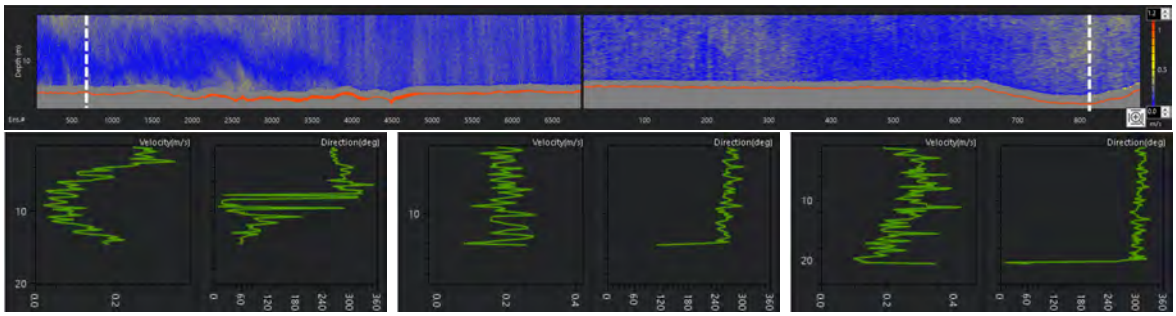

Figure 3.22: 3-second time-averaged velocity throughout the water column along survey segment S3 (top panel) measured on 9/26/2019. The solid (red) line indicates bottom position. Profiles of current speed and direction at the locations of the white dashed lines are shown in the bottom panels.

3.1.2.2 CTD measurements

Profiles of conductivity and temperature over the entire depth of water were measured at the beginning of segment S1 (in the ship channel near Ingleside) using the Sontek CastAway instrument described in Chapter 2. Profiles of water density and salinity are derived from the measured parameters. The date and time of the measurement was 9/26/2019 at 12:36. Figure 3.23 and shows depth profile plots of conductivity, density, temperature, and salinity at the location of the field measurement in the top panels. The coordinates of the measurements are displayed in the map making up the bottom panel of the figure.

3.1.2.3 East bound: S4 – S5

Figure 3.24 shows velocity vectors U_{95} along the 2,913 m long east bound survey path from Port Aransas out through the jetty. A total of 2,317 raw velocity ensembles were obtained on 2019-09-26 from 16:03 to 16:30 (i.e. $\sim$ 0.5 hours) at a sampling rate of

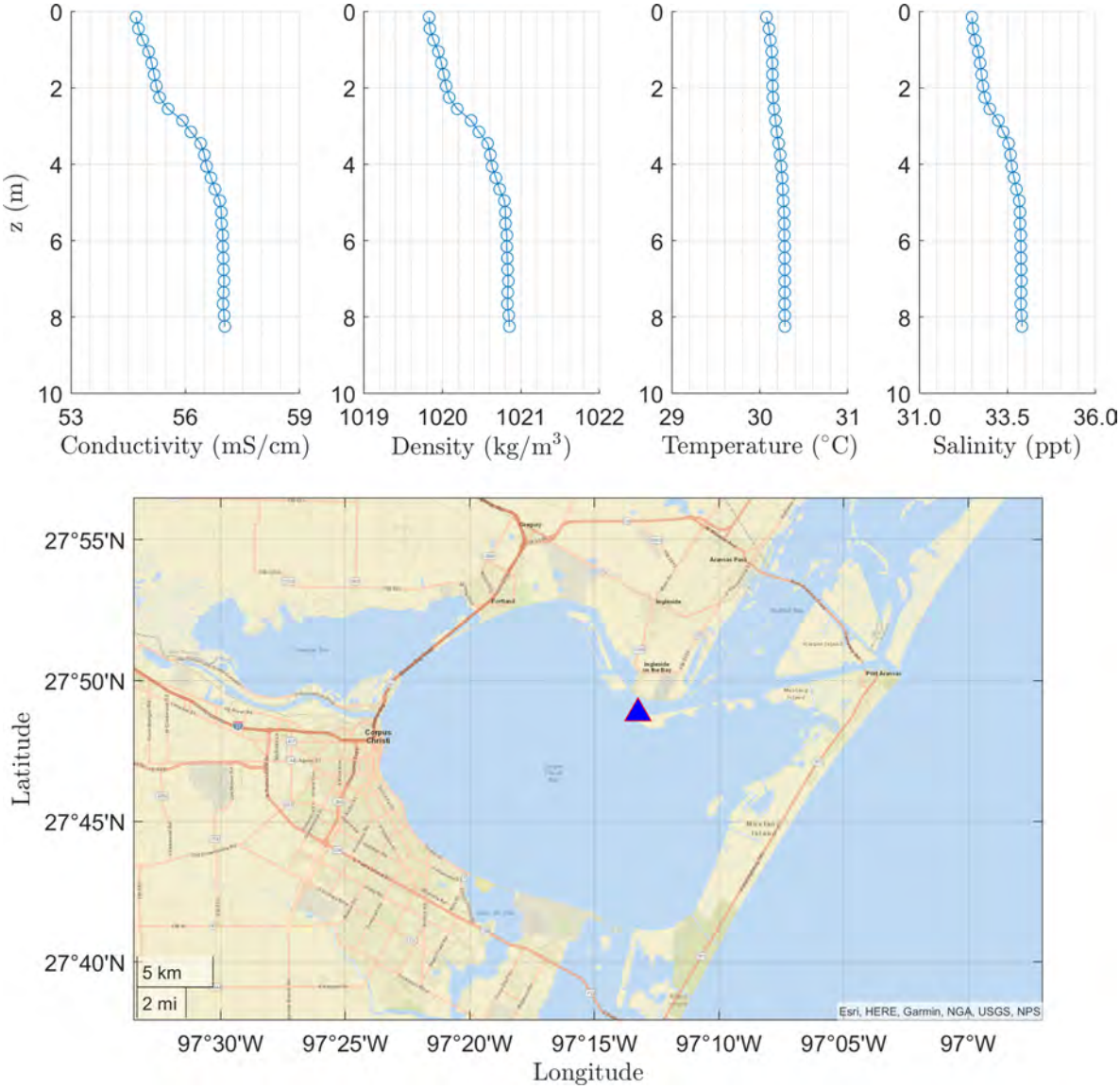

Figure 3.23: Profiles of conductivity, density, temperature, and salinity measured on 9/26/2019 at 12:36 at the beginning of survey segment S1 (top panels). The location of the measurement is indicated by the blue triangle in the map shown in the bottom panel.

2 Hz. Every 50^{th} mean velocity vector ($\sim$ every 25 seconds) is displayed in Figure 3.24. The red boxes indicate the individual segment starting points (S4 – S5) and numbered yellow triangles show the locations where sample velocity profiles are plotted in subsequent figures (7-9).

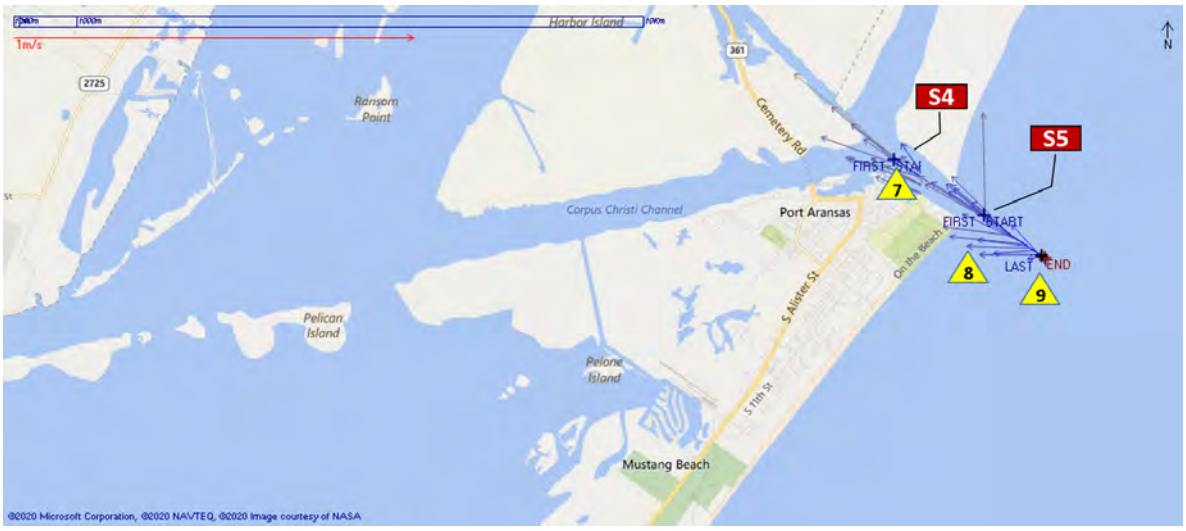

Figure 3.24: Depth-averaged current vectors U_{95} for segments S4 – S5 during east bound survey from Port Aransas out through the jetty.

Figure 3.25 displays the histogram for speed and direction of U_{95} within the survey segment S4, respectively.

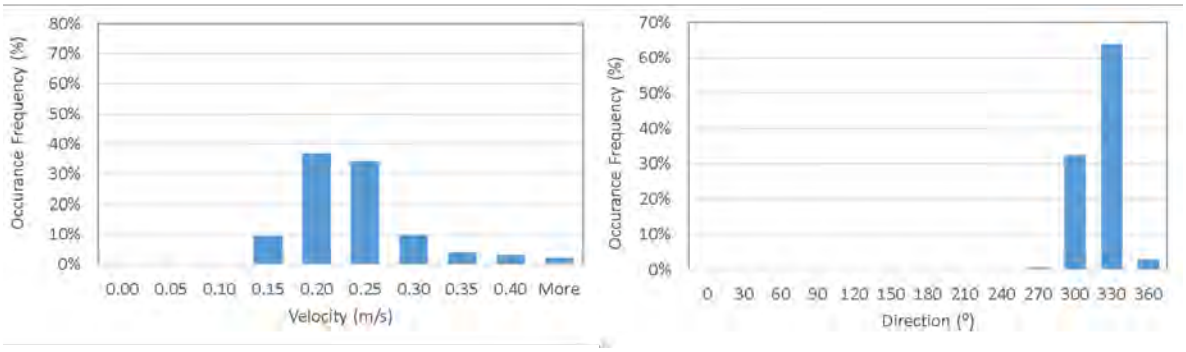

Figure 3.25: Histograms of speed (left panel) and direction (right panel) of U_{95} in survey segment S4 measured on 9/26/2019.

Figure 3.26 shows velocity measurements throughout the water column and measured bed level along survey segment S4 in the top panel. Profiles of current speed and direction at the locations marked by white dashed lines are shown in the bottom panels.

The location of the white dashed lines correspond to the locations of the numbered yellow triangles (7-8) in Figure 3.24. These data are time-averaged over 3 seconds. Water depth within segment S4 varied between 15 and 25 m with an average depth of 20 m. The average mean current in this segment was 0.23 m/s and the most prevalent current direction was toward 321° from true north (i.e., toward NW).

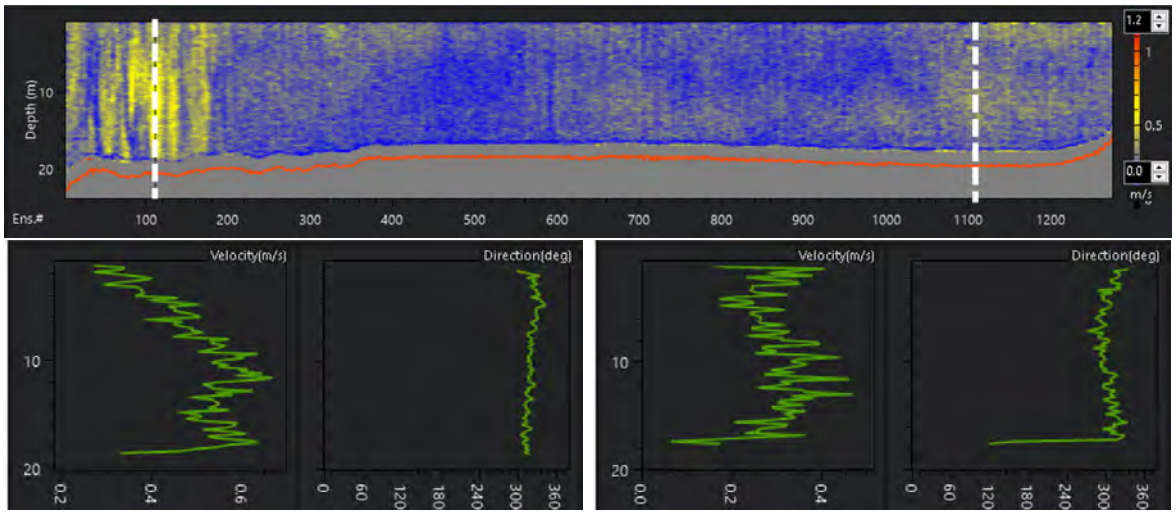

Figure 3.26: 3-second time-averaged velocity throughout the water column along survey segment S4 (top panel) measured on 9/26/2019. The solid (red) line indicates bottom position. Profiles of current speed and direction at the locations of the white dashed lines are shown in the bottom panels.

Figure 3.27 displays the histogram for speed and direction of U_{95} within the survey segment S5, respectively.

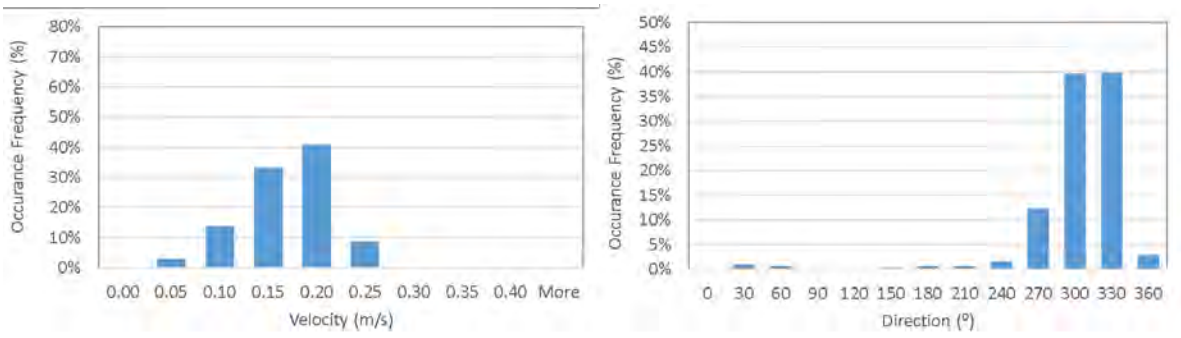

Figure 3.27: Histograms of speed (left panel) and direction (right panel) of U_{95} in survey segment S5 measured on 9/26/2019.

Figure 3.28 shows velocity measurements throughout the water column and measured

bed level along survey segment S5 in the left panel. Profiles of current speed and direction at the location marked by white dashed line are shown in the right panel. The location of the white dashed line corresponds to the location of the numbered yellow triangle (9) in Figure 3.24. These data are time-averaged over 3 seconds. Water depth within segment S5 varied between 16 and 24 m with an average depth of 20 m. The average mean current in this segment was 0.17 m/s and the most prevalent current direction was toward 302° from true north (i.e., toward NW).

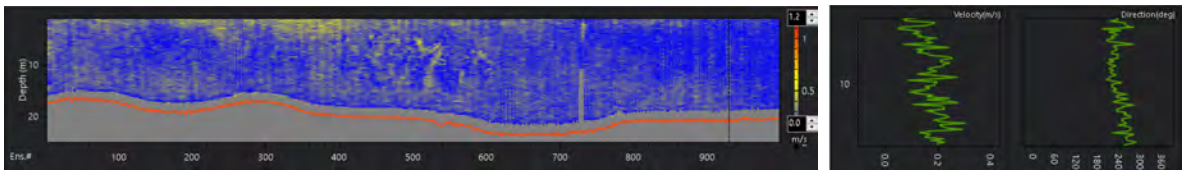

Figure 3.28: 3-second time-averaged velocity throughout the water column along survey segment S5 (left panel) measured on 9/26/2019. The solid (red) line indicates bottom position. Profiles of current speed and direction at the location of the white dashed line are shown in the right panel.

Table 3.4 provides a summary of the conditions measured between Port Ingleside and Port Aransas in segments S1 – S5 as the tidal stage changed from flood to slack tides between 08:00 and 14:00 on September 26, 2019. The mean currents varied from 0.05 to 0.25 m/s throughout the ship channel with a slight increase up to 0.4 m/s at the Port Aransas inlet. The prevalent current headings were toward west and north-west (W - NW) in line with the orientation of the channel alignment and prominent direction of the mean tidal flows. One exception was the current observed at the narrowing entrance near Ingleside on the Bay where an onshore direction toward east-southeast was measured. An east-southeasterly (ESE) wind was prevalent in the area during the field measurement period (87° to 118° from true north).

Table 3.4: Summary of average water depth and mean currents between Port Ingleside and Port Aransas on Sept. 26, 2019 during flood to slack tide.

	S1	S2	S3	S4	S5	SDS
D (m)	17 (16 - 18)	17 (16 - 18)	17 (15 - 19)	20 (15 - 25)	20 (16 - 24)	1.0 - 4.5
U_{95} (m/s | °)	0.12 (0.05 - 0.20)	0.12 (0.05 - 0.20)	0.13 (0.05 - 0.25)	0.23 (0.15 - 0.40)	0.17 (0.05 - 0.25)	0.12 (0.05 - 0.25)
	106 (30 - 150)	278 (210 - 330)	268 (240 -330)	321 (300 - 360)	302 (270 - 330)	275[1] (30 - 360)
	ESE (NNE - SSE)	W (SSW - NNW)	W (WSW - NNW)	NW (WNW - N)	WNW (W - NNW)	W[1] (NNE - N)

[1] The prevalent current direction was calculated by disregarding the currents heading dispersed in the 0 - 180° range.

3.1.2.4 South Dredge Spoils (SDS)

An additional survey pass was made south of existing dredge material placement islands lining the south side of the CCSH between Port Aransas and Port Ingleside. Figure 3.29 shows velocity vectors U_{95} along the 8,270 m long west bound survey path just south of the islands. A total of 5,324 raw velocity ensembles were obtained on 2019-09-26 from 17:39 to 18:24 (i.e. $\sim$ 0.7 hours) at a sampling rate of 2 Hz. Every 50^{th} mean velocity vector ($\sim$ every 25 seconds) is displayed in Figure 3.29. The red box indicates the segment starting point (SDS) and numbered yellow triangles show the locations where sample velocity profiles are plotted in subsequent figures (10-12).

Figure 3.29: Depth-averaged current vectors U_{95} for segment SDS during west bound survey south of the dredge spoil islands.

Figure 3.30 displays the histogram for speed and direction of U_{95} within the survey segment SDS, respectively.

Figure 3.31 shows velocity measurements throughout the water column and measured bed level along survey segment SDS in the top panel. Profiles of current speed and direction at the locations marked by white dashed lines are shown in the bottom panels. The location of the white dashed lines corresponds to the locations of the numbered yellow triangles (10-12) in Figure 3.29. These data are time-averaged over 3 seconds. Water depth within segment SDS varied between 1.0 and 4.5 m. The average mean current in this segment was 0.12 m/s and the most prevalent current direction was toward 275° from true north (i.e., toward W).

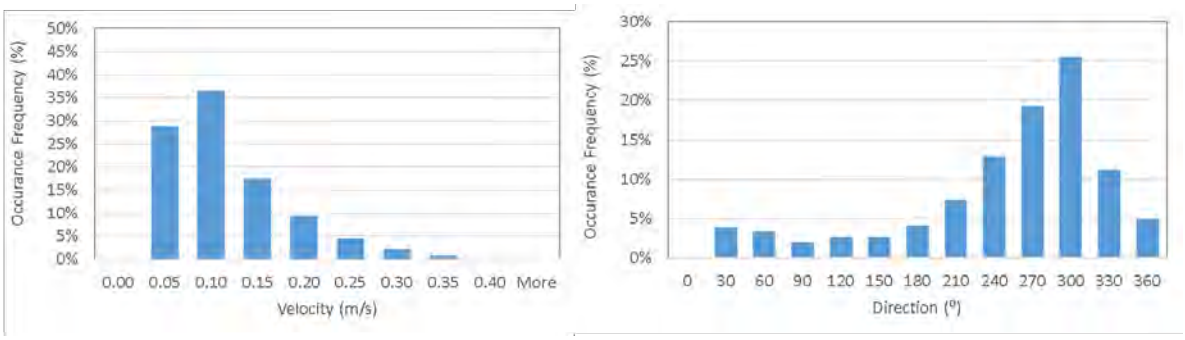

Figure 3.30: Histograms of speed (left panel) and direction (right panel) of U_{95} in survey segment SDS measured on 9/26/2019.

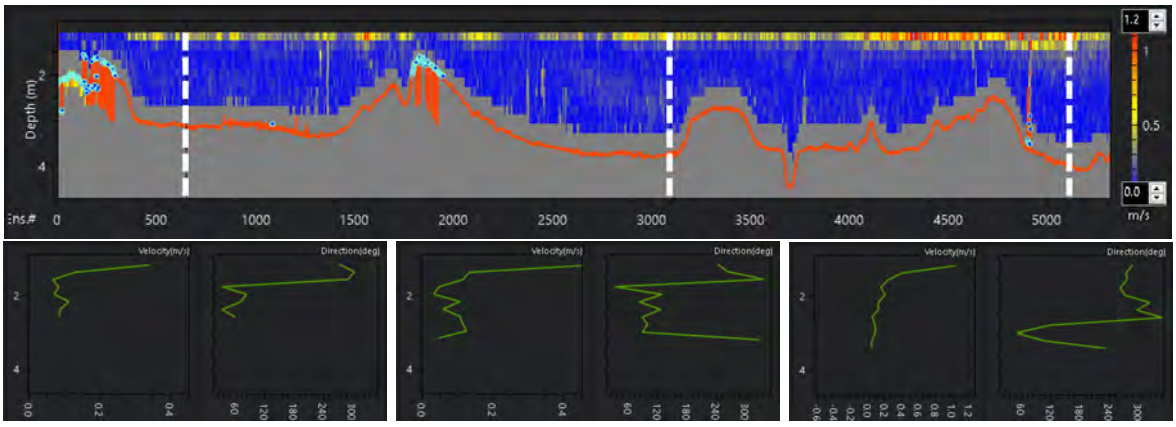

Figure 3.31: 3-second time-averaged velocity throughout the water column along survey segment SDS (top panel) measured on 9/26/2019. The solid (red) line indicates bottom position. Profiles of current speed and direction at the location of the white dashed lines are shown in the bottom panels.

3.1.2.5 CTD measurements

Profiles of conductivity and temperature over the entire depth of water were measured at the end of segment SDS (outside the ship channel near the western tip of the dredge spoil islands) using the Sontek CastAway instrument described in Chapter 2. Profiles of water density and salinity are derived from the measured parameters. The date and time of the measurement was 9/26/2019 at 18:25. Figure 3.32 and shows depth profile plots of conductivity, density, temperature, and salinity at the location of the field measurement in the top panels. The coordinates of the measurements are displayed in the map making up the bottom panel of the figure.

3.2 Corpus Christi Inner Harbor

3.2.1 Slack to Ebb Tide (SE1 – SE4)

During measurements along the survey path through the Corpus Christi Inner Harbor, the tidal stage changed from slack to ebb between 10:00 and 19:00 on Sept. 23, 2019. The tidal water level was reduced to about 0.38 m (NAVD88) during the field measurement period and prevailing winds were east-southeasterly (ESE) with directions in the 107° to 134° range (i.e., ESE to SE). The average wind speed varied between 1.8 and 3.6 m/s during the field measurement period (Figure 1.2). Table 3.5 details the individual segments (S1 - S6) making up this survey path and provides a summary of the wind (W_{30}) and water level (WL) conditions. In the following, depth-averaged velocity vectors along the survey path are displayed and statistical distributions of current speed and direction are presented for each individual segment. To visualize the distribution of current velocity throughout the water column and along the survey path, color maps of velocity distributions and select profiles of current speed and direction are given.

3.2.1.1 Inbound: S1 – S2

Figure 3.33 shows velocity vectors U_{95} along the 14,178 m long west bound survey path through the Corpus Christi Inner Harbor. A total of 10,015 raw velocity ensembles were obtained on 2019-09-23 from 16:12 to 17:36 (i.e. $\sim$ 1.4 hours) at a sampling rate of 2 Hz. Every 50^{th} mean velocity vector ($\sim$ every 25 seconds) is displayed in Figure 3.33. The red boxes indicate the individual segment starting points (S1 – S2) and numbered yellow triangles show the locations where sample velocity profiles are plotted in subsequent figures (1-4).

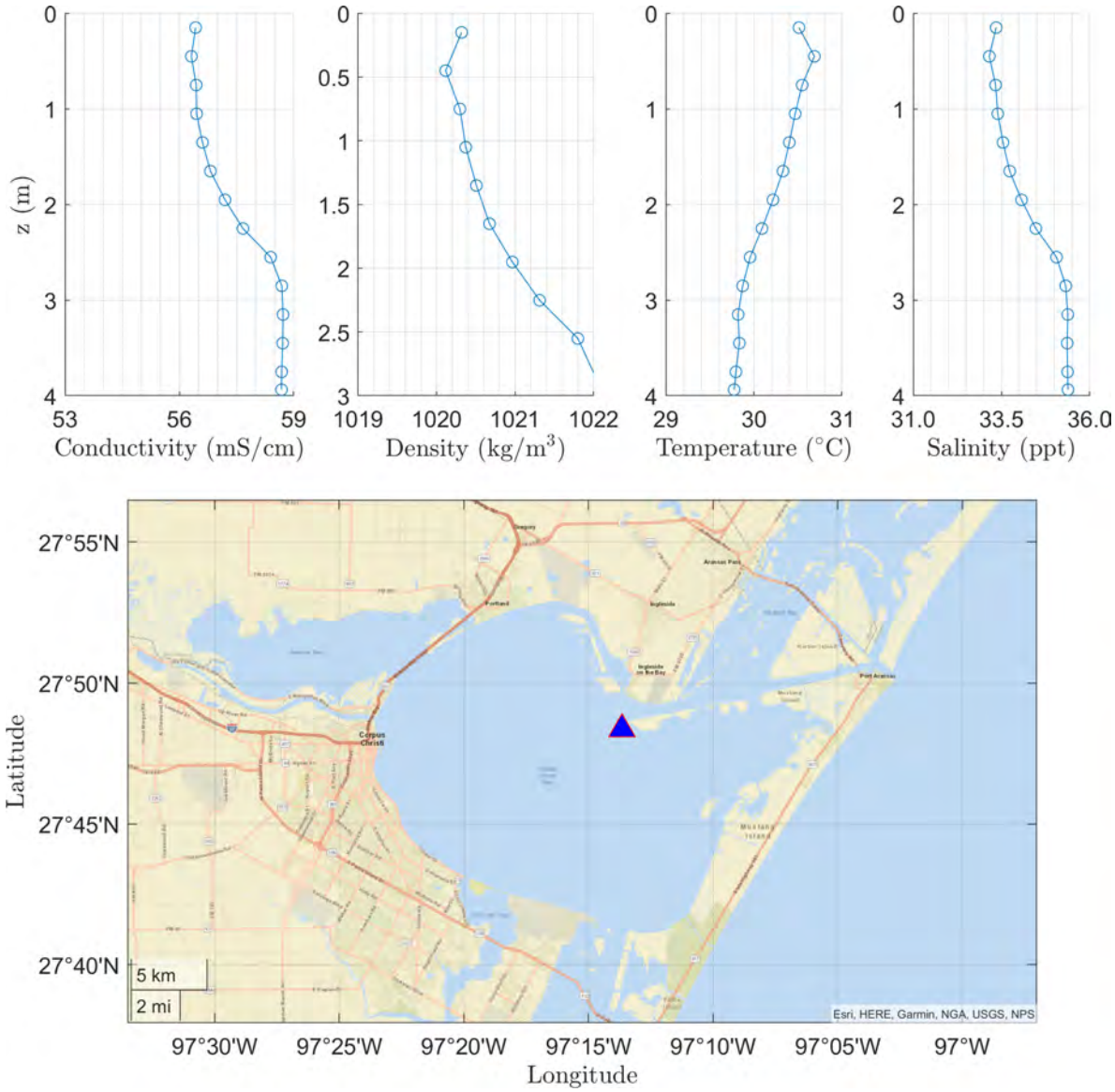

Figure 3.32: Profiles of conductivity, density, temperature, and salinity measured on 9/26/2019 at 18:25 at the end of survey segment SDS (top panels). The location of the measurement is indicated by the blue triangle in the map shown in the bottom panel.

Table 3.5: Segment details, wind, and water level conditions for measurements inside the Corpus Christi Inner Harbor on Sept. 23, 2019 during slack to ebb tide.

	Date & Time (LST, HH:MM)	Lat (UTM)	Lon (UTM)	Path Length (m) [# of ensembles]	Wind & Tide Avrg. (min - max)
S1 Start	2019-09-23 11:12	27° 48.7408 N	97° 23.4863 W	10307	W_{30MIN} (m/s | deg)
End	2019-09-23 12:12	27° 49.5583 N	97° 29.3562 W	[7195]	3.0 (1.8 - 3.6)
S2 Start	2019-09-23 12:13	27° 49.5621 N	97° 29.3621 W	3871	118 (107 - 134)
End	2019-09-23 12:36	27° 50.6342 N	97° 31.3281 W	[2820]	ESE (ESE - SE)
S3 Start	2019-09-23 12:42	27° 50.6378 N	97° 31.2624 W	4764	WL (m, NAVD88)
End	2019-09-23 13:12	27° 49.5247 N	97° 29.4741 W	[3687]	0.47 (0.38 - 0.56)
S4 Start	2019-09-23 13:12	27° 49.5249 N	97° 29.4735 W	9499	
End	2019-09-23 14:12	27° 48.8002 N	97° 24.6440 W	[7200]	
S5 Start	2019-09-23 13:12	27° 48.7999 N	97° 24.6623 W	1625	
End	2019-09-23 14:12	27° 48.7272 N	97° 23.6816 W	[1172]	
S6 Start	2019-09-23 14:22	27° 48.7097 N	97° 23.6750 W	1759	
End	2019-09-23 14:37	27° 48.7820 N	97° 23.2374 W	[1744]	

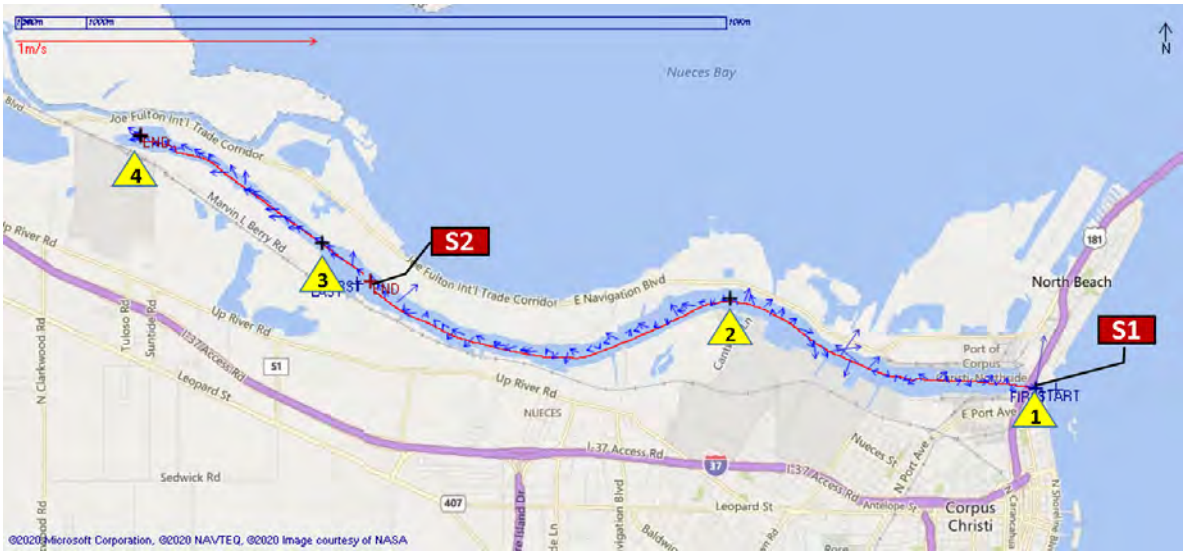

Figure 3.33: Depth-averaged current vectors U_{95} for segments S1 and S2 during west bound survey inside the Corpus Christi Inner Harbor.

Figure 3.34 displays the histogram for speed and direction of U_{95} within the survey segments S1–S2, respectively.

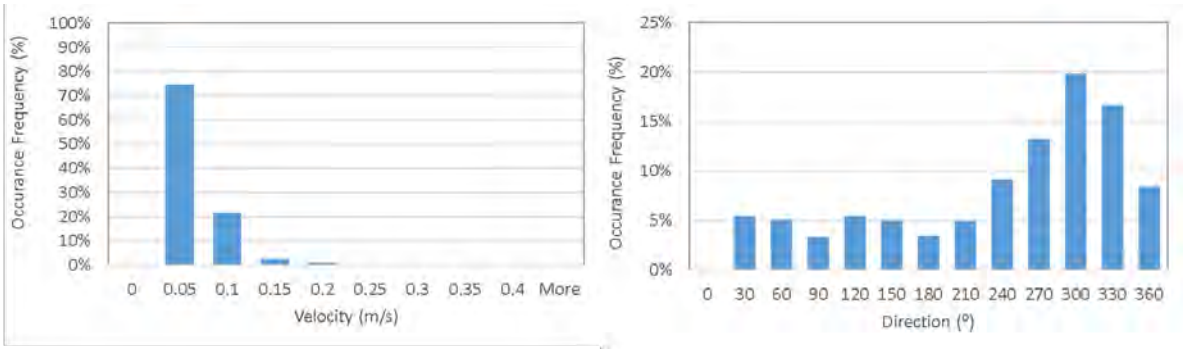

Figure 3.34: Histograms of speed (left panel) and direction (right panel) of U_{95} in survey segments S1–S2 of the Corpus Christi Inner Harbor measured on 9/23/2019.

Figures 3.35 and 3.36 show velocity measurements throughout the water column and measured bed level along survey segments S1 and S2, respectively, in the top panels. Profiles of current speed and direction at the locations marked by white dashed lines are shown in the bottom panels. The location of the white dashed lines corresponds to the locations of the numbered yellow triangles (1-2) in Figure 3.33. These data are time-averaged over 3 seconds. Water depth within segments S1–S2 varied between 14 and 19 m with an average depth of 16 m. The average mean current in this segment was 0.04 m/s and the most prevalent current direction was toward 301° from true north (i.e., toward WNW).

3.2.1.2 CTD measurements

Profiles of conductivity and temperature over the entire depth of water were measured at the beginning of segment S1 (at the entrance of the Corpus Christi Inner Harbor) and at the end of segment S2 (at the end of the turning basin) using the Sontek CastAway instrument described in Chapter 2. Profiles of water density and salinity are derived from the measured parameters. The date and time of the measurement was 9/23/2019 at 16:07 in the S1 segment and 9/23/2019 at 17:38 in the S2 segment. Figures 3.37 and 3.38 show depth profile plots of conductivity, density, temperature, and salinity at the respective locations of the field measurements in the top panels. The coordinates of the measurements are displayed in the map making up the bottom panel of each respective figure.

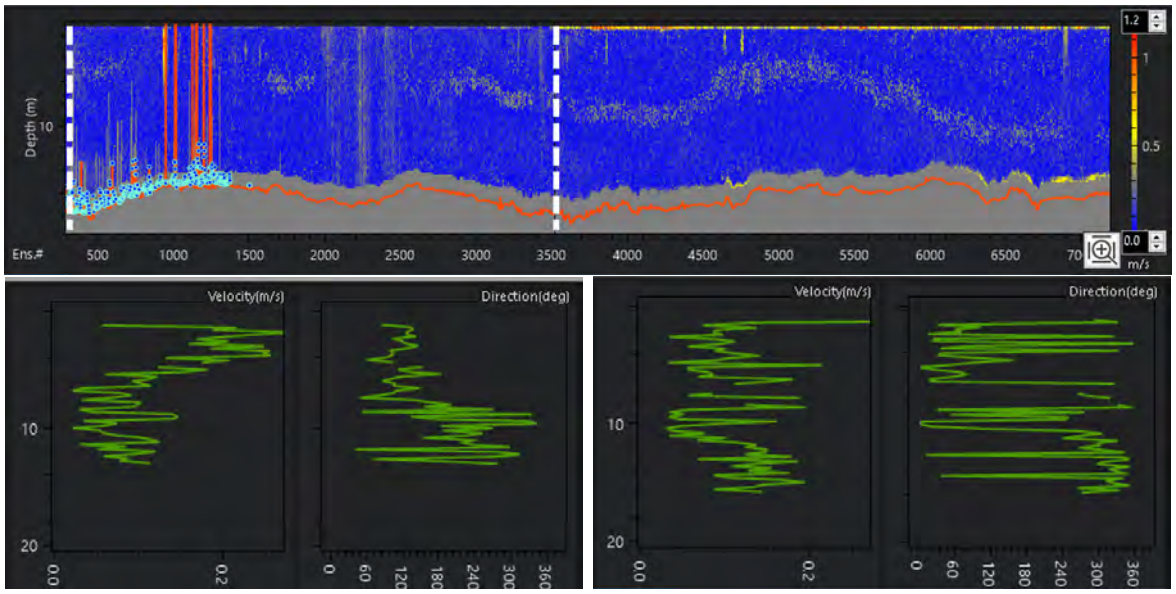

Figure 3.35: 3-second time-averaged velocity throughout the water column along survey segment S1 (top panel) measured on 9/23/2019. The solid (red) line indicates bottom position. Profiles of current speed and direction at the location of the white dashed lines are shown in the bottom panels.

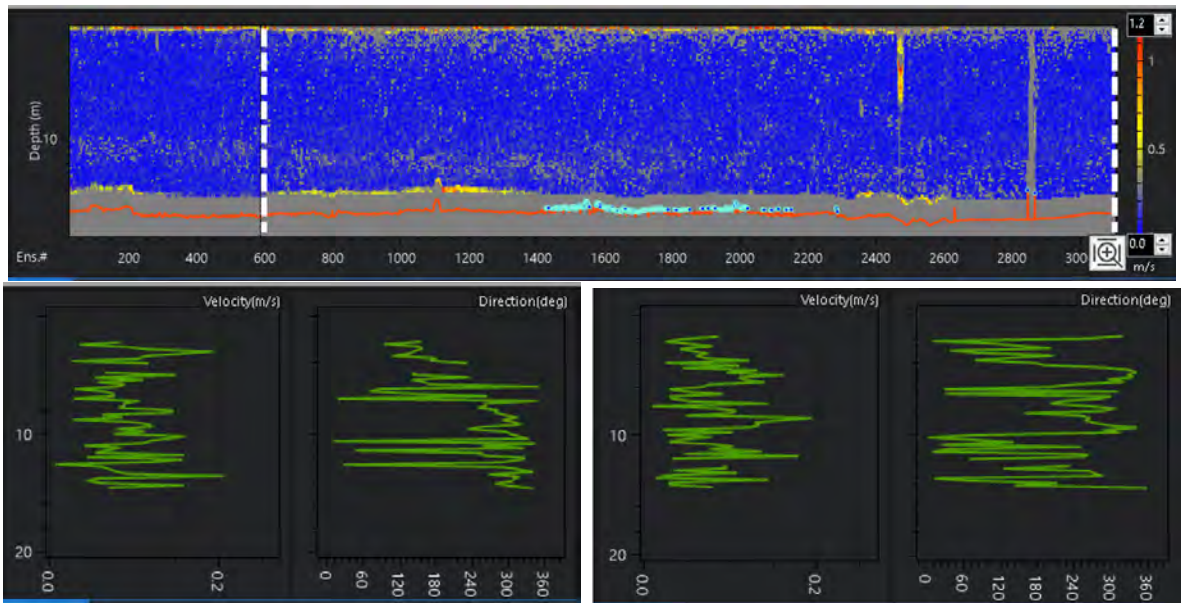

Figure 3.36: 3-second time-averaged velocity throughout the water column along survey segment S2 (top panel). The solid (red) line indicates bottom position. Profiles of current speed and direction at the location of the white dashed lines are shown in the bottom panels.

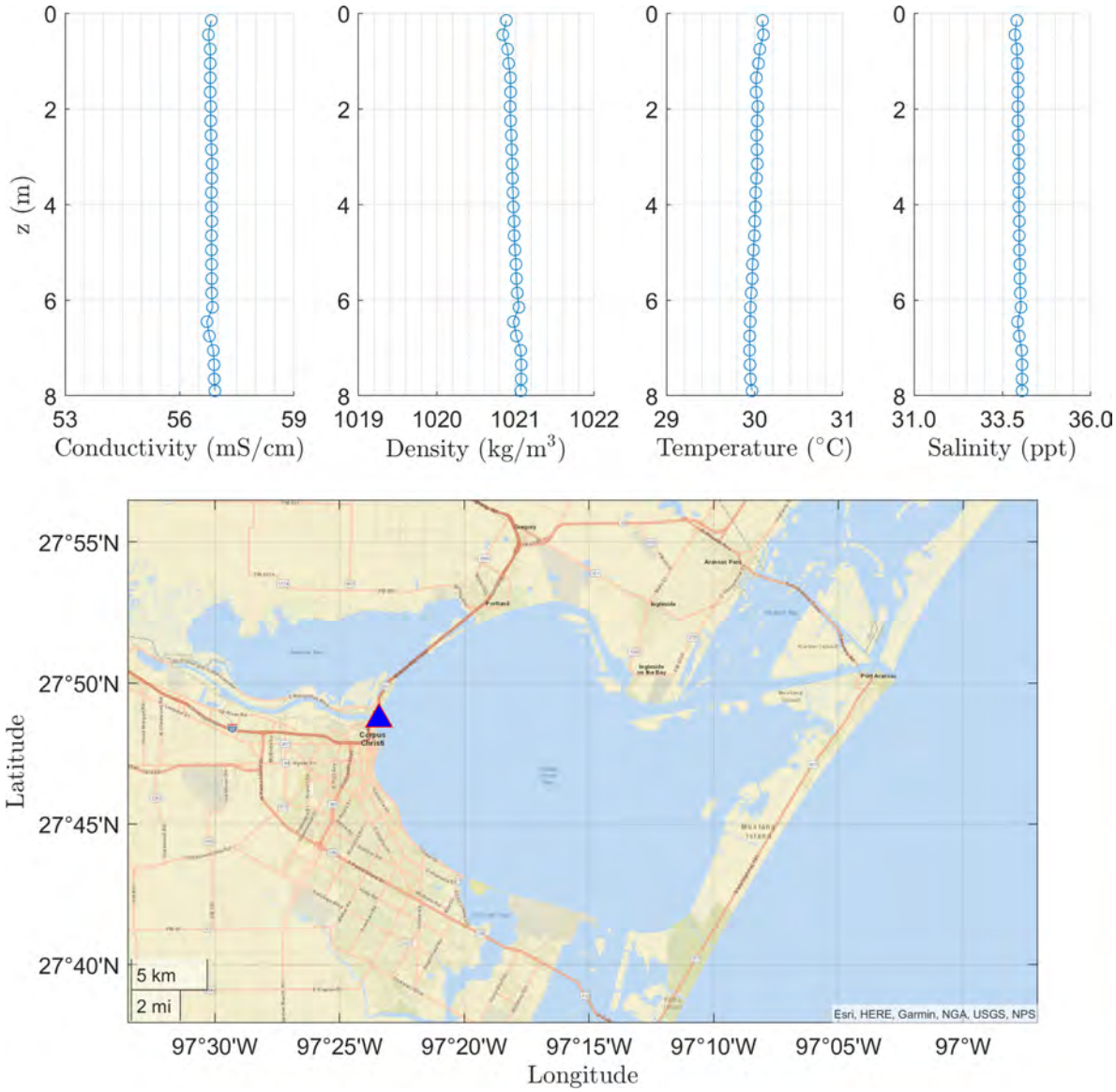

Figure 3.37: Profiles of conductivity, density, temperature, and salinity measured on 9/23/2019 at 16:05 at the beginning of survey segment S1 (top panels). The location of the measurement is indicated by the blue triangle in the map shown in the bottom panel.

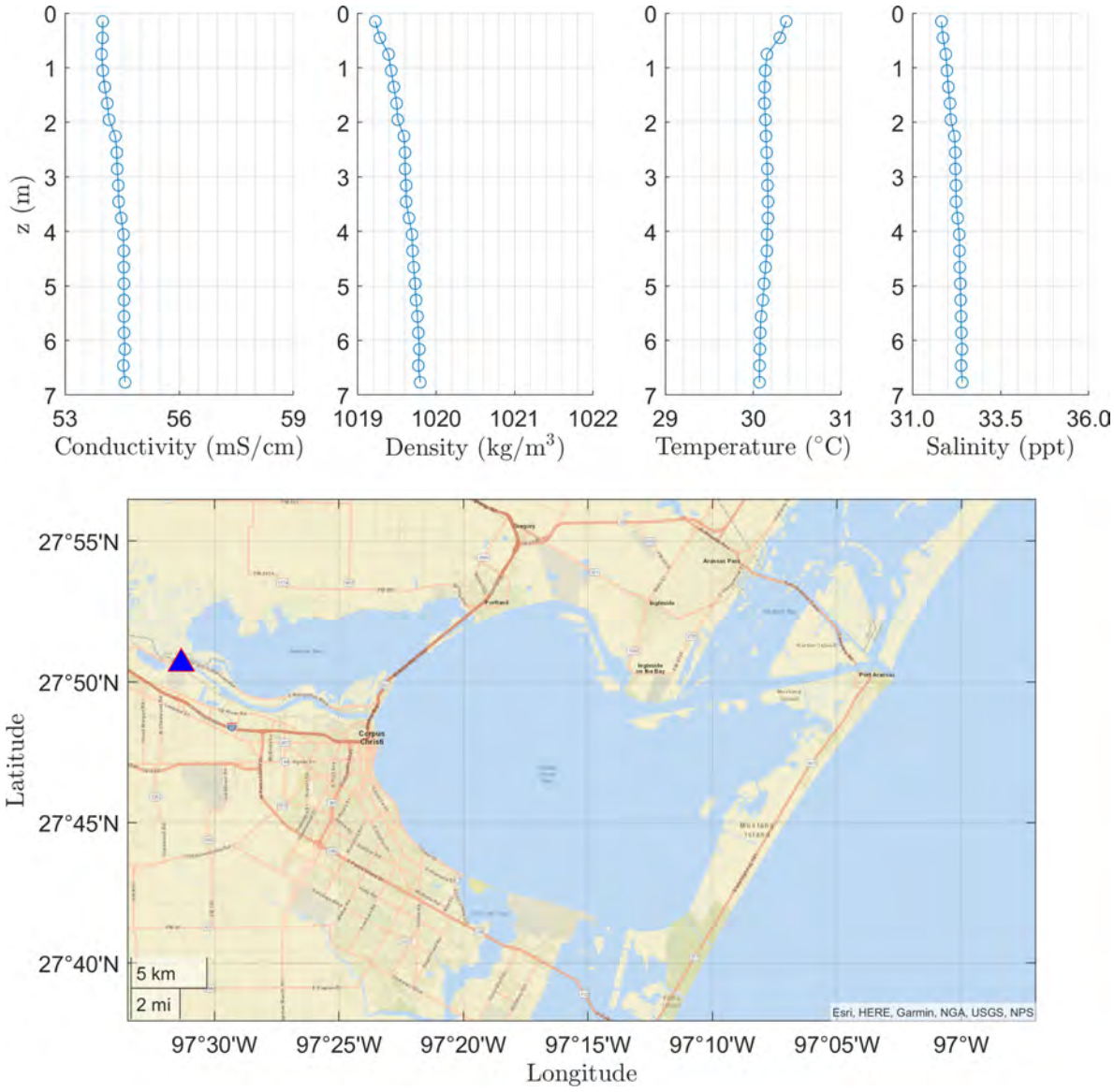

Figure 3.38: Profiles of conductivity, density, temperature, and salinity measured on 9/23/2019 at 17:38 at the end of survey segment S2 (top panels). The location of the measurement is indicated by the blue triangle in the map shown in the bottom panel.

3.2.1.3 Outbound: S3 – S6

Figure 3.39 shows velocity vectors U_{95} along the 17,647 m long east bound survey path through the Corpus Christi Inner Harbor. A total of 13,803 raw velocity ensembles were obtained on 2019-09-23 from 17:42 to 19:37 (i.e. $\sim$ 1.9 hours) at a sampling rate of 2 Hz. Every 50^{th} mean velocity vector ($\sim$ every 25 seconds) is displayed in Figure 3.39. The red boxes indicate the individual segment starting points (S3 – S6) and numbered yellow triangles show the locations where sample velocity profiles are plotted in subsequent figures (5-7).

Figure 3.39: Depth-averaged current vectors U_{95} for segments S3 through S6 during east bound survey inside the Corpus Christi Inner Harbor. A zoomed-in image of the area outlined by the black dashed frame around the harbor entrance is provided in Figure 3.40.

Figure 3.40 provides a zoomed-in view of the harbor entrance area outlined by the black dashed frame in Figure 3.39. Several survey passes across the entrance channel were recorded in this survey segment S6 with sample velocity profiles at the locations of the yellow triangles (8-10) plotted in subsequent figures.

Figure 3.41 displays the histogram for speed and direction of U_{95} within the survey segments S3–S5, respectively.

Figure 3.42 shows velocity measurements throughout the water column and measured bed level along survey segments S3–S5, respectively, in the left panels. Profiles of current speed and direction at the locations marked by white dashed lines are shown in the respective right panels. The location of the white dashed lines corresponds to the

Figure 3.40: Depth-averaged current vectors U_{95} for segment S6 at the harbor entrance measured on 9/23/2019.

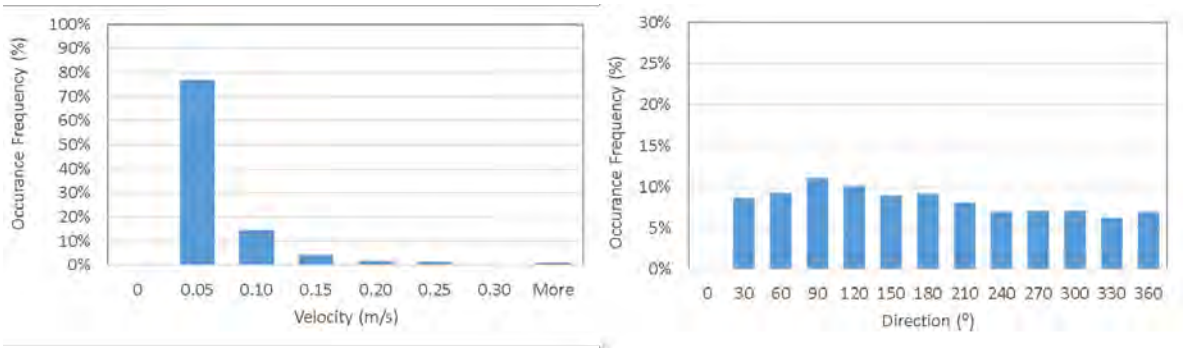

Figure 3.41: Histograms of speed (left panel) and direction (right panel) of U_{95} in survey segments S3 – S5 of the Corpus Christi Inner Harbor measured on 9/23/2019.

locations of the numbered yellow triangles (5-7) in Figure 3.39. These data are time-averaged over 3 seconds. Water depth within segments S3–S5 varied between 13 and 19 m with an average depth of 15 m. The average mean current in this segment was 0.05 m/s. Current directions were very dispersed due to acoustic measuring inaccuracies at such low flow speeds.

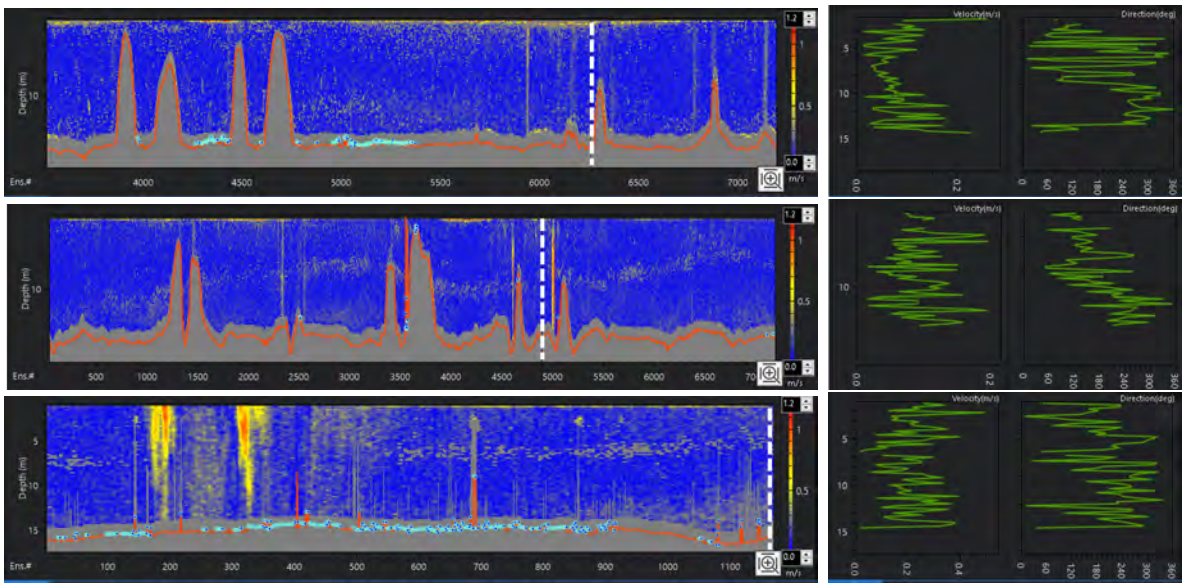

Figure 3.42: 3-second time-averaged velocity throughout the water column along survey segments S3 – S5 (left panels) measured on 9/23/2019. The solid (red) line indicates bottom position. Profiles of current speed and direction at the location of the white dashed lines are shown in the respective right panels.

Figure 3.43 shows velocity measurements throughout the water column and measured bed level along survey segment S6 in the top panel. Profiles of current speed and direction at the locations marked by white dashed lines are shown in the respective bottom panels. The location of the white dashed lines corresponds to the locations of the numbered yellow triangles (8-10) in Figure 3.40. These data are time-averaged over 3 seconds. Water depth within segment S6 varied significantly between 2 and 19 m (17.2 m mean depth) since survey passes included center and banks of the channel. The average mean current in this segment was 0.07 m/s. Current directions were very dispersed due to acoustic measuring inaccuracies at such low flow speeds.

Table 3.6 provides a summary of the conditions measured inside the Corpus Christi Inner Harbor in segments S1 – S6 as the tidal stage changed from slack to ebb between 10:00 and 19:00 on Sept. 23, 2019. The mean currents varied from 0.05 to 0.07 m/s throughout the harbor basin with a slight increase at the entrance. Due to the low flow speeds, current direction readings were very dispersed and should not carry any weight

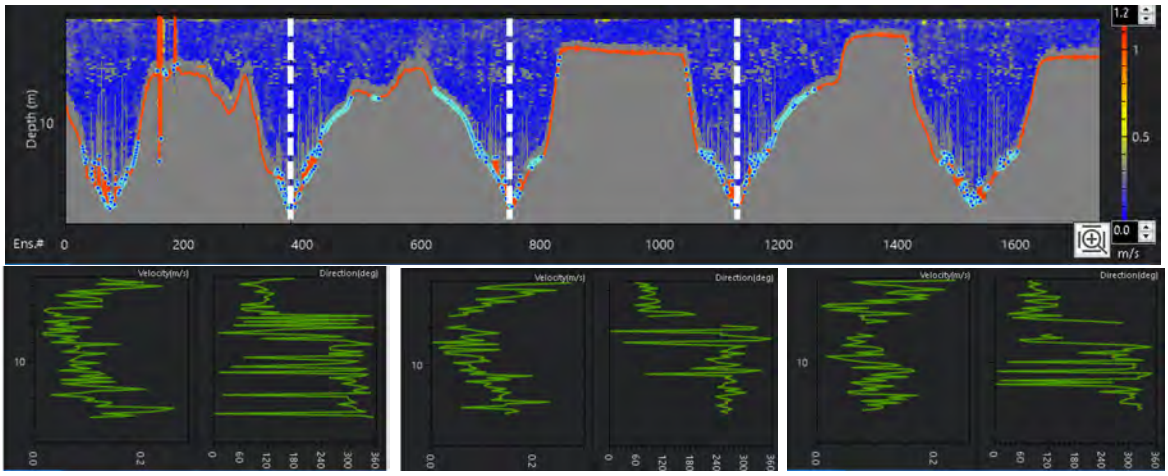

Figure 3.43: 3-second time-averaged velocity throughout the water column along survey segment S6 (top panel) measured on 9/23/2019. The solid (red) line indicates bottom position. Profiles of current speed and direction at the location of the white dashed lines are shown in the respective bottom panels representing channel center axis locations.

in design considerations.

Table 3.6: Summary of average water depth and mean currents inside the Corpus Christi Inner Harbor on Sept. 23, 2019 during slack to ebb tide.

	S1 - S2	S3 - S5	S6 (Channel)[2]
D (m)	16 (14 - 19)	15 (13 - 19)	17.2
U_{95} (m/s | ^{0})	0.04 (0 - 0.3)	0.05 (0 - 0.25)	0.07
	301[1] (30 - 360)	166 (0 - 360)	137
	WNW (NNE - N)	SSE (SSE - SSE)	SE

[1] The average of currents heading beyond 180^0 from the north

[2] Measurement across the centerline of the channel

3.3 Corpus Christi Inner Harbor to Port Ingleside

3.3.1 Flood to Slack Tide (FS1 – FS3)

During measurements along the survey path between the Corpus Christi Inner Harbor and Port Ingleside, the tidal stage changed from flood to slack between 7:30 and 15:30 on Sept. 25, 2019. The tidal water level was reduced slightly from 0.69 to 0.63 m (NAVD88) during the field measurement period and prevailing winds were south-southeasterly (SSE) with directions in the 126° to 160° range (i.e., SE to SSE). The average wind speed varied between 1.0 and 3.5 m/s during the field measurement period (Figure 1.2). Table 3.7 details the individual segments (S1 – S7) making up this survey path and provides a summary of the wind (W_{30}) and water level (WL) conditions. In the following, depth-averaged velocity vectors along the survey path are displayed and statistical distributions of current speed and direction are presented for each individual segment. To visualize the distribution of current velocity throughout the water column and along the survey path, color maps of velocity distributions and select profiles of current speed and direction are given.

Table 3.7: Segment details, wind, and water level conditions for measurements between the Corpus Christi Inner Harbor and Port Ingleside on Sept. 25, 2019 during flood to slack tide.

		Date & Time (LST, HH:MM)	Lat (UTM)	Lon (UTM)	Path Length (m) [# of ensembles]	Wind & Tide Avrg. (min - max)
S1	Start	2019-09-25 07:58	27° 48.7127 N	97° 23.5114 W	3608	W_{30min} (m/s | deg)
	End	2019-09-25 08:21	27° 48.6165 N	97° 21.3681 W	[2696]	2.5 (1.0 - 3.5)
S2	Start	2019-09-25 08:29	27° 48.6165 N	97° 21.3266 W	10226	147 (126 - 160)
	End	2019-09-25 09:29	27° 48.66481 N	97° 15.1048 W	[7200]	SSE (SE - SSE)
S3	Start	2019-09-25 09:29	27° 48.6481 N	97° 15.1041 W	2890	WL (m, NAVD88)
	End	2019-09-25 09:47	27° 48.8112 N	97° 13.3628 W	[2160]	0.66 (0.63 - 0.69)
S4	Start	2019-09-25 09:48	27° 48.8220 N	97° 13.2765 W	3126	
	End	2019-09-25 10:10	27° 48.6498 N	97° 14.8701 W	[2074]	
S5	Start	2019-09-25 10:19	27° 48.6455 N	97° 14.9148 W	7103	
	End	2019-09-25 11:07	27° 48.6357 N	97° 19.2856 W	[4870]	
S6	Start	2019-09-25 11:18	27° 48.5969 N	97° 19.3189 W	3676	
	End	2019-09-25 11:46	27° 48.6264 N	97° 21.5614 W	[2409]	
S7	Start	2019-09-25 11:51	27° 48.5879 N	97° 21.5974 W	2558	
	End	2019-09-25 12:13	27° 48.7007 N	97° 23.2243 W	[1933]	

3.3.1.1 East bound: S1 – S3

Figure 3.44 shows velocity vectors U_{95} along the 16,724 m long east bound survey path from the harbor entrance toward Port Ingleside. A total of 12,056 raw velocity ensembles were obtained on 2019-09-25 from 12:58 to 14:47 (i.e., ∼1.8 hours) at a sampling rate of 2 Hz. Every 75^{th} mean velocity vector (∼ every 37 seconds) is displayed in Figure 3.44. The red boxes indicate the individual segment starting points (S1 – S3) and numbered yellow triangles show the locations where sample velocity profiles are plotted in subsequent figures (1-3).

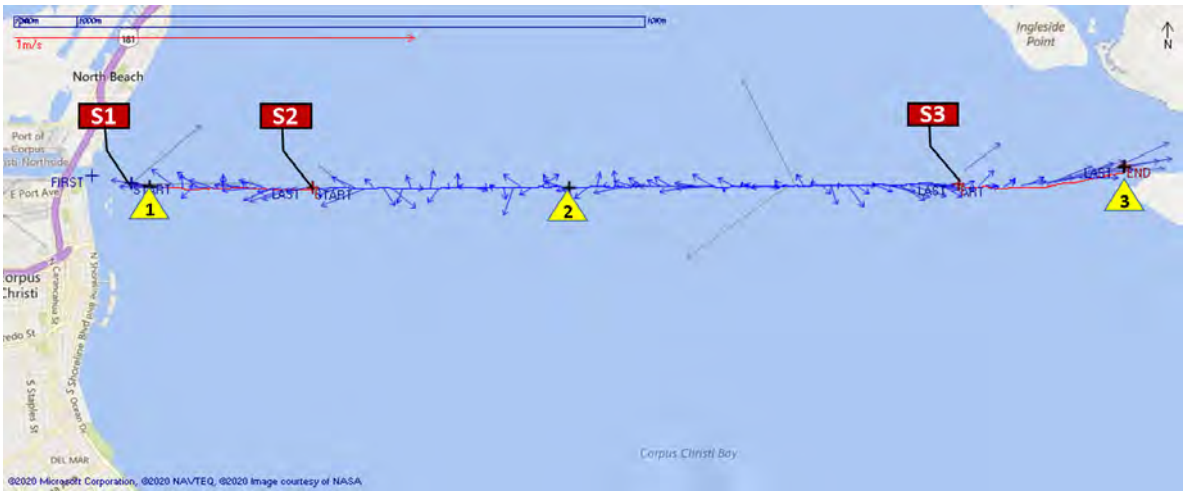

Figure 3.44: Depth-averaged current vectors U_{95} for segments S1 through S3 during east bound survey from the Corpus Christi harbor entrance to Port Ingleside.

Figure 3.45 displays the histogram for speed and direction of U_{95} within the survey segments S1–S3, respectively.

Figure 3.46 shows velocity measurements throughout the water column and measured bed level along survey segments S1 – S3, respectively, in the left panels. Profiles of current speed and direction at the locations marked by white dashed lines are shown in the respective panels on the right of the figure. The location of the white dashed lines corresponds to the locations of the numbered yellow triangles (1-3) in Figure 3.44. These data are time-averaged over 3 seconds. Water depth within segments S1–S3 varied between 16 and 18 m with an average depth of 17 m. The average mean current in this segment was 0.07 m/s and the most prevalent current direction ranged from toward 285° from true north (i.e., toward WNW) at the western end of the survey path to toward 102° from true north at the eastern end (near Port Ingleside).

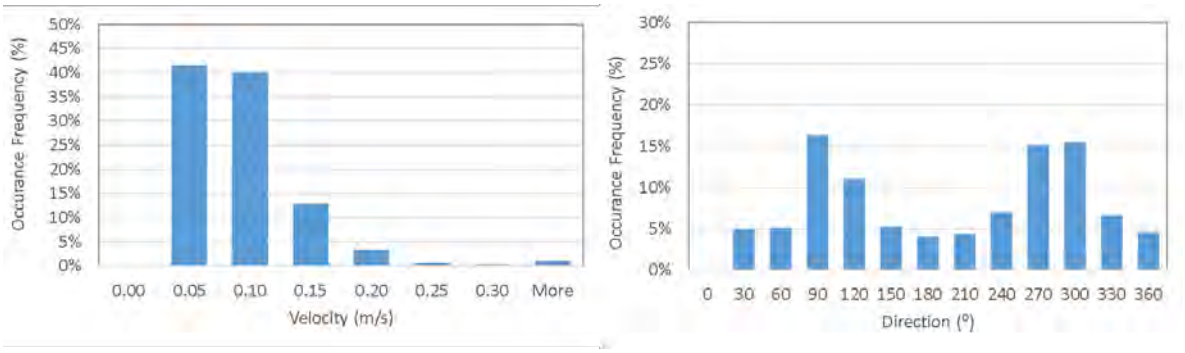

Figure 3.45: Histograms of speed (left panel) and direction (right panel) of U_{95} in survey segments S1 – S3 between the Corpus Christi harbor entrance and Port Ingleside measured on 9/25/2019.

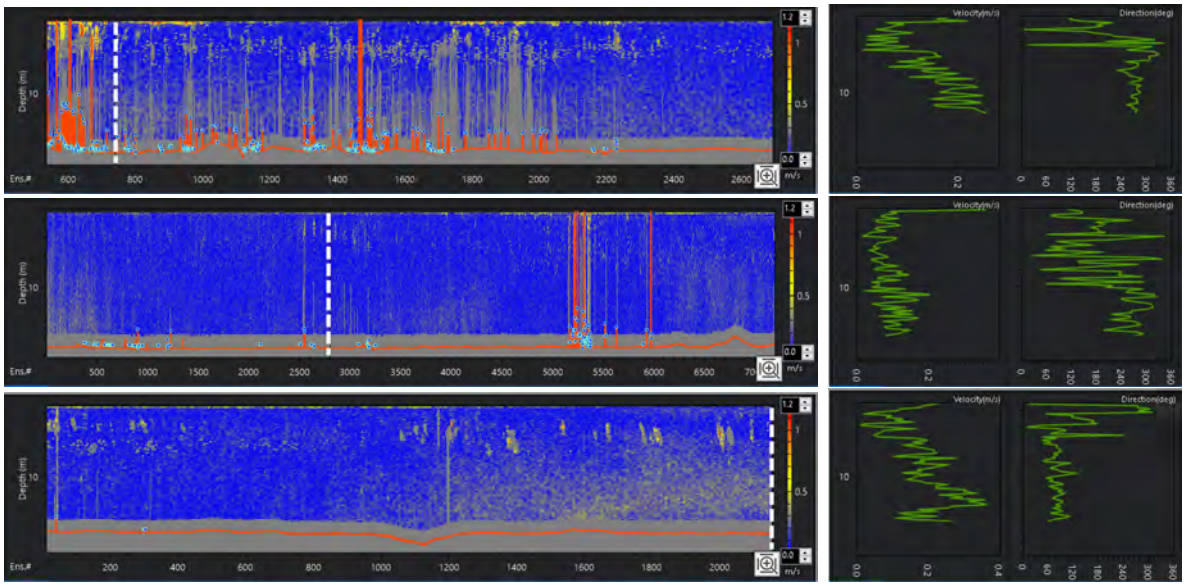

Figure 3.46: 3-second time-averaged velocity throughout the water column along survey segments S1 – S3 (top panel) measured on 9/25/2019. The solid (red) line indicates bottom position. Profiles of current speed and direction at the location of the white dashed lines are shown in the respective bottom panels.

3.3.1.2 CTD measurements

Profiles of conductivity and temperature over the entire depth of water were measured at the beginning of segment S1 (near the entrance of the Corpus Christi Inner Harbor) using the Sontek CastAway instrument described in Chapter 2. Profiles of water density and salinity are derived from the measured parameters. The date and time of the measurement was 9/25/2019 at 12:55. Figure 3.47 and shows depth profile plots of conductivity, density, temperature, and salinity at the location of the field measurement in the top panels. The coordinates of the measurements are displayed in the map making up the bottom panel of the figure.

3.3.1.3 West bound: S4 – S7

Figure 3.44 shows velocity vectors U_{95} along the 16,463 m long west bound survey path from Port Ingleside to the Corpus Christi harbor entrance. A total of 11,286 raw velocity ensembles were obtained on 2019-09-25 from 14:48 to 17:13 (i.e., ∼2.4 hours) at a sampling rate of 2 Hz. Every 75^{th} mean velocity vector (∼ every 37 seconds) is displayed in Figure 3.48. The red boxes indicate the individual segment starting points (S4 – S7) and numbered yellow triangles show the locations where sample velocity profiles are plotted in subsequent figures (4-13).

Figure 3.49 displays the histogram for speed and direction of U_{95} within the survey segment S4.

Figure 3.50 shows velocity measurements throughout the water column and measured bed level along survey segment S4 in the top panel. Profiles of current speed and direction at the locations marked by white dashed lines are shown in the respective bottom panels. The location of the white dashed lines corresponds to the locations of the numbered yellow triangles (4-6) in Figure 3.48. These data are time-averaged over 3 seconds. Water depth within segment S4 varied between 16 and 19 m with an average depth of 17 m. The average mean current in this segment was 0.14 m/s and the most prevalent current direction was toward 106° from true north (i.e., toward ESE).

Figure 3.51 displays the histogram for speed and direction of U_{95} within the survey segments S5 – S6.

Figures 3.52 and 3.53 show velocity measurements throughout the water column and measured bed level along survey segments S5 and S6, respectively, in the top panels. Profiles of current speed and direction at the locations marked by white dashed lines are shown in the respective bottom panels. The location of the white dashed lines corresponds to the locations of the numbered yellow triangles (7-9) and (10-11), respectively, in Figure 3.48. These data are time-averaged over 3 seconds. Water depth within

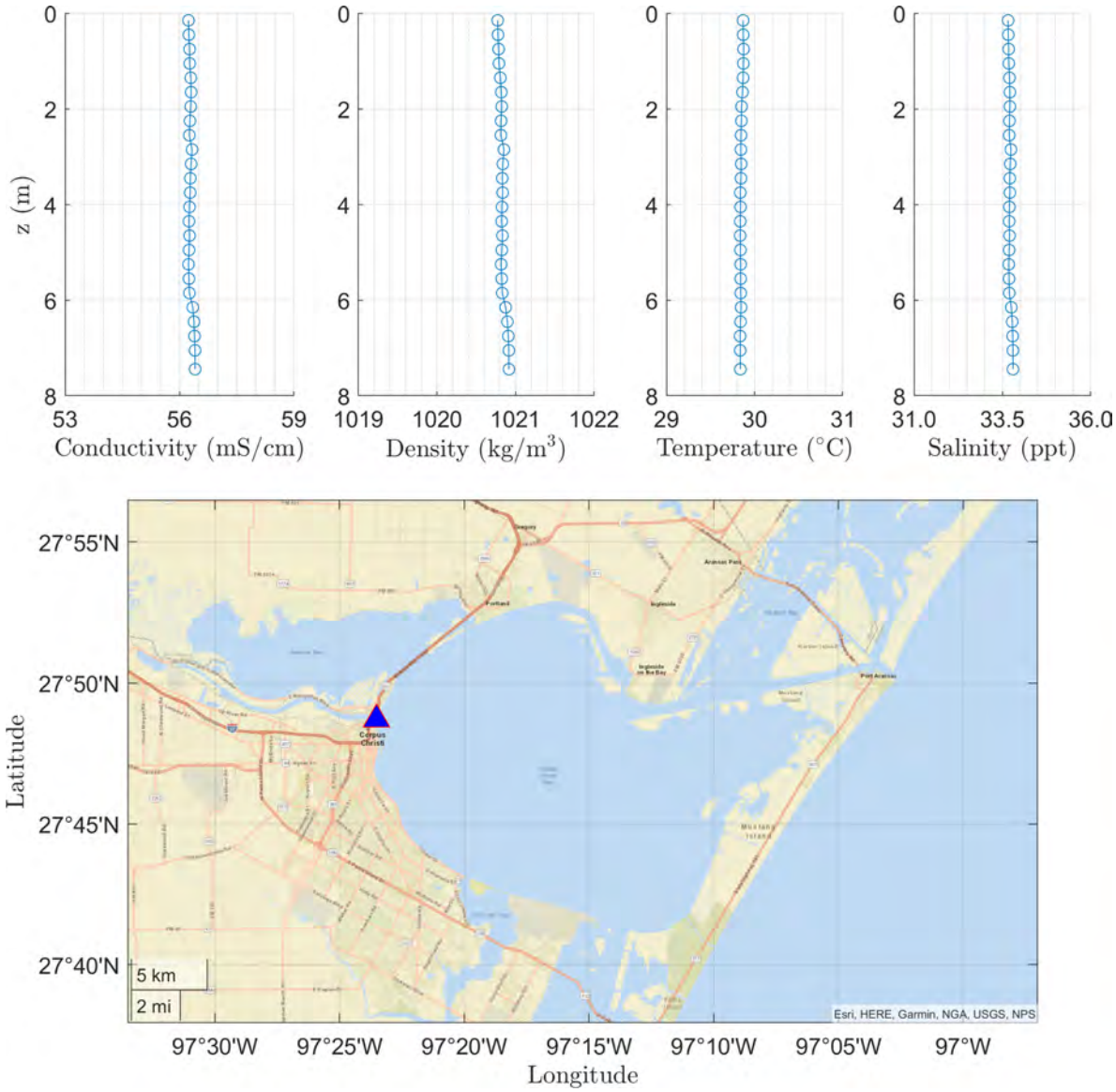

Figure 3.47: Profiles of conductivity, density, temperature, and salinity measured on 9/26/2019 at 18:25 at the beginning of survey segment S1 (top panels). The location of the measurement is indicated by the blue triangle in the map shown in the bottom panel.

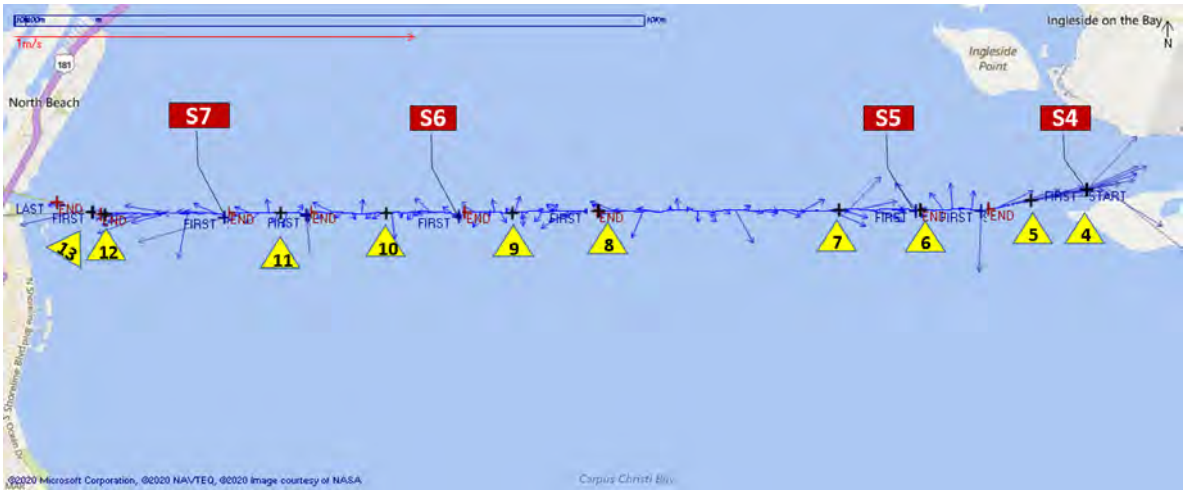

Figure 3.48: Depth-averaged current vectors U_{95} for segments S4 through S7 during west bound survey from Port Ingleside to the Corpus Christi harbor entrance.

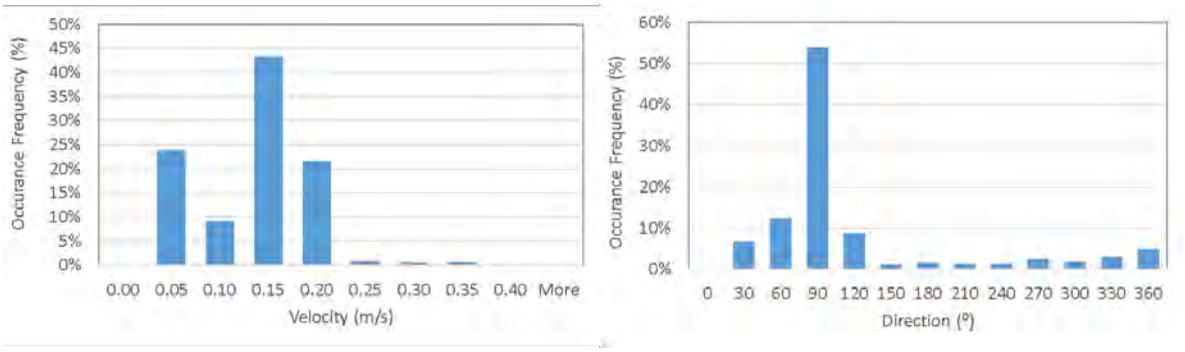

Figure 3.49: Histograms of speed (left panel) and direction (right panel) of U_{95} in survey segment S4 between Port Ingleside and the Corpus Christi harbor entrance measured on 9/25/2019.

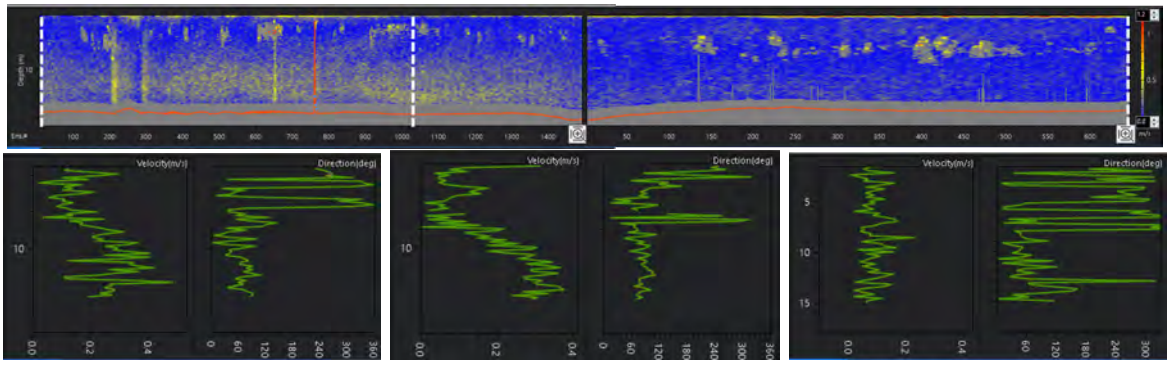

Figure 3.50: 3-second time-averaged velocity throughout the water column along survey segment S4 (top panel) measured on 9/25/2019. The solid (red) line indicates bottom position. Profiles of current speed and direction at the locations of the white dashed lines are shown in the respective bottom panels.

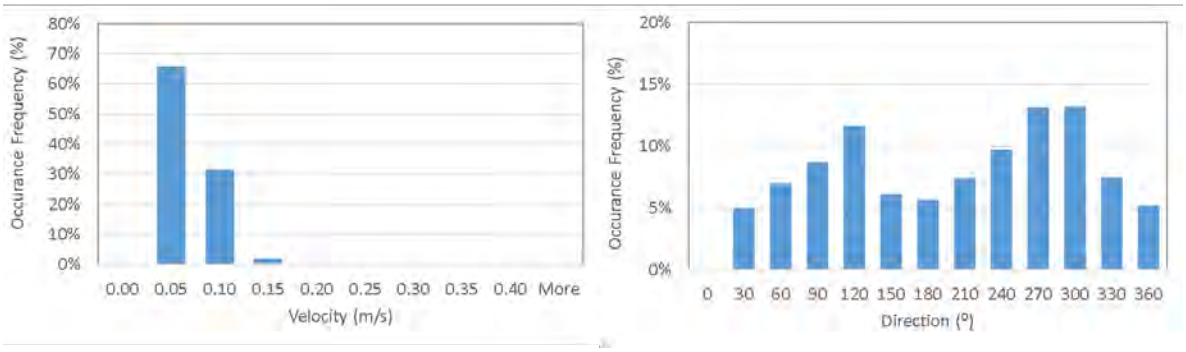

Figure 3.51: Histograms of speed (left panel) and direction (right panel) of U_{95} in survey segments S5 – S6 between Port Ingleside and the Corpus Christi harbor entrance measured on 9/25/2019.

segment S4 varied between 16 and 18 m with an average depth of 17 m. The average mean current in this segment was 0.07 m/s and the most prevalent current direction tended to veer from 120° to 285° (i.e., from east-southeast to west-northwest) as the survey proceeded to the west.

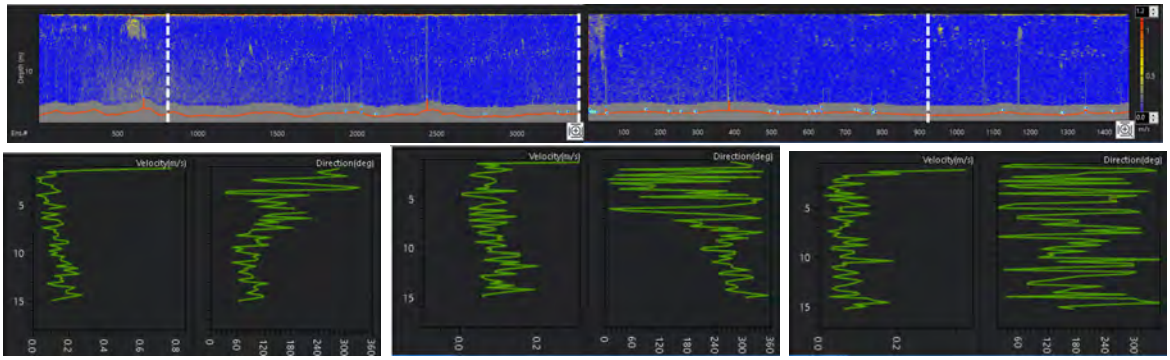

Figure 3.52: 3-second time-averaged velocity throughout the water column along survey segment S5 (top panel) measured on 9/25/2019. The solid (red) line indicates bottom position. Profiles of current speed and direction at the locations of the white dashed lines are shown in the respective bottom panels.

Figure 3.54 displays the histogram for speed and direction of U_{95} within the survey segment S7.

Figure 3.55 shows velocity measurements throughout the water column and measured bed level along survey segment S7 in the top panel. Profiles of current speed and direction at the locations marked by white dashed lines are shown in the respective bottom panels. The location of the white dashed lines corresponds to the locations of the numbered yellow triangles (12-13) in Figure 3.48. These data are time-averaged over 3 seconds. Water depth within segment S7 varied between 13 and 18 m with an average depth of 16 m. The average mean current in this segment was 0.12 m/s and the most prevalent current direction was toward 283° from true north (i.e., toward WNW).

Table 3.8 provides a summary of the conditions measured between the Corpus Christi harbor entrance and Port Ingleside in segments S1 – S7 as the tidal stage changed from flood to slack between 10:30 and 15:30 on Sept. 25, 2019. The mean currents were low and varied from 0.05 to 0.20 m/s throughout these survey segments. Current directions were aligned with the expected tidal flow directions with a heading in the east-southeast (ESE) direction near the Port of Ingleside and a heading of west-northwest (WNW) near the entrance of the inner harbor. Prevailing winds during this field measurement period were south-southeasterly (SSE) ranging between 126° and 160° from true north (i.e., SE to SSE).

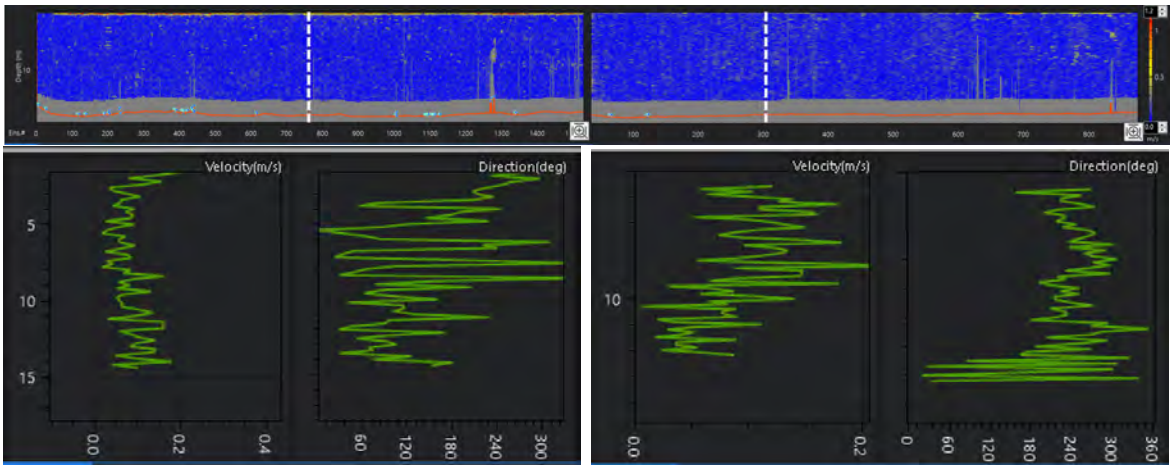

Figure 3.53: 3-second time-averaged velocity throughout the water column along survey segment S6 (top panel). The solid (red) line indicates bottom position. Profiles of current speed and direction at the locations of the white dashed lines are shown in the respective bottom panels.

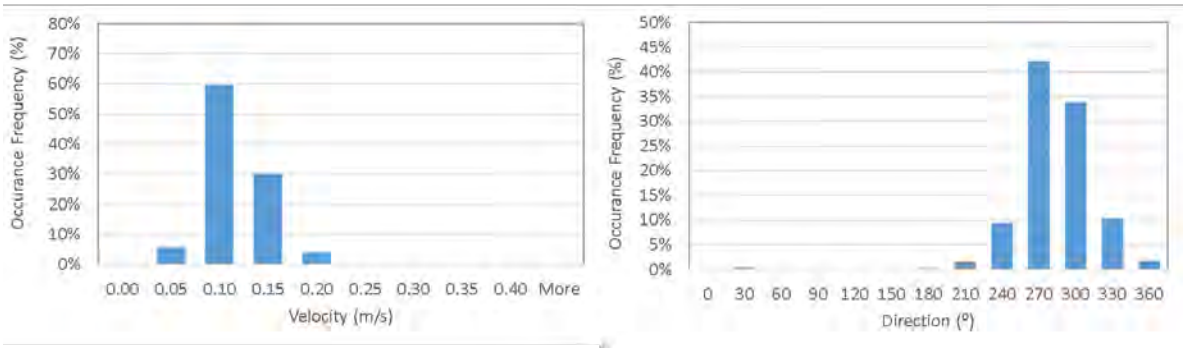

Figure 3.54: Histograms of speed (left panel) and direction (right panel) of U_{95} in survey segment S7 between Port Ingleside and the Corpus Christi harbor entrance measured on 9/25/2019.

Table 3.8: Summary of average water depth and mean currents between the Corpus Christi harbor entrance and the Port of Ingleside on Sept. 25, 2019 during flood to slack tide.

	S1 - S3	S4	S5 - S6	S7
D (m)	17 (16 - 18)	17 (16 - 19)	17 (16 - 18)	16 (13 - 18)
U_{95} (m/s | °)	0.07 (0.05 - 0.20)	0.14 (0.05 - 0.20)	0.07 (0.05 - 0.15)	0.12 (0.05 - 0.20)
	102, 285 (30 - 330)	106 (30 - 360)	120, 285 (30 - 360)	283 (210 - 360)
	ESE, WNW (NNE - NNW)	ESE (NNE - N)	ESE, WNW (NNE - N)	WNW (SSW - N)

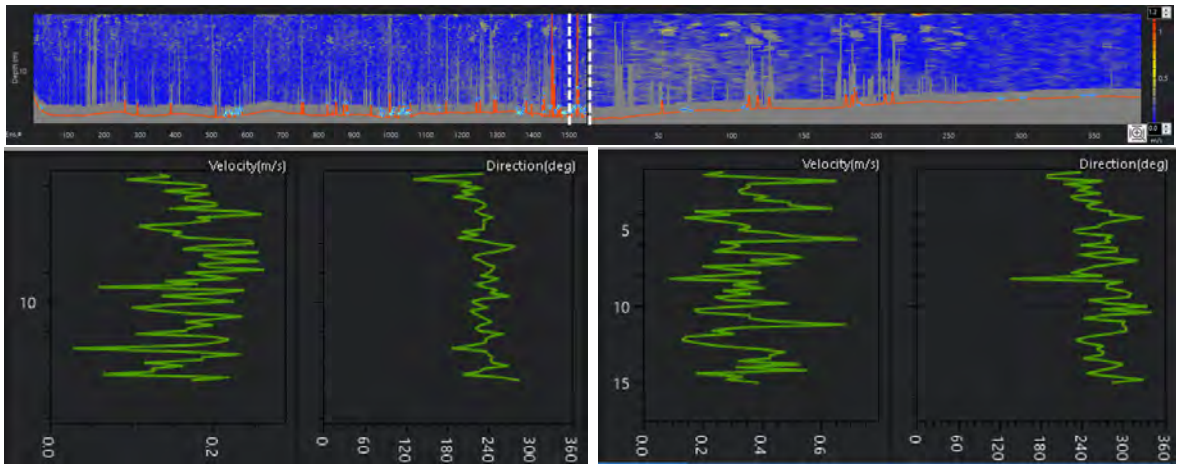

Figure 3.55: 3-second time-averaged velocity throughout the water column along survey segment S7 (top panel) measured on 9/25/2019. The solid (red) line indicates bottom position. Profiles of current speed and direction at the locations of the white dashed lines are shown in the respective bottom panels.

3.3.1.4 CTD measurements

Profiles of conductivity and temperature over the entire depth of water were measured at the end of segment S6 (between the Port of Ingleside and the entrance of the Corpus Christi Inner Harbor) using the Sontek CastAway instrument described in Chapter 2. Profiles of water density and salinity are derived from the measured parameters. The date and time of the measurement was 9/25/2019 at 16:15. Figure 3.56 and shows depth profile plots of conductivity, density, temperature, and salinity at the location of the field measurement in the top panels. The coordinates of the measurements are displayed in the map making up the bottom panel of the figure.

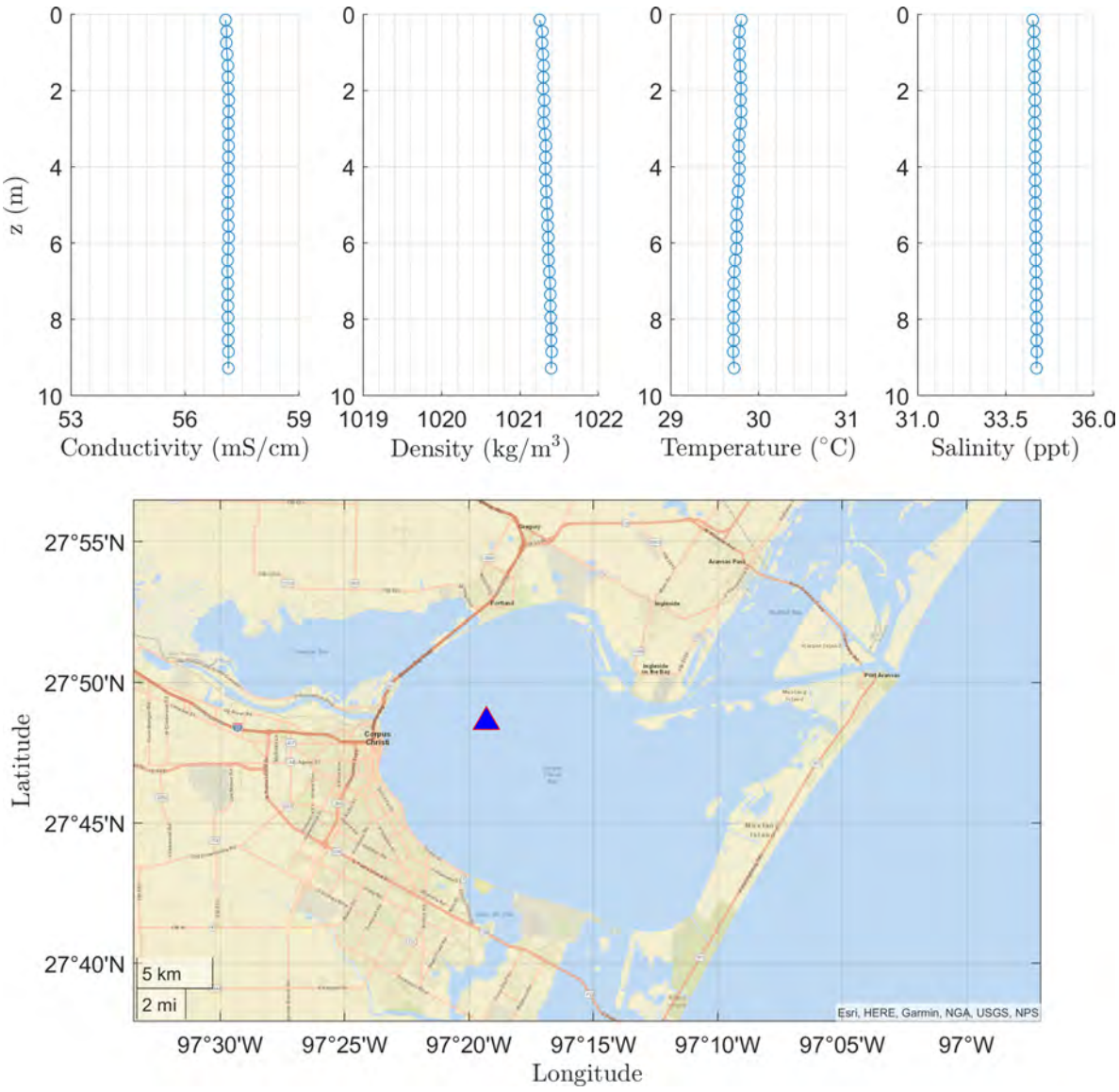

Figure 3.56: Profiles of conductivity, density, temperature, and salinity measured on 9/25/2019 at 16:15 at the end of survey segment S6 (top panels). The location of the measurement is indicated by the blue triangle in the map shown in the bottom panel.

Chapter 4

Summary

This report details measurements of water current profiles collected with a vessel-mounted acoustic Doppler current profiler (ADCP) throughout the entire 30-mile length of the Corpus Christi Ship Channel (CCSC) between September 22 and 26, 2019. An extra 5-mile survey segment south of existing dredge spoil islands was included as well. In addition, profiles of conductivity, temperature, and depth to derive density and salinity over the entire water column were measured at select locations and are displayed in the report. Data were collected during two different tide stages for each survey segment to capture rising as well as falling tidal situations. Environmental data for wind velocity and tidal elevation were downloaded from NOAA CO-OPS station Port Aransas (ID: 8775237) and are displayed alongside the measured field data to describe background conditions during the measurement campaign.

The diurnal tides were fairly regular over the duration of the field measurements with a range of approximately 0.4 m. Wind speeds ranged from as low as 0.4 m/s to about 6.0 m/s with some daily variability. Wind directions were primarily south-southeasterly (SSE) with only few exceptions where winds were south-westerly (SW) or east-southeasterly (ESE).

Measured mean currents were primarily driven by tidal flows and ranged in magnitude from 0.12 m/s to 0.85 m/s with directions along the main ship channel segments. As expected, inside the Corpus Christi Inner Harbor mean velocities were even lower with values as low as 0.04 m/s. Salinity profiles displayed fairly constant values over depth between 32 to 35 ppt at all measuring locations indicating no significant influence of freshwater influx throughout the duration of the field measuring campaign.

The raw data (ADCP and CTD) and a spreadsheet providing all depth-averaged velocity information along each survey segment in electronic format are provided along with this report and copies are available from the PI upon request.