U.S. DEPARTMENT OF COMMERCE

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SERVICE

HORIZONTAL AND VERTICAL CONTROL REPORT

Type of Survey Navigable Area

Project No. OPR-K376-KR-18

Time Frame August 2018 – February 2019

LOCALITY

State Texas

General Locality Port Lavaca, TX

2018 - 2019

CHIEF OF PARTY

ANDREW ORTHMANN

LIBRARY & ARCHIVES

DATE

Horizontal and Vertical Control Report

OPR-K376-KR-18

Port Lavaca, TX

April 25th, 2019

Project Name:	***Port Lavaca, TX***
General Locality:	***Port Lavaca, TX***
Time frame:	***August, 2018 – February, 2019***
Sub Localities:	***F00734 – Matagorda Bay*** ***H13180 – Vicinity of Matagorda Bay Entrance*** ***H13181 – Matagorda Bay Entrance*** ***H13182 – 8 NM WSW of Entrance to Colorado River*** ***H13183 – 7 NM WSW of Pass Cavallo*** ***H13184 – 14 NM ENE of Cedar Bayou*** ***H13185 – 15 NM ESE of Cedar Bayou*** ***H13186 – 9 NM WSW of Pass Cavallo*** ***H13187 – 10 NM WSW of Entrance to Colorado River***
Vessel(s):	***R/V Bella Marie, R/V Bunny Bordelon, M/V Sea Ark***
Field Unit:	***TerraSond Limited***
Lead Hydrographer:	***Andrew Orthmann***

A. Vertical Control

Mean lower low water (MLLW) was the vertical control datum for this survey. All soundings are referenced to MLLW.

All time measurements were made in Universal Time Coordinated (UTC).

A.1. Tide Corrector Stations

The Tides Statement of Work did not specify installation of subordinate tide stations.

The NWLON stations at Matagorda Bay Entrance Channel, TX (8773767) and Port O'Conner, TX (8773701) were used for comparison and QC purposes. Tide Equipment

A.2. Tide Correctors

Soundings were reduced to MLLW using ERS methodology. Raw vessel positioning and attitude data was post-processed to produce precise positions relative to the NAD83(2011) ellipsoid, which was loaded into survey lines in CARIS HIPS software. Then a "GPS Tide" was computed to adjust the NAD83 altitudes to MLLW using the VDATUM grid provided by NOAA for this purpose. The VDATUM grid used to reduce soundings is provided with the survey deliverables.

Filename: VDATUM_Outline_Shape_xyNAD83-MLLW_geoid12b

VDATUM Software Version: 3.6.1

Geoid: 2012 (12b)

Regional Area: Texas

Regional Area Version: TXlagmat01_8301

A.3. VDATUM Validation

The VDATUM separation model was validated in the field. This consisted of an initial check of boat-float GPS data logged at the nearby NWLON tide gauges, followed by an analysis of vessel ellipsoid-referenced waterline data.

The comparisons between the NWLON data and VDATUM models yielded good results with no action item recommendations. The validation check reports, which were completed by TerraSond's tides subcontractor JOA Surveys, LLC, are available in Appendix I.

B. Horizontal Control

The horizontal control datum used for this survey was NAD83 (2011). FInal positions are NAD83 (2011).

Vessel positions were post-processed.

Data from the vessels equipped with Applanix POSMVs (*Bella Marie*, *Bunny Bordelon*) were post-processed in Applanix POSPac MMS software using Trimble PP-RTX. Applanix SmartBase (ASB) was used as well but to compare against PP-RTX results only.

Data from the SBES vessel *Sea Ark* was post-processed in Trimble Business Center software using local CORS base station TXPV located in Port Lavaca, TX, at 28-38-17.42365 N, 96-37-06.66130 W at -15.257 m elevation (NAD83).

Real-time positions were FAA WAAS-based for the *Bunny Bordelon* and *Sea Ark.*

FAA WAAS was also used for real-time positioning on the *Bella Marie* until JD2019-015, when USCG DGPS corrections were used instead. The USCG station used during this period was Angleton, TX, located at 29-18.05 N, 95-29.04 W. The station transmitted on 301 kHz.

Real-time positions were replaced in processing with few exceptions (noted in the applicable DR) for all MBES data. However, side-scan sonar (SSS) positions were not post-processed and utilized the real-time solutions.

POSPac Processing QC reports are included in the subdirectory “Digital_B-Horizontal_Control_Data” included with this report.

Refer to the DAPR for additional details on positioning methodology, processing, and quality control.

APPROVAL SHEET

For

Horizontal and Vertical Control Report: H13180 through H13187 and F00734

This report and the accompanying digital data are respectfully submitted.

Field operations contributing to the completion of this project were conducted under my direct supervision with frequent personal checks of progress and adequacy. This report, digital data, and accompanying records have been closely reviewed and are considered complete and adequate per the Statement of Work and Project Work Instructions. Other reports submitted with this survey include the Descriptive Report (one for each survey sheet) and the Data Acquisition and Processing Report.

This survey is complete and adequate for its intended purpose.

Andrew Orthmann

Digitally signed by Andrew Orthmann
Date: 2019.04.25 13:24:09 -08'00'

Andrew Orthmann
NSPS/THSOA Certified Hydrographer (2005), Certificate No. 225
Charting Program Manager
TerraSond Limited

APPENDIX I

Tide Reports

This Appendix contains the results of JOA Survey's analysis and validation of VDATUM for this survey. This consists of two reports:

1. Port Lavaca Boat Float Analysis

2. OPR-K376-KR-18 Validation of VDATUM

Port Lavaca Boat Float Processing and Analysis

- The boat float data was processed using two different software packages.
  - CSRS-PPP which is an online tool developed by the Canadian Geodetic Survey.
  - GIPSYx which was developed by the Jet Propulsion Laboratory
- GPS data was decimated to 1 Hz prior to processing.
- The NWLON data as linearly interpolated to 1 Hz
- Resulting 1 Hz GPS solutions and NWLON data were compared in MATLAB

Port O'Connor Boat Float

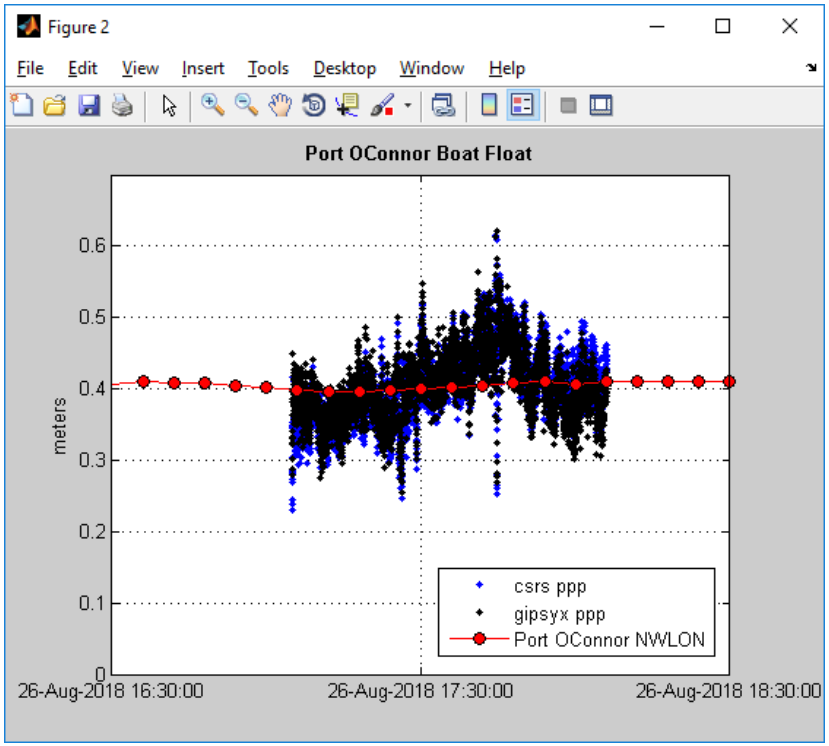
	staff_dates	Avg	Std	Rms	Count
csrs ppp	'26-Aug-2018'	-28.359	0.047045	28.359	3672
gipsyx ppp	'26-Aug-2018'	-28.33	0.045817	28.33	3672

Table above shows stats on the differences between the NWLON and Boat Float data.

The NWLON data is referenced to MLLW.

The Boat Float data is referenced to IGS08.

<u>Ellipsoid Height Offset</u>
NAD83 – IGS08 = 1.317 m



Port O'Connor Boat Float

Shared Solution

PID: BBDN99
Designation: 3701 K 1998
Stamping: 3701 K 1998
Stability: Monument will probably hold position well
Setting: A metal rod driven into ground. Describe below.
Mark Condition: G
Description:
Observed: 2016-09-20T13:42:00Z See Also 2014-07-17
Source: OPUS - page5 1209.04

Close-up View

= h

REF_FRAME: NAD_83(2011) | EPOCH: 2010.0000 | SOURCE: NAVD88 (Computed using GEOID12B) | UNITS: m | SET PROFILE | DETAILS

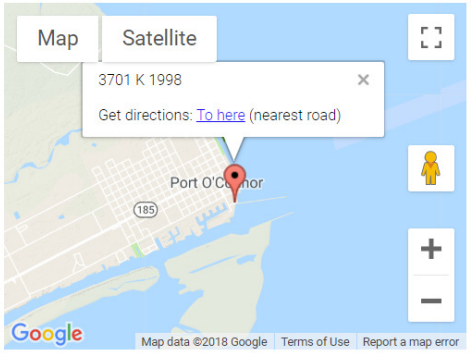
LAT: 28° 26' 42.09602"	± 0.004	m	
LON: -96° 24' 9.60980"	± 0.015	m	
ELL HT: -25.776	± 0.013	m	
X: -592369.522	± 0.013	m	
Y: -5577368.460	± 0.013	m	
Z: 3019948.922	± 0.008	m	
ORTHO HT: 1.147	± 0.025	m	

UTM 14	**SPC** 4201(TX N)	
NORTHING: 3149249.256m	395264.628m	
EASTING: 754367.185m	702641.296m	
CONVERGENCE: 1.23781426°	2.95408591°	
POINT SCALE: 1.00039860	1.00712189	
COMBINED FACTOR: 1.00040265	1.00712597	

CONTRIBUTED BY

zachary.hasdorff
Conrad Blucher Institute

Horizon View



Bench Mark Elevation Information — In METERS above:

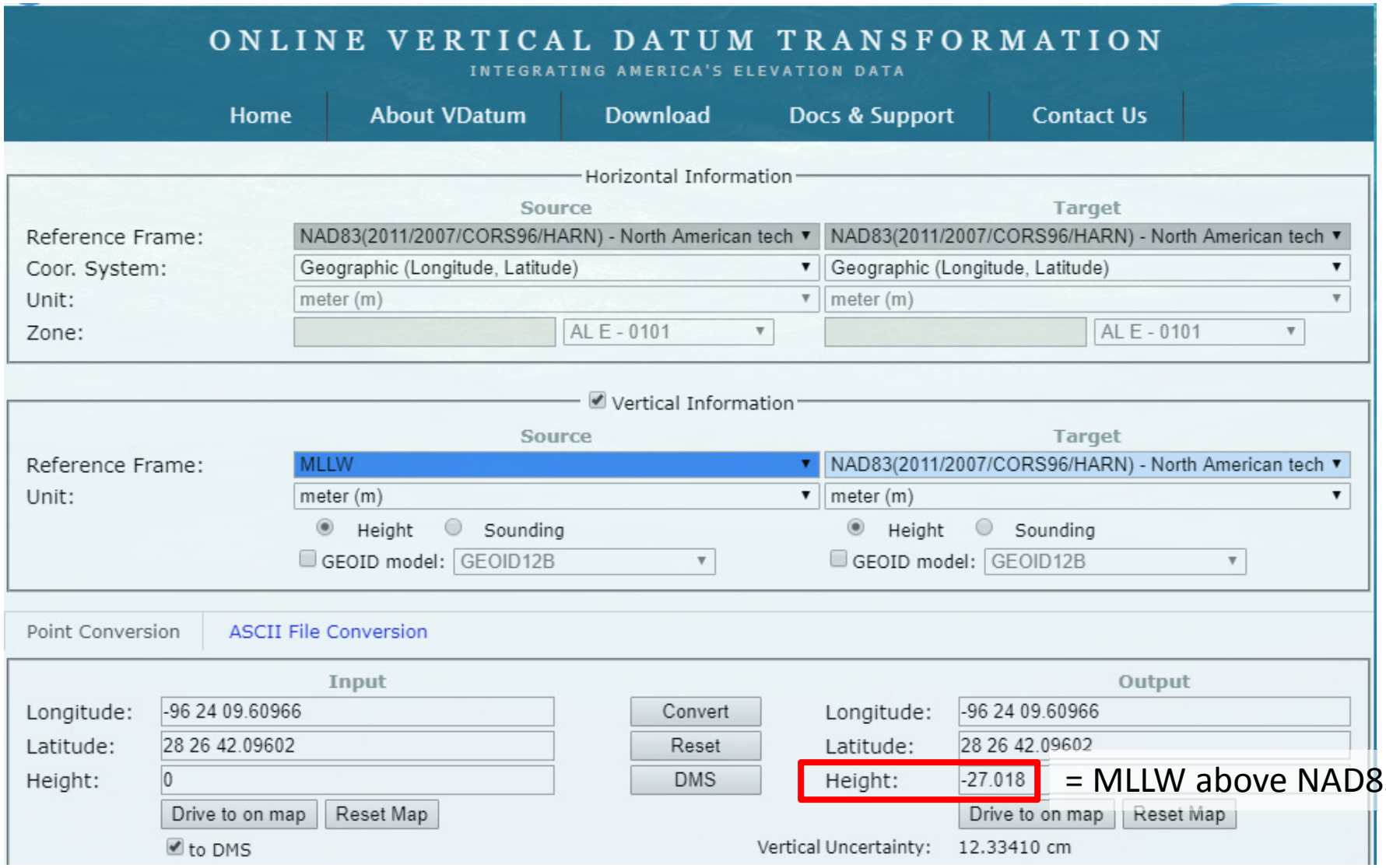
Stamping or Designation		MLLW	MHW
3701 K 1998	H =	1.048	0.826
3701 H 1998		0.888	0.666
3701 I 1998		0.963	0.741
3701 J 1998		0.948	0.726
3701 L 1998		1.227	1.005
3701 M 1998		1.453	1.231

Computation of SEP based on published BM info

SEP = MLLW above NAD83
SEP = h – H
h = ellipsoid height
H = MLLW height

h = -25.776 m (from OPUS Shared Solution)
H = 1.048 m (from tidal BM data sheet)
SEP = -25.776 m – 1.048 m
SEP = -26.824 m

Port O'Connor Boat Float



= MLLW above NAD83

Matagorda Boat Float

	staff_dates	Avg	Std	Rms	Count
csrs ppp	'26-Aug-2018'	-28.208	0.072936	28.208	4044
gipsyx ppp	'26-Aug-2018'	-28.392	0.093356	28.392	4044

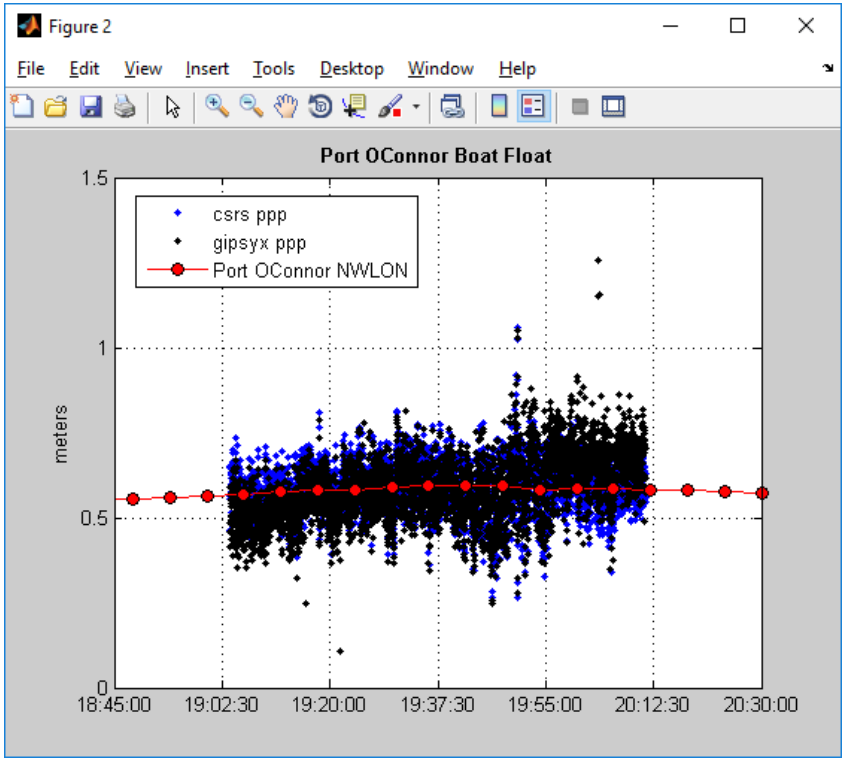
Table above shows stats on the differences between the NWLON and Boat Float data.

The NWLON data is referenced to MLLW.

The Boat Float data is referenced to IGS08.

<u>Ellipsoid Height Offset</u>
NAD83 – IGS08 = 1.319 m

Note: There is a slight trend in the GIPSYx data that is not in the CSRS-PPP data.



Matagorda Boat Float

Shared Solution

PID: BBFG26
Designation: 877 3767 B
Stamping: 3767 B 2016
Stability: Most reliable; expected to hold position well
Setting: Object driven into ground
Description: THE BENCH MARK IS LOCATED 81.5 M (267.4 FT) SOUTH OF BENCH MARK '3767 C', 4.4 M (14.4 FT) NORTH EAST OF THE CENTER LINE OF THE GRAVEL ROAD RUNNING NORTH TO SOUTH ALONG THE ISLAND, AND 3.4 M (11.2 FT) SOUTH OF A WITNESS POST. THE BENCH MARK IS A STAINLESS STEEL ROD DRIVEN 64 FT (19.5 M) TO REFUSAL AND ENCASED IN 5 INCH PVC.
Observed: 2016-06-21T12:52:00Z
Source: OPUS - page5 1209.04

Close-up View

= h

REF_FRAME: NAD_83(2011) | EPOCH: 201[illegible].0000 | SOURCE: NAVD88 (Computed using GEOID12B) | UNITS: m | SET PROFILE | DETAILS

LAT:	28° 25' 35.88289"	± 0.005	m
LON:	-96° 19' 53.54[illegible]5"	± 0.017	m
ELL HT:	-24.886	± 0.019	m
X:	[illegible]	± 0.016	m
Y:	-5579106.602	± 0.015	m
Z:	3018156.901	± 0.014	m
ORTHO HT:	1.947	± 0.035	m

	UTM 14	SPC 4204(TXSC)
NORTHING:	3147363.112m	4068738.607m
EASTING:	761381.035m	861407.713m
CONVERGENCE:	1.27099649°	1.30731165°
POINT SCALE:	1.00044326	0.99998785
COMBINED FACTOR:	1.00044717	0.99999176

CONTRIBUTED BY

brett.gregory
National Oceanic and Atmospheric Administration

Horizon View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Bench Mark Elevation Information                  In METERS above:

     Stamping or Designation                       MLLW      MHW

     3767 A 2016                                   2.262    1.897
     3767 B 2016                                   2.066    1.701
     3767 C 2016                                   2.196    1.831
     3767 D 2016                                   2.108    1.743
     3767 E 2016                                   2.136    1.771
```

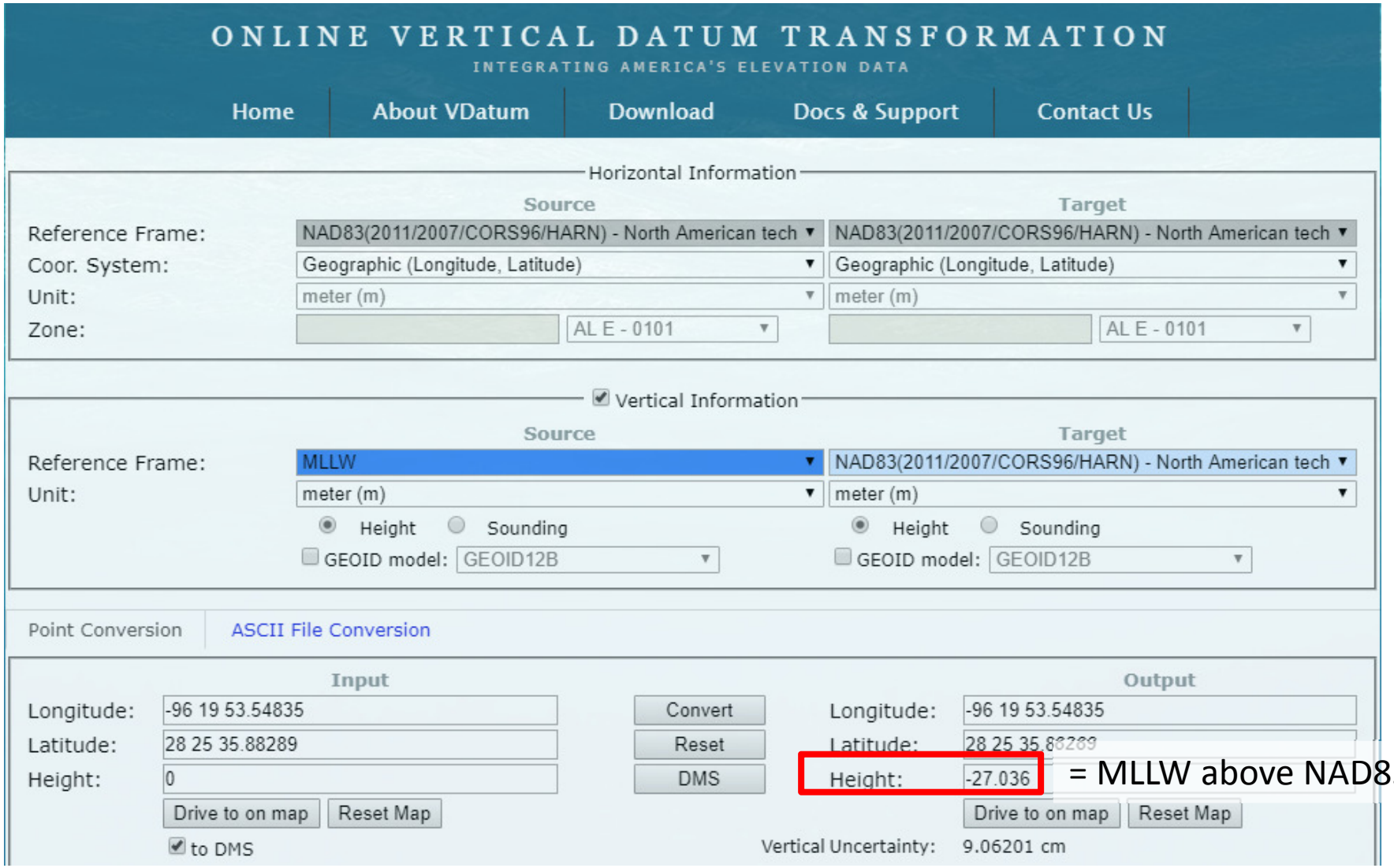
H = 2.066

Computation of SEP based on published BM info

SEP = MLLW above NAD83
SEP = h – H
h = ellipsoid height
H = MLLW height

h = -24.886 m (from OPUS Shared Solution)
H = 2.066 m (from tidal BM data sheet)
SEP = -24.886 m – 2.066 m
SEP = -26.952 m

Matagorda Boat Float

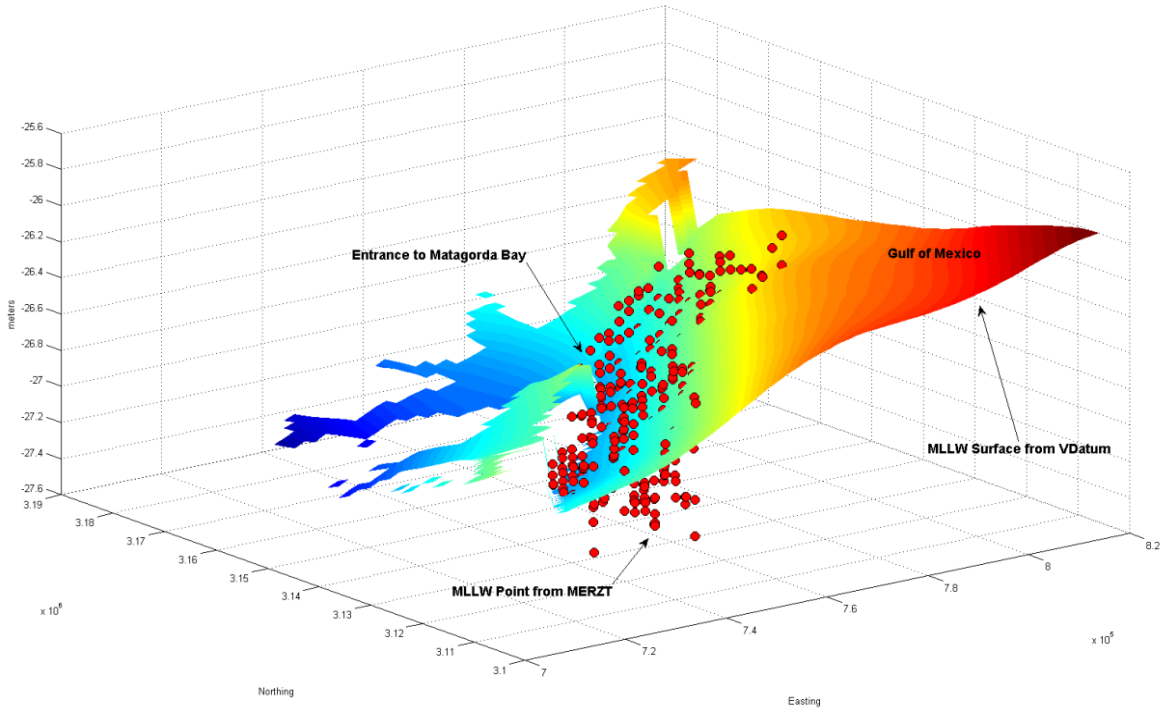


MLLW above NAD83

Source	Port O'Connor	Matagorda
Vdatum	-27.018 m	-27.036 m
OPUS Shared and TBM Datasheet	-26.824 m	-26.952 m
Boat Float and NWLON (CSRS PPP)	-27.042 m	-26.889 m
Boat Float and NWLON (GIPSYx PPP)	-27.013 m	-27.073 m

Summary: There is a difference of approximately 20cm between the Vdatum modeled SEP and the SEP computed from published BM info at Port O'Connor. At both locations the GIPSYx solutions are closer to the Vdatum value than the CSRS-PPP solutions. However, at Matagorda there is a trend in the GIPSYx solutions that may be biasing the results.

Validation of VDatum for OPR-P377-KR-18 using a Modified Ellipsoid Referenced Zoned Tides Approach



To:

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From:

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Anchorage, Alaska 99507
By: Nathan Wardwell

Project Summary

NOAA Office of Coast Survey (OCS) project OPR-K376-KR-18 included the hydrographic survey of 9 sheets near Port Lavaca. One survey sheet in the consisting of 42 polygons located on the lagoon side of the barrier islands (Figure 1). The other 8 sheets were located on the Gulf of Mexico side of the barrier islands.

The work was performed as an ellipsoid referenced survey and the soundings were reduced to Chart Datum using NOAA's VDatum program. Prior to the survey some anomalies were found in the Topography of the Sea Surface (TSS) grids for the lagoon area. Because of this JOA Surveys LLC, (JOA) performed a Modified Ellipsoid Referenced Zoned Tides (MERZT) analysis to assess the quality of the VDatum grids in the survey area.

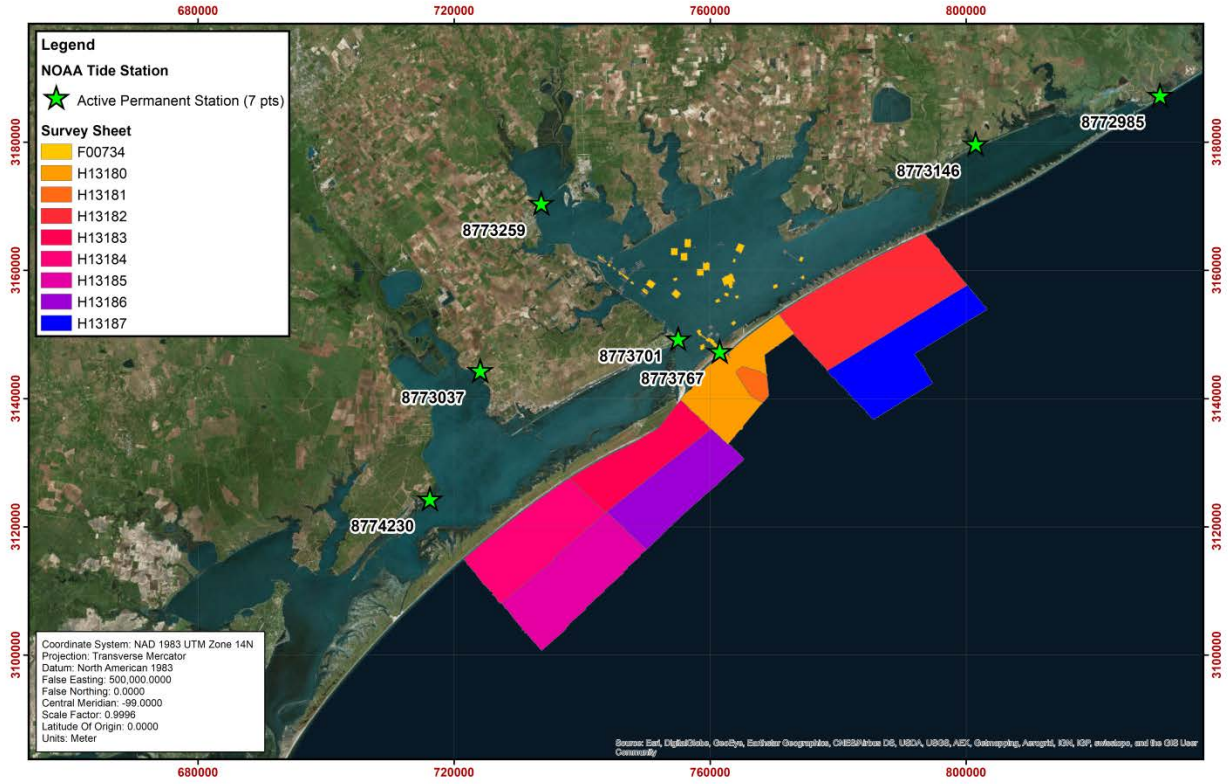

FIGURE 1 - MAP SHOWING THE SURVEY SHEETS FOR OCS PROJECT OPR-K376-KR-18 AND THE ACTIVE NWLON STATIONS.

Analysis Method

The MERZT analysis consisted of creating a grid of equally spaced cells that spans the entire survey area. The ellipsoid referenced water level data from the vessel is then parsed to create unique time series of water levels for each cell. These time series are sparse and irregularly sampled in time (Figure 2). Water level data, referenced to Mean Lower Low Water (MLLW), from the nearest NWLON station are then fit to the time series in each grid cell. An iterative approach is used to solve for the time offset between the NWLON station and the grid cell. The time offset that minimizes the differences is then applied to the NWLON data and the data is then fit to the time series in each grid cell, in a least squares sense, to solve for a range corrector and vertical offset. Because the NWLON data is referenced to MLLW the resulting vertical offset is the estimated separation between MLLW and the reference ellipsoid for each grid cell. This analysis was performed using grid cell sizes of 1km, 2km, 3km, 4km, and 5km. The vessel water levels on the Gulf of Mexico side of the barrier island were not analyzed due to a lack of

vessel data. Figure 3 shows the simultaneous water levels for the NWLON stations in the vicinity of the project. Stations 8773259, 8773701, and 8773767 are the stations nearest to the project area (Figure 1). There is a clear tidal signature at each of these stations with some slight differences in tidal characteristics. The water level differences between these three stations vary daily. For example on 11/14/18 there is a water level draw down at all three stations although the draw down at station 8773259 is significantly larger than the drawdown at the other two stations. Stations 8773701 and 8773767 are located near the lagoon entrance whereas station 8773259 is located more than 20 miles from the entrance. On 11/16/18 the water level at stations 8773259 and 8773701 are within centimeters of each other while the water levels at station 8773767 are approximately 20cm higher.

In addition to the MERZT analysis the vessel water levels were compared directly to the water levels from the NWLON station located in the entrance to the lagoon (station 8773767). Prior to the comparison the vessel water levels were transformed to MLLW using the online version of VDatum. Figure 4 shows the water level differences as a function of distance from the NWLON station 8773767

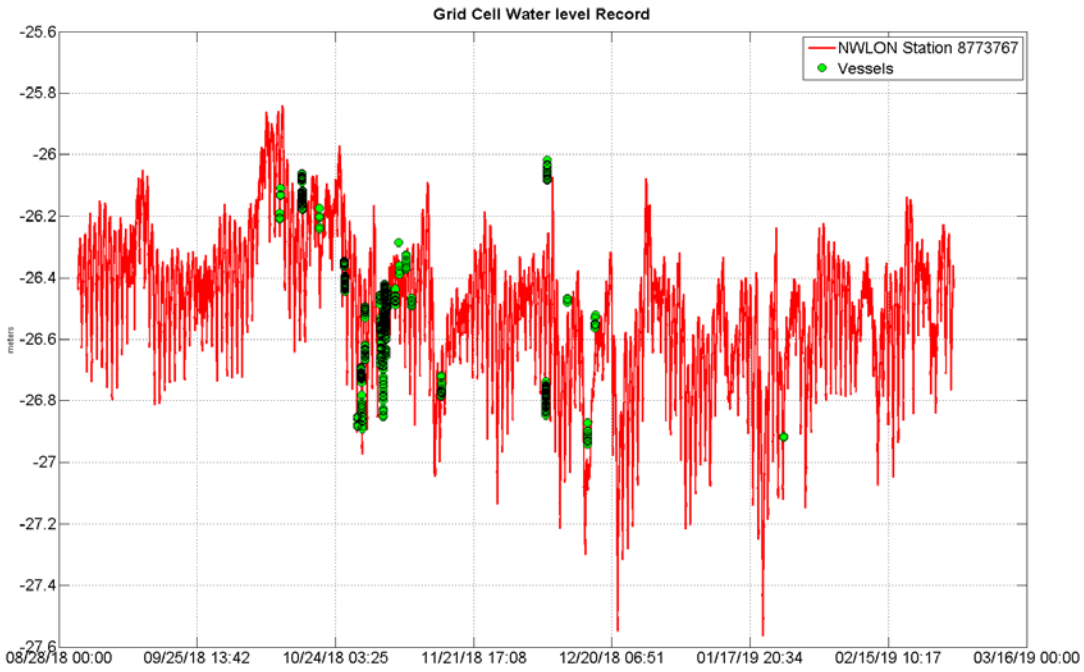

FIGURE 2 - PLOT SHOWING AN EXAMPLE TIME SERIES OF VESSEL WATER LEVELS IN ONE GIRD CELL.

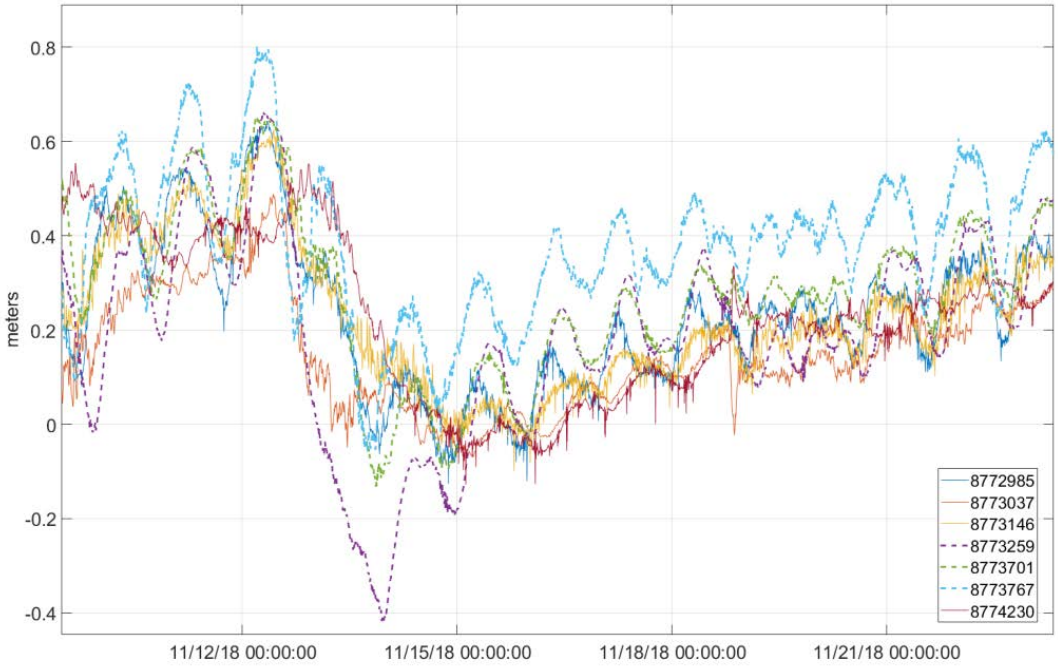

FIGURE 3 - PLOT SHOWING SIMULTANEOUS WATER LEVELS FROM THE ACTIVE WATER LEVEL STATIONS SURROUNDING AND WITHIN THE SURVEY AREA.

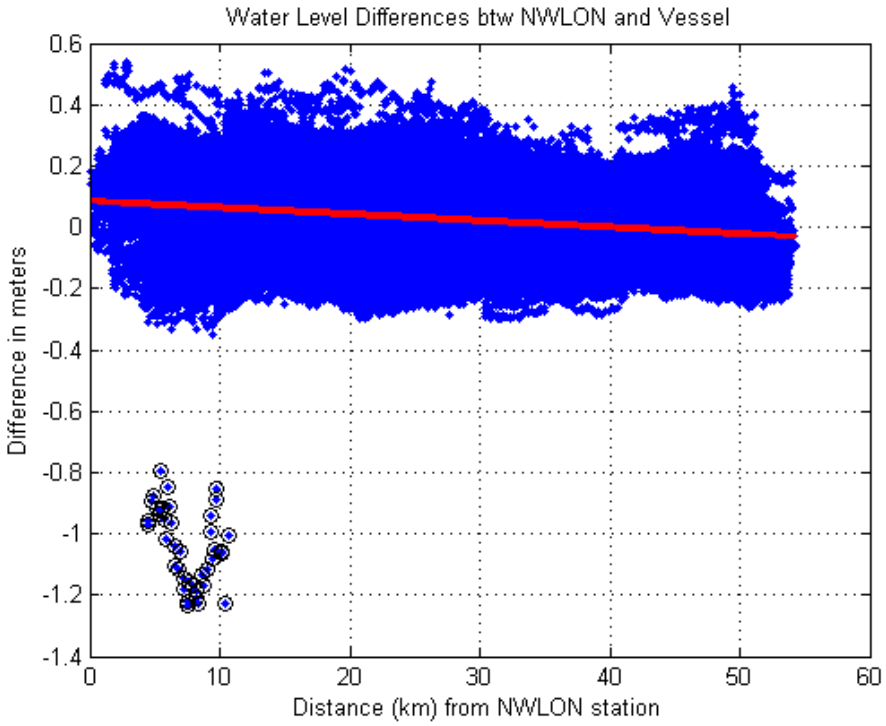

FIGURE 4 - WATER LEVEL DIFFERENCES (VESSEL MINUS NWLON STATION 8773767) AS A FUNCTION OF DISTANCE FROM STATION 8773767. THE BLUE DOTS ARE THE WATER LEVEL DIFFERENCES. THE BLUE DOTS WITH BLACK CIRCLES ARE OUTLIERS. THE RED LINE IS A LINEAR TREND LINE FIT TO THE DIFFERENCES AFTER REMOVING THE OUTLIERS. THE SLOPE OF THE LINE IS -2.1 MM/KM.

Results

The mean difference between the vessel water levels and the water levels at the Matagorda Bay NWLON station is 3cm +/- 11.7cm at 1 sigma (Figure 5). The maximum difference is 54cm and the minimum difference is -123cm. These statistics are based on differences after transforming the vessel water levels to MLLW using VDatum. Of the four grid cell sizes used in the MERZT analysis the 4km cell resulted in the smallest mean difference (-4cm +/-9.9cm at 1 sigma) from VDatum. The analysis performed using a grid cell size of 5km resulted in a larger absolute mean difference and standard deviation (Table 1).

There is substantially more noise in the SEP values derived using the MERZT than there is in the SEP surface from VDatum as can be seen in Figure 6. Histograms of the differences tend to be negatively skewed (Figure 7) suggesting the SEP is either underestimated using the MERZT approach of overestimated by VDatum.

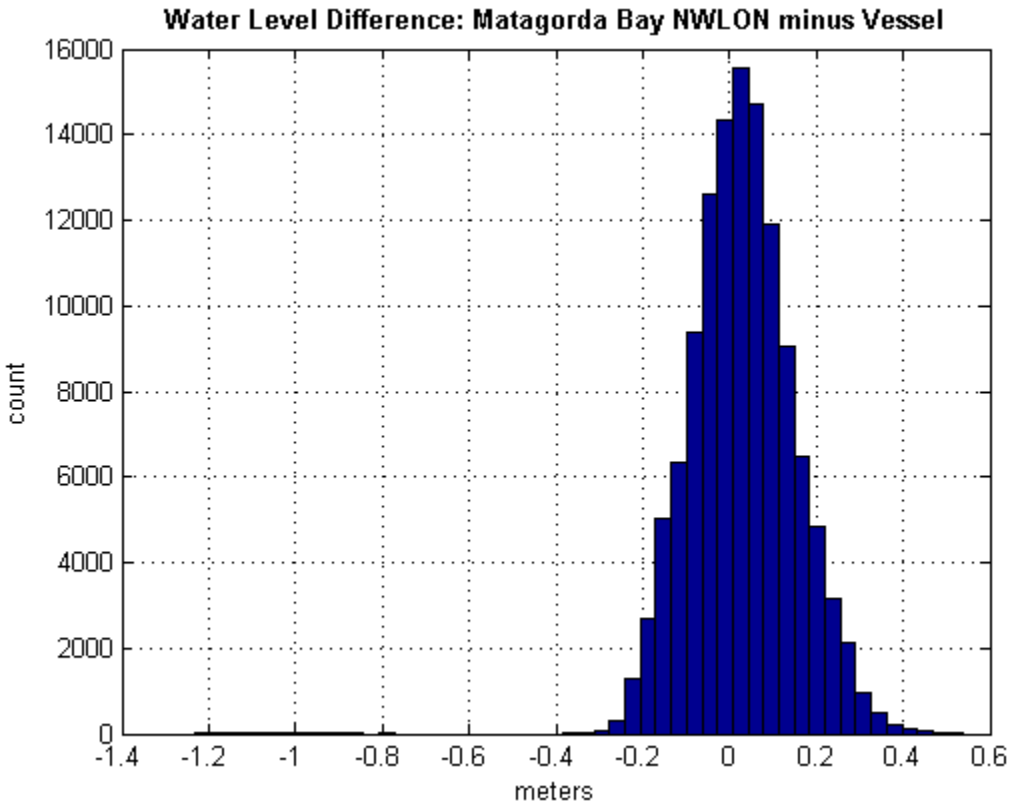

FIGURE 5 - HISTOGRAM OF THE WATER LEVEL DIFFERENCES AT NWLON STATION 8773767 AND THE VESSEL.

TABLE 1 - STATISTICS ON THE DIFFERENCES BETWEEN THE VESSEL AND VDATUM SEP RESULTING FROM THE MERZT ANALYSES PERFORMED USING 4 DIFFERENT GRID CELL SIZES.

Grid Cell Size	Mean	Standard Deviation (1-sigma)
2km	-4.0cm	13.9cm
3km	-4.0cm	13.9cm
4km	-4.0cm	9.9cm
5km	-4.9cm	10.8cm

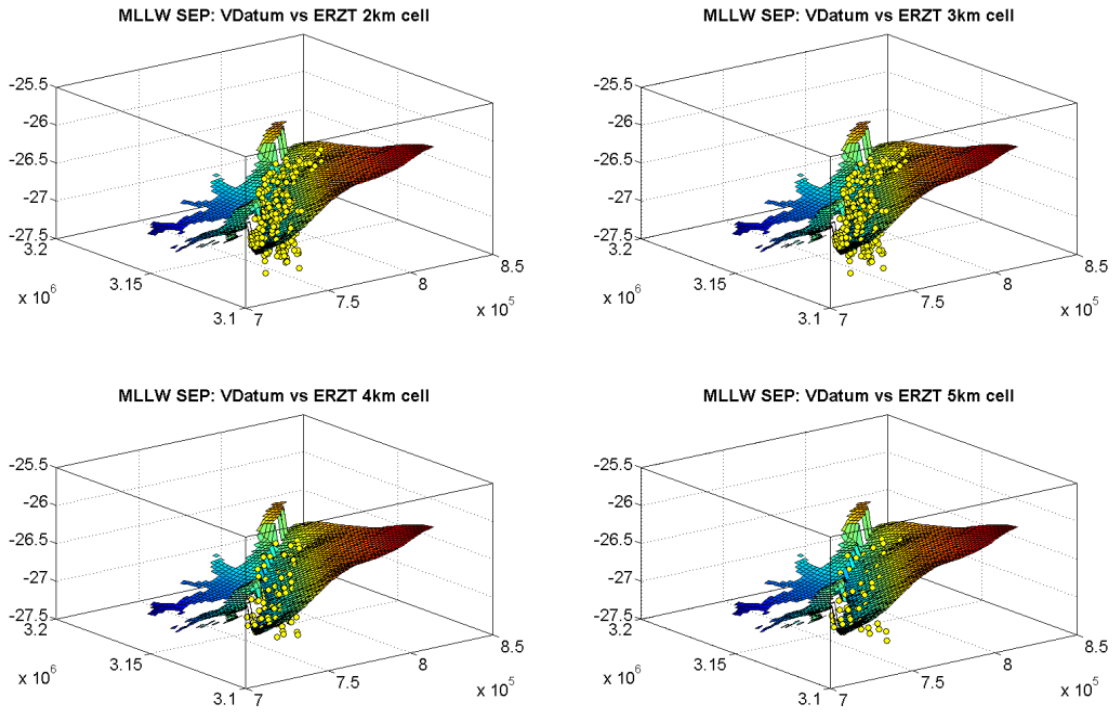

FIGURE 6 - THIS FIGURE SHOWS THE MLLW TO REFERENCE ELLIPSOID SEP FOR VDATUM AND MERZT. THE VDATUM SEP IS REPRESENTED BY THE SMOOTH SURFACE. THE MERZT SEP IS REPRESENTED BY THE YELLOW DOTS. THE PLOTS SHOW THE RESULTS FOR THE MERZT ANALYSIS USING GRID CELL SIZES OF 2KM, 3KM, 4KM AND 5KM (CLOCKWISE IN THAT ORDER STARTING IN THE UPPER LEFT CORNER).

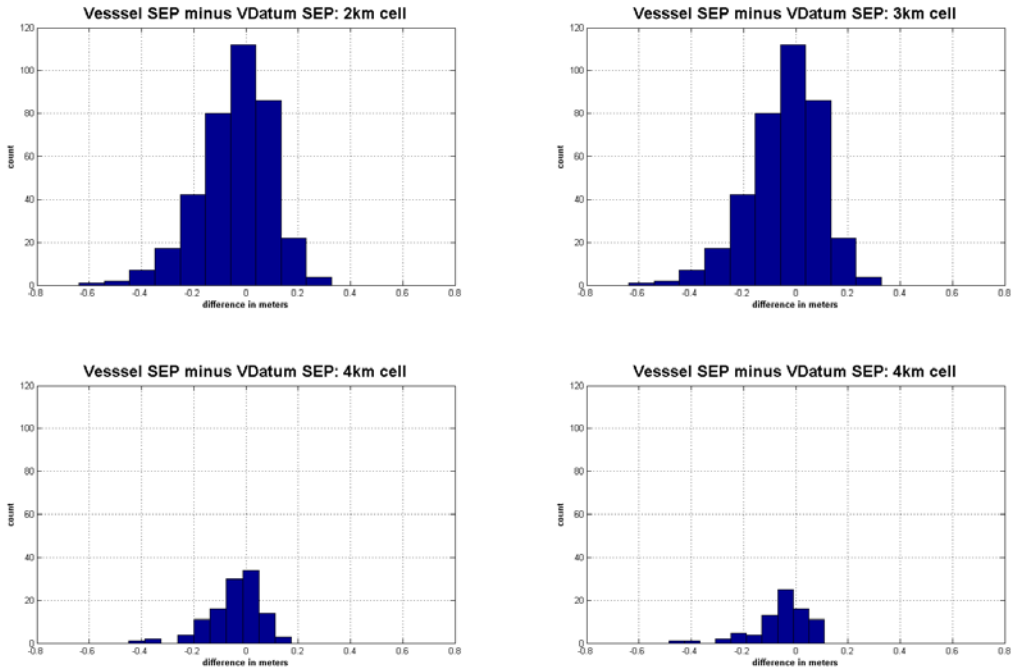

FIGURE 7 - HISTOGRAMS OF THE DIFFERENCES BETWEEN THE VDATUM SEP AND THE SEP DETERMINED USING THE MERZT ANALYSIS.

Conclusions

The large standard deviation resulting from the MERZT analyses is a result of the difference in total water level between the vessel and NWLON station 8773767. For example Figure 8 shows water levels at NWLON station 8773767 (Matagorda Bay Entrance Channel) and water levels measured by vessel while it was performing the survey. The vessel water levels are colored by distance from the NWLON station. This plot spans more than 7 days. On day 325 of 2018 the vessel is surveying approximately 50 km from the NWLON station. The vessel data shows the water levels were lower in this region on this day than they were at eh NWON station. Over the next five days the vessel begins surveying closer to the NWLON and on day 330 of 2018 it is within 20km. Over this period of time the low water at the NWLON and at the vessel is approximately the same height. As the vessel moves from 40km to within 20km of the NWLON there is a significant difference in the shape and height of the high tides. These differences cannot be properly modeled using the MERZT approach with data from a single NWLON station because this approach only solves for time, range and vertical offset. It does not solve for changes in tidal harmonics. The results may improve if analysis used a weighted least squares approach to combine water levels from multiple NWLON stations with varying tidal harmonics to estimate a best fit to the vessel water levels.

Due to the large standard deviation of the MERZT solutions it is not possible to identify small scale errors in VDatum. Additionally, the relatively large standard deviation does not allow for a definitive determination of the cause for the moderate skewness to the difference histograms shown in Figure 7. The spatial distribution of the differences is shown in Figure 9. From this map it appears that in the northeast and offshore regions of the project area the majority of the SEP values determined using the MERZT approach were smaller than the SEP values from VDatum.

Based on this analysis it is reasonable to assume the VDatum grid used to reduce the offshore hydrographic soundings is within survey spec.

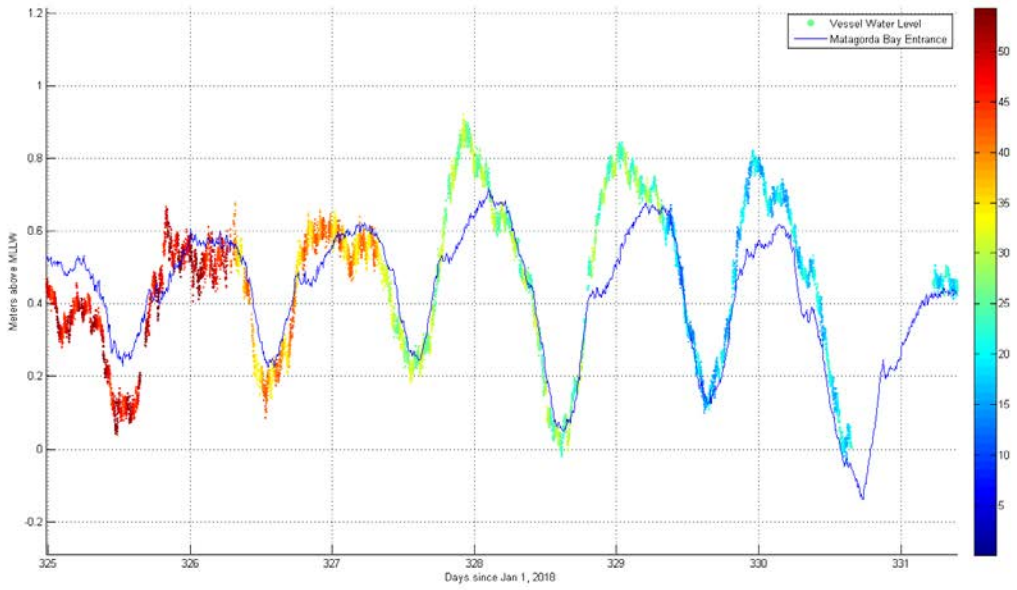

FIGURE 8 - TIME SERIES OF WATER LEVELS FROM THE MATAGORDA BAY NWLON STATION (BLUE LINE) AND FROM THE VESSELS. THE VESSEL WATER LEVELS ARE COLORED BASED ON DISTANCE (KM) FROM THE NWLON STATION.

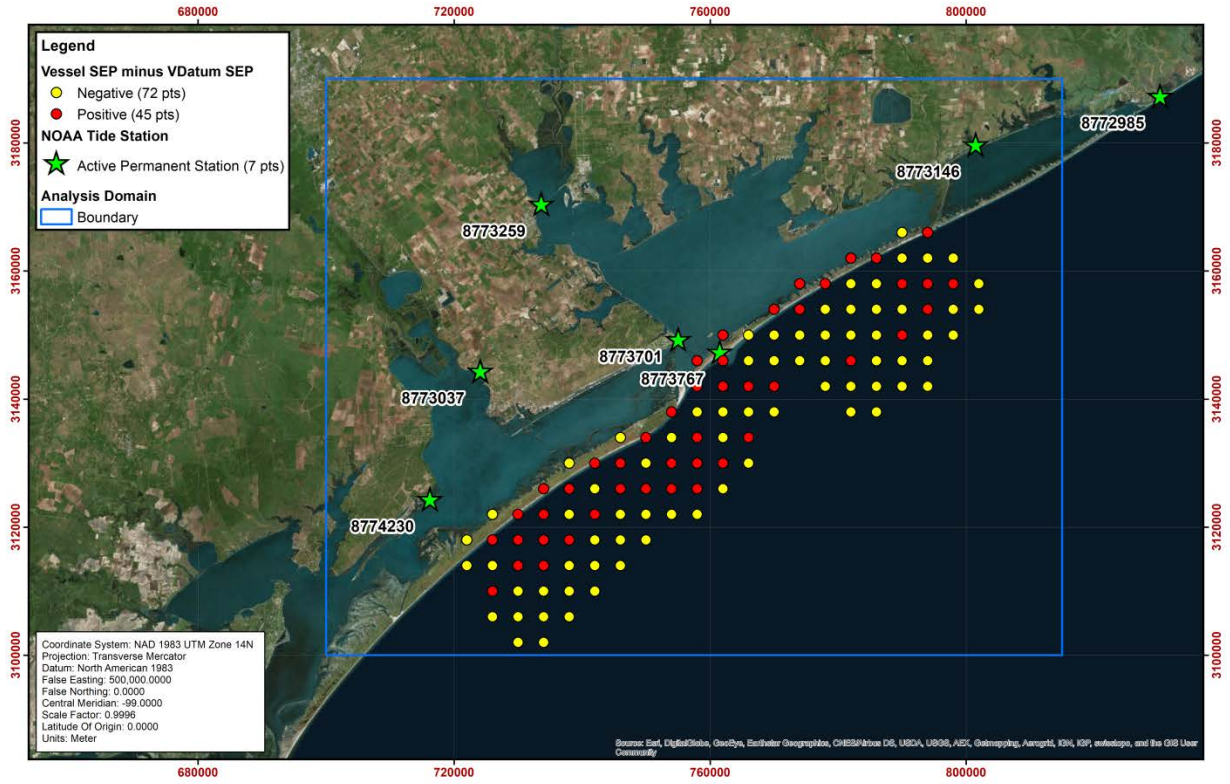

FIGURE 9 – MAP SHOWING THE DIFFERENCES BETWEEN THE MEZRT SEP VALUES AND THE VDATUM SEP VALUES. THE RED DOTS SHOWS LOCATIONS WHERE THE DIFFERENCES ARE POSITIVE (I.E. MERZT SEP IS LARGER THAN THE VDATUM SEP). THE YELLOW DOTS ARE LOCATIONS WERE THE DIFFERENCES ARE NEGATIVE.