2017-2018 Estuarine Bathymetry Data Collection, Analysis, and Archiving at Coos Bay, OR

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Photo Credit: Matthew Conlin

Estuarine Bathymetry Survey

During the weeks of 11 April 2017, 9 May 2017, and 29 May 2018, Oregon State University performed bathymetric surveys throughout the Coos Bay Estuary in Oregon (Figure 1) using the Coastal Profiling System (high-speed maneuverable personal water-craft (PWC) equipped with an echo-sounder and Global Positioning System, see Figure 4). The complete 2017 Coos Bay survey coverage is shown in Figure 2. A total of 299 bathymetric profiles and 56 push core sediment samples were collected during the two weeks of the survey campaign in 2017 (Figure 2). The additional 2018 Coos Bay survey coverage is shown in Figure 3. The 2018 survey focused on obtaining better coverage in the upper sloughs and river inputs of the estuary, 17 additional transects and 44 sediments samples were collected during the week of 29 May 2018 (Figure 3). Each daily survey was performed with 2 PWCs, outfitted with OSU's CPS, utilizing the Oregon Real-Time GPS Network (ORGN) to receive differential corrections broadcast through an internet server to provide Real Time Kinetic (RTK) positioning data. Survey data were collected in the horizontal datum NAD83 (2011) epoch 2010.00 in Oregon State Plane South (ORSP-S) coordinates (*meters*) with elevation data referenced to the vertical datum NAVD88 (*meters*). The final bathymetric measurements observed during the 2017 surveys have been corrected for speed of sound using an average speed of sound of 1483 *m/s*, observed throughout the estuary by Dr. David Sutherland of the University of Oregon on 21 April 2017. The 2018 survey data was not corrected for speed of sound due to the lack of recent observations in the survey area; these data were measured with a preset speed of sound of 1500 *m/s*. The bathymetric surveys were performed to acquire needed data for a National Estuarine Research Reserves funded study of the estuary, housed out of the University of Oregon. These data will serve to provide needed inputs to develop model simulations of estuarine circulation processes, and will also be used to verify and aggregate digital elevation models (DEMs) available for the estuary.

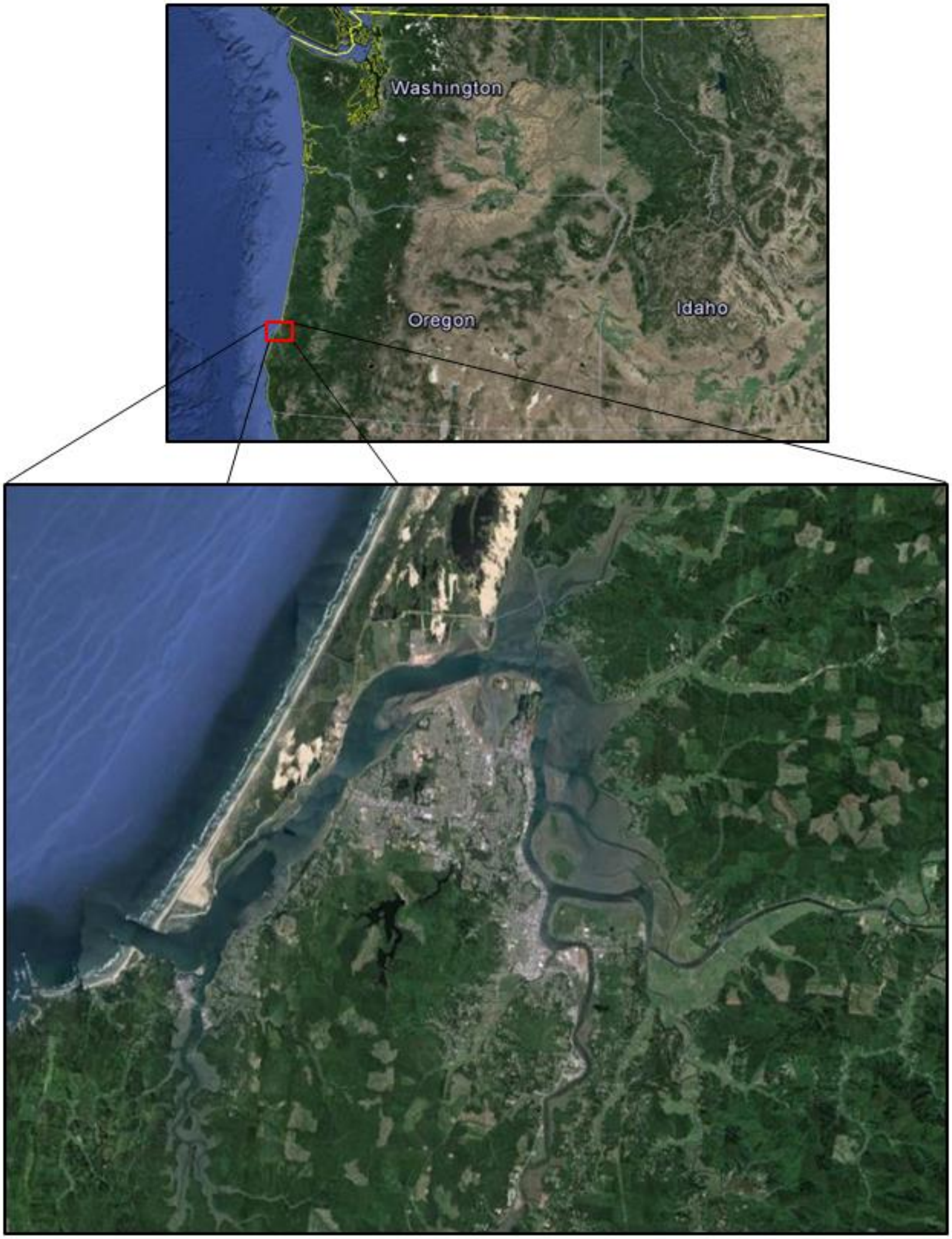


Figure 1) Google Earth images showing the location of the Coos Bay Estuary in Oregon.

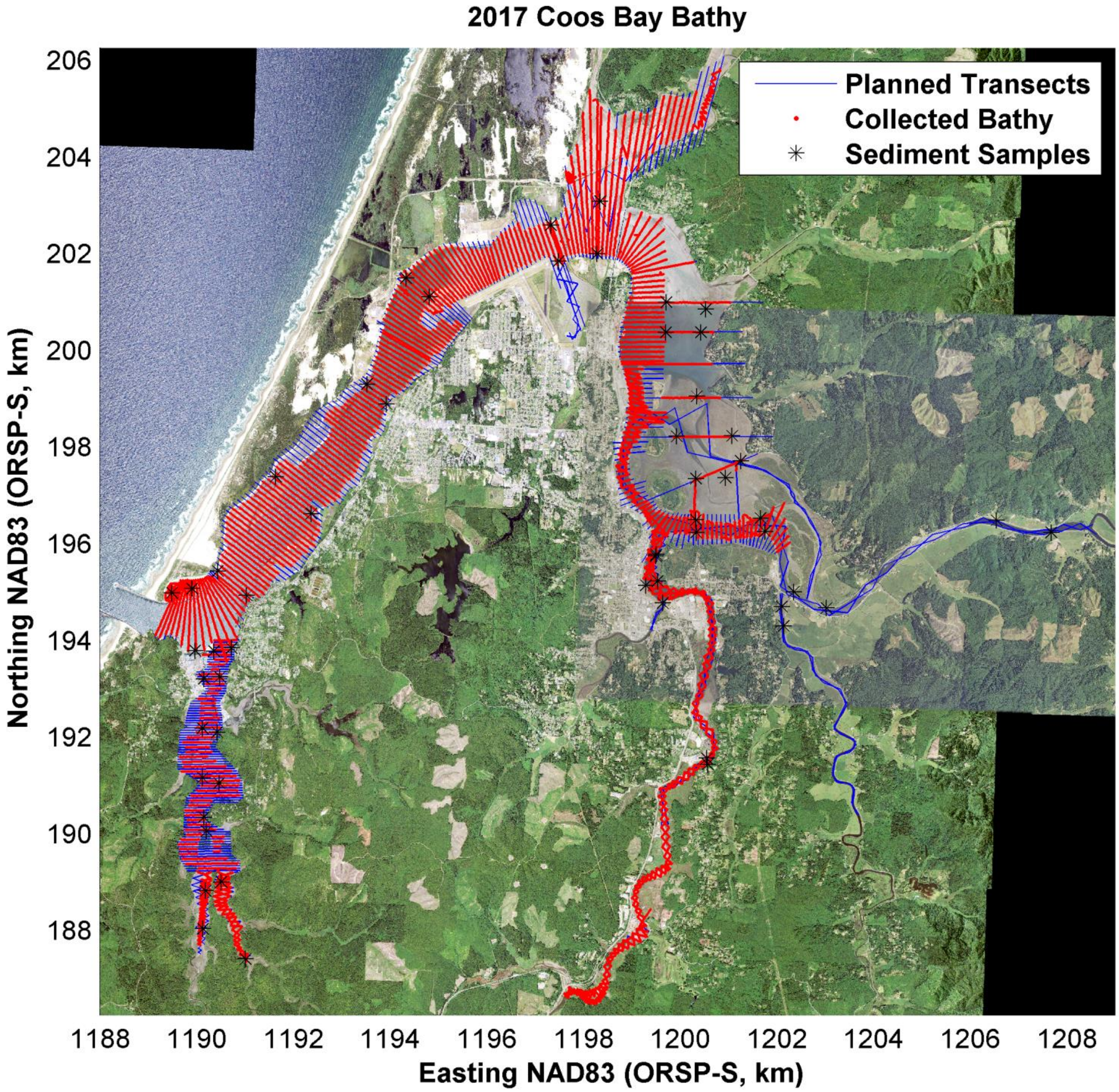


Figure 2) Bathymetry survey profiles and sediment sample locations collected in the Coos Bay Estuary during the 2017 survey. Planned transects (blue) are shown with extent of RTK data collected on each transect (red) plotted on top of aerial imagery to show the survey design and data coverage achieved. Sediment samples (black) were collected from the survey vessels with a push pole. Easting and Northing values are shown in Oregon State Plane South coordinates, *kilometers*, referenced to the horizontal datum NAD83 (2011) epoch 2010.00.

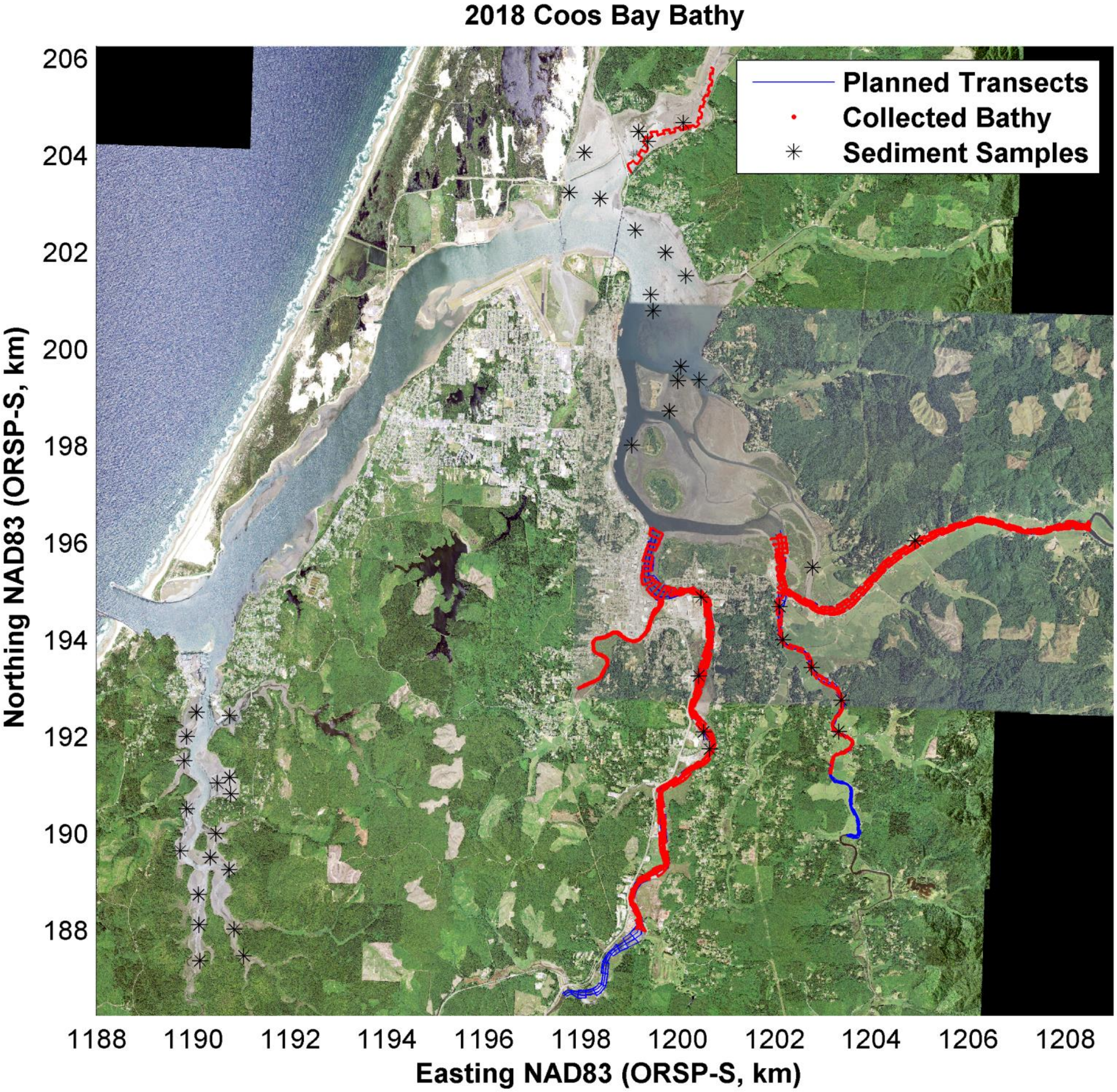


Figure 3) Bathymetry survey profiles and sediment sample locations collected in the Coos Bay Estuary during the 2018 survey. Planned transects (blue) are shown with extent of RTK data collected on each transect (red) plotted on top of aerial imagery to show the survey design and data coverage achieved. Sediment samples (black) were collected from the survey vessels with a push pole. Easting and Northing values are shown in Oregon State Plane South coordinates, *kilometers*, referenced to the horizontal datum NAD83 (2011) epoch 2010.00.

Table 1. The 2017-2018 Coos Bay bathymetry survey participants and their affiliations.

Participant	Responsibility	Affiliation
**Peter Ruggiero	Chief Scientist	Oregon State University
*Jeffrey Wood	Faculty Research Assistant	Oregon State University
Matthew Conlin	Undergraduate Research Assistant	Oregon State University
Paige Hovenga	Graduate Research Assistant	Oregon State University
Michael Pollard	Graduate Research Assistant	Oregon State University
Charles Murdock	Graduate Research Assistant	Oregon State University

**Chief scientist of survey campaign, not present for survey data collection
*Lead field technician.

Field Equipment and Data Quality

The Coastal Profiling System (CPS), mounted on a Personal Watercraft (PWC), consists of a single beam echo sounder, survey grade GPS receiver and antenna, and an onboard computer system running Hypack hydrographic survey software (Figure 4). This system is capable of measuring water depths from approximately 0.5*m* to approximately 50*m*, with bathymetric data collected at a GPS sample frequency of 10*Hz*. The survey-grade GPS equipment used in this project have manufacturer reported RMS accuracies of approximately ±3*cm* + 2ppm of baseline length (typically 10*km* or less) in the horizontal and approximately ±5*cm* + 2ppm in the vertical while operating in Real Time Kinematic (RTK) surveying mode. These reported accuracies are, however, additionally subject to multi-path errors, satellite obstructions, poor satellite geometry, and atmospheric conditions that can combine to cause a vertical GPS drift that can be as much as 10*cm*.

Survey data were collected using the Oregon Real-Time GPS Network (ORGN), a network of permanently installed, continuously operating GPS reference stations. The GPS network provides RTK correctors to GPS users through an internet connection to the ORGN server, with a reported horizontal accuracy level of one centimeter while operating in RTK mode. A Verizon Jetpack 4G LTE Mobile Hotspot MiFi 5510L was used with each CPS to establish and maintain the internet connection with the ORGN server and receive RTK corrections. The ORGN coordinates are referenced to the horizontal datum NAD83 (2011) epoch 2010.00 and have been aligned to the National Spatial Reference System maintained by the National Geodetic Survey (NGS). The most current NGS geoid model, GEOID12A, was used for the survey to transform between NAD83 (2011) epoch 2010.00 ellipsoid heights and

NAVD88 orthometric heights. The NTRIP-Client used to maintain the connection with the ORGN server was run as a device driver through the Hypack survey software used on each CPS. The NTRIP-Client established a connection to an IMAX_RTCM3 mount point to receive true-network, multi-base station real-time correctors based upon a cell of several reference stations within the ORGN. The IMAX (individualized master auxiliary) correctors eliminate most distant dependent GPS error sources, such as troposphere, ionosphere, and ephemeris errors, through use of multi-base station solutions for RTK correctors. Further detailed information on ORGN coordinates and data products can be viewed at their website (http://www.theorgn.net/orgn_coordinates.html).

While the horizontal uncertainty of individual data points is approximately 0.05*m*, the CPS operators cannot stay "on line" with wind chop and currents to this level of accuracy. Typically, mean offsets are less than 2.0*m* from the preprogrammed track lines and maximum offsets are typically less than 10.0*m*. While repeatability tests and merges with topographic data from previous nearshore bathymetry surveys, performed by Dr. Ruggiero's Geomorphology Lab, suggest sub-decimeter vertical accuracy, significant variability in seawater temperature (~10 degrees Celsius) can affect depth estimates by as much as 20*cm* in 12*m* of water. However, water temperatures usually remain within a few degrees of the temperature associated with the preset sound velocity estimate of 1500 *m/s* and attempts are made to correct for variations in sound velocity depending on environmental conditions. Therefore, a conservative estimate of the total vertical uncertainty for these bathymetry measurements is approximately 0.15*m*. When available, CTD data is used to apply a speed of sound correction to the bathymetric data collected at an assumed speed of sound of 1500 *m/s*. An estuary averaged speed of sound of 1483 *m/s* was observed on 21 April 2017 by Dr. Sutherland of the University of Oregon through various CTD transects and was used to correct the depth measurements collected during the 2017 survey. Bathymetric measurements collected during the 2018 survey were not corrected for speed of sound due to the lack of recent observations in the survey area.

For more information regarding equipment, field techniques, and data quality please refer Ruggiero et al., 2005 and Ruggiero et al., 2007.

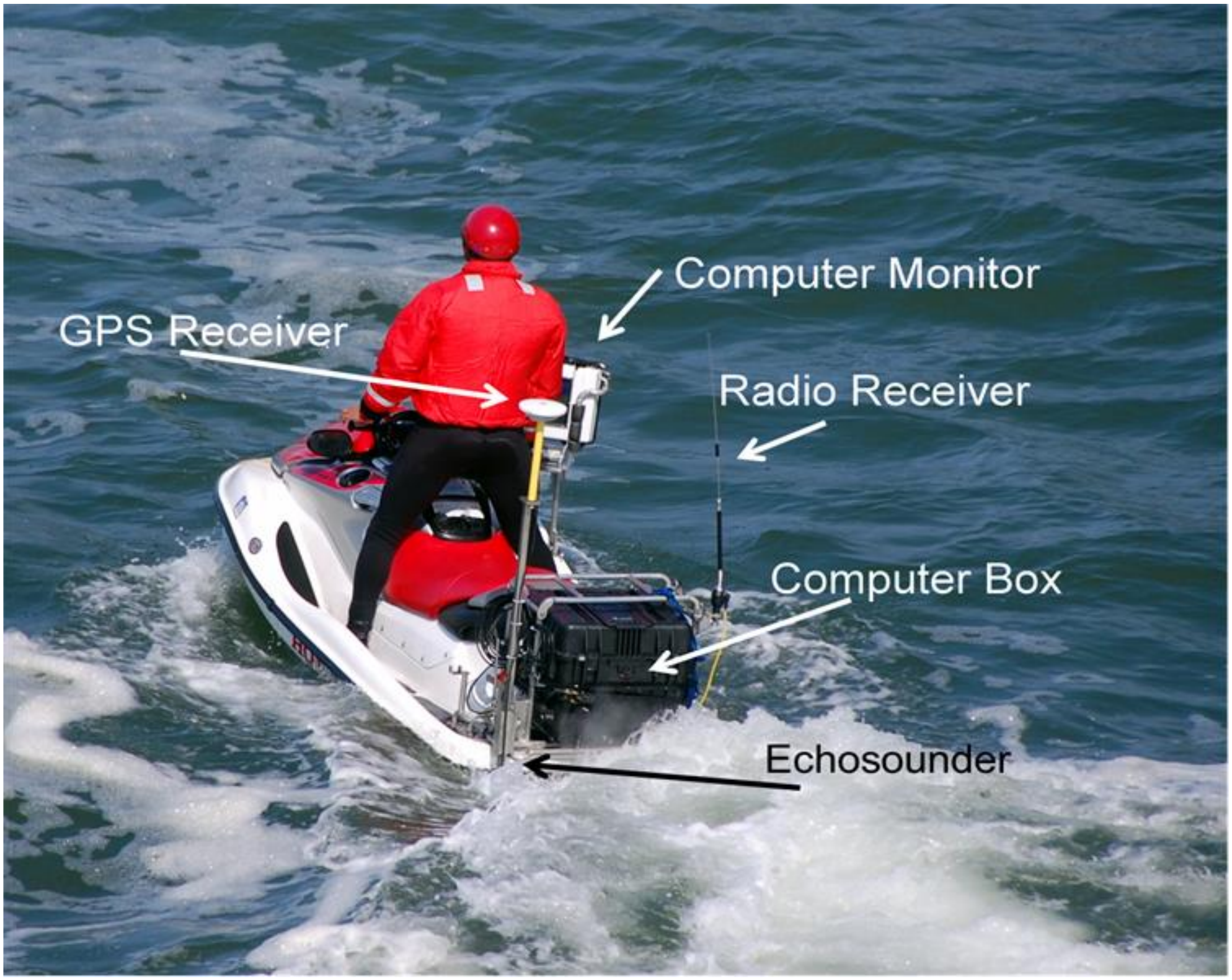


Figure 4) Oregon State University's Coastal Profiling System and onboard equipment.

Data Processing and Archiving

The Coos Bay survey data were collected in the horizontal datum NAD83 (2011) epoch 2010.00 (*meters*) in Oregon State Plane South (FIPS 3602, *meters*) coordinates with elevation measurements referenced to the vertical datum NAVD88 (*meters*). GPS positioning data were acquired using the Oregon Real-Time Geodetic Network (ORGN) to receive RTK corrections through a wireless internet connection, based on a true network, multi-base station solution from a cell of several reference stations in the ORGN (IMAX RTCM 3.0). Bathymetric sounding data were referenced to the land based vertical datum NAVD88 (*meters*). Sounding data were collected with a preset speed of sound of 1500 *m/s* during the survey and were later corrected with recent observations from CTD transect surveys if available.

Data processing was carried out using the Matlab script *transectViewer.m* developed by Andrew Stevens from the US Geological Survey in coordination with Peter Ruggiero of OSU. This code loads and displays the digitized data files and allows the user to navigate through the data and perform appropriate filtering and smoothing. Echosounder digitized depths can be compared to the raw acoustic backscatter signal, collected by the echosounder at a sample frequency of 200*kHz*, to ensure accuracy of the data and proper digitization of the bottom profile. Obvious bad, or noisy, data due to echosounder dropouts or poor returns can be easily eliminated from the data record, which is common while collecting data in the shallow depths and turbulent environments. Erroneous digitization of the bottom signature in the raw acoustic backscatter signal is easily corrected by manually digitizing the bottom profile when the bottom signature is clear. This was common throughout the shallow shoals and edges of the estuary where the presence of eel grass caused the echosounder digitized bottom profile to reflect the top of the eel grass beds. The true bottom profile stands out in the raw acoustic backscatter signal and can be corrected through use of the manual digitization tool in *transectViewer*, as shown in Figure 5. Various smoothing operations can be applied to eliminate scales of morphological variability below which the user is not interested. Small variations in depth measurements due to the pitch and roll of the CPS vessel from wave activity and wind chop are also eliminated through data smoothing. Due to the high quality of the raw data only very moderate smoothing was performed (10 point median average, Figure 6).

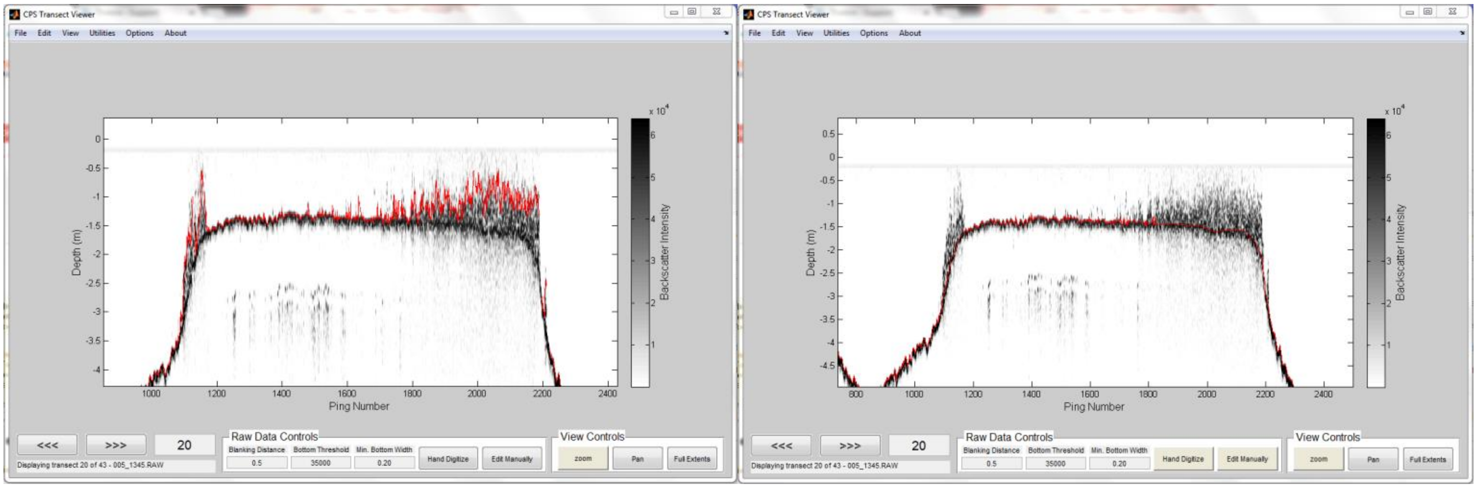


Figure 5) Investigation of erroneous acoustic backscatter signals along a bathymetric transect (Line005). The echosounder digitized bottom profile, shown as red points, is incorrect in the presence of dense eel grass beds (*left*). The erroneous sounding points are removed and the true bottom signature is manually digitized to correct the sounding data (*right*).

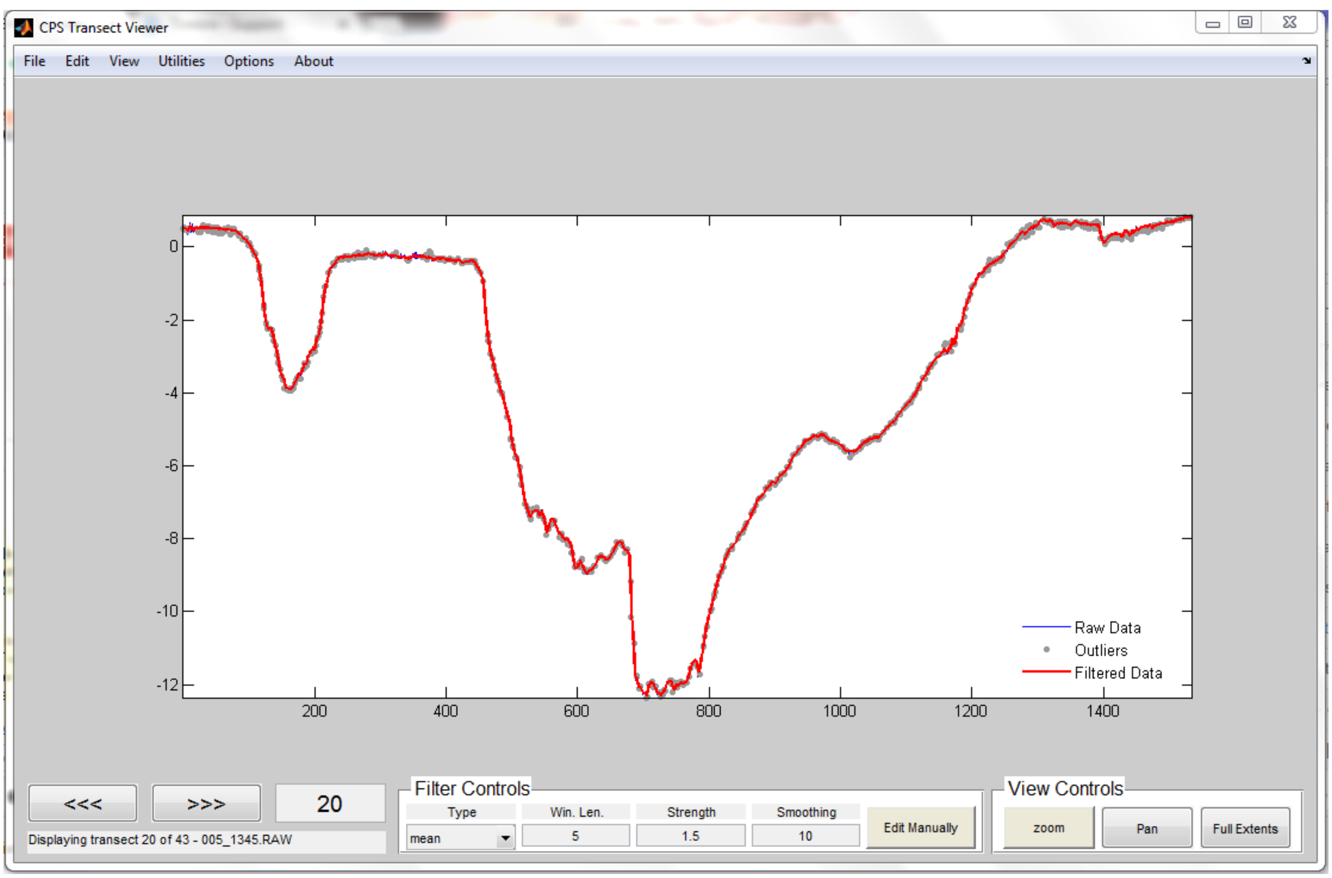


Figure 6) Processed cross-channel profile (Line 005) collected within the southwest portion of the Coos Bay estuary, displayed in transectViewer.

Estuarine Bathymetry

In order to maximize the coverage of each transect, bathymetric profiles were collected during high tides, surveying approximately 3.0 hours before and after the high tide. Sediment samples were collected either prior to or following bathymetric data collection to allow samples to be obtained more easily and to optimize the time allotted for bathymetry data collection. Surveying around high tides maximized the coverage obtained in the shallow portions of the estuary and sloughs. Two CPS systems worked together to collect as many profiles as possible within the tide window. At least one repeat profile per day was collected on the same transect by both CPS systems in order to compare the repeatability between the two survey vessels. Typically, the repeat transect for each daily survey would be measured by both vessels along the last transect where data was collected on the previous survey day or campaign. Repeatability of the two platforms was assed using a statistical analysis of comparable depth measurements along a repeat transect within a user specified horizontal separation. Figures 6 and 7 indicate the repeatability of the two survey vessels for a single transect (Line 012) collected during the 2017 survey. Figure 6 displays the repeatability of the survey platforms between the 13 April 2017 and 9 May 2017 surveys, showing the offline positioning of each vessel along the designed transect, the processed elevation data, and the corresponding elevation difference. Figure 6 also shows the results of the statistical analysis of comparable sounding data that are within 5 *meters* horizontally between the two survey vessels. Figure 7 displays the repeatability of the survey platforms along this transect during the same survey day, comparing data collected by both boats along the length of the transect. Figure 7 shows the offline positioning of each vessel along the designed transect, the processed elevation data, the corresponding elevation difference, and statistical analysis of point pairs within 5 *meters*. The statistical analyses includes the number of points compared (*n*), the root mean squared error (*RMSE*), systematic error (*RMSA*), unsystematic error (*RMSU*), and the mean offsets that were determined through use of the "compare profiles" tool available in *transectViewer*. The vertical offsets shown between the two survey vessels, and between survey campaigns, are within the uncertainty range of the two identical instrument platforms (having an estimated uncertainty of 15 *cm*). Bathymetric sounding data collected during 29 May 2018 survey campaign was compared to data collected in previous years' campaigns using the same statistical comparison tool. Since 2018 data was collected on newly designed transects in order to optimize the coverage of the upper sloughs and rivers feeding into the greater estuary, there were no transects repeated from previous survey campaigns. All data collected throughout the same region from previous years' surveys was aggregated into a single file and run through the analysis with a horizontal separation of 1 *meter* specified for selecting point pairs. Figure 8 shows the statistical analysis for all comparable sounding data from the 2018 and 2017 survey campaigns throughout the extent of Isthmus Slough. The analysis yielded a mean offset of 2 *cm*, which is less than the uncertainty of the instrument platforms. The same analysis was performed for data collected throughout the survey extent for Coos River, comparing point pairs within 1 *meter* for data collected in 2018 and 2014, shown in Figure 9. No data was collected in Coos River during the 2017 campaigns. The analysis also yielded a mean offset of 2 *cm*, with some notable variations occurring at deeper sounding measurements between the 2018 and 2014 surveys. Figure 10 shows all processed elevation data collected in 2017 and 2018. All data were gridded to 5 meters in the horizontal, bathymetric soundings were interpolated over the gridded domain and plotted on top of aerial imagery of the estuary. Figure 11 shows a close-up view of one interesting feature that was observed previously in 2014, a scoured hole at the confluence of the Millicoma River and the South Fork Coos River. Bathymetric data was collected at higher density around this feature to provide better resolution during the 29 May 2018 survey.

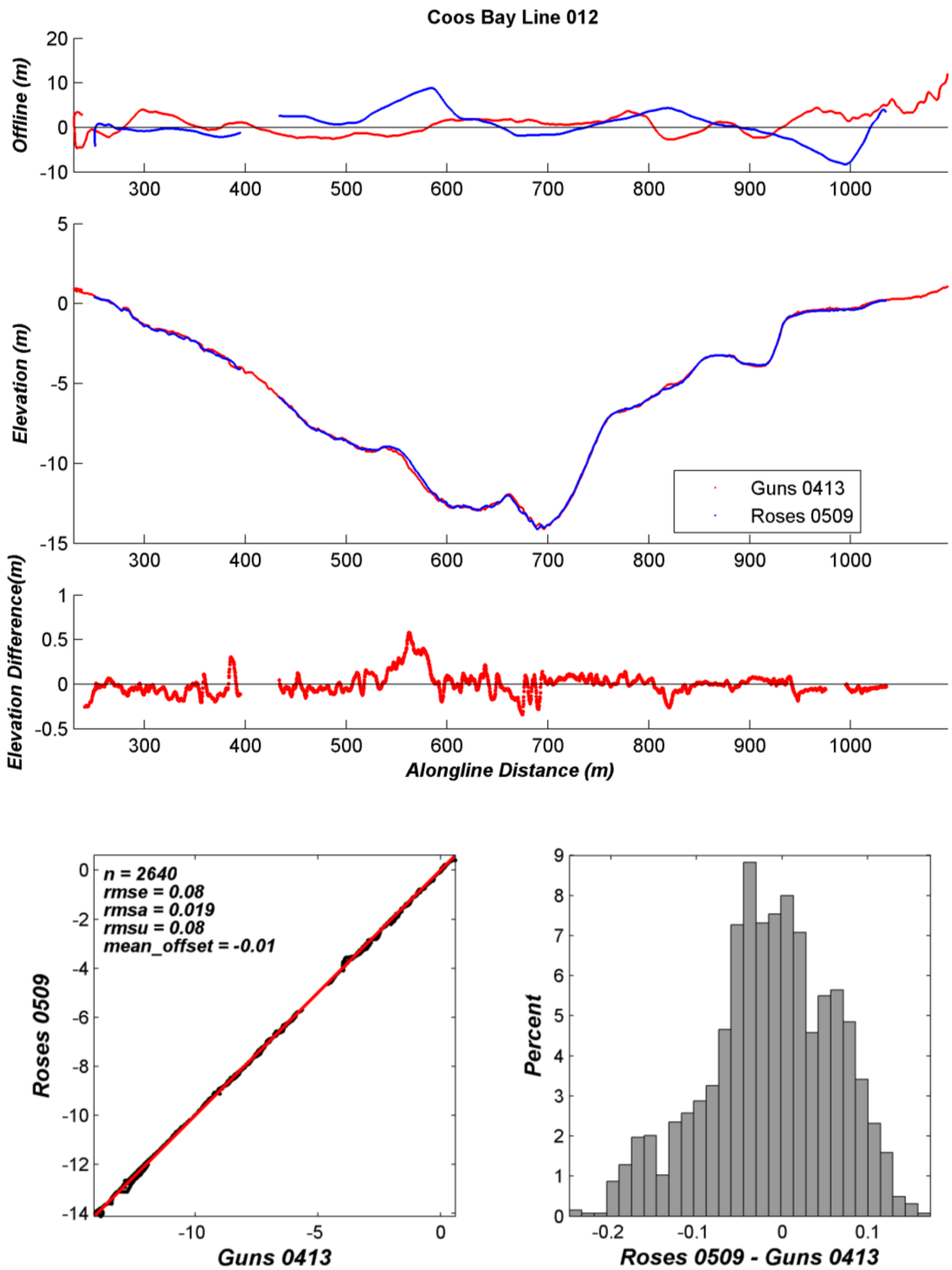


Figure 6) Results from statistical analysis performed for corresponding data collected within 5 *meters* between the two survey vessels on the repeat transect collected on 13 April 2017 and 9 May 2017. The analysis shows a 1 *cm* vertical offset between survey campaigns, which is within the uncertainty of the instrument platforms.

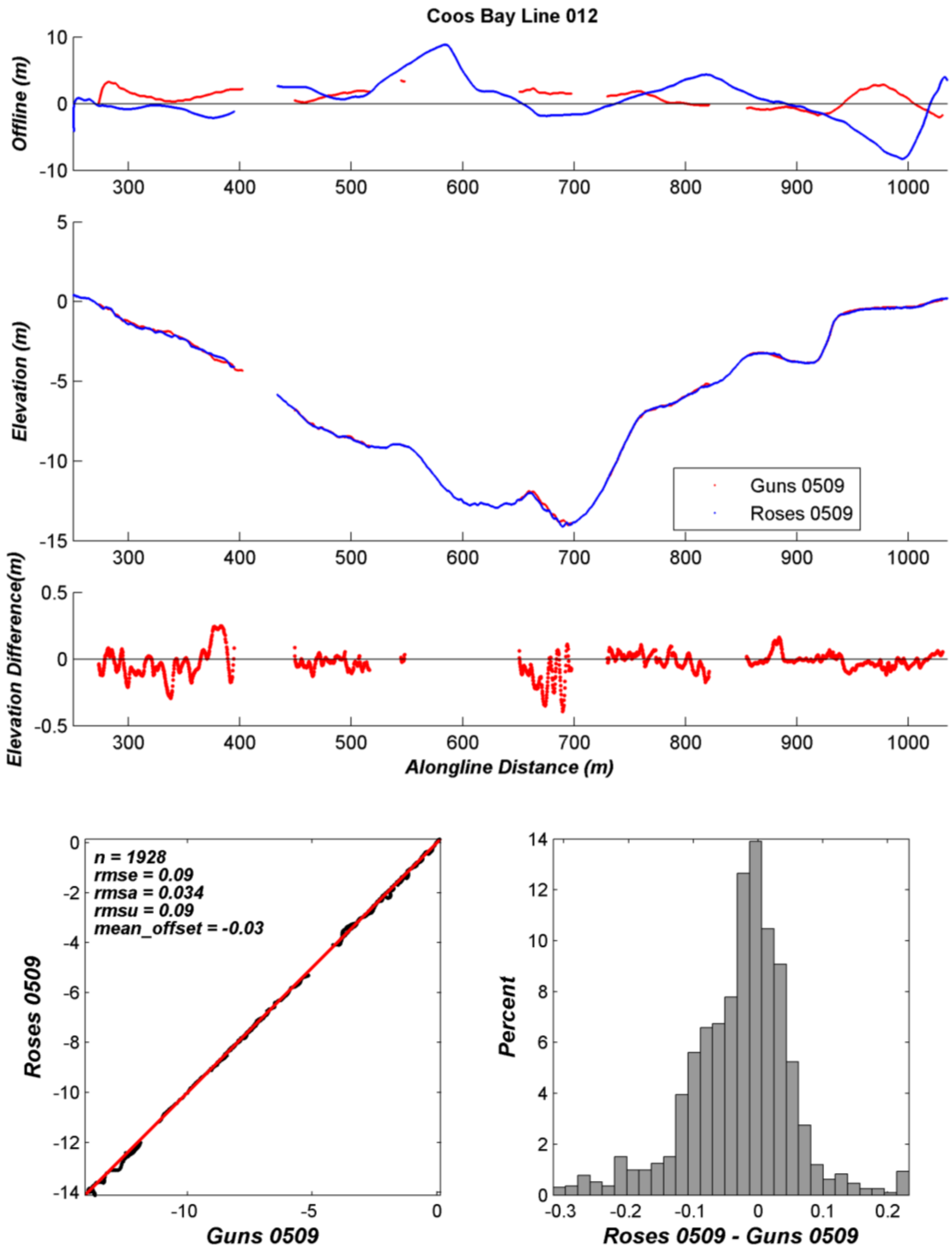
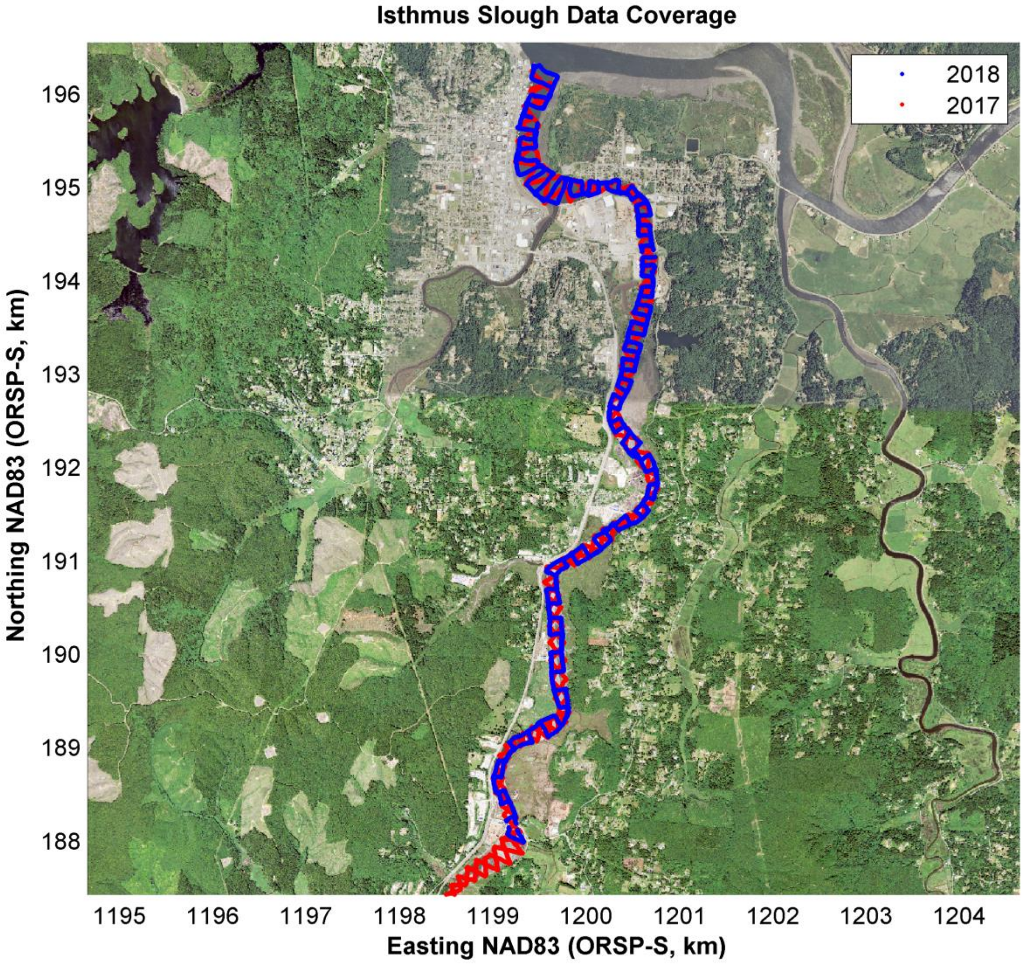


Figure 7) Results from statistical analysis performed for corresponding data collected within 5 *meters* between the two survey vessels on the repeat transect for 9 May 2017. The analysis shows a 0 *cm* vertical offset between the two vessels, which is within the uncertainty of the instrument platforms.



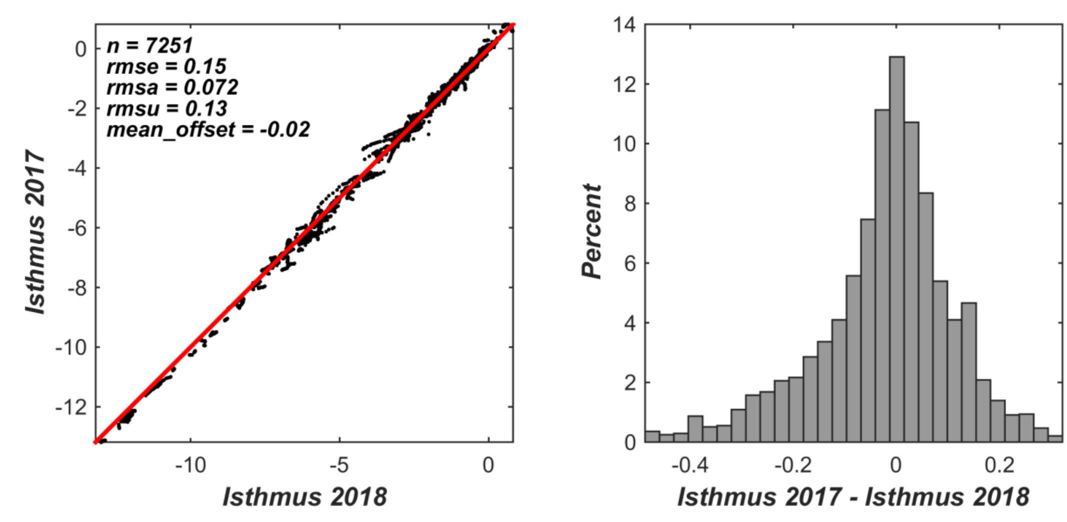


Figure 8) Results from statistical analysis performed for corresponding data collected within 1 *meter* between the 2018 and 2017 survey campaigns throughout Isthmus Slough. The analysis shows a 2 *cm* vertical offset between the two campaigns. The mean offset is within the uncertainty of the instrument platforms.

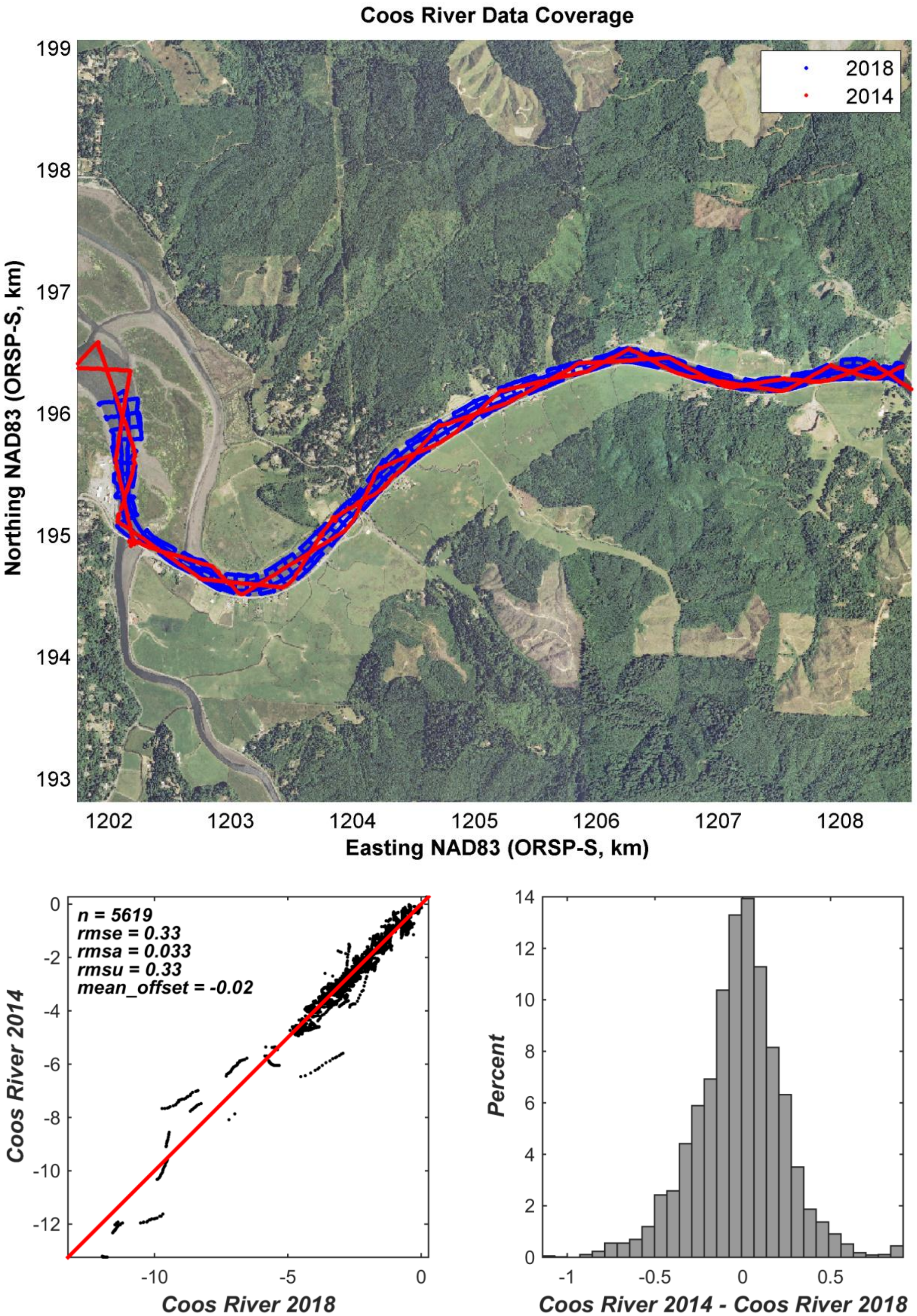


Figure 9) Results from statistical analysis performed for corresponding data collected within 1 *meter* between the 2018 and 2014 survey campaigns throughout Coos River. The analysis shows a 2 *cm* vertical offset between the two campaigns. The mean offset is within the uncertainty of the instrument platforms.

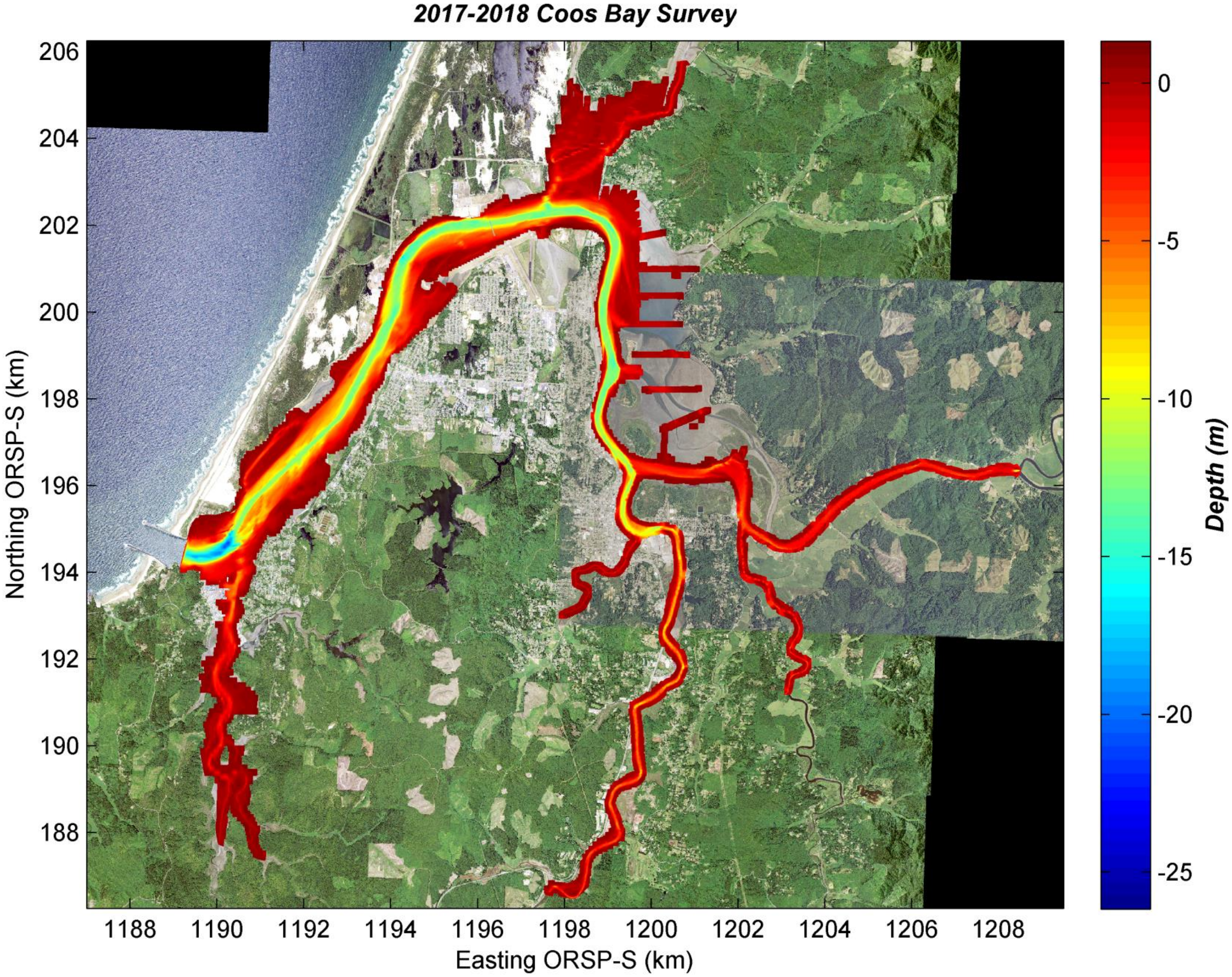


Figure 10) Aerial image of the Coos Bay Estuary with gridded processed elevation data collected during the 2017 and 2018 surveys plotted on top. All data were gridded to 5 meters in the horizontal, bathymetric soundings were interpolated over the gridded domain. The range of depth values shown covers the range of depths observed throughout the estuary. Easting and Northing values are shown in Oregon State Plane South coordinates in kilometers referenced to the horizontal datum NAD83 (2011) epoch 2010.00. Elevations are reported in meters and the vertical datum is NAVD88.

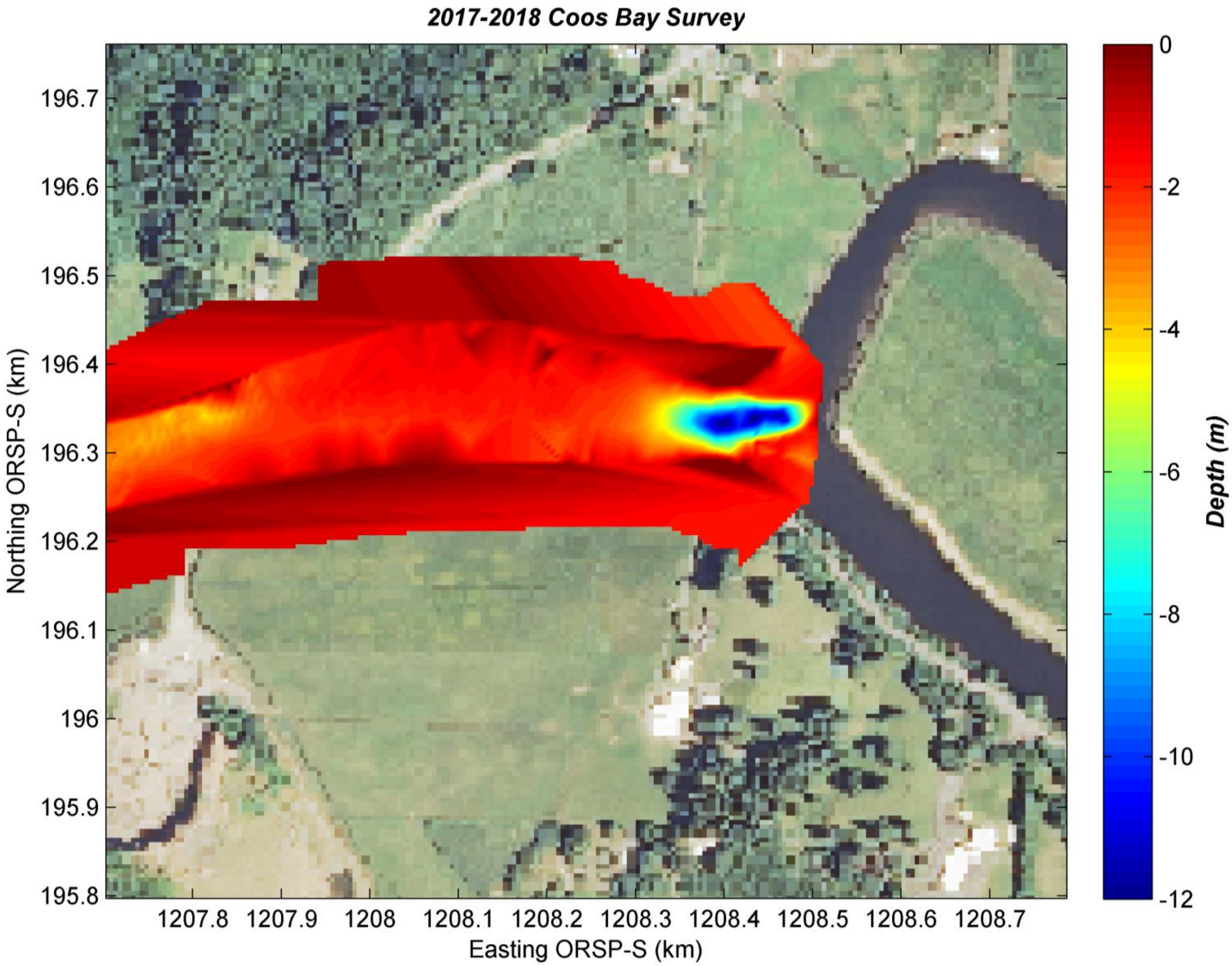


Figure 11) Aerial image of the confluence of the Millicoma River and the South Fork Coos River with gridded elevation data collected during the 2018 survey plotted on top. This plot shows an interesting scour feature observed during the survey at the confluence of these two rivers. All data were gridded to 5 meters in the horizontal, bathymetric soundings were interpolated over the gridded domain. The range of depth values shown covers the range of depths observed throughout data collected along the Coos River. Easting and Northing values are shown in Oregon State Plane South coordinates in kilometers referenced to the horizontal datum NAD83 (2011) epoch 2010.00. Elevations are reported in meters and the vertical datum is NAVD88.

Deliverables

The Coos Bay bathymetry profiles collected during the 11 April 2017, 9 May 2017, and 29 May 2018 survey campaigns are supplied in four different formats for each profile collected. Data collected in each year is located in the folder corresponding to that year with the format 'data_##' where ## indicates the two digit representation of the year, ie. 'data_17' includes all data collected in the year 2017. Each year has two subdirectories containing the data files for the bathymetric measurements in the 'bathy' folder, and the sediment sample location files in the 'sediment' folder. The subdirectories within the 'bathy' folder are as follows: the 'GoogleEarth' folder contains Google Earth files for each transect collected (*.kml*, those that were not collected as a continuous profile are given as A, B, C, etc.); the 'InfoBank' folder contains text files (*.txt*) with elevation data (meters, NAVD88) reported corresponding to geographic coordinates (Lat/Lon); the 'Netcdf' folder contains Net CDF library style metadata information (*.nc*) with various information for each individual transect; the 'output_fin' folder contains ASCII text files (*.xyz*) with the final elevation measurements (meters, NAVD88) reported corresponding to Oregon State Plane South coordinates (meters, NAD83 (2011) epoch 2010.00) in which the data were collected. All 2017 data have been corrected for speed of sound, using an average speed of sound of 1483 *m/s*, observed throughout the estuary. 2018 data were not corrected for speed of sound due to lack of recent observations, the default speed of sound of 1500 *m/s*, preset while collecting sounding data, was left unchanged.

Within the 'bathy' folder, each subdirectory has the same naming format for each transect collected, given as "coosbay14_line###_b.*ext*" where '###' is the three digit number of each transect and '*ext*' designates the file extension type between the four different formats of bathymetric data. Some transects have the naming format "coosbay14_line###_#_b" where '#' is either "1" or "2" for transects that were added for better coverage prior to the survey. Transects that were collected by both boats, as repeat lines, are given the naming format "coosbay14_line###_b_*boatname_date*" (i.e. "coosbay14_line007_b_roses_0318"). Areas where additional data was collected that was not on a previously planned transect have the naming format "coosbay14_filleddata_..._b" where '...' is a description of where the data was collected (i.e. “coosbay14_filleddata_haynes_b” was collected to better define the main channel in Haynes Inlet).

The ‘sediment’ directories for each year contain ASCII text files (*.xyz*) with the sediment sample locations and depth values at the sample site (if recorded). Each text file in the ‘output_fin’ and the ‘sediment’ folders (*.xyz*) are composed of 3 columns of data: Eastings, Northings, and Elevation (depth). Easting and Northing values are referenced to NAD83 (2011) epoch 2010.00 (*m*) in Oregon State Plane South coordinates (*m*). Elevation values are referenced to NAVD 88 (*m*) in the vertical.

References:

Ruggiero, P., Eshleman, J., Kingsley, E., Kaminsky, G., Thompson, D.M , Voigt, B., Kaminsky, G., and Gelfenbaum, G., 2007. Beach monitoring in the Columbia River littoral cell: 1997-2005., U. S. Geological Survey Data Series 260.

Ruggiero, P., Kaminsky, G.M., Gelfenbaum, G., and Voigt, B., 2005. Seasonal to interannual morphodynamics along a high-energy dissipative littoral cell, *Journal of Coastal Research*, 21(3), 553-578.