NOAA Technical Memorandum NOS OES 002

QUALITY ASSURANCE OF TAMPA BAY PORTS: CURRENT MEASUREMENTS AT THE SUNSHINE SKYWAY BRIDGE

Rockville, Maryland
June 1992

noaa **National Oceanic and Atmospheric Administration**

U.S. DEPARTMENT OF COMMERCE
National Ocean Service

Office of Ocean and Earth Science
National Ocean Service
tional Oceanic and Atmospheric Administration
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NOTICE

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CONVERSION FACTORS, SI TO NON-SI (ENGLISH)
Units of Measurement

Multiply	By	To Obtain
cm/s	1.945×10^{-2}	knots
m/s	1.945	knots

Note: 53 cm/s $\simeq$ 1 knot

ABSTRACT

This study finds that the physical oceanographic real-time system (PORTS) acoustic Doppler current profiler (ADCP) at the Sunshine Skyway Bridge is measuring water flow accurately and is located in the appropriate position to sample navigation channel currents. Velocity measurements during the intercomparison between towed and bottom-mounted ADCPs showed that both were within the instruments' 5 cm/s accuracy as demonstrated by calibration tests in a tow tank. Current speeds measured by a towed 600 kHz ADCP along the main channel are higher in the vicinity of the 1200 kHz PORTS ADCP than at any other location. Current speeds measured during June at the center of the navigation channel are slightly higher than those measured by the PORTS as is evidenced in contour plots. There is also evidence of a velocity maximum from near-surface to a depth of 4 meters in the navigation channel under the Sunshine Skyway Bridge. PORTS speeds on August 8, 1991 were within 10 percent of those measured by Lagrangian drifters having trajectories which passed through the main channel. Ebb and flood speeds on the order of 1.0 m/s should be expected during periods of maximum astronomic forcing and may be even higher due to elevated sea levels resulting from the combined or independent effects of storms and increased river discharge. The present location of the PORTS ADCP in the middle of the navigation channel serves to report velocities accurate to 5 cm/s.

1. INTRODUCTION

1.1 Background-Perspective

This technical memorandum was prepared in response to concerns from several members of the Tampa Bay Pilots Association that current velocities reported by the PORTS ADCP at the Sunshine Skyway Bridge (SSB) are at times significantly lower than velocities estimated by mariners from vessel way. An authoritative response to these concerns requires answering the following four technical questions.

1. Is the PORTS ADCP operating satisfactorily (i. e., is it reporting numbers within technical specification)?

2. Is the PORTS sited at the optimal location (i. e., the location of the highest velocities in the vicinity of the SSB)?

3. What is the magnitude of current shear in the vicinity of the SSB? Are there high velocity eddies or streaks in the current which may be undetected by the fixed system due to spatial and temporal variability?

4. Are there large vertical current shears close to the surface? Such shears could be undetected by the PORTS ADCP since it does not accurately measure currents which are less than 2 meters from the surface.

Question 1 is addressed by a review of the quality assurance (QA) steps taken to ensure the acquisition of reliable data. Questions 2 and 3 are resolved by analyzing maps of the velocity field parallel and transverse to the SSB obtained by a towed ADCP and comparing the results with velocity profiles obtained from the PORTS ADCP. Question 4 is answered by comparing surface velocities measured by oceanographic drifters with the PORTS near-surface data.

1.2 Deployment Scheme

The towed ADCP was deployed from a catamaran to measure currents from near the surface almost to the bottom (Figure 1). The PORTS was configured to measure currents from a fixed position in the main navigation channel under the SSB. Data collected during this intercomparison study was part of the 15-month Tampa Bay Survey (Hess 1990).

Differences between towed and PORTS current measurements were evaluated. This was accomplished by anchoring the vessel above the PORTS ADCP, taking measurements with the towed system, and calculating the percent difference in measurements from corresponding depths.

Instrument configurations used in this study are shown in Table 1.

Table 1. Tampa Bay PORTS ADCP Configurations.

Name	Frequency	Pressure Sensor	Sampling Rate	Averaging Increment	Location
Towed ADCP	600 KHz	No	5/s	15 sec	Vicinity of SSB
PORTS ADCP, #1	1200 KHz	Yes	1/s	10 min	27°37.25'N 82°39.31'W
PORTS ADCP, #2	1200 KHz	NO	1/s	6 min	27°37.12'N 82°39.25'W

The PORTS ADCP began transmitting and recording data on August 22, 1990, at location 27°37.25'N, 82°39.31'W. It ceased data transmission on June 11, 1991 and was replaced by an ADCP on August 8, 1992 at location 27°37.12'N, 82°39.25'W. This latter ADCP is part of the fully operational Tampa PORTS, and plans are for it to remain in place indefinitely (Figure 2). The first location was slightly to the north of the SSB, and northwest of the center of the channel, whereas the present location is directly under the SSB in the center of the channel (Figure 2, inset). ADCPs accurately measure water velocity from 1 m in front of the transducer to 85% of the distance to the nearest boundary: the bottom for the towed ADCP, and the surface for the bottom-mounted ADCP.

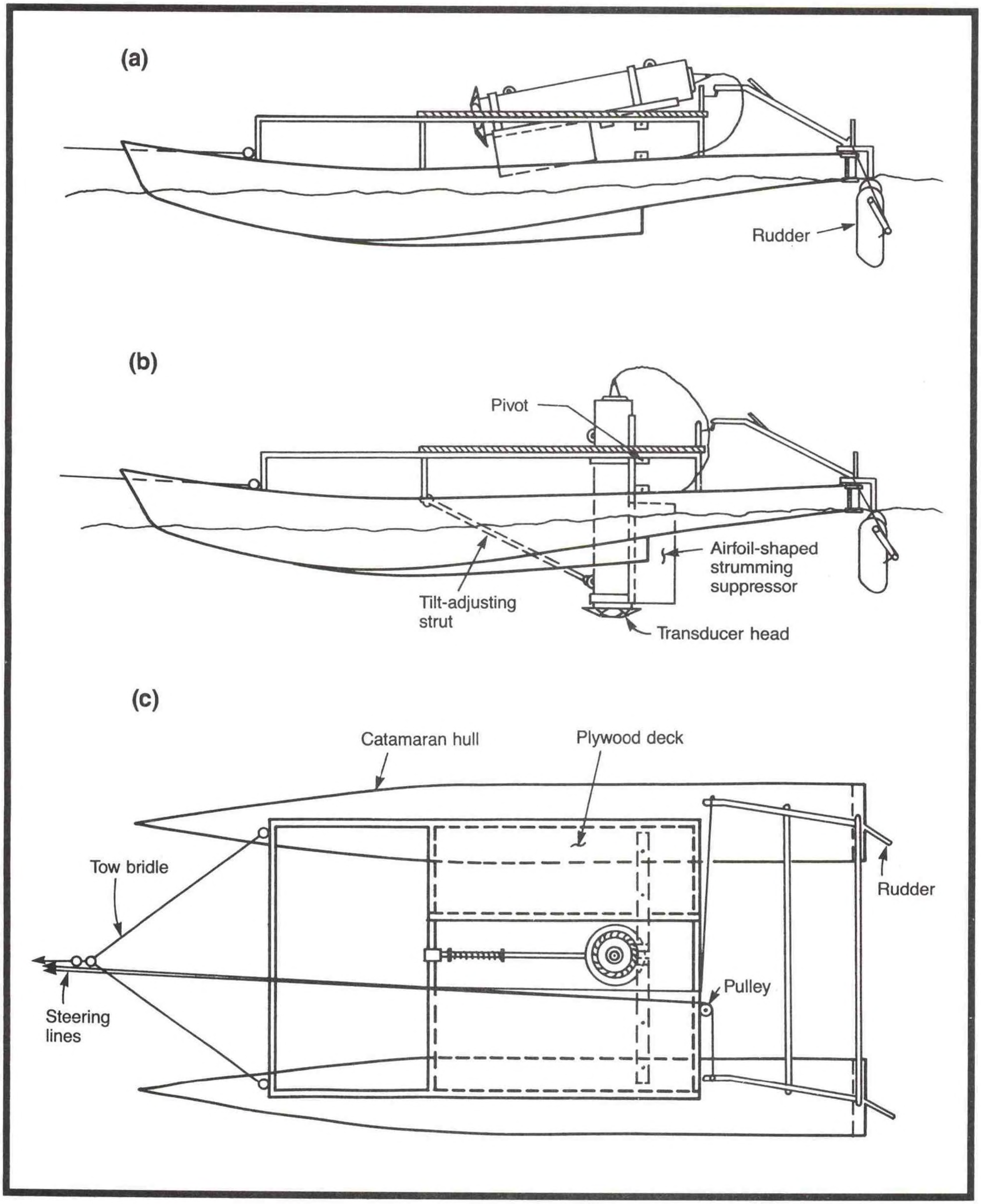


Figure 1. Schematic of the towed ADCP. (a) ADCP in transport, (b) ADCP during tow, and (C) Top view of the towed ADCP platform.

Water velocities closer to the boundaries cannot be considered reliable because of acoustical interference (RD Instruments, 1989).

No strong meteorological or oceanographic features affected the site during field data collection efforts in June and October 1991. Conditions were quiescent on a regional scale. Atmospheric or oceanographic driving forces affecting the measurements were of local origin.

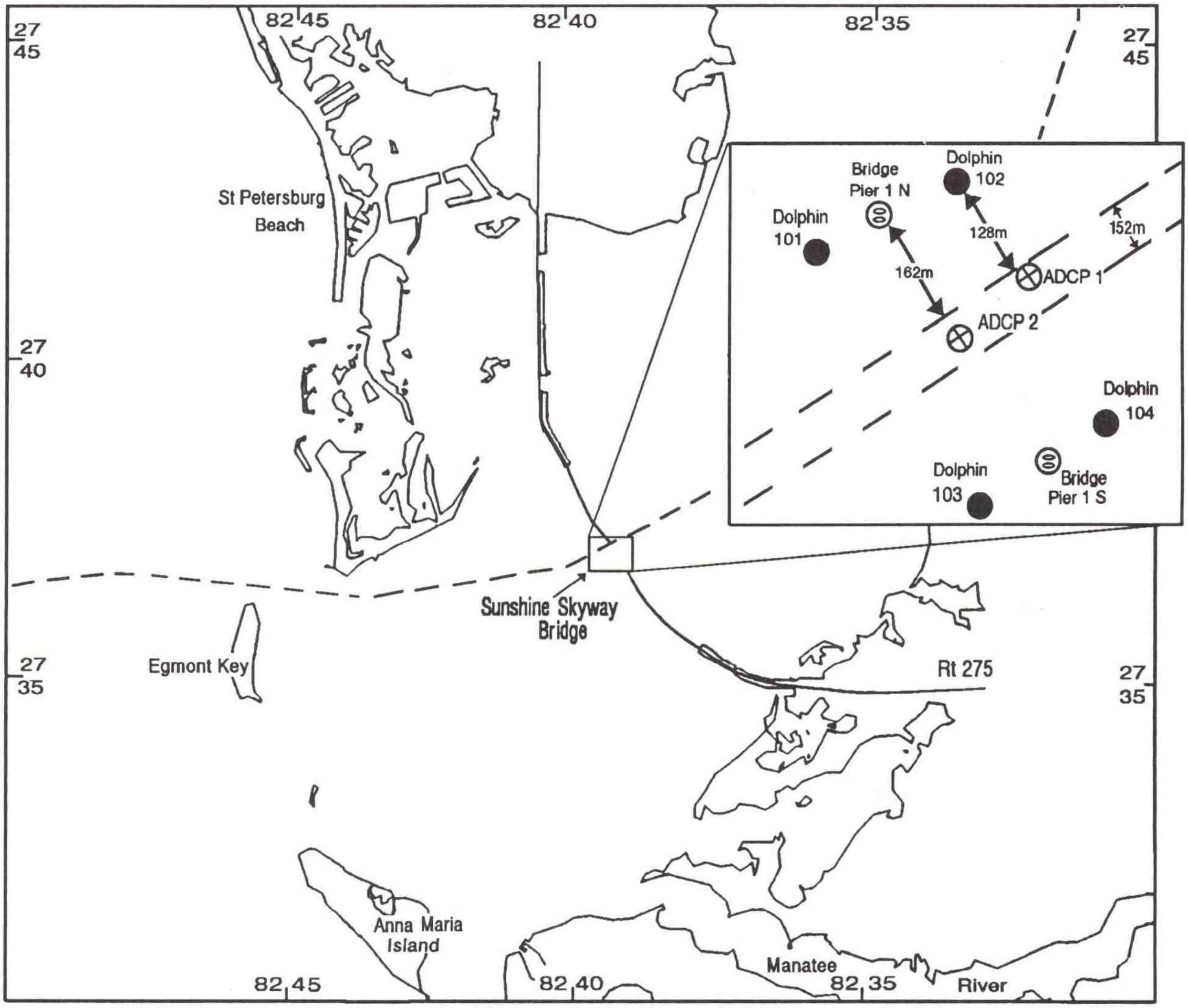


Figure 2. Map of study location in Tampa Bay, Florida. Major channels are dashed. The ADCP deployment sites are indicated by a (⊗).

2. ADCP CALIBRATION

The ADCPs used to collect the data described in this report were calibrated at the Naval Ship Research and Development Center in Carderock, Maryland. Each instrument was affixed to a hydraulic tow carriage and moved through a 305-m long, 15-m wide and 6-m deep towing basin at precisely known speeds up to 175 cm/s to determine its ability to measure water flow accurately. Profile measurements were taken at four depths from the surface to the bottom of the tow basin and compared to carriage speed. The errors were well below 10 percent and results of these calibrations indicate measurement accuracies within 5.0 cm/s. A typical example of calibration results is provided in Figure 3.

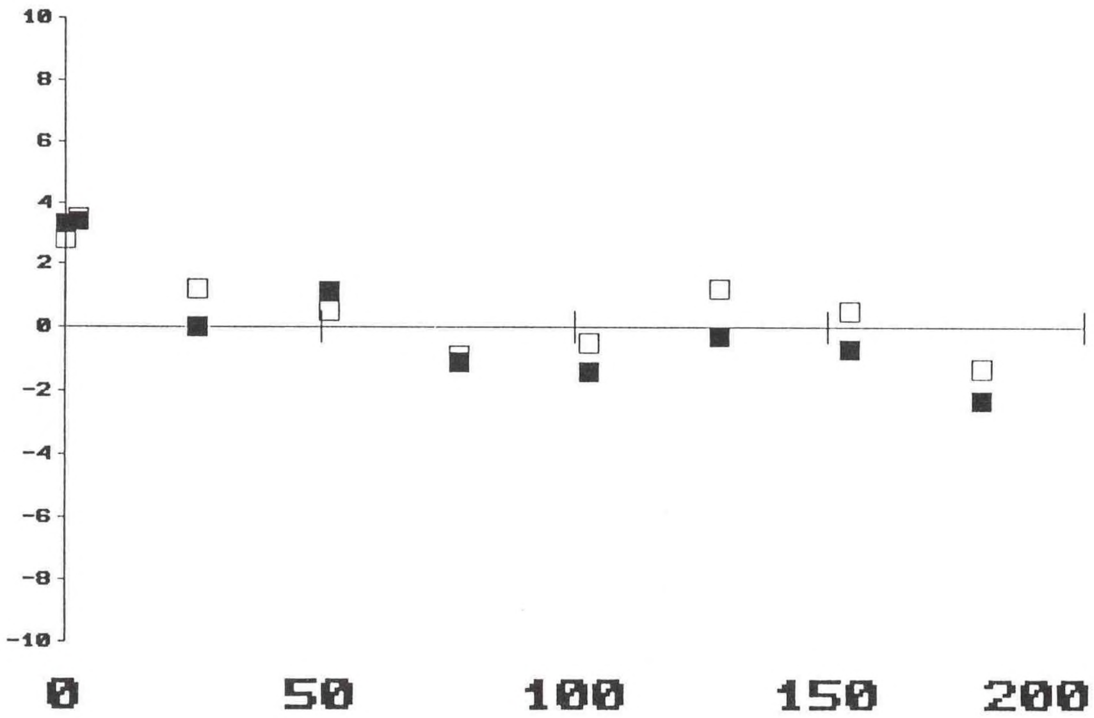


Figure 3. PORTS ADCP calibration. NOS ADCPs are calibrated for speed before and after deployment at the Naval Ship Research and Development Center. The surface depth bin is represented by (■) mid depth bin by (□). Measurement error is less than 10 percent.

3. DATA ANALYSIS

3.1 Analysis of Towed Acoustic Doppler Current Profiler (ADCP) Data

A spatial and temporal survey of the navigation channel near the SSB was obtained from three separate towed ADCP tracks from which contour plots of currents were obtained for June 1, 1991, June 7, 1991, and October 2, 1991. The towed ADCP measures average velocity within a series of one meter depth bins from 2 m below the surface to within 85% of the distance to the bottom. The towed ADCP tracklines were divided into 16 cells for averaging velocity profiles which occur within a respective cell. The along-channel course on June 7, 1991 obtained current measurements over a 1.5 hour period. Data were collected over a 2 hour period from the cross-channel course on June 1, 1991 and the October 2, 1991 along-channel course. In June towed surveys were made during periods of increasing ebb flow while the October survey coincided with decreasing ebb conditions. Towed ADCP tracklines were from 1.6 km to 3.5 km in length. The swath of water measured by the PORTS ADCP at 2 m below the surface is 200 m^2.

The first trackline described in this report was made on June 1, 1991 from 2156 to 2350 universal time (UT). This towed ADCP track crossed the main channel from the southeast to the northwest, a distance of 3.5 km (Figure 4). Relative to the trackline, the PORTS bottom-mounted ADCP is located in the southeast corner of cell 8 immediately below a core of water having speeds on the order of 65 cm/s (Figure 4). The surface water velocity within a diameter of approximately 400 meters above the ADCP is uniform and in excess of 65 cm/s. These surface speeds decrease from approximately 65 to 55 cm/s at a depth of 4 meters. The velocity maximum is within the navigation channel; the current here decreases from 65 to 55 cm/s over a depth of approximately 10 meters. The along-channel tow course was completed on June 7, 1991 from 1712 to 1847 UT. Figure 5 depicts the towed ADCP track during June 7, 1991 which followed the channel from cell 16 to cell 1 and remained stationary above cell 8, the PORTS site, from 1755 to 1845 hours UT. The corresponding contour plot is provided as Figure 5. Relative to this trackline, the PORTS ADCP is located at the southern extent of cell 8 in approximately 12.5 meters of water. The strongest currents recorded by the towed ADCP on June 7, 1991 are on the order of 60 cm/s and found approximately 200 meters south of the PORTS ADCP. This core of swift flowing ebb water extends to a depth of nine meters before diminishing to speeds that are on the order of 50 cm/s. Surface flow during this transect ranges from 30 to 60 cm/s, with slower speeds located north of the PORTS. The trackline during October 2, 1991 was 1.6 km long and measured currents from near-surface (i.e., 2 meters) to 11 meters. Peak currents from cell 1 to cell 13 were located in the near-surface layer and in excess of 75 cm/s. The flow in cell 11 contained the highest speeds which declined from 85 cm/s to 70 cm/s at a depth of 9 meters (Figure 6). The largest gradient occurred when the ship changed course and went from 65 to 40 cm/s over a distance of 200 meters. Relative to the trackline, the PORTS ADCP was located in the northwest portion of cell 12 and centered in the main navigation channel.

3.2 Multiple Depth Plot Comparisons

The north and east velocity components from the PORTS ADCP were rotated by principal component analysis in order to represent the ebb and flood flow along the appropriate azimuth (Preisendorfer, 1988). Flood flow at SSB is oriented toward 59° and ebb flow is directed toward 239°. Positive along-channel flow denotes a flood and negative along-channel flow is an ebb.

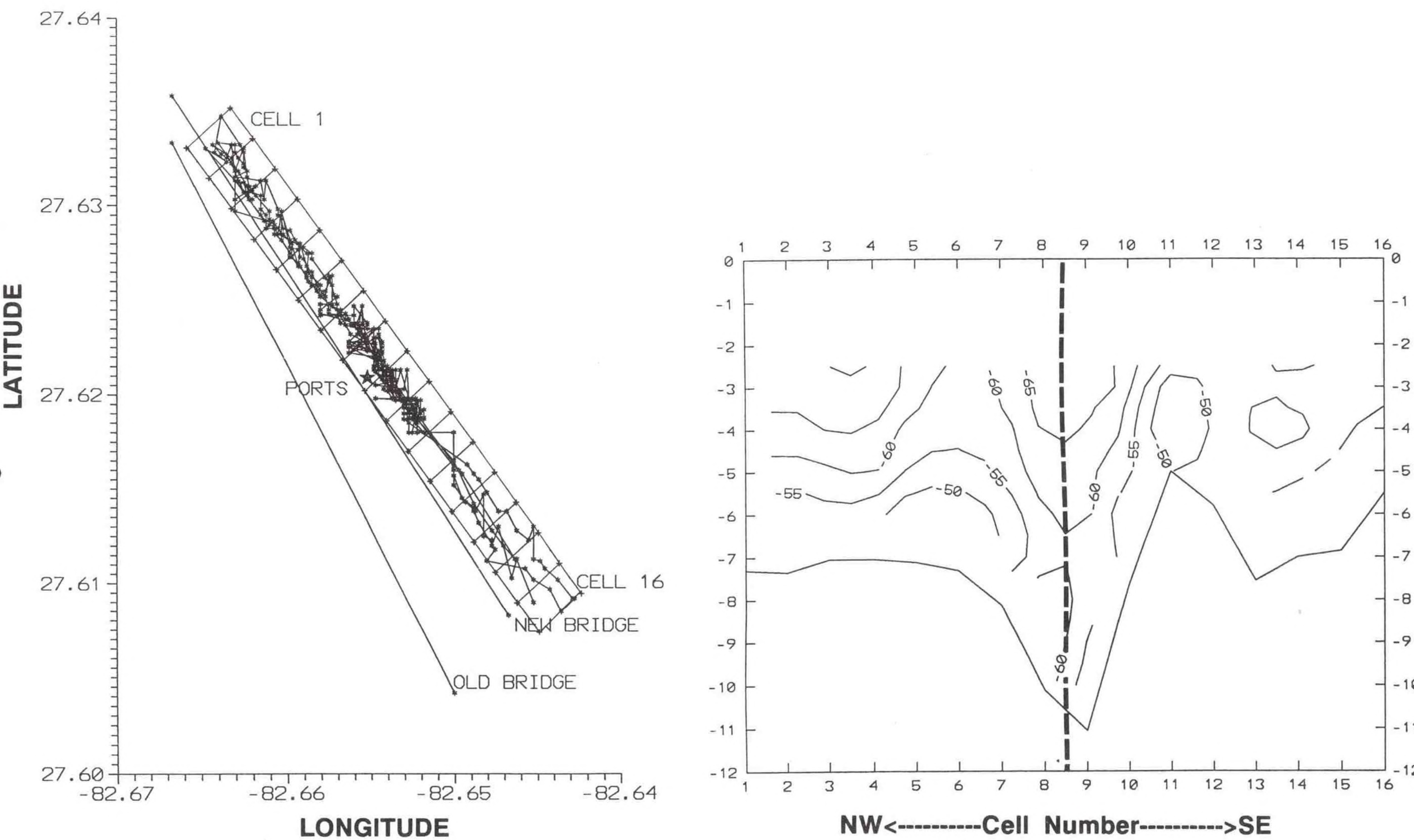


Figure 4. Towed ADCP cross-channel trackline and velocity contours on June 1, 1991. The left panel illustrates the towed ADCP trackline from 2156 to 2350 UT. The trackline is 3.5 km long and divided into 16 cells. The right panel shows the towed velocity during the ebb in cm/s. The contour interval is 5 cm/s. The PORTS location in cell 8 is highlighted.

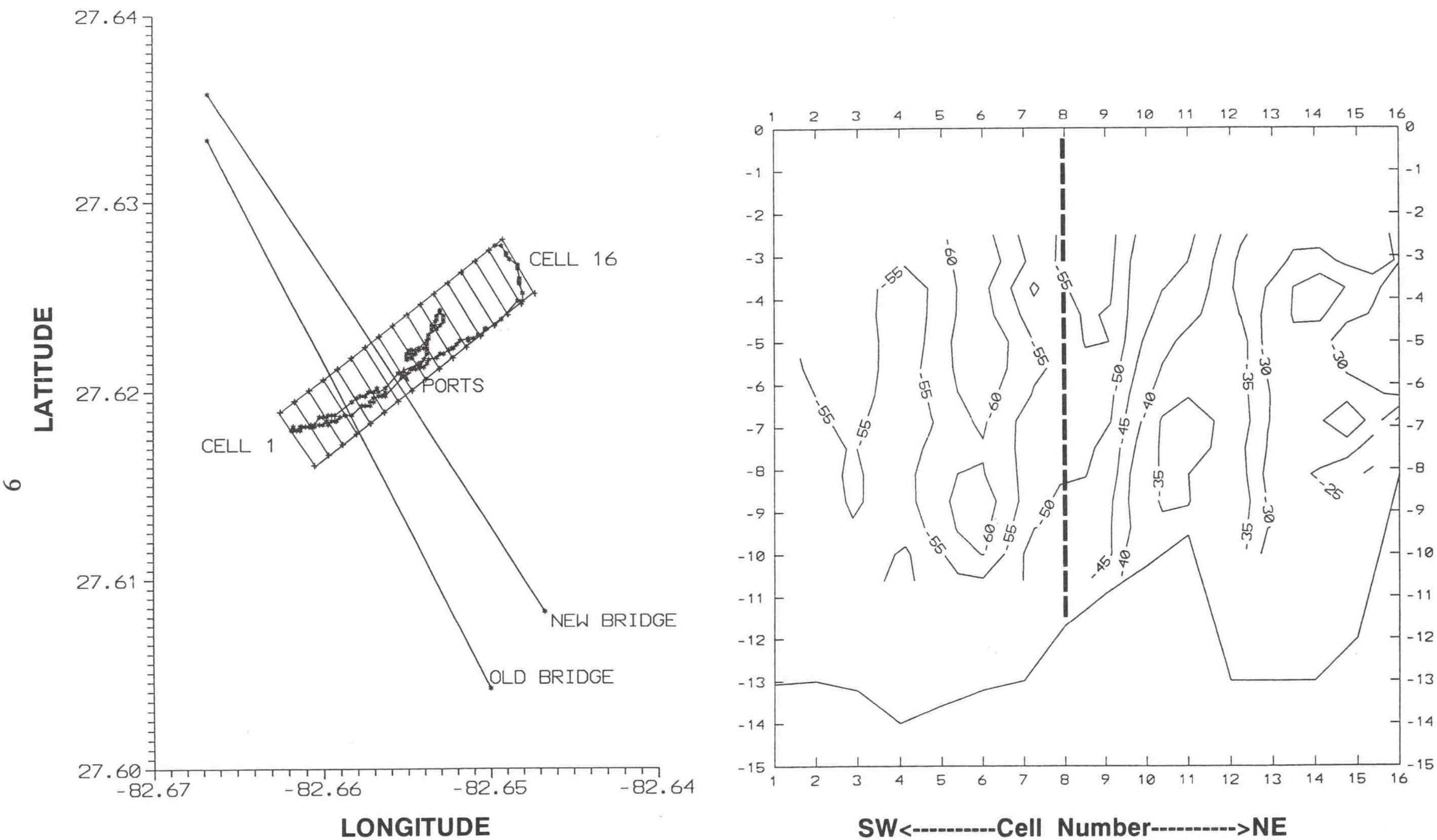


Figure 5. Towed ADCP along-channel trackline and velocity contours on June 7, 1991. The left panel illustrates the towed ADCP trackline from 1712 to 1847 UT. The trackline is 1.65 km long and divided into 16 cells. The right panel shows the towed velocity during the ebb in cm/s. The contour interval is 5 cm/s. The PORTS location between cells 7 and 8 is highlighted.

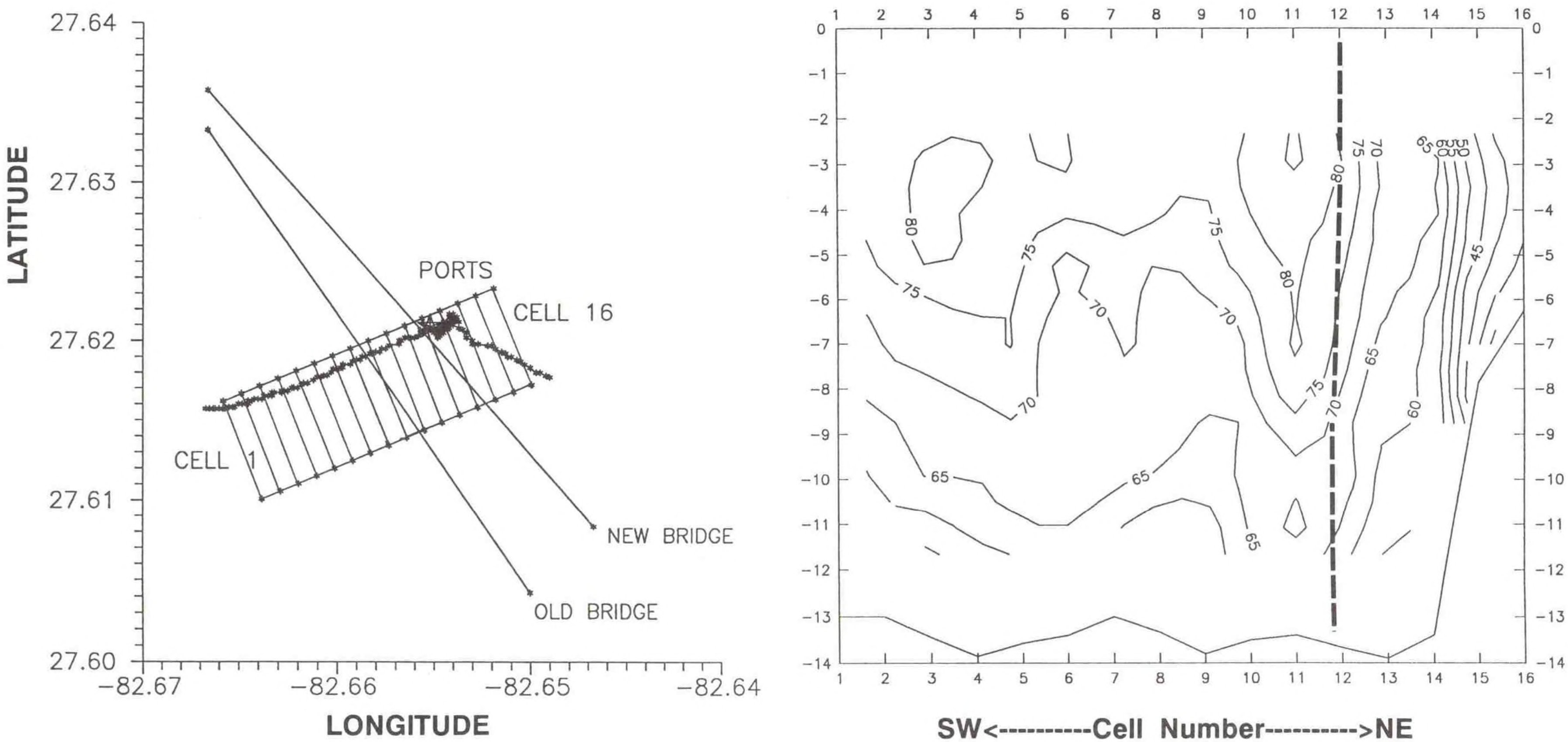


Figure 6. Towed ADCP along-channel trackline and velocity contours on October 2, 1991. The left panel illustrates the towed ADCP trackline from 1730 to 1921 UT. The trackline is 1.6 km long and divided into 16 cells. The right panel shows the towed velocity during the ebb in cm/s. The contour interval is 5 cm/s. The PORTS location in cell 12 is highlighted.

The highest current speed measured by PORTS during the sampling period from February 21, to June 11, 1991 was 116.0 cm/s and occurred in near-surface waters during a flood on March 3, 1991. Similarly, the maximum PORTS speed during the October 1991 time period was 104.0 cm/s during an ebb on October 3, 1991. Maximum ebb flow in near-surface waters on June 1, 1991 was 82.0 cm/s at 2345 UT. On June 7, 1991 maximum flow of the minor component was 12.3 cm/s while maximum flow in the direction of the major component was 65.9 cm/s. Similarly, on October 2, 1991 flow of the minor component averaged 16 cm/s while maximum flow of the major component was on the order of 70 cm/s.

The towed system was stationary and above the PORTS ADCP from 1755 to 1845 hours UT on June 7, 1991. The range of speed from June towed ADCP measurements was 51.6 to 74.8 cm/s while corresponding June PORTS ADCP measurements were from 49.0 to 82.0 cm/s. On October 2, 1991 towed ADCP speeds ranged from 42.0 to 75.4 cm/s while corresponding PORTS ADCP values ranged between 48.5 to 74.0 cm/s. Figure 7 demonstrates that current magnitudes vary with depth from speeds on the order of 50 to 40 cm/s in the main navigation channel. The October 2, 1991 profile shows the nature of Tampa Bay mixed currents as evidenced by the inequality between floods at 0100 and 1200 UT and ebbs at 0540 and 1754 UT (Figure 8). The boxed portion corresponds with the time period when measurements were taken by the towed ADCP.

3.3 Comparison of Vertical Profiles

The vertical profile graphs show a comparison between towed (dashed) and bottom-mounted (solid) ADCP measurements at five different time intervals between 1755 and 1835 UT on June 7, 1991 and seven different time intervals on October 2, 1991. Throughout the first period, currents were ebbing in excess of 50.0 cm/s (Figures 9 and 10). Maximum ebb speeds of 72.0 cm/s were reached at 1915 UT. During the October period, flood and ebb speeds are in excess of 70.0 cm/s at the surface and nearly 50.0 cm/s at 11 meters (Figures 11 and 12). Maximum ebb speeds of 76.0 cm/s were reached at 1754 UT. There was also a slight increase in towed ADCP speed with depth to 4 meters below which the speed began to diminish. This is indicative of the 60 cm/s water flow that is located off-center of the PORTS which we observe on contour plots (Figures 4, 5, and 6). The PORTS ADCP was located slightly northwest of the main navigation channel prior to August 1991 (Figure 2). The contour plots show currents to a depth of 10 meters.

One problem with comparing readings from a static instrument with measurements from a towed instrument is determining what motions are on the tow-body which potentially reduce the accuracy of ADCP measurements. The mean difference between the towed and PORTS measurements is less than 5.0 cm/s which is close to the limit of accuracy as determined from ADCP calibrations. These differences are highlighted in Figures 12. Differences which are in excess of one standard deviation may be caused by unresolved system motion and uncertainty in position.

3.4 Measurement Differences

To assess the reliability of NOS techniques and hardware, differences between towed and bottom-mounted ADCP's were calculated from data collected during the intercomparison. The percent difference provides a reasonable estimate of accuracy from two independent measurements. The relative uncertainty between instruments arises from the inherent difficulty in removing the effects of system motion on the data and pinpointing exact towed ADCP position. Errors due to instrument motion are not a concern with the bottom-mounted ADCP. Despite these complicating factors, the only time interval on June 7, 1991 showing differences in excess of 6.0 cm/s was hour 1835 (Figure 13a). As previously mentioned, this error is believed to result from unresolved ship or tow-body motion. On October 2, 1991, there were only three measurements with differences above 10.0 cm/s. The last time interval in the 2 meter depth indicated that the PORTS measured 12.2 cm/s higher than the towed ADCP and the opposite situation occurred at the 11 meter depth during the second time interval (Figure 14). These differences were also displayed earlier on the bar charts found in Figures 12. Figure 13b shows the percent difference between the June towed and PORTS ADCP speeds. Errors around 10 percent during the June trackline correspond to the 4- and 5- meter mid-depth layer. Figure 15 shows the percent difference between the towed and PORTS ADCP speeds during the October period. The largest errors during the October trackline corresponded with depths between 10 and 11 meters near the bottom. The standard deviation of differences was 2.1 cm/s in June and 4.5 cm/s in October. The differences are a combination of random and systematic error where towed ADCPs tend to record higher speeds than the PORTS ADCP.

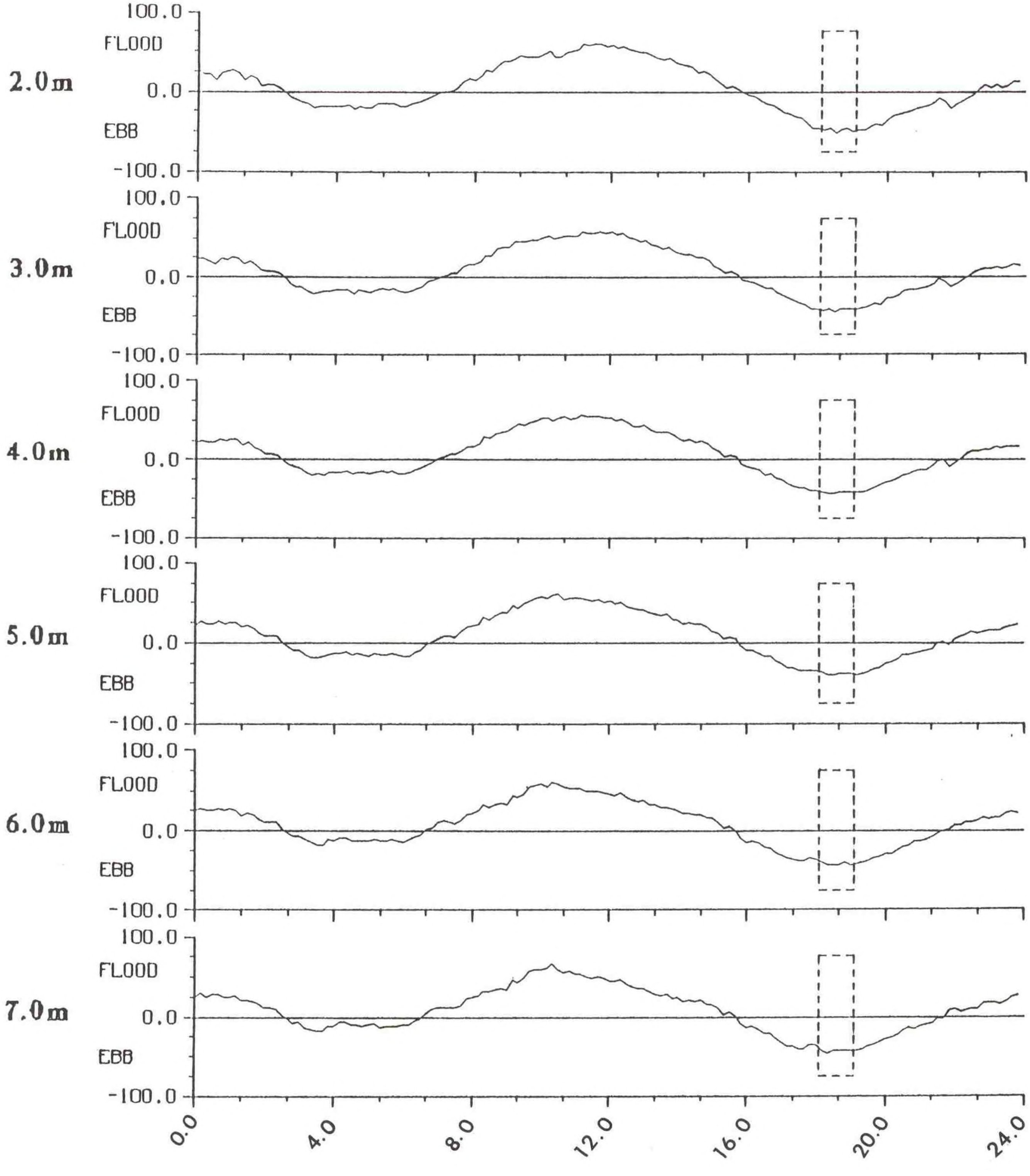


Figure 7. Along-channel currents at the Sunshine Skyway Bridge on June 7, 1991. The speed profile of the major component in cm/s is plotted for each depth from 2 to 7 meters. The time interval is 1 hour 20 minutes from 0000 to 2400 hours UT. The boxed portion highlights the time period when towed ADCP measurements were taken above the PORTS.

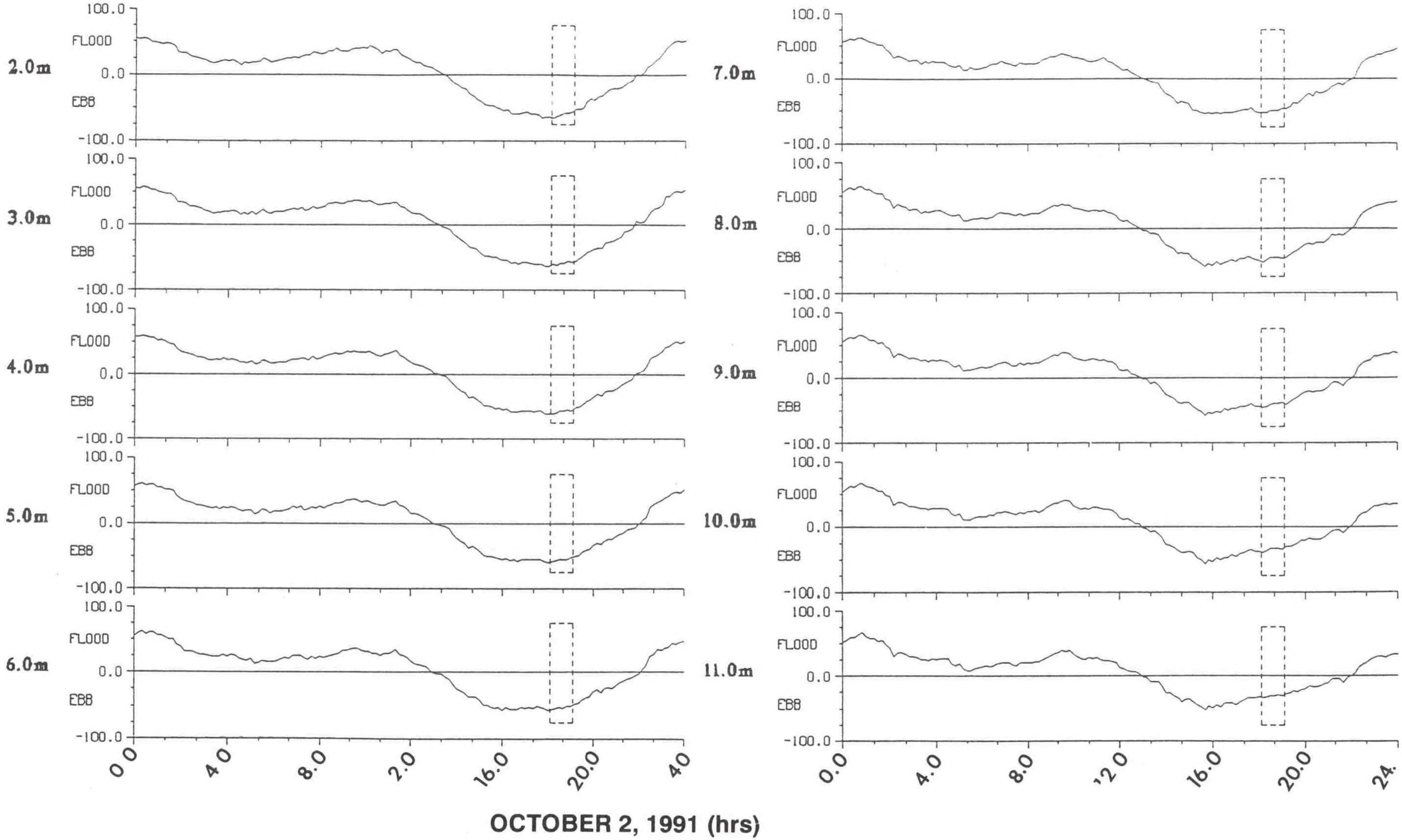


Figure 8. Along-channel currents at the Sunshine Skyway Bridge on October 2, 1991. The speed profile of the major component in cm/s is plotted for each depth from 2 to 11 meters. The time interval is 1 hour 20 minutes from 0000 to 2400 hours UT. The boxed portion highlights the time period when towed ADCP measurements were taken above the PORTS.

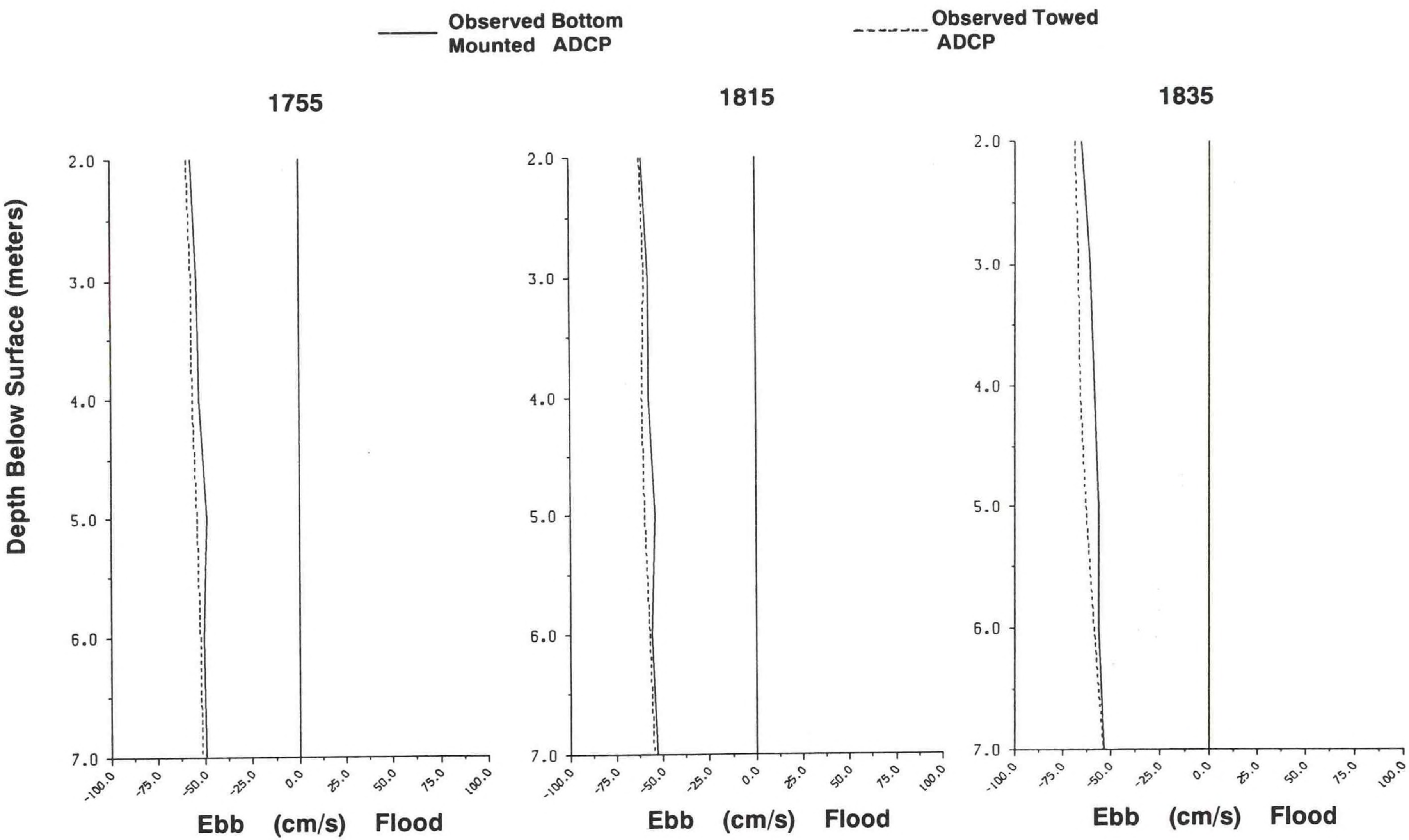


Figure 9. Along-channel current profile on June 7, 1991 at the Sunshine Skyway Bridge. PORTS and towed ADCP speeds are plotted against depth.

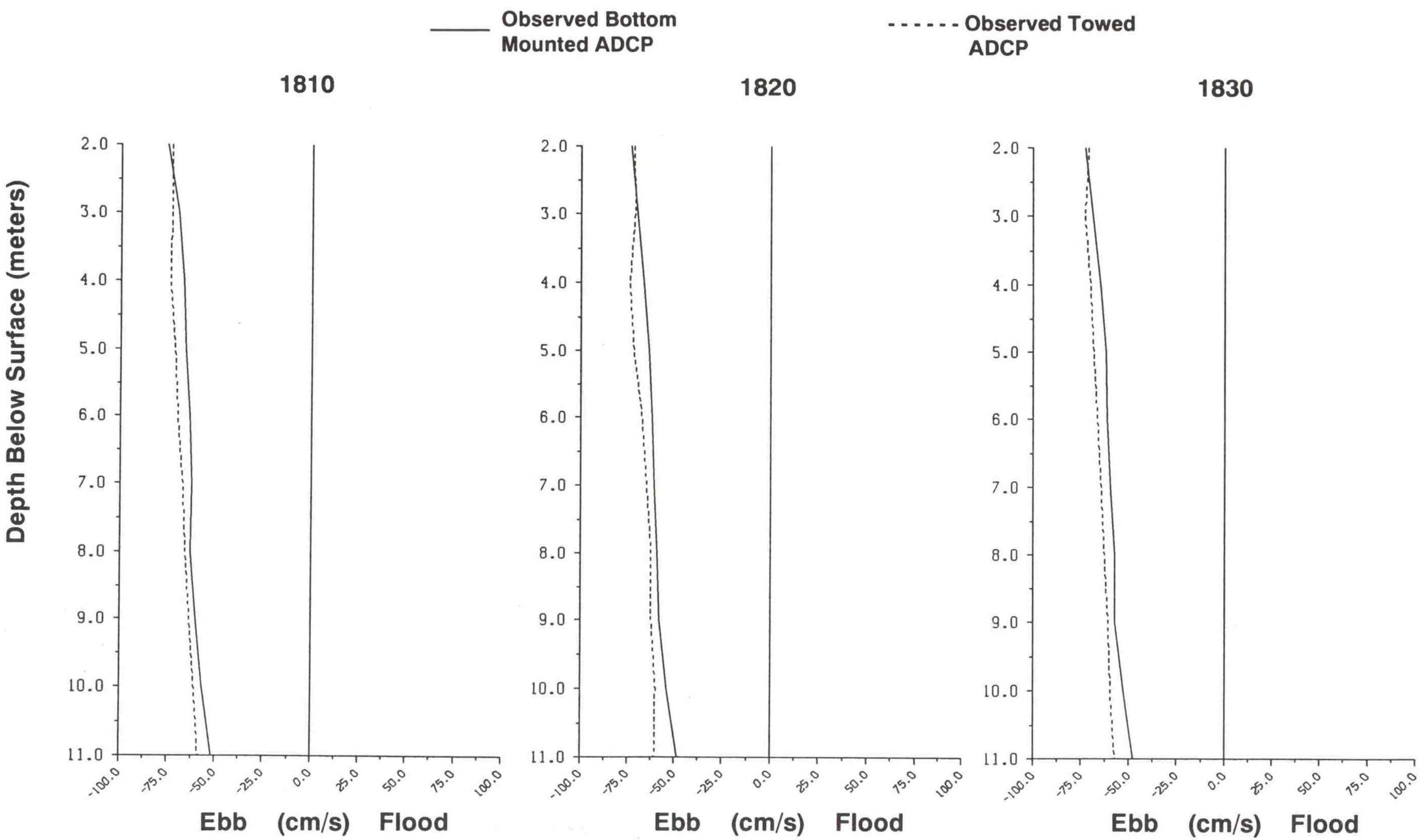


Figure 10. Along-channel current profile on October 2, 1991 at the Sunshine Skyway Bridge. PORTS and towed ADCP speeds are plotted against depth on October 2, 1991.

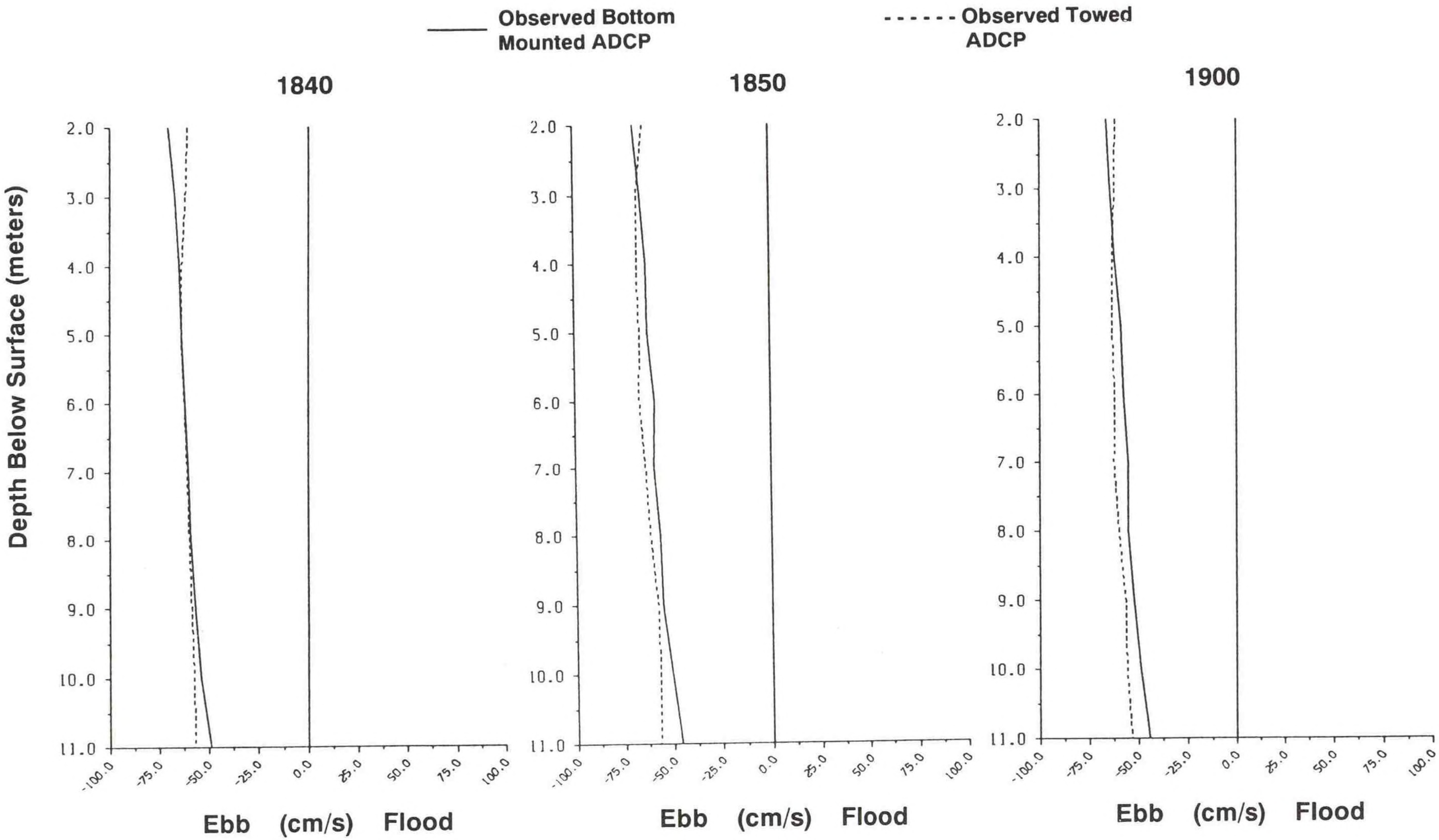
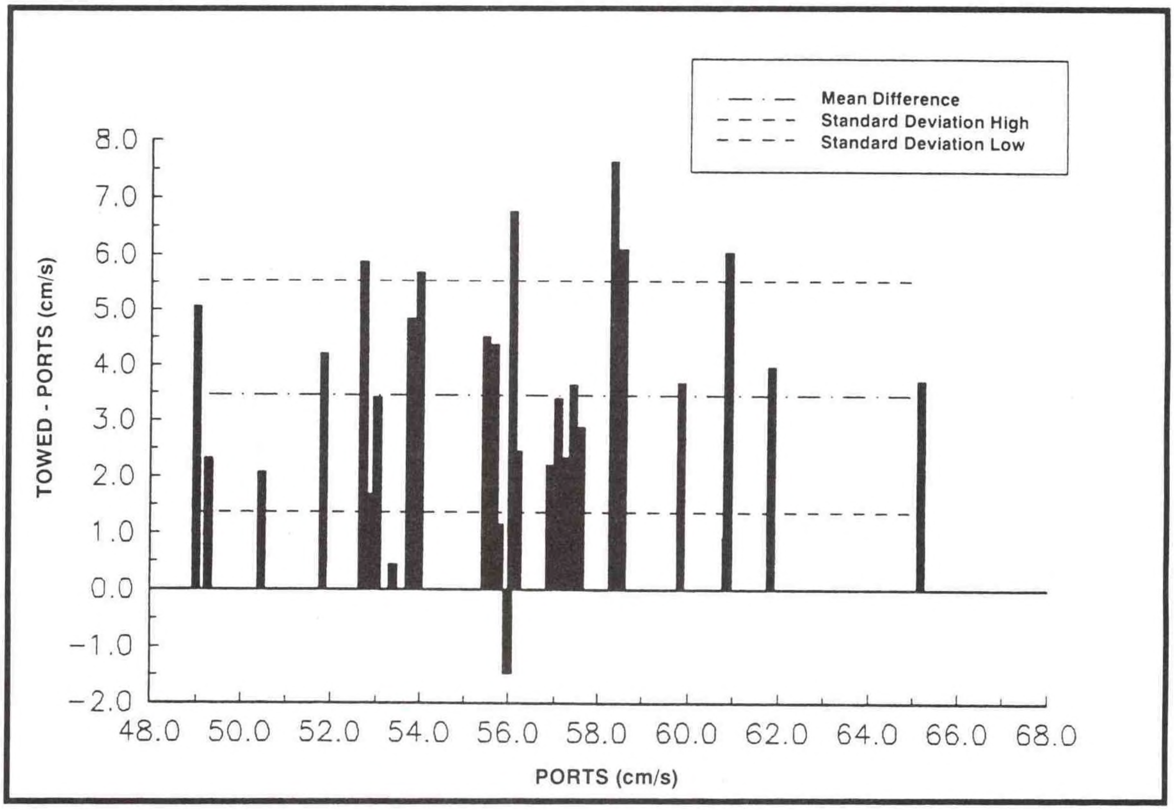


Figure 11. Along-channel current profile on October 2, 1991 at the Sunshine Skyway Bridge. PORTS and towed ADCP speeds are plotted against depth.

(a)



(b)

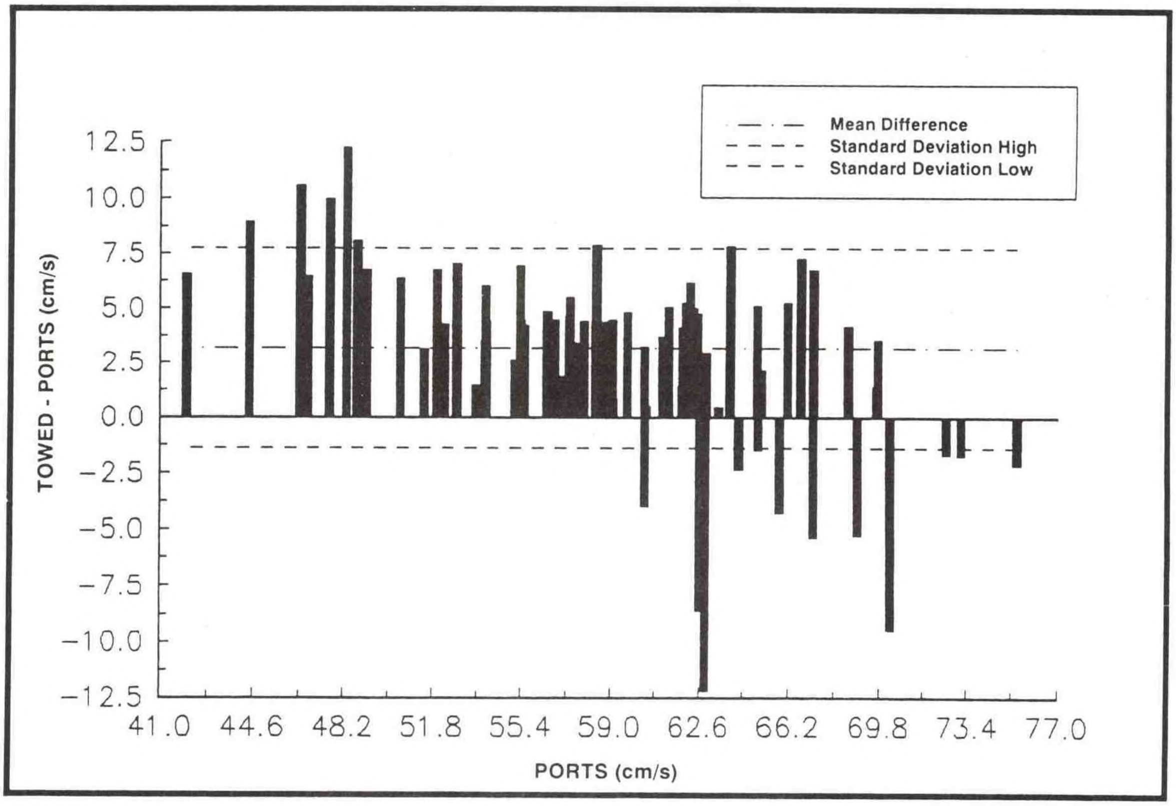


Figure 12. Towed and PORTS speeds at the Sunshine Skyway Bridge. (a) The differences between the towed and PORTS ADCP measurements are compared with PORTS values from 1755 to 1830 UT on June 7, 1991. (b) The difference between the towed and PORTS ADCP measurements are compared with PORTS values from 1810 to 1910 UT on October 2, 1991.

(a)

TIME (UT) / DEPTH (M)	MEASUREMENT DIFFERENCE (cm/s)					
	1755	1805	1815	1825	1835	MEAN DIFFERENCE PER DEPTH
2	2.2	2.9	0.9	4.0	3.7	2.7
3	3.1	4.5	2.4	6.1	6.0	4.4
4	3.4	3.4	3.6	3.7	7.6	4.4
5	5.0	5.9	5.7	4.4	6.8	5.6
6	2.1	4.8	1.1	0.4	2.5	2.2
7	2.3	4.2	1.7	-1.5	0.4	1.4
MEDIAN DEPTH (M)	3.0	4.3	2.6	2.8	4.5	STANDARD DEVIATION
4.5	MEAN DIFFERENCE PER TIME INTERVAL (TOWED - PORTS) ADCP					2.1

(b)

TIME (UT) / DEPTH (M)	PERCENT DIFFERENCE				
	1755	1805	1815	1825	1835
2	3.8	4.9	1.5	6.2	5.5
3	5.6	7.8	4.0	9.9	9.4
4	6.3	5.8	6.1	5.9	12.3
5	9.8	10.6	9.9	7.5	11.3
6	4.1	8.6	2.0	0.6	4.3
7	4.6	7.8	3.2	-2.7	0.8

$\frac{\text{(TOW + PORTS) ADCP}}{2} = \text{m ADCP}$ $\frac{\text{(TOW - PORTS) ADCP}}{\text{mADCP}} \times 100 = \text{\% difference}$

Figure 13. Descriptive statistics at the Sunshine Skyway Bridge for June 1991. (a) Matrix of measurement differences. Median depth is 4.5 m and differences of (towed - PORTS) values are indicated in the 6 X 5 matrix. Average differences are recorded for each depth and each time interval. The mean difference of 3.4 cm/s is within the accuracy range determined during instrument calibration. Therefore, both instruments measured comparable velocities. (b) Percent difference matrix. A reasonable estimate of accuracy is obtained by finding the percent of difference between the towed and PORTS ADCP values for each time period and depth.

TIME (UT) / DEPTH (M)	NEW SUNSHINE SKYWAY BRIDGE OCTOBER 2, 1991 (TOWED - PORTS) cm/s							
	1810	1820	1830	1840	1850	1900	1910	MEAN DIFFERENCE PER DEPTH (TOW-PORTS) ADCP
2	–2.2	–1.7	–1.7	–9.5	-5.3	–4.3	–12.2	–5.3
3	3.6	1.4	4.2	–5.4	2.1	–2.3	–8.7	–0.7
4	6.7	7.3	5.1	–1.5	4.7	1.4	–4.0	2.8
5	5.2	7.8	6.1	0.4	4.2	4.4	2.3	4.3
6	6.0	5.2	5.0	0.2	7.9	4.6	4.2	4.7
7	5.0	3.7	4.8	0.5	4.4	6.9	4.4	4.2
8	2.9	3.3	5.5	0.8	4.9	4.4	1.5	3.3
9	3.2	4.4	3.4	1.8	2.6	4.3	3.1	3.3
10	4.4	6.0	7.0	3.5	6.3	6.7	6.4	5.8
11	6.7	12.2	9.9	8.0	10.6	8.9	6.5	9.0
MEDIAN DEPTH (M)	4.2	5.0	4.9	–0.1	4.2	3.5	0.4	STANDARD DEVIATION OF DIFFERENCES (DEPTH X TIME)
6.5	MEAN DIFFERENCE PER TIME INTERVAL (TOW-PORTS) ADCP cm/s							±4.5

Figure 14. October 1991 matrix of differences. Median depth is 6.5 m and differences of (towed - PORTS) values are indicated in the 7 X 10 matrix. The standard deviation of differences indicates measurements are within 5 cm/s of each other.

DEPTH (M) / TIME (UT)	NEW SUNSHINE SKYWAY BRIDGE OCTOBER 2, 1991 PERCENT DIFFERENCE						
	1810	1820	1830	1840	1850	1900	1910
2	−2.9	−2.4	−2.3	−14.5	−8	−6.7	−21.6
3	5	2	5.9	−8.3	3.2	−3.7	−14.9
4	9.5	10.3	7.5	−2.3	7.3	2.2	−6.8
5	7.6	11.5	9.4	0.7	6.5	7.2	3.8
6	9	8.1	7.9	0.3	12.6	7.8	7.3
7	7.7	5.9	7.8	0.8	7.2	11.8	7.9
8	4.5	5.4	9.1	1.3	8.3	7.7	2.7
9	5.2	7.4	5.7	3.1	4.6	7.9	5.9
10	7.5	10.5	12.4	6.3	11.8	12.8	12.9
11	12.1	22.5	18.9	15.2	20.4	18.3	14.4

$$\frac{(\text{TOW} + \text{PORTS})\ \text{ADCP}}{2} = \text{m ADCP} \qquad \frac{(\text{TOW} - \text{PORTS})\ \text{ADCP}}{\text{mADCP}} \times 100 = \%\ \text{difference}$$

Figure 15. October 1991 percent difference matrix. A reasonable estimate of accuracy is obtained by finding the percent of difference between the towed and PORTS ADCP values for each time period and depth.

4. DRIFTER STUDIES

Comparison tests between ADCP and near-surface drifter measurements were conducted on August 8, 1991 from 1100 to 1400 GMT under the Sunshine Skyway Bridge. These tests compared the average track speed of near-surface drifters with the near-surface current measurements of the ADCP. The measurements also served to investigate possible large vertical shears near the surface or eddies caused by the bridge and bottom topography. Two windowshade-design Lagrangian drifters (Figure 16) were deployed in the main navigation channel from a small Coast Guard boat at a time interval of 3 seconds. The drifters were ballasted at a depth of 1 meter and were tracked between protective Dolphins located on either side of the bridge. Figure 17 shows results of the test during a period of increasing ebb. Differences between ADCP and drifter near-surface speeds are less than 10 percent. These differences are attributed to the spatial averaging used in the drifter test.

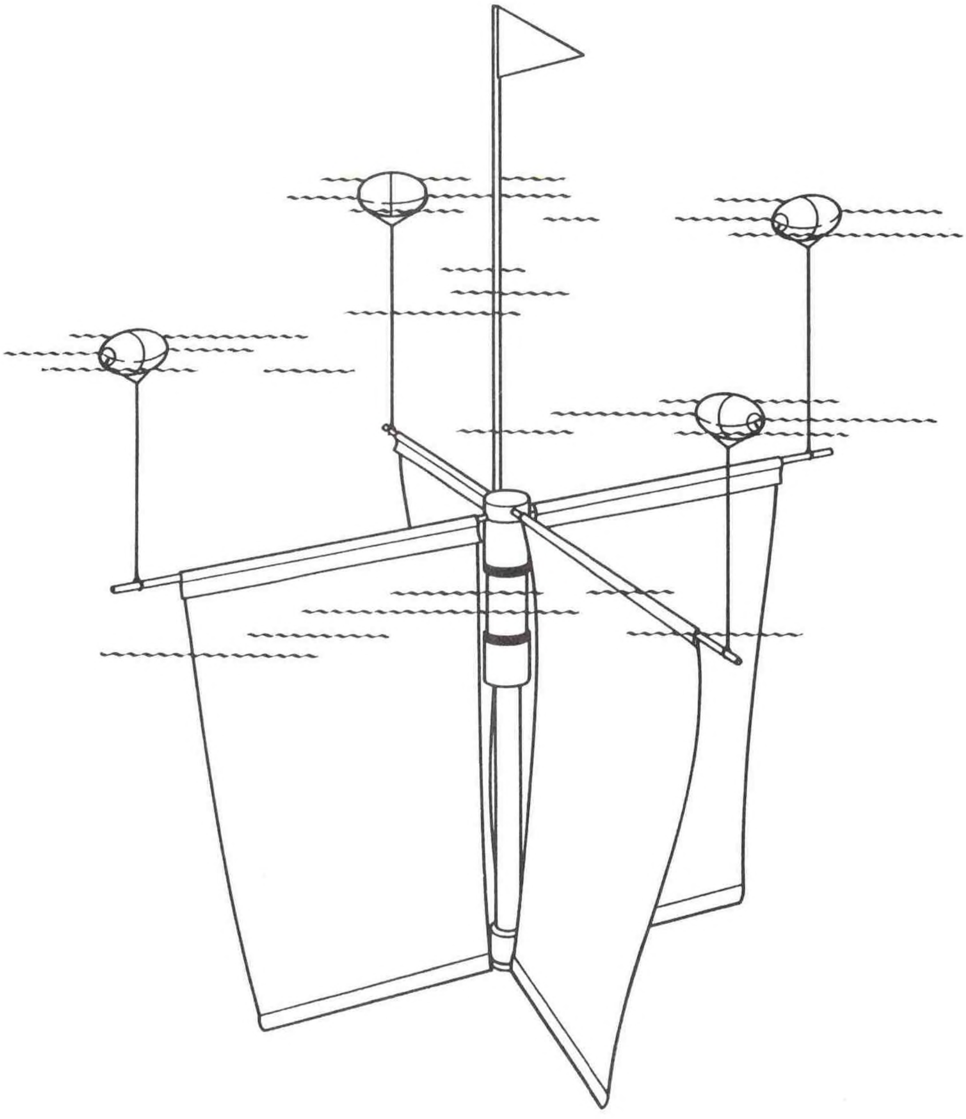


Figure 16. Diagram of a windowshade-design Lagrangian drifter.

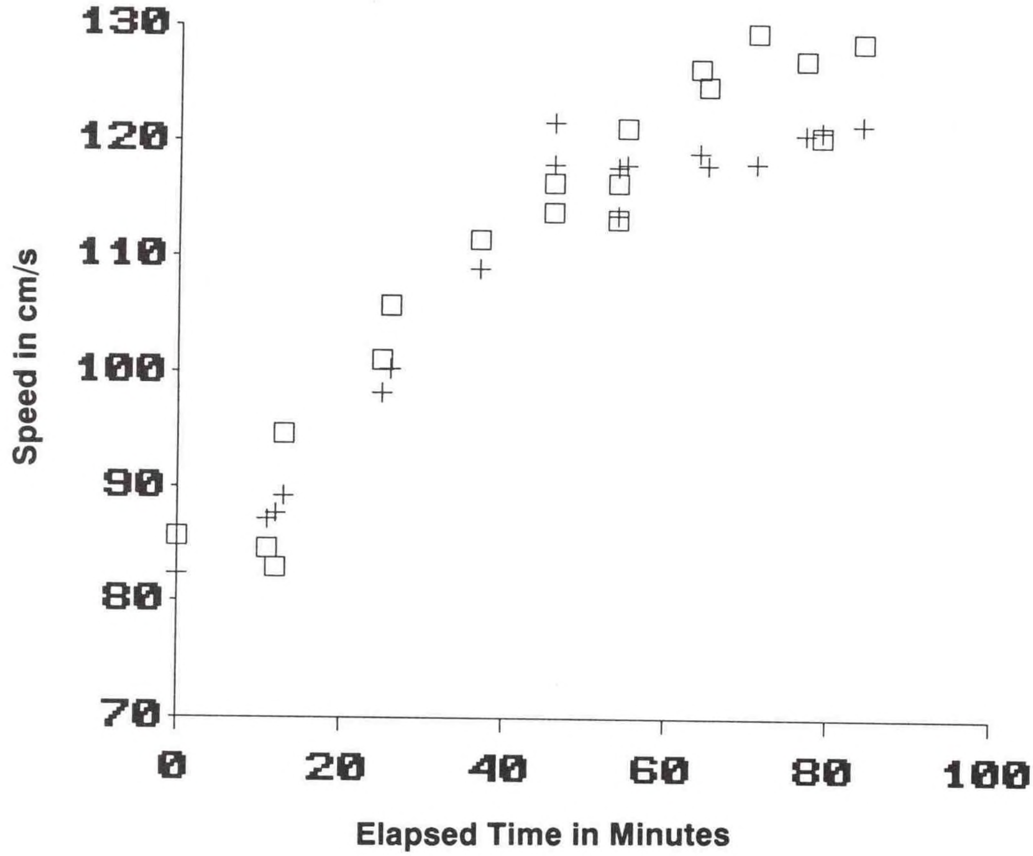


Figure 17. Results of the skyway Bridge drifter comparison. Langrangian drifter speeds from 1500 to 1640 EDT are displayed with a (□). Values from the PORTS near surface depth are depicted with a (+). NOAA tidal current predictions (NOAA 1991) called for a maximum ebb of 1.25 m/s at 1727 EDT on August 8, 1991.

5. CONCLUSIONS

This study indicates that the PORTS ADCP is measuring current speeds with an accuracy of 5 cm/s. Measurements during the intercomparison were within the 5.0 cm/s accuracy as demonstrated by calibration tests in a controlled basin. The first PORTS ADCP, located northwest of the center of the channel, is likely to have under- reported current speeds with respect to mid-channel as shown in Figure (6 and 10). The present PORTS ADCP is located in the appropriate position to sample navigation channel currents. The standard deviation of differences between towed and bottom-mounted ADCPs was less than 5.0 cm/s.

Current speeds as evidenced by towed ADCP measurements in the main channel are generally higher than at other measured locations in the vicinity of the PORTS ADCP. June current speeds from the towed system at the center of the navigation channel are slightly higher than those measured by the PORTS as demonstrated by contour plots. There is evidence for a velocity maximum at a depth of 4 meters in the navigation channel. Towed ADCP contour plots which show a spatial image of speeds over a predetermined time interval found maximum ebb flow above the PORTS on June 1, 1991. On June 7, maximum ebb flow was approximately 200 meters southwest of the PORTS. Peak flow on October 2, was approximately 40 meters southwest of the PORTS.

In August 1991, the PORTS ADCP was deployed to measure currents directly from the center of the navigation channel. The August 8, 1991 Lagrangian drifter study during an increasing ebb does not show any near-surface shears that would be beyond the range of the PORTS ADCP. PORTS speeds were within 10 percent of those measured by drifters having trajectories which passed through the main channel. In general, speeds on the order of 1.0 m/s should be expected at the PORTS location and could be even higher due to the effects of high winds and increased levels of river discharge. The present location of the PORTS ADCP, in mid-channel, serves to give accurate water velocity information for navigation.

6. ACKNOWLEDGMENTS

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