Chapter 5
At Sea Experiment of Data Acquisition System

This chapter presents the mission at sea conducted for the observation of the motion data acquisition system measurements in the field as well as the collection and correction of unreferenced ADCP data.

Both the motion data acquisition system and TRDI ADCP are installed on a test vessel, the R/V Oceaneer IV, which performs a series of specifically chosen maneuvers in open sea while the motion data along with the ADCP data are simultaneously collected to be later post-processed. The mission is performed off the southeast coast of Florida where the currents run predominately near shore in a north-south direction with velocity ranging up to 1m/s (Figure 56). The Florida Current receives its water from two main sources, the Loop Current and the Antilles Current. The Loop current is the most significant of these sources and can be considered the upstream extension of the Gulf Stream System [NOAA].

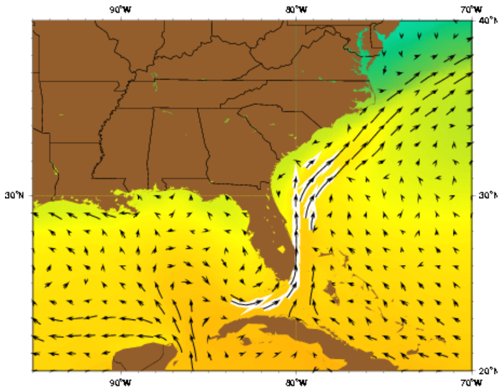

Fig. 56 The Florida Current

The ship maneuvers follows two different tracks: an L-shape track (going south then east) and a straight line roundtrip track along the south-north direction. In the first section of this chapter, results of the navigational data fusion for each maneuver are presented. The second section examines the unreferenced ADCP velocity profiles and their correction, by subtracting the vessel motion from the measurements. The correction is performed on both its Beam coordinate frame,

C. Gelin: A Low-Cost, High Rate Motion Measurement System, NAMESS 1, pp. 61–84.
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where the data is recorded, and in its Earth Reference frame (North-East-Up frame). The last section summarizes the results of the mission at sea.

5.1 Motion Data Acquisition Measurements and Navigational Data Fusion Results

The following analysis presents further details of each maneuver observing motion data acquisition measurements. It concludes on the enhanced velocity measurement of the ship obtained by navigational data fusion, which is used in the subsequent section to correct ADCP data.

The first maneuver, L-shape track, is performed by heading south for 623.56m at approximately 1.04m/s and then east for 1274.8m at approximately 2.04m/s (according to the GPS measurements). The trajectory of the boat exhibits a slight drift to the east when heading south and a more noticeable drift to the north when heading east (Figure 57.a). This indicates the presence of a water current, as expected, mainly along shore in the south-north direction with a secondary transverse east component. The water current is quantified when observing the ADCP measurements in the next section. The water currents' influence on the vessel's motion can also be observed during the second maneuver (Figure 57.b), where the straight line maneuver goes 687.6m south-east at approximately 1.07m/s, and then goes 1988m north-east at approximately 2.92m/s. The boat drifts off the track (Figure 57) because of the water current.

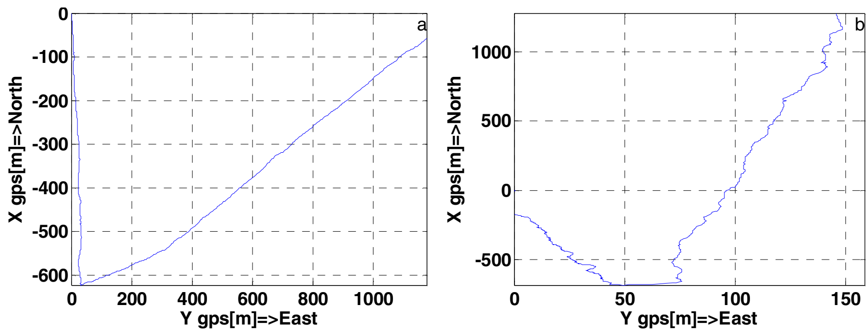

Fig. 57 Trajectory perceived by the DGPS during the first (a) and second (b) maneuver at sea.

The low frequency component of the velocity measured by the DGPS is merged with acceleration estimates from the IMU. A data fusion point chosen at 0.05Hz is used to obtain an enhanced velocity estimate using a complementary filter. A close up around the data fusion frequency is shown in Figure 58 using the signal's Power Spectral Density (PSD) on a logarithmic scale. The top (respectively bottom) figures (a) and (c) (respectively (b) and (d)) represent the PSD of the north (respectively east) component of the signals during the L-track maneuver (left) and the straight line maneuver (right).The focus is made before and after the data fusion point to follow the behavior of the merged signal. As predicted, the figures demonstrate how the enhanced estimate of the vessel's velocity supports the DGPS spectra below the data fusion point and the IMU acceleration measurement above it.

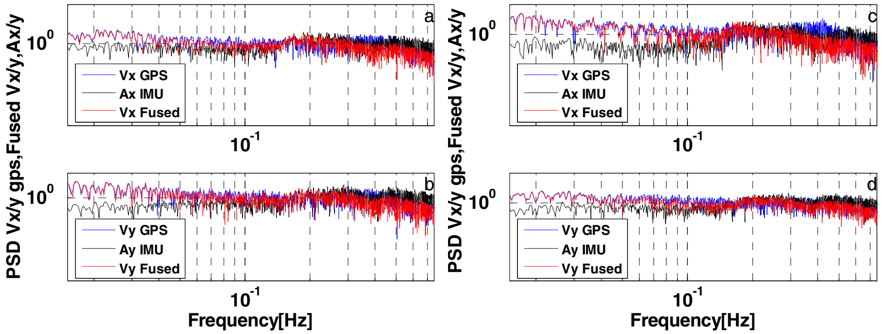

Fig. 58 Close ups around the data fusion frequency, 0.05Hz, of the PSD of the velocity measurement from the DGPS (blue), the acceleration estimate from the IMU (black) and the enhanced estimate of the velocity obtained by data fusion (red).

The time series of the three components, north, east and down, of the enhanced velocity estimate for the two maneuvers is plotted in Figure 59. The vessel travels at 1.1m/s when heading south and 2.06m/s when heading east according to the enhanced velocity signal, for the first maneuver (Figure 59 a, b and c). During the second maneuver, (Figure 59 d, e, and f) the boat is traveling at 1.14m/s when heading south and 2.94m/s when heading north. The enhanced velocity estimate, updated every 1/128 s, leads to a more accurate measurement of the vessel's motion since measured over a larger range of frequency of motion when compared to the GPS velocity measurement updated every 2 s. The enhanced velocity is later removed from the ADCP measurements in order to obtain true current measurements.

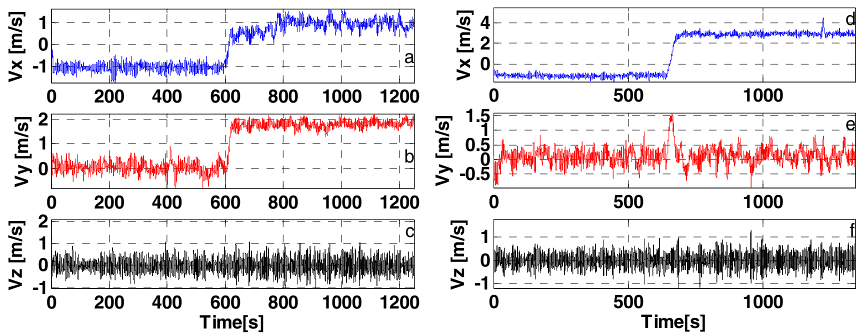

Fig. 59 Time series of the vessel's enhance velocity measurement obtained by data fusion with its north (east, down) component in blue (red, black) for the first maneuver (a, b, c) and second maneuver (d, e, f)

According to the tilt sensor the boat rolled 1.66° and pitched 0.58° during the first maneuver. It rolled 1.9° and pitched 0.56° during the second maneuver. These tilts are taken into account in the navigational data fusion and for the corrections of the ADCP data. Characteristic of the maneuvers at sea, like the distance travelled, the headings and the enhanced velocity measurement of the ship are now available to study and correct the water current measured by the ADCP.

5.2 ADCP Unreferenced and Corrected Measurements

The following section presents ADCP current measurements collected during the two maneuvers at sea as well as the correction applied to the data in order to recover water velocity profiles not contaminated by the vessel's motion. The removal of the ship's velocity is necessary to quantify the water current measured since the vessel surge, sway and heave account for the majority of the velocity measured by the ADCP [Ray 2002]. Two parts compose the section, illustrating the results of the correction of the ADCP data in two different reference frames for comparison purposes. The first part illustrates the results from correcting the ADCP velocity data in the ADCP radial beam coordinate frame, which allows us to manipulate ADCP data in its rawest form, i.e. no internal ADCP corrections applied. The second part illustrates the results of the ADCP corrected velocity data in the North-East-Up Frame, the Earth coordinate frame of the ADCP.

For this mission, the ADCP is a 600 kHz Teledyne RDI Broadband Workhorse Sentinel. Its reference beam, beam 3, is mounted 45° counter-clockwise from the centerline of the ship in order to increase noise rejection and the effective ADCP measured velocity by a factor of 1.4. As a result, beams 2 and 3 are pointing forward, and beams 1 and 4 are pointing aft. The water profile will be composed of 16 bins, each 4m in length. A default blanking distance of 88cm is used in order to avoid measuring currents when the ADCP is ringing; resultantly the center of the first bin is located 5.05m away from the ADCP which puts the center of the last bin 65.05m away from the ADCP.

To properly construe the raw ADCP data, it is noted that when the ship moves in a particular direction, with the ADCP mounted looking down, the velocity of the boat creates a relative flow that is opposite in direction of the actual movement of the boat. For example, when looking at the following raw ADCP data, one has to take into account this inverted bias. In addition to looking at the ADCP velocity profiles, the raw velocity at the first bin, where the water current is its strongest in the middle of the bin (~5m depth relative to the ADCP), is compared to the corrected ADCP velocity and the merged ship velocity. All velocities presented are in m/s. Finally the standard deviation of the error velocity, which is also the estimated standard deviation of the measured velocity, is calculated.

5.2.1 Correction of the ADCP Data in the Beam Coordinate Frame

The water current measurements resulting from the correction of the ADCP data in the Beam coordinate frame is presented here. In this reference frame, where beams 2 and 3 are looking forward and beams 1 and 4 are looking aft, the radial velocity sign is positive when the water is moving towards the transducer. The enhanced vessel's velocity measured by the data acquisition system is in the North-East-Down frame so it needs to be converted to the ADCP Beam coordinate frame before being subtracted from the ADCP data. The conversion is done through three consecutive transformations (Figure 60). The velocity is transformed from the North-East-Down vessel coordinates to the ADCP Ship reference frame (Forward-Starboard-Up). The vessel's velocity is then converted from the ADCP Ship coordinate system to the ADCP instrument coordinate frame, with its x-axis is pointing from beam 1 to beam 2, its y-axis from beam 4 to beam 3 and its z-axis pointing upward. Finally, the transformation is performed between the ADCP instrument coordinate frame and the Beam coordinate Frame.

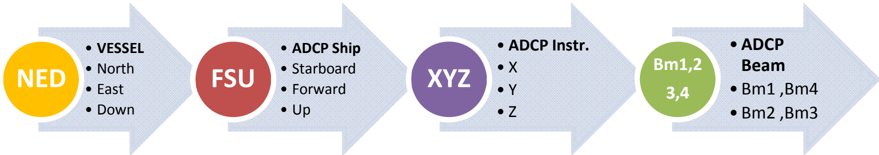

Fig. 60 Diagram of the necessary reference frame transformations to transform the vessel's enhanced velocity measured by the data acquisition system into the ADCP Beam coordinate frame.

The results of correction of the ADCP data in the beam coordinate frame are presented for the first maneuver, then the second maneuver. For each section, the currents at the first bin and the velocity profiles along the 16 bins are presented. The last two bins of the water profile were discarded by the ADCP internal quality algorithms and are represented by a white space in the water profile figures.

5.2.1.1 Water Current Measured for the First Maneuver, L-Shape Track Heading South Then East

The following presents, for the L-shape track, an estimate of the water current measured at the first bin then observes the 16 bins of the ADCP velocity profile. The ship's velocity along beams 2 and 3 (looking forward) as well as the uncorrected and corrected water current measure along beam 2 and 3 (Figure 61) are computed, plotted and examined. The same procedure is done for the data along beams 1 and 4, looking aft (Figure 62).

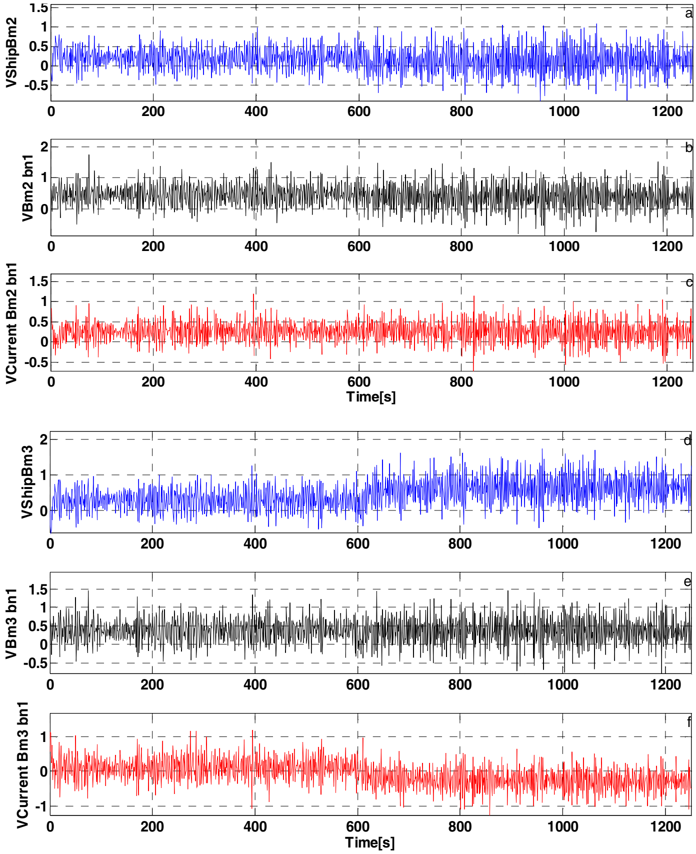

Fig. 61 Ship velocity, in blue, along beam 2 (a), and 3 (d) compare to the contaminated measurement of the water current, in black, along beam 2 (b) and 3 (e), and to the true water current, in red, along beam 2 (c) and 3 (f) during the first maneuver while the beams 2 and 3 are looking forward.

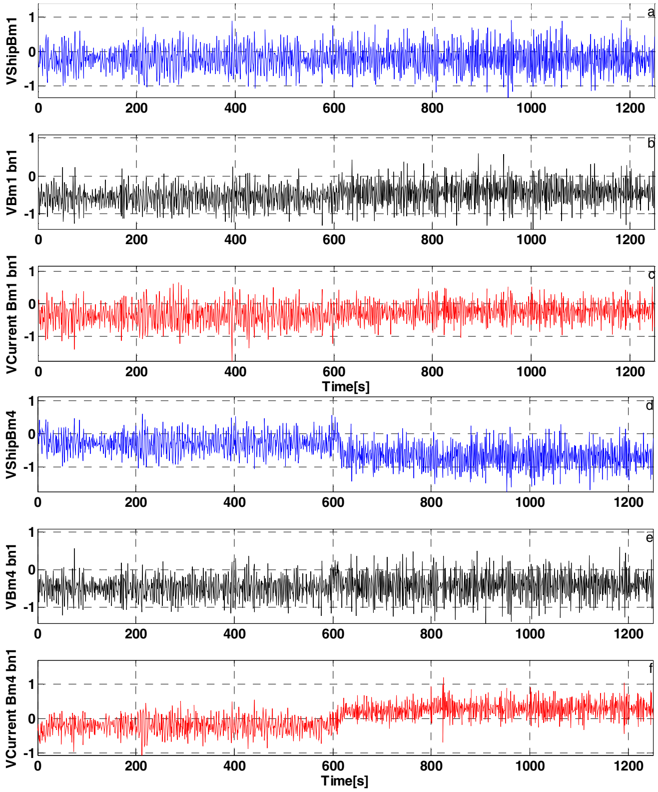

Fig. 62 Ship velocity, in blue, along beam 1 (a), and 4 (d) compare to the contaminated measure of the water current, in black, along beam 1 (b) and 4 (e), and to the true water current, in red, along beam 1 (c) and 4 (f) during the first maneuver while the beams 1 and 4 are looking aft.

Figure 61 and Figure 62 demonstrates the difficulty interpreting the ADCP recording of current, in black, as it is contaminated by the ship's motion, in blue, which needs to be subtracted from the latter leading to a true measurement of the water current, in red. The observations of the signals led to estimates which are compiled in Table 9.

Table 9 Ship's enhanced velocity measurement, uncorrected and corrected ADCP water current measurement in beam coordinates, at the first bin, during the first maneuver

Beam Coordinates, 1st maneuver, bin 1 L- Shape Track		**Ship's velocity,** [m/s]	**ADCP uncorrected Water current,** [m/s]	**Corrected Water current,** [m/s]
Forward	**Beam 2**	0.2 then 0.13	0.46 then 0.38	**0.26 then 0.25**
	Beam 3	0.27 then 0.62	0.39 then 0.37	**0.12 then –0.25**
Aft	**Beam 1**	-0.22 then -0.21	–0.55 then –0.42	**–0.33 then –0.21**
	Beam 4	-0.29 then -0.71	–0.48 then –0.41	**–0.19 then 0.30**

Using Table 9 and basic trigonometric equations, the water current measured at the first bin during the first maneuver is estimated at 4.74° North, 0.5m/s when the ship is heading south and 7.5° North, 0.72m/s when heading east. The subsequent part studies the ADCP velocity profiles to estimate the water current along all bins.

There are a number of options for representing time series water current data depending on the desired analyses. For this investigation of the ADCP velocity profiles and for the two maneuvers, the Matlab 'colormap plot' is the tool used to conceptualize the current velocity amplitudes. The direction and magnitude of the water current is then calculated using basic trigonometric equations. Uncorrected (Figure 63 and Figure 65) and corrected (Figure 64 and Figure 66) ADCP velocity profiles along the beams 2 and 3 and uncorrected (Figure 67 and Figure 69) and corrected (Figure 68 and Figure 70) velocity profiles along the beams 1 and 4 are presented below for the 16 bins of the water profile of the first maneuver. The bin 15 and 16 contain only the ADCP flag for 'bad data', i.e. -32768, indicating the limits of the ADCP range has been reached. Estimations of the water current are compiled in Table 10.

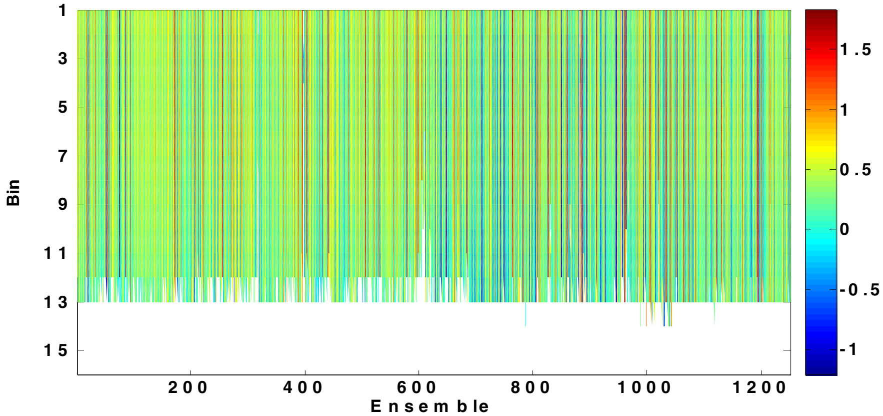

Fig. 63 Uncorrected ADCP velocity profile along beam 2, looking forward, during the first maneuver going south then east

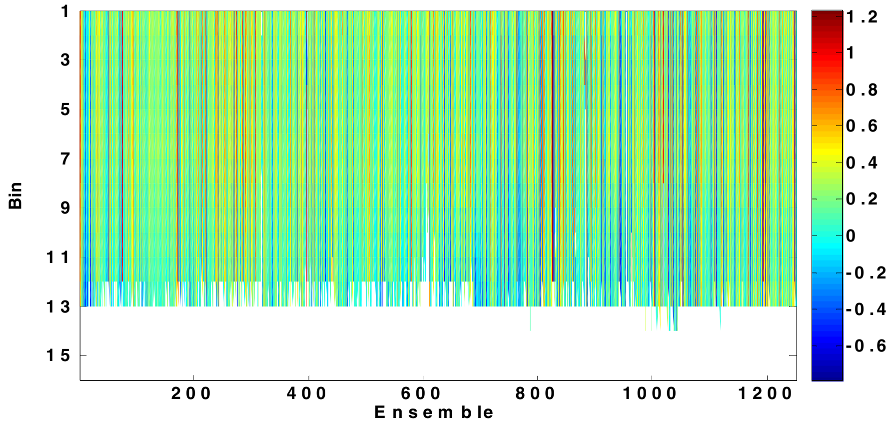

Fig. 64 Corrected ADCP velocity profile along beam 2, looking forward, during the first maneuver going south then east.

Figure 64 show the water current along beam 2 is of positive value across the maneuver with a slight increase in value when the boat is heading east. Peaks in current velocity occur along beam 2 when the boat is heading south.

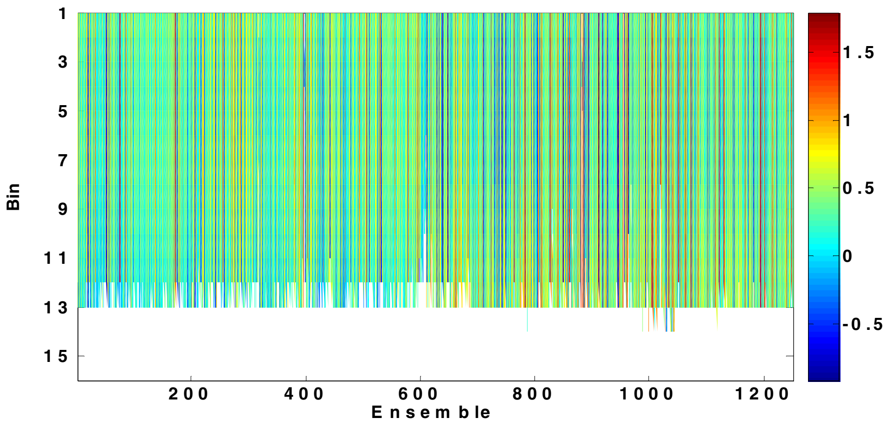

Fig. 65 Uncorrected ADCP velocity profile along beam 3, looking forward, during the first maneuver going south then east

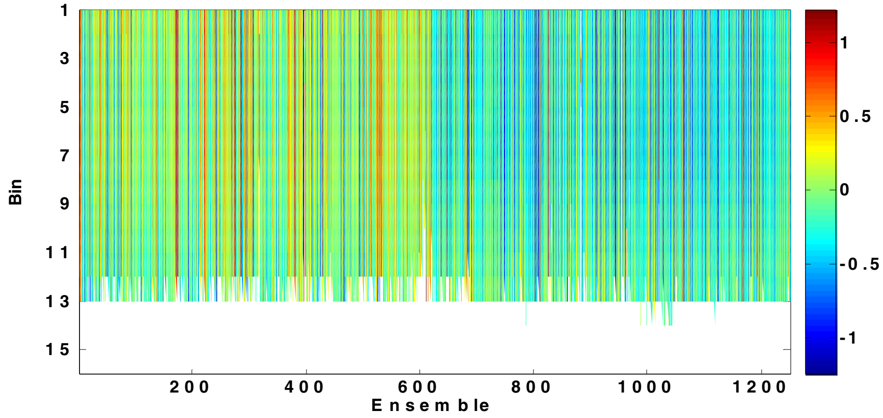

Fig. 66 Corrected ADCP velocity profile along beam 3, looking forward, during the first maneuver going south then east.

Figure 67 shows the water current along beam 3 has approximately the same range of value but of opposite signs when the boat heads south (positive) and east (negative). Peaks in current velocity mostly occur along beam 3 when the boat is heading south.

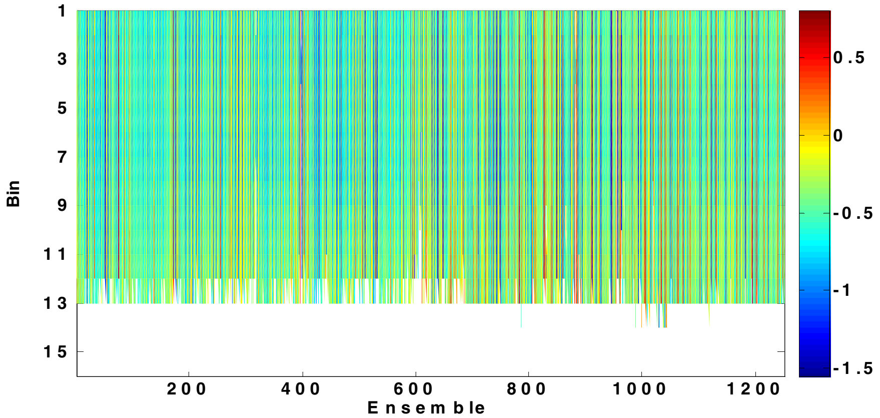

Fig. 67 Uncorrected ADCP velocity profile along beam 1, looking aft, during the first maneuver going south then east

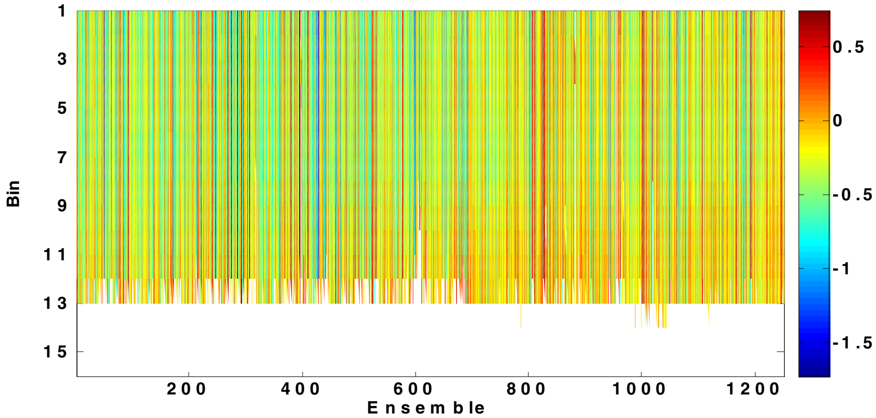

Fig. 68 Corrected ADCP velocity profile along beam 1, looking aft, during the first maneuver going south then east.

Figure 69 shows the water current along beam 1 is of negative value across the maneuver with a slight increase in value when the boat is heading south. Peaks in current velocity occur sporadically along beam 1 throughout the maneuver.

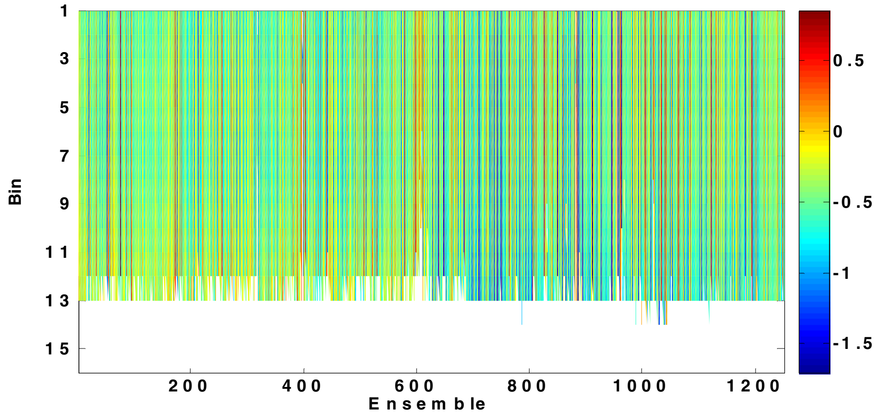

Fig. 69 Uncorrected ADCP velocity profile along beam 4, looking aft, during the first maneuver going south then east

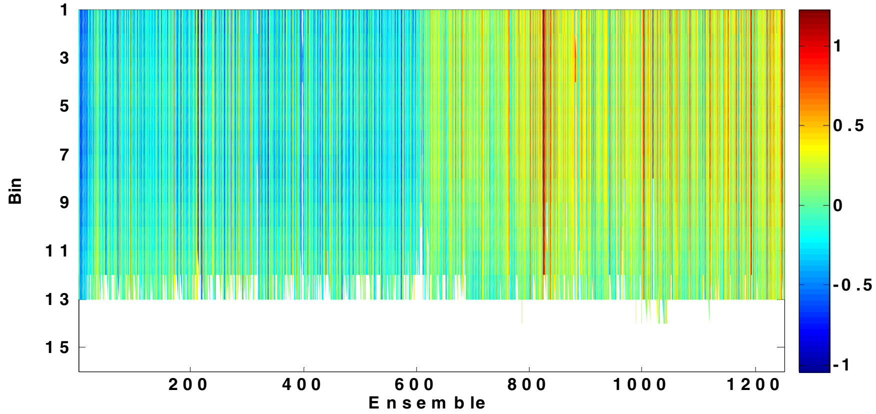

Fig. 70 Corrected ADCP velocity profile along beam 4, looking aft, during the first maneuver going south then east.

Figure 70 shows the water current along beam 4 has a negative value when the boat is heading south and a positive value when the boat heads east. Peaks in current velocity mostly occur along beam 3 when the boat is heading east. Looking at both of the corrected velocity profiles of the beams 2 and 3, looking forward, the peaks in current velocity appears in dark red and mostly occurs when the boat is heading south, i.e. when the water current is coming towards the beams. Plotting the time series using the colormap method reveals the variations in current magnitude according to direction and depth. Along the four beams, the water current is found to be homogeneously distributed over the water column, i.e. the coloring is mostly the same from the surface to the limit of the ADCP range. Quantifications of the uncorrected and corrected water current along the four beams and all bins are summarized in Table 10. In the table the abbreviation ‘Bm’ stands for ‘beam’.

Table 10 Estimates of uncorrected and corrected ADCP water current measurement looking at the velocity profiles in beam coordinates during the first maneuver.

Beam Coordinates, 1st maneuver, all bins L- Shape Track		**Uncorrected ADCP Water Profile, [m/s]**	**Corrected Water profile, [m/s]**
Forward	**Bm 2**	Going South: between 0.3 and 0.7	Going South: **between 0.1 and 0.5**
		Going East: between 0.2 and 0.5	Going East: **between 0.1 and 0.3**
	Bm 3	Going South: between 0.3 and 0.5	Going South: **between 0.1 and 0.3**
		Going East: between 0.3 and 0.5	Going East: **between –0.3 and -0.1**
Aft	**Bm 1**	Going South: between -0.7 and -0.5	Going South: **between -0.5 and -0.2**
		Going East: between -0.5 and -0.3	Going East: **between -0.3 and -0.1**
	Bm 4	Going South: between -0.6 and -0.2	Going South: **between -0.3 and -0.1**
		Going East: between -0.5 and -0.3	Going East: **between 0.2 and 0.4**

The water current is estimated averaging the water current measurements along each beam (Table 10) and using basic trigonometric equations. For the first maneuver, the water current is estimated at 13° north, 0.72m/s when the ship is heading south and 8.8° north, 0.64m/s when the vessel's heading east.

The following section presents estimates of the water current during the second maneuver, using the same method as the study of the first maneuver.

5.2.1.2 Water Current Measured for the Second Maneuver, Linear Track Heading South Then North

The following presents, for the linear track, an estimate of the water current measured at the first bin then observes the 16 bins of the ADCP velocity profile. The ship's velocity along beams 2 and 3 (looking forward) is computed, plotted and examined as well as the uncorrected and corrected water current measure along beam 2 and 3 (Figure 71). The same procedure is done for the data along beams 1 and 4, looking aft (Figure 72).

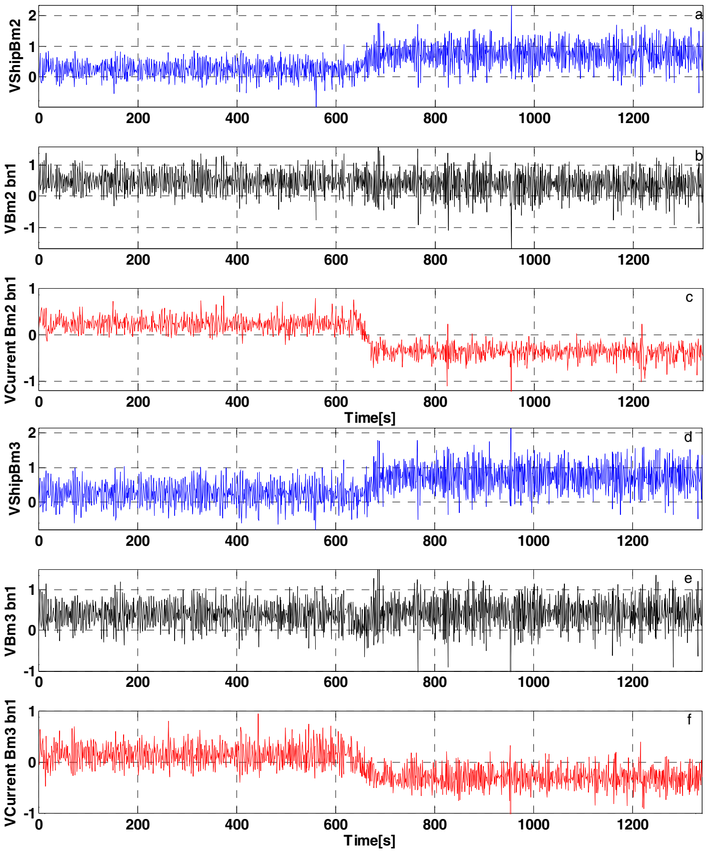

Fig. 71 Ship velocity, in blue, along beam 2 (a), and 3 (d) compare to the contaminated measure of the water current, in black, along beam 2 (b) and 3 (e), and to the true water current, in red, along beam 2 (c) and34 (f) during the second maneuver while the beams 2 and 3 are looking forward.

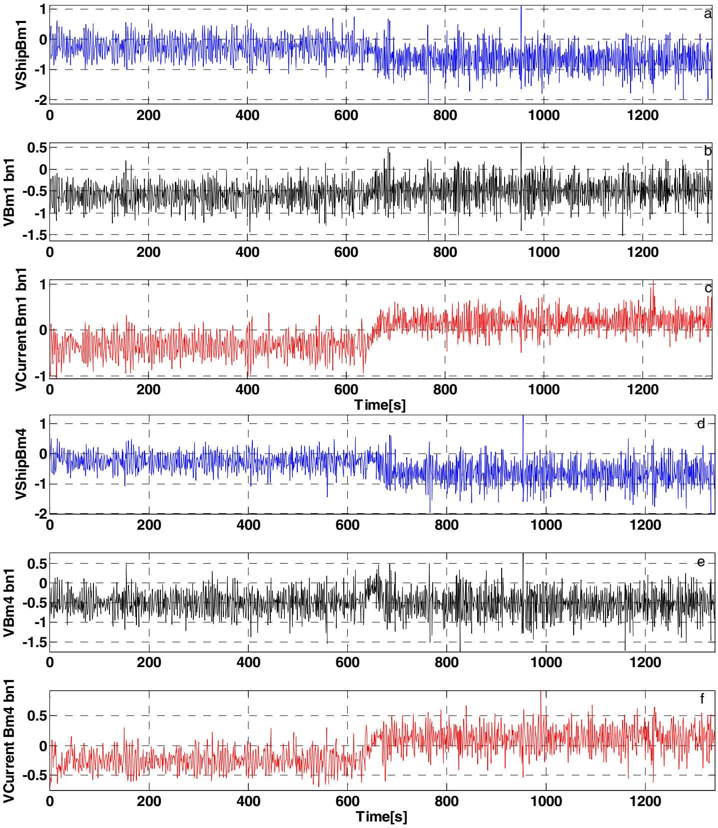

Fig. 72 Ship velocity, in blue, along beam 1 (a), and 4 (d) compare to the contaminated measure of the water current, in black, along beam 1 (b) and 4 (e), and to the true water current, in red, along beam 1 (c) and 4 (f) during the second maneuver while the beams 1 and 4 are looking aft.

Figure 71 and Figure 72 demonstrate the influence of the ships' motion (blue) on the ADCP measurement of the current (black) and it is only when this contamination is eliminated that one can interpret the water current measurement (red). Table 11 compiles the data estimates.

Table 11 Ship's velocity, uncorrected and corrected ADCP water current measurement in beam coordinates, for the first bin, during the second maneuver

Beam Coordinates, 2^{nd} maneuver, bin 1 Straight Line Track		**Ship's velocity, [m/s]**	**ADCP uncorrected Water current, [m/s]**	**Corrected Water current, [m/s]**
Forward	**Bm 2**	0.25 then 0.75	0.48 then 0.36	**0.22 then –0.36**
	Bm 3	0.26 then 0.75	0.39 then 0.42	**0.12 then -0.32**
Aft	**Bm 1**	-0.24 then -0.65	-0.59 then –0.48	**-0.32 then 0.16**
	Bm 4	-0.24 then –0.66	-0.51 then -0.53	**-0.25 then 0.12**

Using Table 11 and basic trigonometric equations, the water current measured at the first bin during the second maneuver is estimated at 5.49° north, 0.65m/s when the ship is heading south and 4.8° north, 0.68m/s when heading north. The subsequent part studies the ADCP velocity profiles to estimate the water current along all bins.

As for the first maneuver, the Matlab ‘colormap plot’ is the tool used to conceptualize the current velocity amplitudes. The uncorrected and corrected ADCP velocity profiles along the beams 2 and 3 and the uncorrected and corrected ADCP velocity profiles along the beams 1 and 4 are observed for the second maneuvers. The bin 15 and 16 contain only the ADCP flag for ‘bad data’(-32768), indicating that the limits of the ADCP water profile range have been reached. The estimation of the water current is compiled in Table 12.

The corrected velocity profiles of the beams 2 and 3, looking forward, shows peaks in current velocity (dark red) mostly occurring when the boat is heading south, i.e. when the water current is coming towards the beams while peaks in current velocity appear on the beams 1 and 4, looking aft, when the boat is heading north. Along the four beams, the water current is considered homogeneously distributed over the water column although one can note slight changes in the colors, compare to the first maneuver profiles, showing the water current amplitude reducing with depth. The estimations of the uncorrected and corrected water current along the four beams and all bins are summarized in Table 12 where the abbreviation ‘Bm’ stands for beam.

Table 12 Estimation of uncorrected and corrected ADCP water current measurement looking at the velocity profiles in beam coordinates during the second maneuver.

Beam Coordinates, 2nd maneuver, all bin Straight Line Track		**Uncorrected ADCP Water Profile**, [m/s]	**Corrected Water profile,** [m/s]
Forward	**Bm 2**	Going South: between 0.35 and 0.6	**Going South: between 0.1 and 0.3**
		Going North: between 0.25 and 0.6	**Going North between -0.5 and -0.2**
	Bm 3	Going South: between 0.35 and 0.5	**Going South: between 0.1 and 0.2**
		Going North: between 0.3 and 0.65	**Going North between -0.5 and -0.1**
Aft	**Bm 1**	Going South: between -0.65 and -0.5	**Going South: between -0.4 and -0.2**
		Going North: between -0.55 and -0.45	**Going North: between 0.1 and 0.2**
	Bm 4	Going South: between -0.65 and -0.35	**Going South: between -0.4 and -0.1**
		Going North: between -0.55 and -0.4	**Going North: between 0.1 and 0.2**

The water current is estimated averaging the water current measurements along each beam (Table 12) and using basic trigonometric equations. For the second maneuver, the water current is estimated 1.25° north, 0.64m/s when the ship is heading south and 3.2° north, 0.67m/s when the vessel's heading north.

The following section presents the ADCP data correction in the North-East-Up Frame, this time for comparison purposes.

5.2.2 Correction of the ADCP Data in the North-East-Up Frame, the ADCP's Earth Reference Frame

The water current measurements resulting from the correction of the ADCP data in the North-East-Up frame, for the 2 maneuvers, are presented here. The north and east component of the corrected water current measurement are first quantified separately. For each component of the water current, the currents at the first bin and the velocity profiles along the 16 bins are presented. The last two bins of the water profile were discarded by the ADCP internal quality algorithms and are represented by a white space in the water profile figures. Finally, the results are combined to conclude on the direction and magnitude of the water current during the two maneuvers.

The ADCP data are recorded in the Beam coordinate frame, its rawest form, so it needs to first be converted to the North-East-Up frame before the measurement correction can occur. This is done through three consecutive transformations (Figure 73). The ADCP data are transformed from the Beam coordinate frame to the ADCP instrument coordinate frame, with its x-axis pointing from beam 1 to beam 2, its y-axis from beam 4 to beam 3 and its z-axis pointing upward. The data are then converted to the ADCP Ship reference frame (Forward-Starboard-Up) to finally be converted to the ADCP Earth frame (North-East-Up).

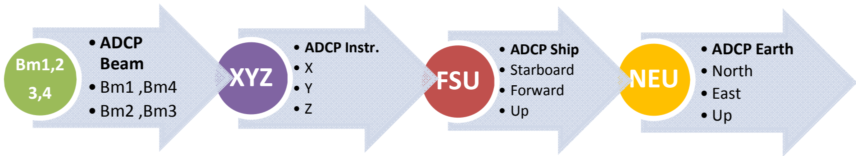

Fig. 73 Diagram of the necessary reference frame transformations to transform the ADCP data into the North-East-Up coordinate frame where the enhanced velocity measurement of the vessel is available.

The enhanced velocity measurement of the ship is also transformed to the North-East-Up coordinate frame since it is measured in the North-East-Down reference frame. The subsequent sections covers the study of the water current measured for the first bin during the two maneuvers.

5.2.2.1 Water Current Measured, at the First Bin, in the NEU Frame for the L-Shape Track and the Linear Track

This section quantifies the north and east component of the corrected water current measurement at the first bin in the North-East-Up reference frame for the two maneuvers. The north (respectively east) component of the ship's velocity is shown in Figure 74.a (Figure 75.a) for L-shape track and in Figure 74.d (Figure 75.d) for the linear track. The north (east) component of the uncorrected and corrected currents, at the first bin, is presented in Figure 74.b (Figure 75.b) and Figure 74.c (Figure 75.c) for the L-shape track and in Figure 74.e (Figure 75.e) and Figure 74.f (Figure 75.f) for the linear track.

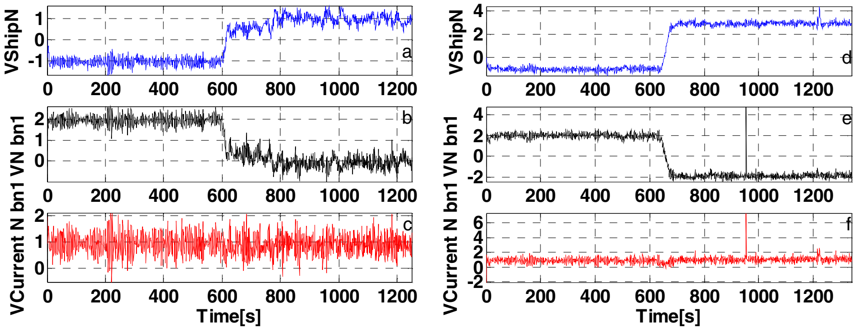

Fig. 74 Time series of the north component of the ship (blue), of the contaminated water current measured by the ADCP in the middle of the first bin (black) and of the water current resulting from its correction (red) in the NEU during the first (a, b an c) and the second maneuver (d, e, and f).

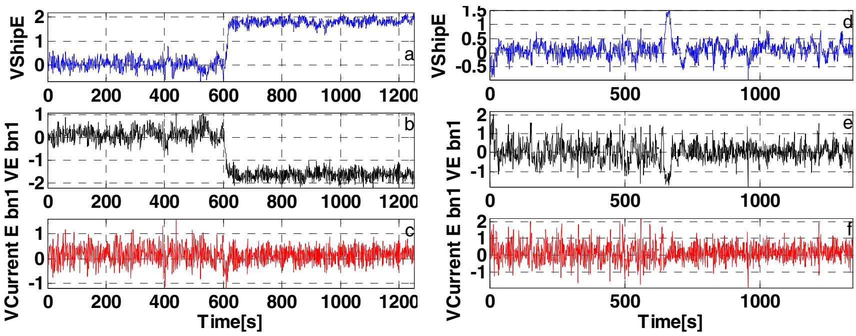

Fig. 75 Time series of the east component of the ship (blue), of the contaminated water current measured by the ADCP in the middle of the first bin (black) and of the water current resulting from its correction (red) during the first (a, b an c) and the second maneuver (d, e, and f).

The boat changes direction after 600s for the first maneuver and 630s for the second maneuver. The impact can be seen on the east component of the data (Figure 75a and Figure 75b) where there is a temporary inversion in the velocity sign. These brief reversals are due to the ship's dynamic response to waves. Another perturbation on the ADCP data can be noted after 950s on the second maneuver (Figure 74 and Figure 75 d, e and f). Each figure is accounted for and the data estimations are presented in Table 13 for the first and second maneuver.

Table 13 Ship's velocity, uncorrected and corrected ADCP water current measurement in North-East-Up coordinates, for the first bin, during the first and second maneuver

NEU Coordinates, 1st bin		**Ship's velocity,**[m/s]	**ADCP uncorrected Water current, bin 1** [m/s]	**Corrected Water current, bin 1** [m/s]
L- Shape Track	**North Component**	–1.038 then 0.927	1.959 then 0.048	**0.9**
	East Component	0.069 then 1.79	0.14 then – 1.65	**0.16**
Linear Shape Track	**North Component**	-1 then 2.9	1.99 then –1.88	**0.96**
	East Component	0.075 then 0.15	–0.17 then 0.02	**0.12**

The water current measured has an estimated 0.93m/s north component and a 0.14m/s east component (Table 13). Hence the water current measured, at the first bin, in the NEU frame and on average over the two maneuvers, is estimated at 8.6° north, 0.94m/s. The next part examines the ADCP velocity profiles to estimate the water current along all bins.

5.2.2.2 Water Current Measured Observing the ADCP Velocity Profiles in the NEU Frame for the L-Shape Track and the Linear Track

The next step is to observe and quantify the north and east component of the uncorrected (Figure 76, Figure 78, Figure 80 and Figure 82) and corrected (Figure 77, Figure 79, Figure 81 and Figure 83) ADCP velocity profiles along all bins for the two maneuvers.

There are a number of options for representing time series water column current data, depending on the desired analyses. For this investigation of the ADCP velocity profiles and for the two maneuvers, the Matlab 'colormap plot' is the tool used to conceptualize the current velocity amplitudes. The direction of the water current is then calculated using basic trigonometric equations. Bin 15 and 16 contain only the ADCP flag for 'bad data', i.e. -32678, indicating that the limits of the ADCP range have been reached.

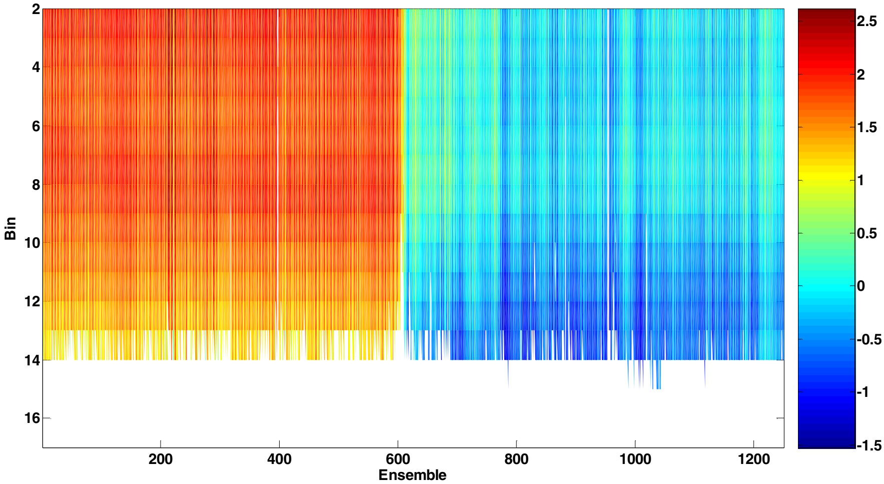

Fig. 76 Uncorrected north component of the ADCP velocity profile during the first maneuver of the mission at sea, creating an L-shape track going south then east.

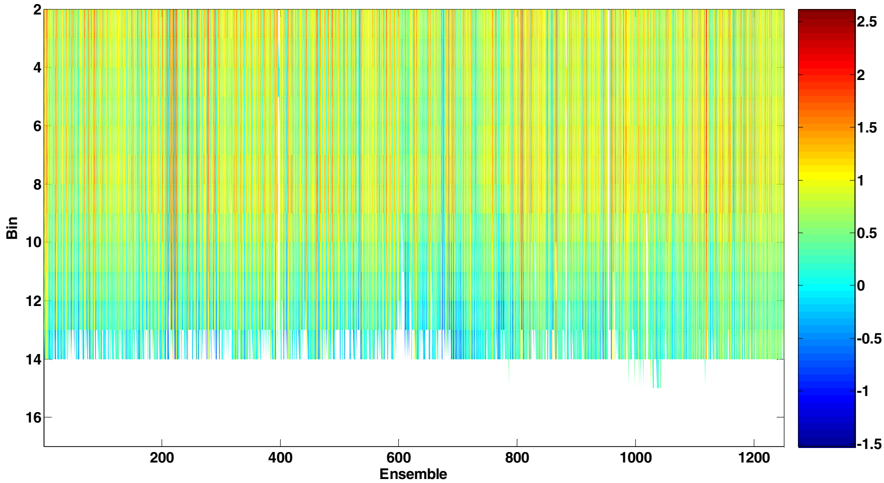

Fig. 77 Corrected north component of the ADCP velocity profile during the first maneuver of the mission at sea, creating an L-shape track going south then east.

Figure 77 shows the north component of the water current is of positive value across the maneuver with a peak in current velocity when the boat changes directions.

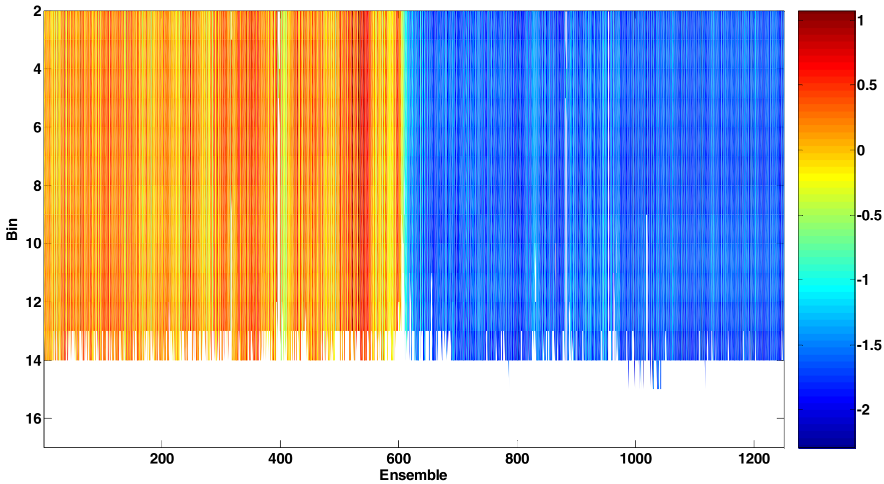

Fig. 78 Uncorrected east component of the ADCP velocity profile during the first maneuver of the mission at sea, creating an L-shape track going south then east.

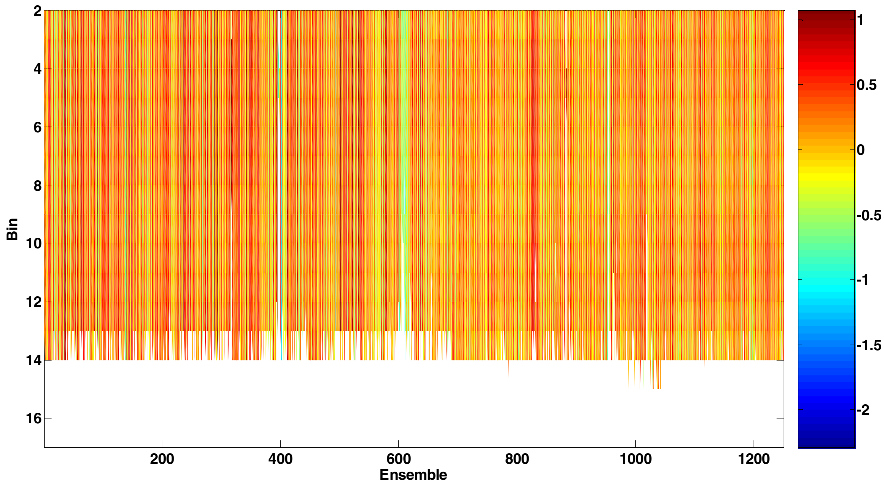

Fig. 79 Corrected east component of the ADCP velocity profile during the first maneuver of the mission at sea, creating an L-shape track going south then east.

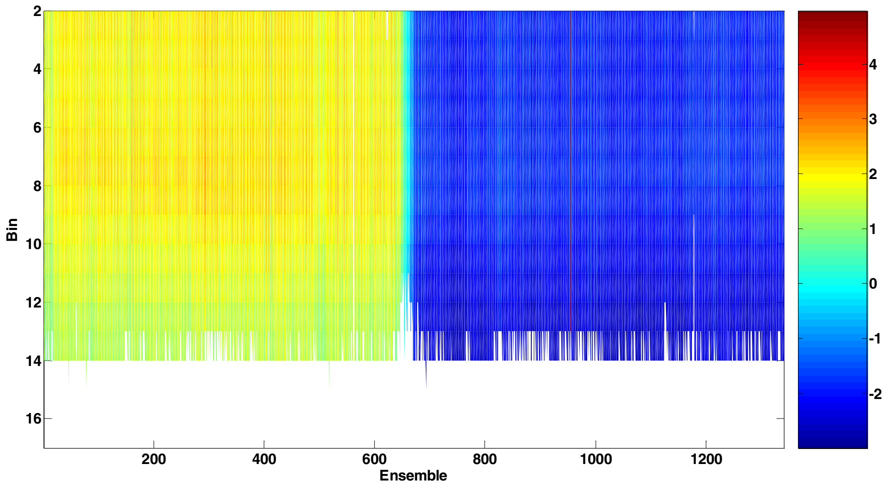

Fig. 80 Uncorrected north component of the ADCP velocity profile during the second maneuver of the mission at sea, following a straight line track going south then north.

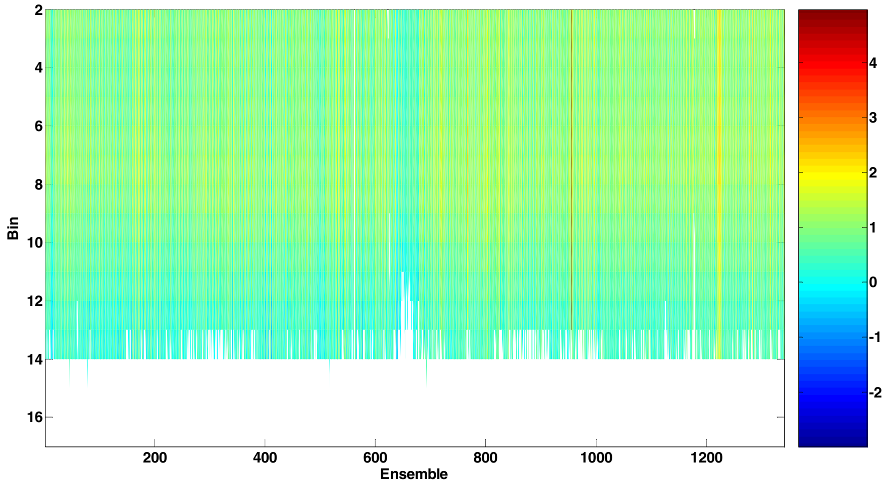

Fig. 81 Corrected north component of the ADCP velocity profile during the second maneuver of the mission at sea, following a straight line track going south then north.

Figure 81 shows the water current is of positive value across the maneuver with a decrease in value when the boat is changing direction.

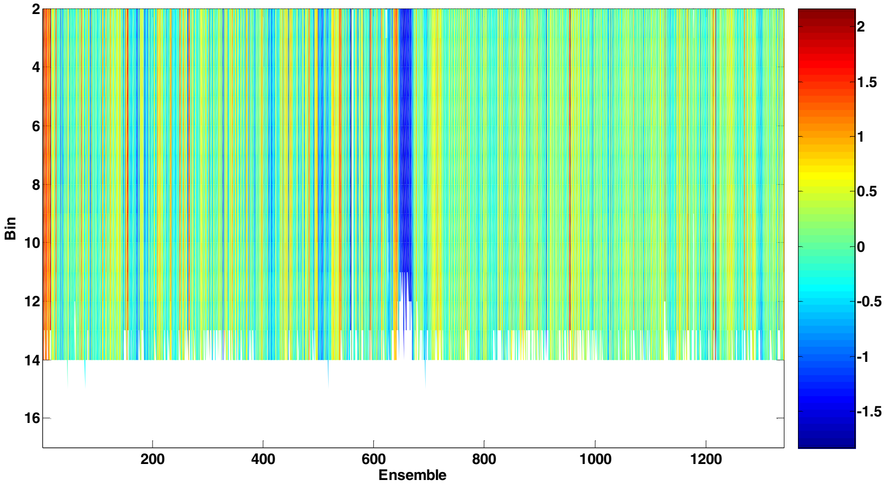

Fig. 82 Uncorrected east component of the ADCP velocity profile during the second maneuver of the mission at sea, following a straight line track going south then north.

A drop in velocity is visible on Figure 82 when the boat changes direction.

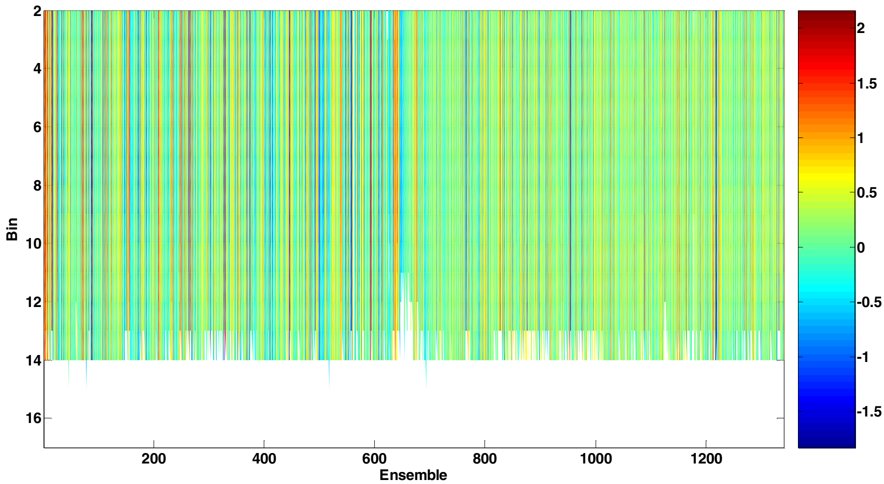

Fig. 83 Corrected east component of the ADCP velocity profile during the second maneuver of the mission at sea, following a straight line track going south then north.

The figures are analysed individually and estimations of the water current measurements are presented in Table 14.

Table 14 Estimation of uncorrected and corrected ADCP water current measurement looking at the velocity profiles in NEU coordinates during the first and second maneuver.

NEU Frame, all bins	**Component**	**Uncorrected ADCP Water Profile,** [m/s]	**Corrected Water profile,** [m/s]
L-shape track going south then east	**North**	Going South: between 1 and 1.7	**between 0 and 1.8** [average 0.9]
		Going East: between -0.7 and 0.5	
	East	Going South: between -0.1 and 0.6	**between -0.3 and 0.5** [average 0.1]
		Going East: between -1.7 and -1.3	
Straight line track going south then north	**North**	Going South: between 1.5 and 2.2	**between 1 and 1.5** [average 1.25]
		Going North: between -2.5 and -2	
	East	Going South: between -0.7 and 0.5	**between -0.2 and 0.3** [average 0.1]
		Going North: between -0.4 and 0.5	

The average water current measured from the two maneuvers is composed of a longshore current in the northerly direction, estimated at 1.07m/s and a weaker offshore current of 0.1m/s (Table 14). The water current measured, observing all bins and averaging the two maneuvers, is estimated at 5.3° north, 1.07m/s in the NEU frame.

5.3 Conclusion on the At-Sea Mission

The mission at sea was conducted for the observation of the motion data acquisition system measurements in the field as well as the collection and correction of unreferenced ADCP data. The ship maneuvers followed two different tracks, an L-shape track, going south then east, and a straight line roundtrip track along the south-north direction. The mission was performed off the southeast coast of Florida where the currents run predominately near shore in a north-south direction with magnitudes ranging up to 1m/s.

The unreferenced ADCP velocity profiles collected during the mission were corrected by subtracting the vessel motion from the measurements. The correction of the ADCP data was obtained in the ADCP beam coordinate frame, where the data are recorded, and in its Earth Reference frame, North-East-Up frame, for comparison purposes.