Current meter observations from the east coast of Grand Manan Island, Bay of Fundy in 2014

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TABLE OF CONTENTS

ABSTRACT

Chang, B.D., Haigh, S.P., Losier, R.J., and Page, F.H. 2017. Current meter observations from the east coast of Grand Manan Island, Bay of Fundy in 2014. Can. Tech. Rep. Fish. Aquat. Sci. 3239: iv + 110 p.

Five Acoustic Doppler Current Profilers (ADCPs) were deployed to collect water depth and current velocity data along the eastern shore of Grand Manan Island, Bay of Fundy, during April-May 2014. The ADCPs were mounted near the seafloor, facing upwards, to collect data throughout the water column. Each meter was deployed for 48-52 d. In addition to the water depth and current velocity data collected in these 5 deployments, data from three earlier ADCP deployments in this area, during 2000 and 2002, are also included in this report.

RÉSUMÉ

Chang, B.D., Haigh, S.P., Losier, R.J., and Page, F.H. 2017. Current meter observations from the east coast of Grand Manan Island, Bay of Fundy in 2014. Can. Tech. Rep. Fish. Aquat. Sci. 3239: iv + 110 p.

Cinq profileurs de courant à effet Doppler (ADCP) ont été déployés afin de recueillir des données sur la vitesse du courant et la profondeur d'eau le long de la côte est de l'île Grand Manan, dans la baie de Fundy, en avril et mai 2014. Les ADCP étaient fixés près du fond marin, orientés vers le haut, afin de recueillir des données dans la colonne d'eau. Chaque courantomètre a été déployé pendant 48 à 52 jours. En plus des données sur la vitesse du courant et la profondeur d'eau recueillies lors de ces cinq déploiements, des données recueillies à partir de trois déploiements d'ADCP dans cette zone, en 2000 et en 2002, font également partie du présent rapport.

INTRODUCTION

Salmon farming is an important industry along the eastern shore of Grand Manan Island in the southwestern New Brunswick (SWNB) area of the Bay of Fundy. Within the current Aquaculture Bay Management Area (ABMA) framework, this area is designated as ABMA 2b (Fig. 1). The first salmon farm in eastern Grand Manan Island was established in 1988. In 2013, twelve salmon farms in this area were stocked with smolts.

Efforts to operate, manage, and regulate the farms must incorporate knowledge in aspects of the transport and dispersal of disease vectors, parasites, and treatment products in the vicinity of salmon farms, as well as the deposition of organic farm wastes. This information can also be useful in reviews of the ABMA designations to inform decisions regarding ABMA boundary amendments to support disease and parasite management.

This knowledge of transport and dispersal is generally based on outputs from water circulation and particle transport and dispersal models. These models require empirical measurements of currents for model calibration and skill assessment. Modelling for these purposes in the eastern Grand Manan Island area has used an adaptation of the QUODDY circulation model (Greenberg et al. 2005; Page et al. 2005; Chang et al. 2006). Research is now being conducted on developing improved water circulation predictions in SWNB using the Finite Volume Community Ocean Model (FVCOM) (Chen et al. 2006). To calibrate and validate the new model, additional current velocity data are desired. The primary purpose of this report is to summarize current meter data collected in the eastern Grand Manan Island area in 2014. Also included are some current meter data collected in this area in 2000 and 2002.

METHODS

Current meter deployment

Current velocities were measured at locations in the mouths of channels distributed along the eastern shore of Grand Manan Island using Teledyne RD Instruments WorkHorse Sentinel Acoustic Doppler Current Profilers (ADCPs). ADCPs use the Doppler effect by transmitting sound at a fixed frequency and listening to echoes returning from sound scatterers (such as small particles or plankton) in the water (Teledyne RD Instruments 2011).

Five 600 kHz ADCPs were deployed at locations shown in Fig. 1 (deployments 540-544) on 3 April 2014 and retrieved after 48-52 d (Table 1). Earlier data were obtained from deployments of a similar model ADCP (but 300 kHz) at three locations in 2000 and 2002 (deployments 212, 308 and 309 in Fig. 1); these three deployments were 26-46 d in duration (Table 1).

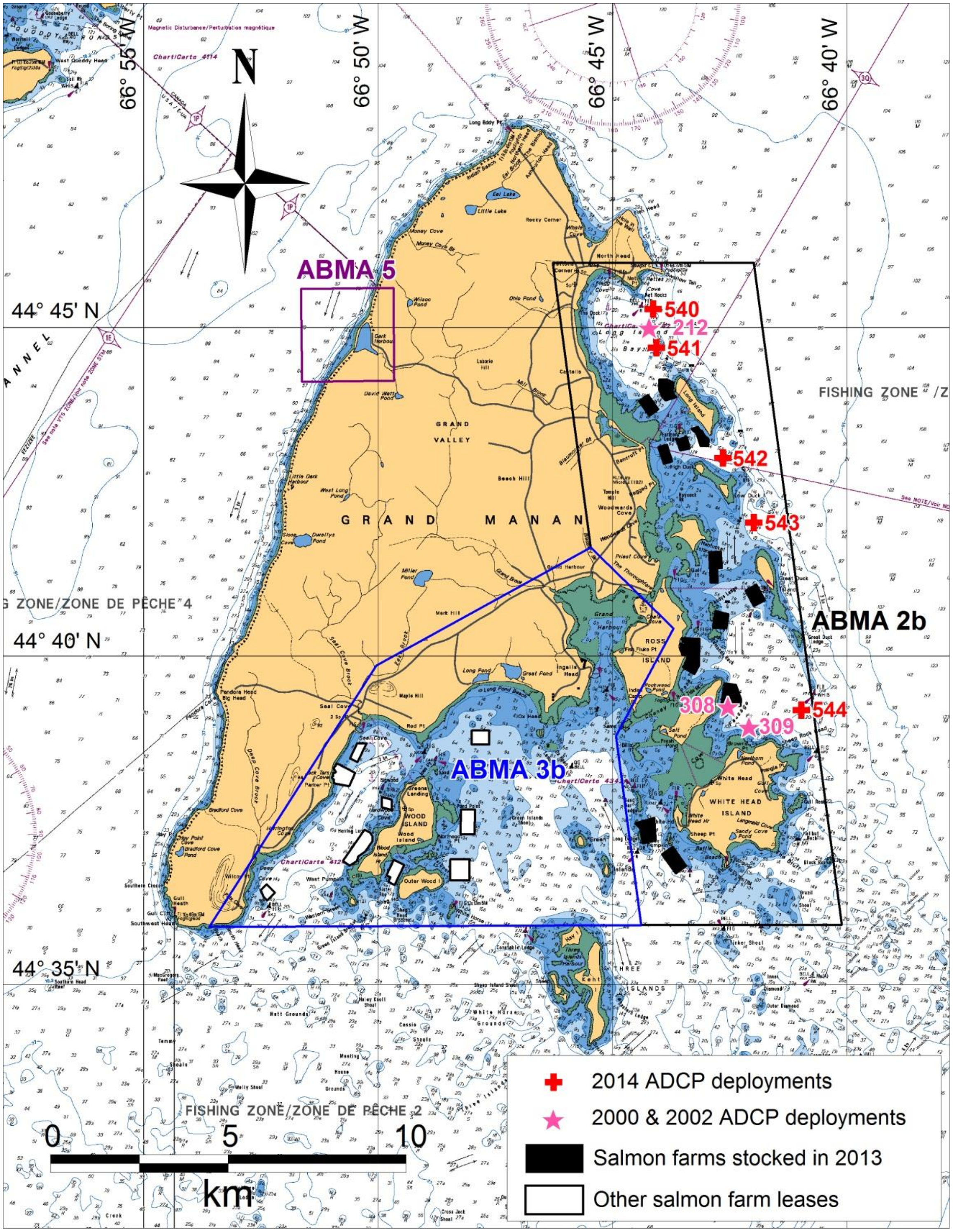

Fig. 1. Map of Grand Manan Island showing the locations of ADCP deployments in April-May 2014 and previous deployments in 2000 and 2002. Thick lines indicate boundaries of Aquaculture Bay Management Areas (ABMAs). The background map is part of Canadian Hydrographic Service chart 4340 (Grand Manan, January 2003 edition); depths are in metres below Chart Datum (lowest normal tide).

Table 1. Dates of deployment and retrieval of Acoustic Doppler Current Profilers (ADCPs) off the east coast of Grand Manan Island. See Fig. 1 for deployment locations.

Deploy-ment	Serial No.	Latitude (°N)	Longitude (°W)	Deployment Date	Retrieval Date	Duration (d)	Duration (h)
2014 deployments							
540	12627	44.75475	66.73564	3-Apr-2014	25-May-2014	51.9	1 246
541	12570	44.74491	66.73439	3-Apr-2014	22-May-2014	48.9	1 174
542	12610	44.71688	66.71084	3-Apr-2014	21-May-2014	48.0	1 153
543	12605	44.70050	66.69987	3-Apr-2014	21-May-2014	48.0	1 153
544	12608	44.65295	66.68291	3-Apr-2014	21-May-2014	48.0	1 153
2000 & 2002 deployments							
212	222	44.75020	66.7369	24-May-2000	9-Jul-2000	46.2	1 108
308	222	44.65452	66.7089	28-Aug-2002	8-Oct-2002	40.9	982
309	222	44.64898	66.7014	9-Oct-2002	4-Nov-2002	26.2	629

The ADCPs were deployed near the seafloor, facing upwards. Each ADCP was mounted in a SUBS™ ADCP model A2 buoy (Open Seas Instrumentation Inc.), which was attached via a Teledyne Benthos 866-A acoustic release to an anchor (~90 kg of steel chain), so that the pressure sensor at the top of the meter was ~1.5 m above the seafloor (Fig. 2). A groundline (~100 m) was attached to the anchor to facilitate instrument recovery.

Prior to each deployment, battery packs were degaussed and ADCP compasses were calibrated and swung. An overall compass error <2° (calculated by the ADCP calibration software) is considered to be acceptable (Teledyne RD Instruments 2014). Results for compass calibrations conducted in July 2014 (shortly after the 2014 deployments) are presented in Appendix A. Compass calibration data were not available for the 2000 and 2002 deployments.

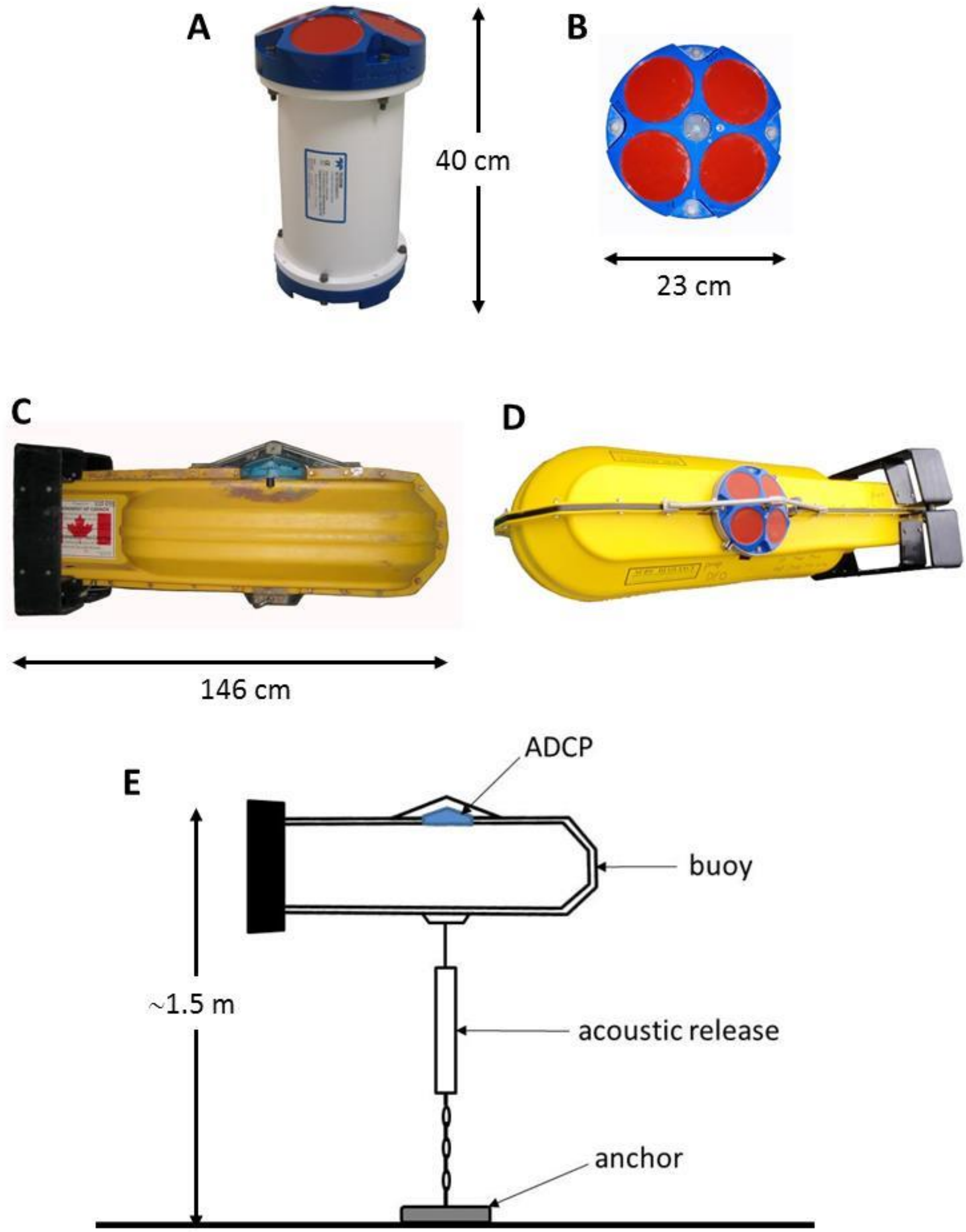

Fig. 2. RDI Workhorse Sentinel Acoustic Doppler Current Profiler (ADCP). A: side view. B: top view. C & D: side and top views of ADCPs mounted in SUBS™ ADCP buoys (model A2). E: schematic diagram of an ADCP deployment; there was also a groundline (~100 m) attached to the anchor (not shown).

Data collection and editing

ADCP data were collected in raw internally processed mode. The raw data records contained data read directly by the ADCP and were for the most part not scaled or corrected by offsets that could be entered by the user when initializing the ADCP for deployment. This allows the user to do the necessary adjustments and scaling when post processing the raw ADCP data. Data that were adjusted at post processing were the depth of the transducer face and the current direction, which was adjusted to account for magnetic variation. Variables that were entered during the initialization of the ADCP were salinity and temperature estimates which were used for computation of the speed of sound in water; in all deployments, the temperature entered was 5°C and the salinity was 32 psu. Data collected in SWNB during 1995-1997 indicate that the average water temperature during April-May (which was the time of year for the 2014 ADCP deployments) is ~5°C (Chang et al. 2011). Water temperatures in this area can reach ~14°C during the late summer to fall (the time of year for the 2002 ADCP deployments), but at this temperature, the speed of sound would increase by only 2% (compared to 5°C). The limited salinity data available for SWNB indicate that 32 psu is typical throughout the year, although lower salinities can occur during short periods, especially near the surface (Chang et al. 2011).

Editing of the current meter data was done after the raw ADCP data was output into a readable ASCII text matrix file. Each data segment (data collection period) generated from the output included averages of the current speed, echo intensity, correlation magnitude, and “percent good” data for each depth bin collected in the segment. Echo intensity, correlation magnitude, and “percent good” are key quality control parameters. Echo intensity is a measure of the signal strength returned to the transducer. Correlation magnitude is a measurement of how much the particle distribution changes between phase measurements; the less the distribution changes, the higher the correlation, and the more precise the velocity measurement. “Percent good” indicates the fraction of the pings that pass a variety of criteria in each of the 4 beams. Rejection criteria include low correlation, large error velocity, and false target thresholds; we used instrument default values for each of the thresholds. Ancillary data describing the instrument setup, date, time, pitch, and roll for each ensemble were also exported to the data matrix.

The ambiguity velocity (the maximum allowable radial motion for phase measurements to be unambiguous) was set at the default value (175 cm s^{-1}) in all deployments. Other ADCP set up parameters are shown in Appendix B. For the 2014 deployments, the ADCPs were set to collect data at 20-min intervals. At each 20-min interval, the ADCPs transmitted one ping per second during a 4-min segment (for a total of 240 pings in each 4-min segment). The data output was an average of the 240 pings collected during each segment in each 1-m depth bin. For the 2000 and 2002 deployments, the ADCPs were set to collect data at 15-min intervals. At each 15-min interval, the ADCPs transmitted one ping every 3 s during each 5-min segment (for a total of 100 pings in each 5-min segment). The data output was an average of the 100 pings collected during each segment in each 1-m depth bin. The time stamp associated with each average ping value was the time half-way through each segment and the depth was the mid-depth within each 1-m depth bin.

The standard deviation (SD) of the current velocity measurements was calculated by the instrument software:

$$SD_{velocity} = \frac{SD_{single\ ping}}{\sqrt{number\ of\ pings\ per\ segment}}$$

Values for the SD of a single ping vary with the instrument frequency and bin size, and are available in the ADCP Operation Manual (Teledyne RD Instruments 2014).

The ADCPs were deployed near the seafloor, facing upwards, and the first recorded raw depth interval in the 2014 deployments was usually 2.1 m above the transducer head (range: 1.6-2.6 m). Depths were calculated by the instrument software from the pressure sensor output:

$$\text{Depth(m)} = \text{Pressure(kPa)} * (1.02 - 0.00069 * \text{ES})$$

where ES is the salinity setting (Teledyne RD Instruments 2016). Depths were compensated to include the mooring height, which was ≅1.5 m (the distance between the seafloor and the pressure sensor located on the top of the ADCP) in all deployments, so the deepest measurements were usually 3.6 m above the seafloor (range: 3.1-4.1 m). The only exception in 2014 was deployment 542, where due to improper mounting of the ADCP in the flotation device, a metal bar on the top of the flotation device interfered with the beams from two of the transducers, resulting in errors in measurements nearest those transducers; for this deployment, the deepest measurements used for the analyses were 6.6 m above the seafloor (range: 6.1-7.1 m). In the 2000 and 2002 deployments the first recorded raw depth interval was 3.0 m above the transducer head (range: 2.5-3.5 m), so the deepest measurements were 4.5 m above the seafloor (range: 4.0-5.0 m).

Data were edited to exclude records beyond the water depth recorded by the ADCP pressure sensor. The tidal amplitudes in this area require that measurements be taken at depths beyond the highest predicted tides in the area of the mooring. Accordingly, the ADCPs sampled well beyond the maximum water depth (i.e. including some measurements above the water surface). Therefore, the echoes and backscatter caused by the surface water layer must be identified and removed. This echo contaminated data was within 2.5 bin sizes of the water surface in most deployments. Therefore, with bin sizes set to 1-m intervals, measurements from the top 2.5 m were removed in most cases. Exceptions were deployments 541 (2014) and 308 (2002) where measurements from the top 3.5 m were removed, and deployment 309 (2002) where measurements from the top 5.5 m were removed. Data segments with recorded pitch or roll in excess of 15° were removed. Within each data segment, data from depth bins with <90% “percent good” values were also removed.

To show differences in current velocity among depths, data were analyzed for three depth levels in each deployment: near bottom, mid-water, and near surface. The near bottom level was the closest depth bin to the seafloor which had good data in ≥85% of the segments (see Appendix C). The mid-water level was the bin which contained the mid-depth between the seafloor and the mean sea level. The near surface level was the depth range equal to the bin size (1 m) closest to the sea surface, which had good data in ≥85% of the segments (usually 2.5-3.5 m below the surface; see Appendix C). The depths for each of the three depth levels in each deployment, as well as the number and percentage of data records for each depth level, are shown in Table 2.

Data processing

Principal current direction (PCD)

The average speed, $||\vec{u}||$, and magnetic direction, θ, of the ocean current were recorded by the instrument for each depth bin and each time segment. As the direction does not take into account the local magnetic variation, δ, nor the instrument magnetic variation adjustment, δ_{ADCP}, these must be included when converting the current data into their east-west, u, and north-south, v, components:

$$u = \left||\vec{u}|\right| \sin(\theta + \delta - \delta_{ADCP})$$

$$v = ||\vec{u}|| \cos(\theta + \delta - \delta_{ADCP})$$

where u and v are positive in the eastward and northward directions, respectively. Magnetic declination varies with location and time. For the 2014 deployments (540-544), δ = -17.l° (i.e. 17.l° West); for deployment 212, δ = -18.7°; and for deployments 308 and 309, δ = -18.4°. For all deployments, the instrument magnetic variation was not adjusted pre-deployment, so $\delta_{ADCP} = 0$.

Before performing a tidal analysis on the current data, for each vertical level the horizontal currents were transformed from the recorded east-west and north-south components into the components along the major and minor principal axes, u_{maj} and u_{min}, respectively, as described in section 4.3 of Emery and Thomson (2004):

$$u_{maj} = u \cos\theta_p + v \sin\theta_p$$

$$u_{min} = -u \sin\theta_p + v \cos\theta_p$$

where θ_p is the principal angle (measured counter-clockwise from the x-axis) and is given by

$$\theta_p = \frac{1}{2}\tan^{-1}\left[\frac{2\overline{u'v'}}{\overline{u'^2} - \overline{v'^2}}\right]$$

Table 2. Depths and numbers of current velocity records for three depth levels (near surface, mid-water, and near bottom) in ADCP deployments off the east coast of Grand Manan Island. See Table 1 and Fig. 1 for deployment dates and locations.

Deployment	Total water depth (m)	Total no. of segments	Depth level	Depth below surface (m)	Depth above seafloor (m)	No. of velocity records	% of total
2014 deployments							
540	23.4 – 30.3	3 741	Near surface	2.5 – 3.5	20.6 – 27.6	3 446	92
			Mid-water	11.6 – 15.6	11.6 – 15.6	3 670	98
			Near bottom	19.8 – 26. 7	3.6	3 720	99
541	14.3 – 21.3	3 525	Near surface	3.5 – 4.5	10.6 – 17.6	3 078	87
			Mid-water	7.6 – 10.6	6.7 – 10.7	3 496	99
			Near bottom	10.7 – 17.7	3.6	3 506	>99
542	18.7 – 25.6	3 460	Near surface	2.5 – 3.5	15.6 – 22.6	3 205	93
			Mid-water	9.0 – 13.0	9.6 – 12.6	3 408	99
			Near bottom	12.1 – 19.0	6.6	3 048	88
543	19.4 – 26.3	3 459	Near surface	2.5 – 3.5	16.6 – 23.6	3 129	91
			Mid-water	9.6 – 13.6	9.6 – 13.6	3 436	99
			Near bottom	15.8 – 22.7	3.6	3 439	99
544	19.6 – 26.4	3 458	Near surface	2.5 – 3.5	16.6 – 23.6	3 033	88
			Mid-water	9.6 – 13.6	9.6 – 13.6	3 447	>99
			Near bottom	16.0 – 22.9	3.6	3 451	>99

Table 2 (cont'd).

Deployment	Total water depth (m)	Total no. of segments	Depth level	Depth below surface (m)	Depth above seafloor (m)	No. of velocity records	% of total
2000 & 2002 deployments							
212	20.6 – 29.3	4 430	Near surface	2.5 – 3.5	17.5 – 26.5	4 077	92
			Mid-water	10.1 – 14.8	10.5 – 14.5	4 394	99
			Near bottom	16.1 – 24.8	4.5	4 430	100
308	10.8 – 18.7	3 930	Near surface	2.5 – 3.5	7.5 – 15.5	3 560	91
			Mid-water	5.3 – 9.4	5.5 – 9.5	3 903	99
			Near bottom	6.3 – 14.2	4.5	3 925	>99
309	14.5 – 21.6	2 518	Near surface	5.5 – 6.4	8.5 – 15.5	2 281	91
			Mid-water	7.0 – 11.1	7.5 – 10.5	2 486	99
			Near bottom	10.0 – 17.1	4.5	2 517	>99

In the above equation, the overbar indicates that the quantities were averaged over the time series and *u'* and *v'* are the velocity fluctuations which were obtained by removing the means from the velocity components, i.e., $u' = u - \bar{u}$ and $v' = v - \bar{v}$.

Tidal Analysis

Tidal analysis of the ADCP data was performed on both the water depths and the horizontal velocities using the versatile tidal analysis program described by Foreman et al (2009). This program eliminates some of the restrictions of the earlier Institute of Ocean Sciences (IOS) tidal analysis package (Foreman 2004) that resulted from computer limitations. The newer versatile tidal analysis program allows for unevenly spaced data, gaps in the data, and multiple inferences from a single constituent. Unlike the original IOS tidal package (Foreman, 2004), which, based on record length, determined the constituents to include in the analysis, the newer versatile tidal analysis program requires the user to specify which constituents to include in the analysis. The methodology used to analyse the data is that suggested by Foreman et al. (2009).

The tidal analysis was performed in a two pass process. For the first pass, a set of constituents that depends on the record length, and is based on the Rayleigh criterion decision tree described in Foreman (2004), was used.

Table 3 lists the constituents included in the first pass of the tidal analysis program for three different time ranges. With the exception of deployment 309, the record lengths (durations) of the ADCP deployments were between 982 and 1246 h (Table 1) and thus fell into the time range 764-4383 h. Deployment 309 had a record length of 629 h which, based on Table 3, would not have N2 included in the analysis. As the record length was just below the lower limit of 662 h for including N2, it was decided to use the constituents for record lengths between 662 h and 764 h. This is a reasonable approach if the correlation coefficients of N2 with M2 and S2 are below 0.5 (M. Foreman, personal communication). The largest correlation coefficient between included constituents – which is part of the output from the tidal analysis program – was 0.15, indicating that including N2 in the shorter record still gave reasonable estimates of the constituents.

For each constituent included, the tidal analysis program outputs the results of a Student's t-test. These results were used to determine if a given constituent should be included in the final analysis. If, for a given constituent, the t-test value was ≥2.58 (for an infinite degrees of freedom, 99% confident that the constituent is significant), then it is included in the final call to the tidal analysis program. Note that Z0 (mean depth, for water depth analyses; mean flow, for current velocity analyses) was always included in the analysis.

Due to the record lengths being shorter than 6 months, certain constituents were not included in the tidal analysis. Through inference, amplitudes and phases of constituents that were not included in the tidal analysis due to the record length could be computed by using the relationship between the inferred constituent's amplitude/phases and a reference constituent's amplitude/phase at a nearby station. Inference removes the interaction between the reference constituent and the inferred constituent, thus resulting in a better estimate of the amplitude and phase of the reference constituent. In the analysis presented here, a constituent was inferred from one of the five reference constituents (M2, principal lunar semidiurnal; N2, lunar elliptical semidiurnal; S2, principal solar semidiurnal; K1, lunisolar diurnal; O1, principal lunar diurnal) if it satisfied the following three criteria: 1) the record length was such that the constituent was not included in the analysis; 2) the constituent was connected to the reference constituent through one of Foreman's (2004) Rayleigh criterion decision trees; 3) constituent data were available for inference. For the eastern Grand Manan Island data, Table 4 lists the inferred constituents used for the analysis of water depths. Inference relies on the availability of tidal constituent information based on long term time series at a nearby geographic location. Here, constituent data for sea level heights at Eastport, ME, were obtained from the NOAA Tides and Currents website (https://tidesandcurrents.noaa.gov/) and used for inference in the tidal analysis of water depths. As no nearby long term time series of currents were available, equilibrium tides were used for inference. Ratios for the amplitudes were calculated using values from Tables 2 and 3 in Foreman (2004). Phase differences were set to zero as described in Pugh (1987).

Table 3. List of constituents included in the tidal analysis of both depth and current data based on record length.

Record length	Constituents					
355-662 h	Z0	M3	2SK5			
	MSF	SK3	M6			
	O1	M4	2MS6			
	K1	MS4	2SM6			
	M2	S4	3MK7			
	S2	2MK5	M8			
662-764 h	Z0	K1	S2	MN4	2MN6	
	MSF	J1	ETA2	M4	M6	
	2Q1	OO1	MO3	MS4	2MS6	
	Q1	UPS1	M3	S4	2SM6	
	O1	N2	MK3	2MK5	3MK7	
	NO1	M2	SK3	2SK6	M8	
764-4383 h	Z0	O1	N2	ETA2	M4	2MN6
	MM	NO1	EPS2	MO3	SN4	M6
	MSF	K1	MU2	M3	MS4	2MS6
	ALP1	J1	M2	MK3	S4	2SM6
	2Q1	OO1	L2	SK3	2MK5	3MK7
	Q1	UPS1	S2	MN4	2SK5	M8

Table 4. Inferred constituents used in the tidal analysis of depths, based on record length.

Record length	Reference constituent	Inferred constituent	Amplitude ratio[1]	Phase difference[2]
662-764 h	M2	MKS2	-	-
		H1	-	-
		GAM2	-	-
		H2	-	-
	N2	NU2	0.232	-4.1
		MU2	0.037	-94.5
		2N2	0.120	22.9
	S2	K2	0.27	1.0
		L2	0.321	4.8
		LDA2	-	-
		T2	0.088	23.5
		R2	0.021	-217.2
	K1	P1	0.333	0.9
		PHI1	-	-
		PI1	-	-
		S1	0.064	86.2
		PSI1	-	-
	O1	TAU1	-	-
764-4383 h	M2	MKS2	-	-
		H1	-	-
		GAM2	-	-
		H2	-	-
	N2	NU2	0.232	-4.1
	S2	K2	0.276	1.0
		T2	0.088	23.5
		R2	0.021	-217.2
	K1	P1	0.333	0.9
		PHI1	-	-
		PI1	-	-
		S1	0.064	86.2
		PSI1	-	-
	O1	TAU1	-	-

[1] The ratio of the amplitude of the inferred constituent to the amplitude of the constituents from which it is inferred [e.g., amplitude(MKS2)/amplitude(M2)].

[2] The difference between the phase of a constituent and the phase of a constituent that is being inferred [e.g., phase(M2)–phase(MKS2)].

RESULTS AND DISCUSSION

Water depth

The mean observed water depths for the ADCP deployments were 18-27 m in the 2014 deployments and 15-26 m in the older deployments (Table 5 & Fig. 3). The mean observed tidal ranges were 5.3-5.5 m in the 2014 deployments, and 5.0-5.8 m in the older deployments (Table 5 & Fig. 3). The mean predicted tidal range at North Head (near deployment 540) during the deployment period was 5.3 m (WWW Tide and Current Predictor: http://tbone.biol.sc.edu/tide/).

Grand Manan is located in the Bay of Fundy and is dominated by the M2 tides. With a mean amplitude (equal to one-half of the mean range) of 2.6 m, the M2 amplitudes are roughly five times greater than those of N2, the next largest constituent (Table 6).

For the 2014 deployments (540 to 544), the five main tidal constituents, M2, N2, S2, K1 and O1, account for over 98% of the variance of the water depth time series, with M2 accounting for over 96% of the variance (Table 7). For the older deployments (212, 308 and 309), the signal is still dominated by the tides which account for over 95% of the variance, of which M2 accounts for over 82% of the variance (Table 7). Some possible reasons for the differences between the results for the 2014 deployments and the older deployments include differences in the setup parameters (see Appendix B); seasonal differences (the 2014 deployments were in the spring, while deployment 212 was in the late spring to early summer, and deployments 308 and 309 were in the late summer to fall); and interannual differences.

Table 5. Summary water depth and tidal range data from ADCP deployments off the east coast of Grand Manan Island. See Table 1 and Fig. 1 for deployment dates and locations. The mean predicted tidal range at North Head (near deployment 540) during the April-May 2014 deployment period was 5.3 m (range: 4.1-6.4 m) (WWW Tide and Current Predictor: http://tbone.biol.sc.edu/tide/).

		Sea surface height (m)			Tidal range (m)		
Deployment	Location	Mean	Min.	Max.	Mean	Min.	Max.
2014 deployments							
540	Long Island Bay	26.8	23.4	30.3	5.5	4.0	6.8
541	Long Island Bay	17.7	14.3	21.3	5.5	2.7	6.9
542	Long Island	22.1	18.7	25.6	5.4	3.9	6.9
543	Great Duck Island	22.8	19.4	26.3	5.3	3.8	6.8
544	White Head Island	23.0	19.6	26.4	5.3	3.8	6.7
2000 & 2002 deployments							
212	Long Island Bay	25.5	20.6	29.3	5.8	3.9	8.6
308	Cow Passage	14.9	10.8	18.7	5.2	2.6	7.5
309	Cow Passage	18.3	14.5	21.6	5.0	3.5	7.1

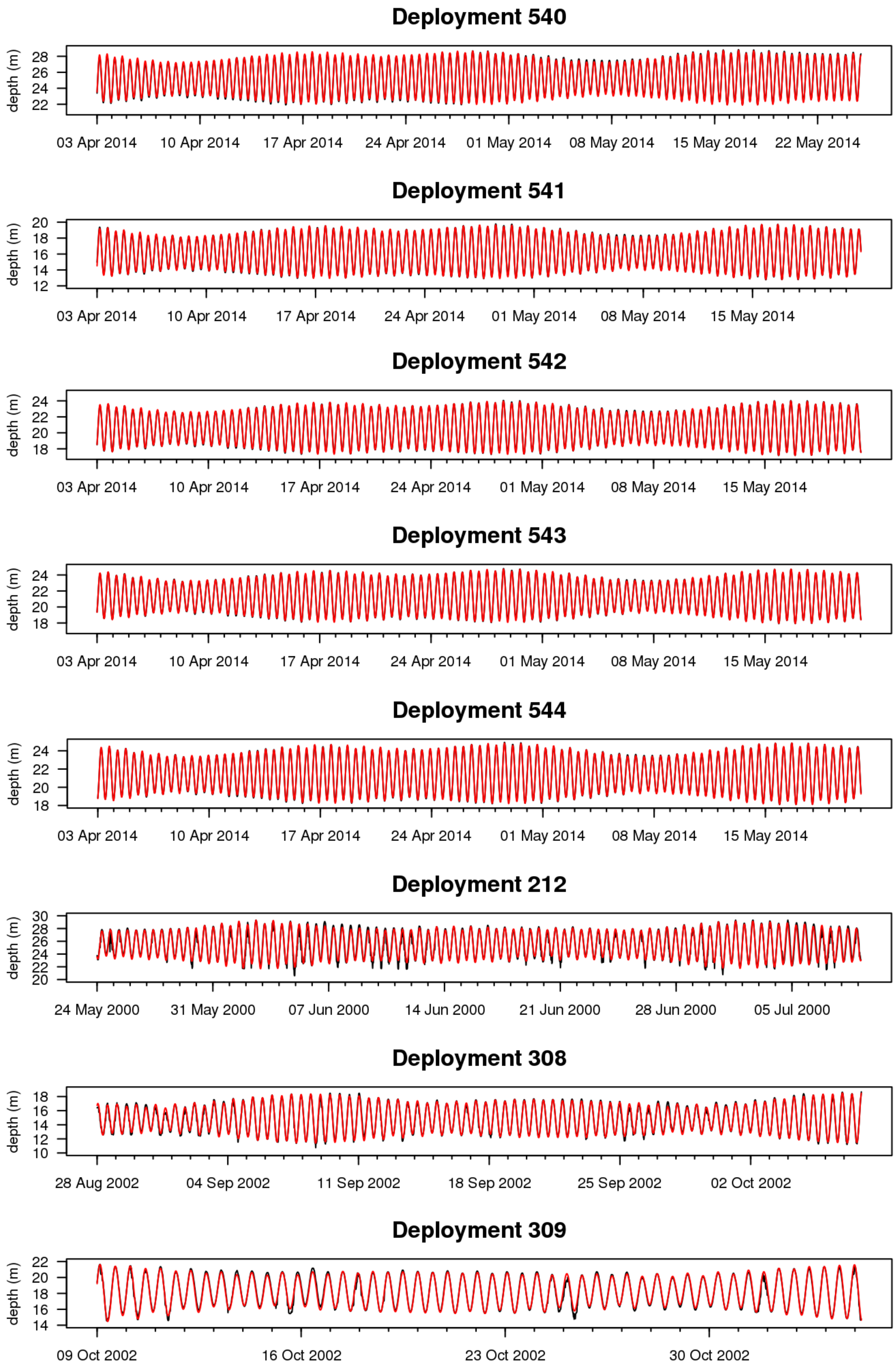

Fig. 3. Time series plots of water depth for ADCP deployments off the east coast of Grand Manan Island. Black lines are the observed depths; red lines are the reconstructed time series from the tidal analyses. See Fig. 1 and Table 1 for deployment locations.

Table 6. Tidal analysis of water depth from ADCP deployments off the east coast of Grand Manan Island. Data are shown for the 5 main tidal constituents (M2, N2, S2, K1, O1). Z0 represents the mean depth (from seafloor to water surface) during the time series. Amplitude = one-half of the range. Time zone used in calculation of phases = UTC.

Deploy-ment	Consti-tuent	Amplitude (m)	Phase (°)
540	Z0	26.814	-
	M2	2.653	91.8
	N2	0.523	62.8
	S2	0.403	130.4
	K1	0.154	189.9
	O1	0.111	172.6
541	Z0	17.726	-
	M2	2.659	91.6
	N2	0.527	61.8
	S2	0.407	130.6
	K1	0.152	190.1
	O1	0.112	172.8
542	Z0	22.133	-
	M2	2.613	91.7
	N2	0.521	61.5
	S2	0.399	131.1
	K1	0.152	189.2
	O1	0.113	172.5
543	Z0	22.842	-
	M2	2.550	91.3
	N2	0.524	61.2
	S2	0.400	130.6
	K1	0.152	189.5
	O1	0.114	173.8
544	Z0	22.962	-
	M2	2.577	91.4
	N2	0.521	61.1
	S2	0.398	130.5
	K1	0.152	189.9
	O1	0.114	173.6
	O1	0.177	154.6

Deploy-ment	Consti-tuent	Amplitude (m)	Phase (°)
212	Z0	25.505	-
	M2	2.505	95.1
	N2	0.581	70.2
	S2	0.315	121.2
	K1	0.156	172.6
	O1	0.161	177.1
308	Z0	14.878	-
	M2	2.483	92.9
	N2	0.536	61.5
	S2	0.415	131.5
	K1	0.181	177.6
	O1	0.138	165.3
309	Z0	18.226	-
	M2	2.471	91.8
	N2	0.546	60.5
	S2	0.431	129.2
	K1	0.141	190.5

Table 7. Variance of observed water depth (m) time series, with the percent contribution of the 5 main constituents (M2, N2, S2, K1, and O1) to the variance and the percent contribution of the M2 constituent to the variance for each ADCP deployment off the east coast of Grand Manan Island. The percent contribution is calculated by reconstructing the time series from the specified tidal constituents when they were included in the analysis, as well as any constituents that were inferred from these. The variance was then calculated for the reconstructed signal and used to calculate the percent contribution to the total signal. All variances were calculated using N degrees of freedom where N is the total number of observations in a given record.

Deployment	Variance	% of variance contributed by M2+N2+S2+K1+O1	% of variance contributed by M2 only
540	3.895	98.5	96.3
541	3.875	99.0	97.2
542	3.737	99.1	97.3
543	3.559	99.2	97.3
544	3.630	99.2	97.4
212	3.958	95.2	82.2
308	3.409	98.5	88.7
309	3.183	97.6	93.7

Current velocity

Summary current speed data for ADCP deployments off the east coast of Grand Manan Island, at three depth levels, are presented in Table 8.

Table 8. Summary of current speed data from ADCP deployments off the east coast of Grand Manan Island. Data are presented for three depth levels: near surface, mid-water, and near bottom. See Table 1 and Fig. 1 for deployment dates and locations.

Deployment	Mean depth (m)	Depth level	Current speed ($cm\ s^{-1}$)			
			Mean	Median	Min	Max
2014 deployments						
540	26.8	Near surface: 2.5–3.5 m below surface	16.5	14.9	0.3	69.5
Long		Mid-water: 11.6–15.6 m above seafloor	9.0	8.3	0.2	38.4
Island Bay		Near bottom: 3.6 m above seafloor	11.7	9.1	0.1	65.1
541	17.7	Near surface: 3.5–4.5 m below surface	14.0	12.1	0.2	59.2
Long		Mid-water: 6.7–10.7 m above seafloor	10.4	8.9	0.2	40.7
Island Bay		Near bottom: 3.6 m above seafloor	10.7	10.0	0.1	38.7
542	22.1	Near surface: 2.5–3.5 m below surface	10.8	9.3	0.4	60.1
Long		Mid-water: 9.6–12.6 m above seafloor	5.9	5.1	0.1	28.0
Island		Near bottom: 6.6 m above seafloor	4.3	3.7	0.1	24.5
543	22.8	Near surface: 2.5–3.5 m below surface	22.0	19.4	0.2	96.4
Great Duck		Mid-water: 9.6–13.6 m above seafloor	18.2	16.5	0.4	55.7
Island		Near bottom: 3.6 m above seafloor	15.7	15.0	0.3	48.7
544	23.0	Near surface: 2.5–3.5 m below surface	32.2	30.8	1.0	88.0
White Head		Mid-water: 9.6–13.6 m above seafloor	30.0	29.0	0.2	87.4
Island		Near bottom: 3.6 m above seafloor	27.9	26.9	0.6	82.2
2000 & 2002 deployments						
212	25.5	Near surface: 2.5–3.5 m below surface	11.4	9.9	0.3	48.4
Long		Mid-water: 10.5–14.5 m above seafloor	8.8	8.1	0.1	25.4
Island Bay		Near bottom: 4.5 m above seafloor	11.4	11.4	0.1	31.6
308	14.9	Near surface: 3.5–4.5 m below surface	16.6	14.9	0.2	45.9
Cow		Mid-water: 5.5–9.5 m above seafloor	15.9	14.6	0.2	46.5
Passage		Near bottom: 4.5 m above seafloor	15.3	13.9	0.0	43.8
309	18.3	Near surface: 5.5–6.5 m below surface	11.0	10.7	0.3	29.1
Cow		Mid-water: 7.5–10.5 m above seafloor	10.6	10.3	0.2	29.1
Passage		Near bottom: 4.5 m above seafloor	10.1	9.7	0.2	28.6

Current velocity data for each ADCP deployment are presented in a series of Tables and Figures:

- Stick plots of current velocities in each data segment at three depth levels (near surface, mid-water, near bottom).
- Current speed histograms and current velocity rose diagrams for three depth levels.
- Scatter plots of current velocities for observed and residual currents at three depth levels.
- Table of tidal analysis of current velocities. Amplitudes and phases are shown for the 5 main tidal constituents (M2, N2, S2, K1, O1). Current data have been decomposed into major and minor axes, for three depth levels.
- Table of variances of observed water current velocity time series, the percent contribution of the current in the major and minor directions to the total variance of the currents, the percent contribution by the 5 main tidal constituents, and the percent contribution of the M2 constituent. Current variances are presented for three depth levels.
- Time series plots of current velocities at three depth levels, including observed currents and reconstructed time series from the tidal analysis (tidal constituent); current speeds are plotted in the major and minor directions.
- Progressive vector plots for three depth levels.

Tidal analysis results (amplitudes and phases for the 5 main tidal constituents, decomposed into major and minor axes, plotted versus depth using three depth scales) are also presented in Appendix D.

Deployment 540 (Long Island Bay)

In deployment 540 at the entrance to Long Island Bay, current speeds were relatively strong: means at the three depth levels (near surface, mid-water, and near bottom) ranged from 9.0-16.5 cm s^{-1} and maxima were 38.4-69.5 cm s^{-1} (Table 8). Current directions and the major axis (from the principal components analysis) were primarily in the east and west directions at the surface and north-east and south-west directions at md-water and near bottom depths (Figs. 4-6). Tidal analysis of current velocity amplitudes (Table 9 & Appendix D) indicated that M2 was by far the largest tidal constituent along the major axis at all depths. Along the minor axis, M2 was the largest constituent at mid-water and near bottom levels but at the near-surface, the amplitudes of all five tidal constituents were of the same order of magnitude.

The major axis (from the principal components analysis) accounted for 76-90% of the total variance (Table 10). Unlike the water depth, whose variance can be attributed primarily to the tides (Table 7), the tides accounted for much less of the currents' variance (Table 10), explaining at most 32% of the variance (at near surface) along the major axis and as little as 4% (mid-water). Common to all deployments, the tides contributed little (0.1% at all three depth levels) to the variation of the currents along the minor axis from the principle component analysis (Table 10 & Fig. 7).

The progressive vector plot (Fig. 8) indicated that the net displacement at the end of the data record (51.9 d) was ~150 km at all three depth levels, to the east (out of the bay) near the surface and near the bottom, and to the west (into the bay) mid-water.

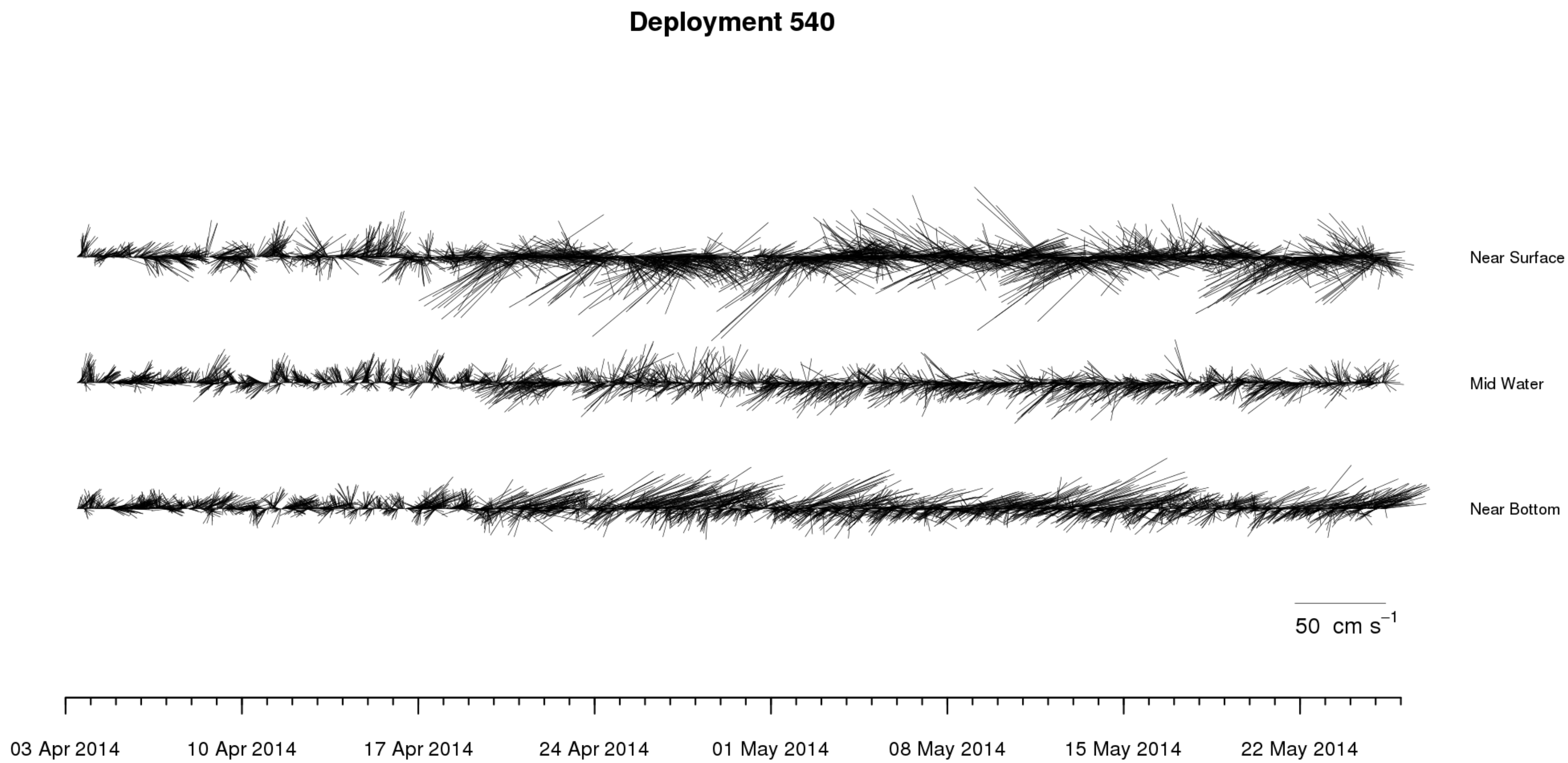

Fig. 4. Stick plots of current velocities in ADCP deployment 540 (Long Island Bay, 3 April to 25 May 2014) at three depth levels (near surface, mid-water, and near bottom). The lines show the current direction (true north is straight up) and speed (see scale on graph) in each data segment (20-min intervals).

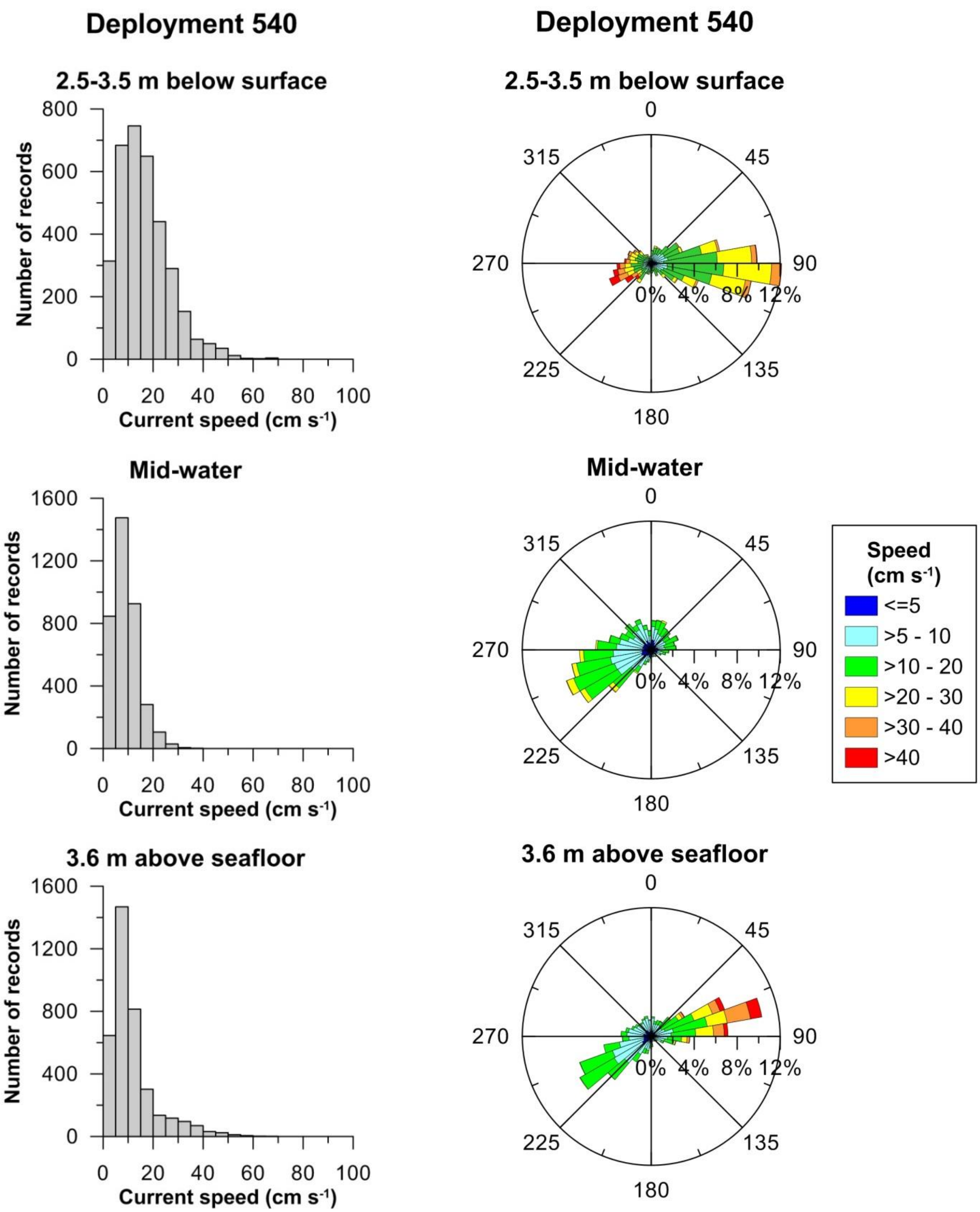

Fig. 5. Current speed histograms (left) and current velocity rose diagrams (right) for ADCP deployment 540 (Long Island Bay, 3 April to 25 May 2014). Data are presented for three depth levels: near surface (top), mid-water (middle), and near bottom (bottom).

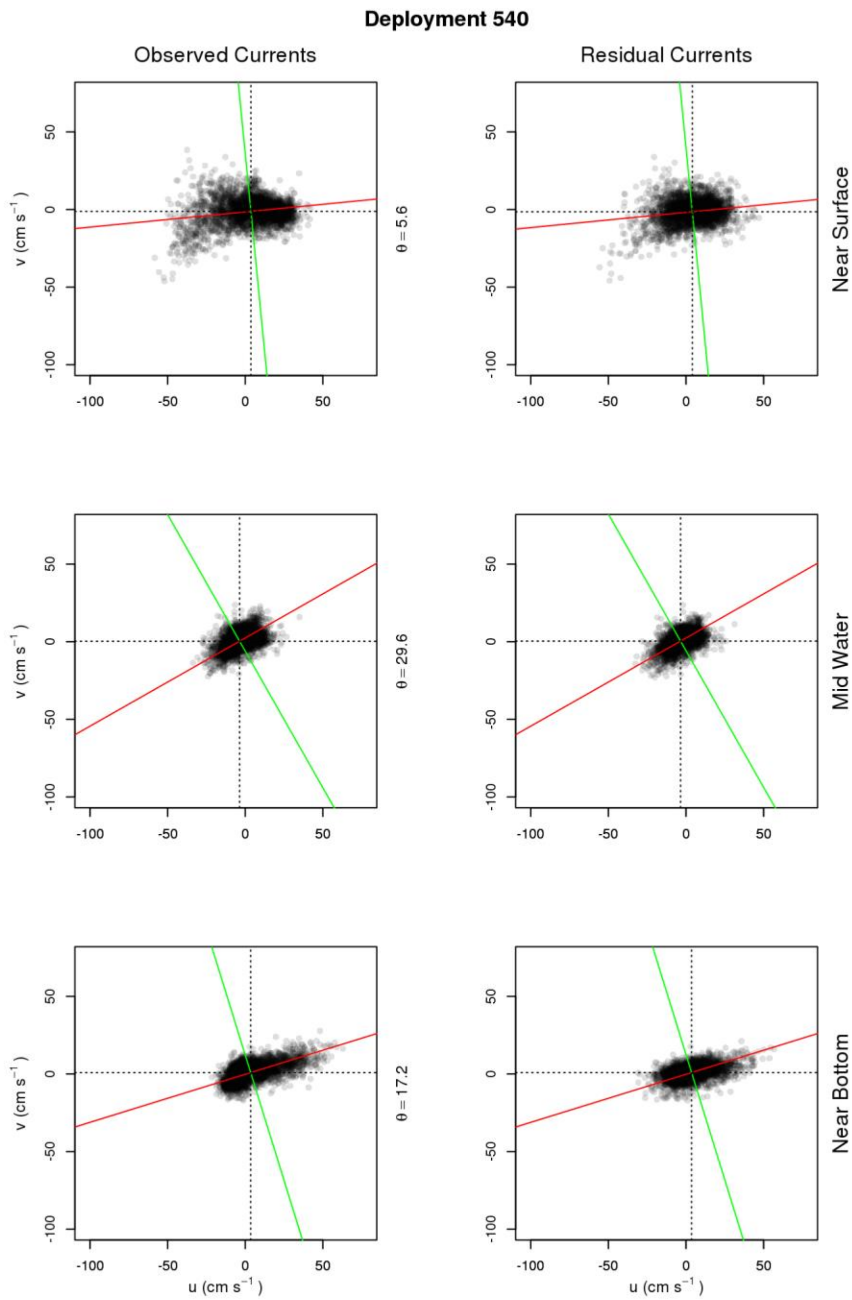

Fig. 6. Scatter plots for current velocities in ADCP deployment 540 (Long Island Bay, 3 April to 25 May 2014). Left: observed currents. Right: residual currents where residuals are obtained by removing the tidal signal from the original observation. Current velocity data in the east-west (u) and north-south (v) directions are presented for three depth levels: near surface (top), mid-water (middle), and near bottom (bottom). The red line is the major principal axis and the green line is the minor principal axis. θ = angle of the major axis (degrees from the east-west axis, in a counter-clockwise direction). The dotted lines indicate the mean currents in the east-west and north-south directions.

Table 9. Tidal analysis of water current velocities for ADCP deployment 540. Data are shown for the 5 main tidal constituents (M2, N2, S2, K1, O1). Z0 represents the mean flow in the direction of each principal axis at each depth level (near surface, mid-water, and near bottom). Amplitude = one-half of the range. Maj = in the direction of the major principal axis. Min = in the direction of the minor principal axis. * indicates that the constituent was not included in the 2nd pass of the tidal analysis program based on the value of the t-test. θ = angle of the major axis (degrees from the east-west axis, in a counter-clockwise direction). Time zone used in calculation of phases = UTC.

Deployment 540	Constituent		Amplitude	Phase (°)
Near surface currents (cm s^{-1}) θ = 5.6	Z0	Maj	3.892	-
		Min	-1.842	-
	M2	Maj	12.063	177.3
		Min	1.726	8.8
	N2	Maj	2.917	162.2
		Min	1.753	117.3
	S2	Maj	2.103	42.6
		Min	*	*
	K1	Maj	3.638	118.8
		Min	1.175	70.2
	O1	Umaj	*	*
		Min	0.653	301.0
Mid-water currents (cm s^{-1}) θ = 29.6	Z0	Maj	-2.864	-
		Min	2.101	-
	M2	Maj	1.924	272.5
		Min	2.337	5.6
	N2	Maj	1.051	272.3
		Min	0.610	213.5
	S2	Maj	0.719	266.8
		Min	0.685	20.2
	K1	Maj	0.968	313.7
		Min	0.419	127.5
	O1	Umaj	*	*
		Umin	*	*
Near bottom currents (cm s^{-1}) θ = 17.2	Z0	Maj	3.692	-
		Min	-0.203	-
	M2	Maj	9.621	341.4
		Min	2.198	316.5
	N2	Maj	2.891	296.0
		Min	0.878	236.6
	S2	Maj	1.163	259.3
		Min	0.500	16.9
	K1	Maj	1.645	291.3
		Min	0.497	188.1
	O1	Umaj	*	*
		Min	*	*

Table 10. Variance of observed water current velocity (cm s^{-1}) time series for ADCP deployment 540, with the percent contribution of the current in the major (Maj) and minor (Min) directions to the total variance of the currents, the percent contribution of the 5 main constituents (M2, N2, S2, K1, and O1) to the variances in the Maj and Min directions, and the percent contribution of the M2 constituent to the variances in the Maj and Min directions. The percent contribution was calculated by reconstructing the time series from the specified tidal constituents when they were included in the analysis, as well as any constituents that were inferred from these. The variance was then calculated for the reconstructed signal and used to calculate the percent contribution to the total signal. All variances were calculated using N degrees of freedom where N is the total number of observations in a given record. Maj = in the direction of the major principal axis. Min = in the direction of the minor principal axis.

Deployment 540		Variance	% of variance in Maj and Min directions	% of variance contributed by M2+N2+S2+K1+O1	% of variance contributed by M2 only
Near surface	Maj	292.532	81.9	31.9	26.9
	Min	64.779	18.1	0.1	<0.05
Mid-water	Maj	72.154	76.0	4.1	2.8
	Min	22.795	24.0	0.1	0.1
Near bottom	Maj	187.313	90.0	28.9	26.5
	Min	20.786	10.0	0.1	0.1

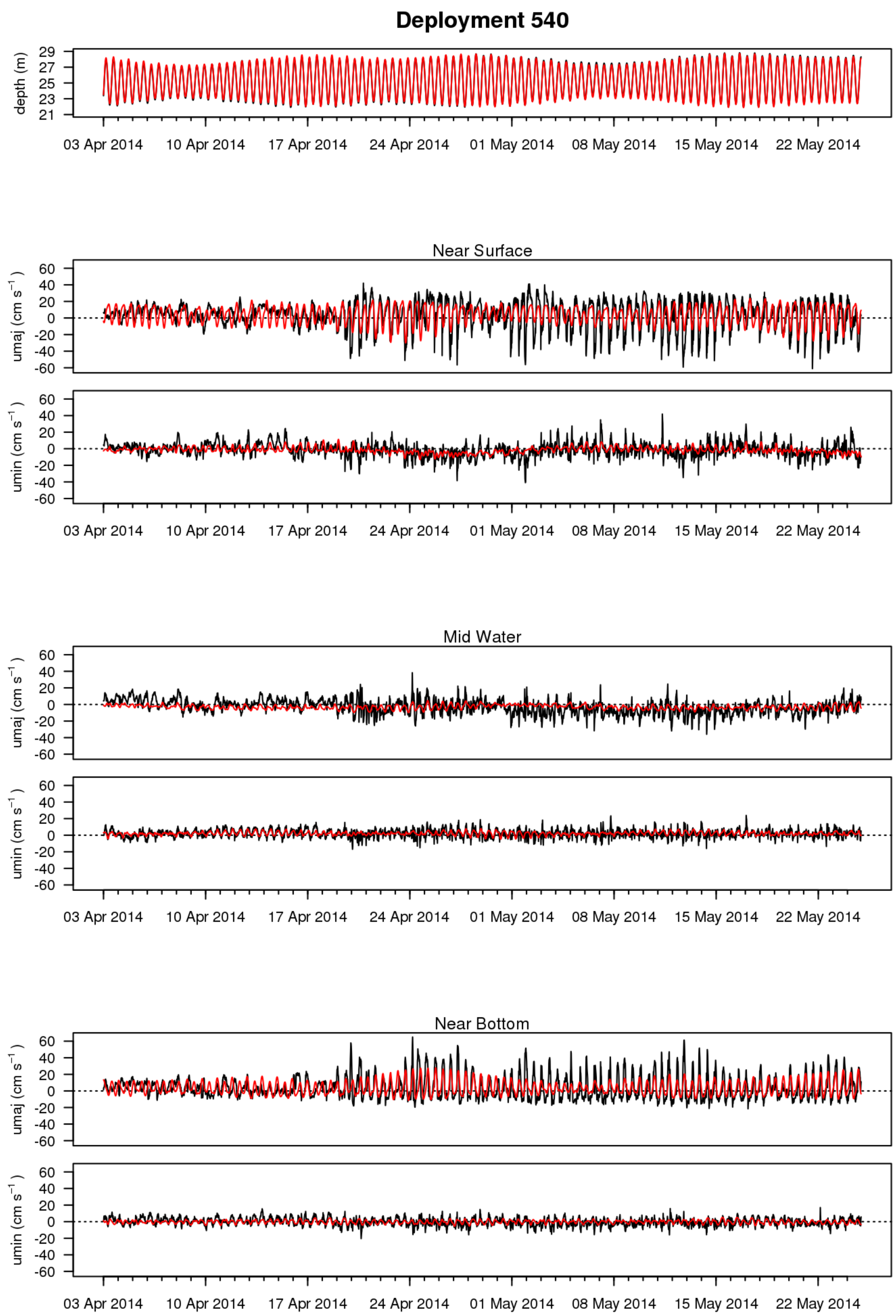

Fig. 7. Time series plots of water depth and current velocity for ADCP deployment 540 (Long Island Bay, 3 April to 25 May 2014). Current speeds are plotted in the major (umaj) and minor (umin) directions (as determined by the principal component analysis), for three depth levels (near surface, mid-water, and near bottom). Black lines are the observed currents; red lines are the reconstructed time series from the tidal analysis (tidal constituent).

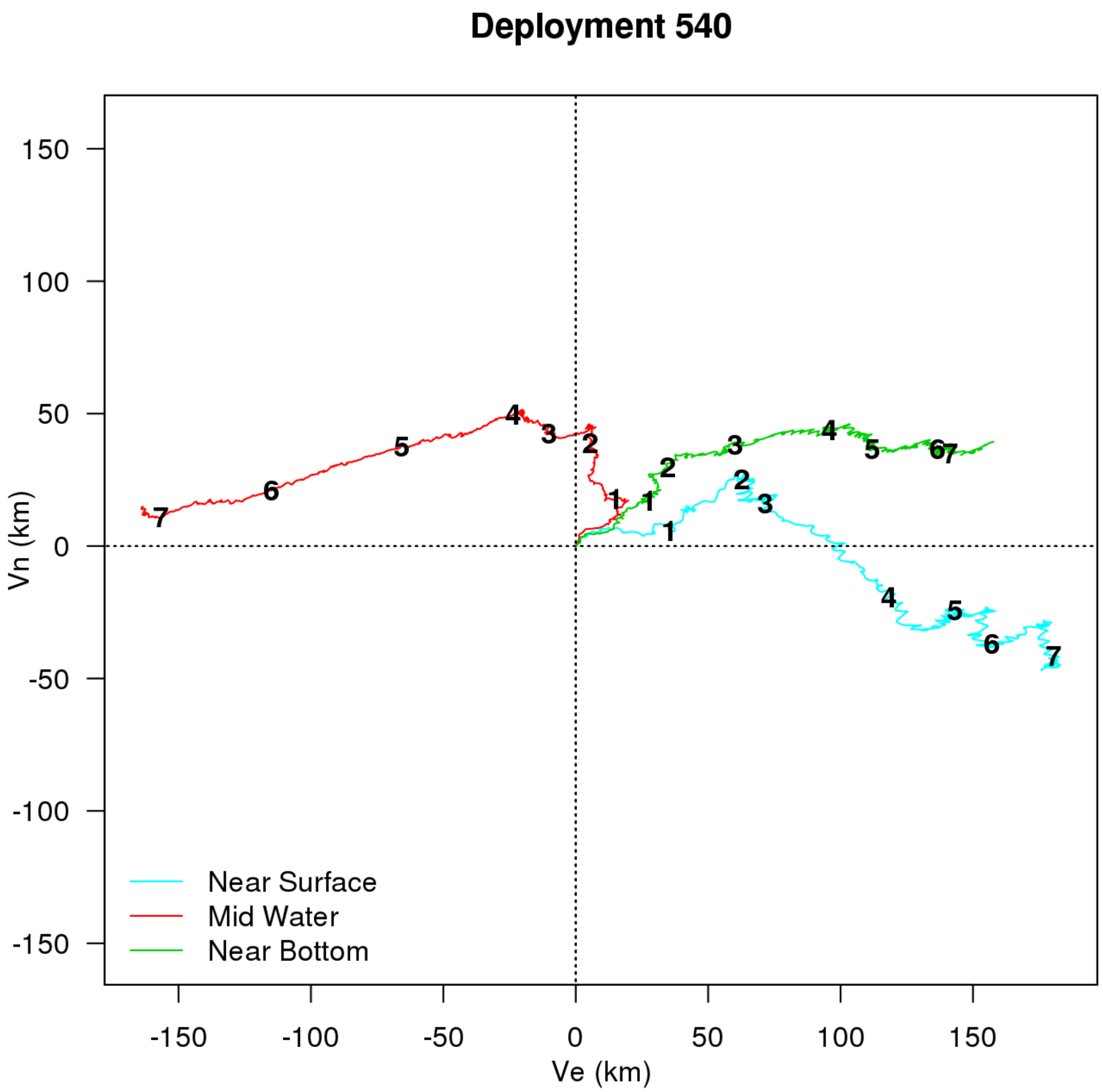

Fig. 8. Progressive vector plot for ADCP deployment 540 (Long Island Bay, 3 April to 25 May 2014). Successive movements of a particle are estimated using current velocities measured at 20-min intervals by the current meter. Ve = east-west direction; Vn = north-south direction. Data are presented for three depth levels: near surface (blue), mid-water (red), and near bottom (green). Numbers on the vectors indicate the number of weeks from the time of the first data record. Duration = 51.9 d (7.4 weeks).

Deployment 541 (Long Island Bay)

In deployment 541 at the entrance to Long Island Bay, current speeds were relatively strong, similar to deployment 540: means at the three depth levels ranged from 10.4-14.0 cm s^{-1} and maxima were 38.7-59.2 cm s^{-1} (Table 8). Current directions and the major axis (from the principal components analysis) were mostly in the east and west directions at all three depth levels (Figs. 9-11). Tidal analysis of current velocity amplitudes (Table 11 & Appendix D) indicated that M2 was by far the largest tidal constituent along the major axis at near- surface and mid-water depths, but M2 was not the dominant constituent near-bottom having an amplitude smaller than, but of the same order of magnitude, as that of S2. Along the minor axis, the M2 constituent had the largest amplitude at mid-water and near-bottom depths, but at near-surface N2 had the largest amplitude. The major axis (from the principal components analysis) for these deployments accounted for 70-87% of the total variance (Table 12). The tides explained 43-50% of the variance along the major axis at near-surface and mid-water, but only 8% near-bottom (Table 12). Common to all deployments, the tides contributed little (≤0.1%) to the variation of the currents along the minor axis (Table 12 & Fig. 12).

The progressive vector plot (Fig. 13) indicated that the net displacement at the end of the data record (48.9 d) was ~200-250 km at all three depth levels, to the southwest near the bottom and mid-water, and to the south-southwest near the surface.

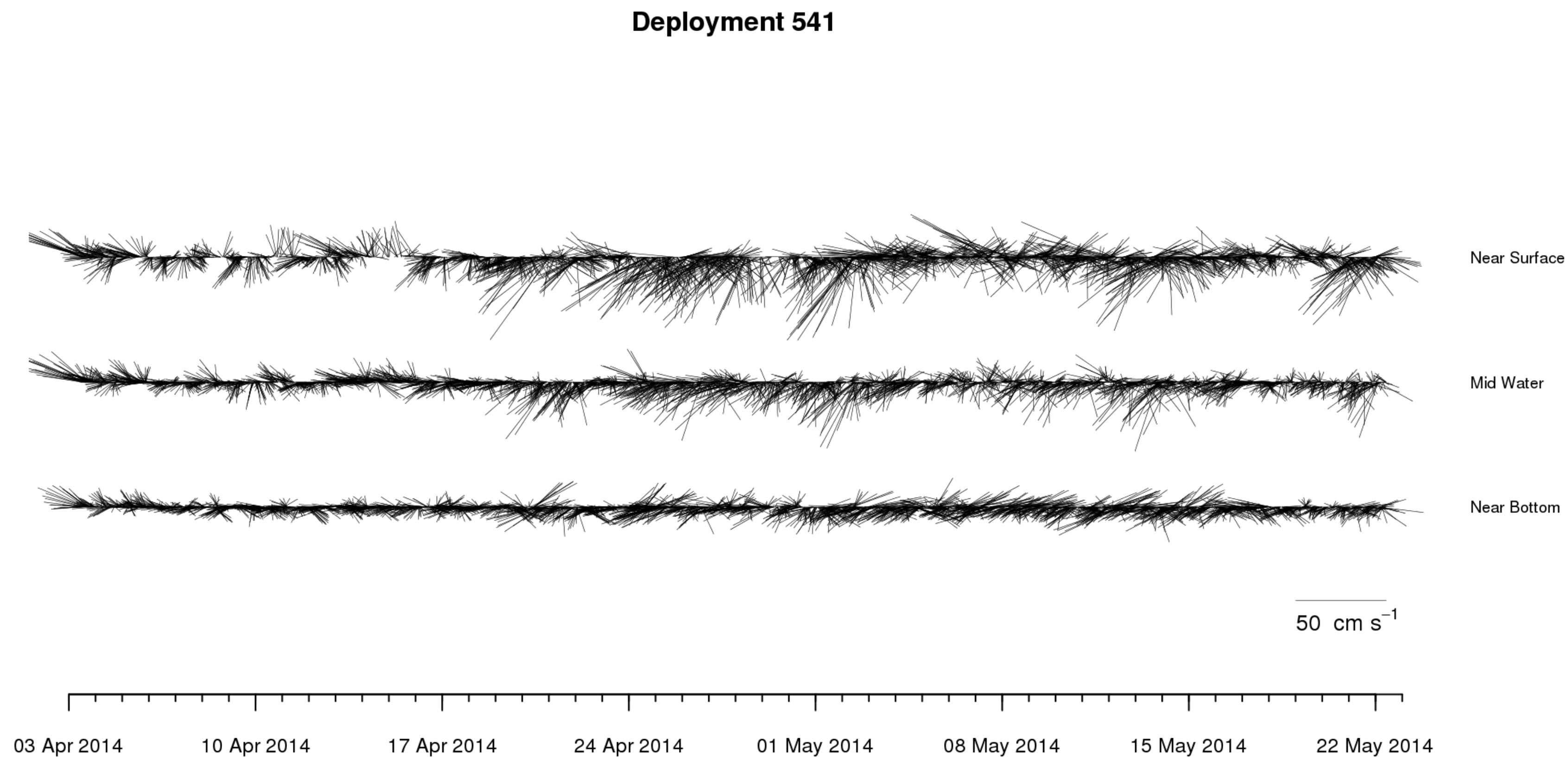

Fig. 9. Stick plots of current velocities in ADCP deployment 541 (Long Island Bay, 3 April to 22 May 2014) at three depth levels (near surface, mid-water, and near bottom). The lines show the current direction (true north is straight up) and speed (see scale on graph) in each data segment (20-min intervals).

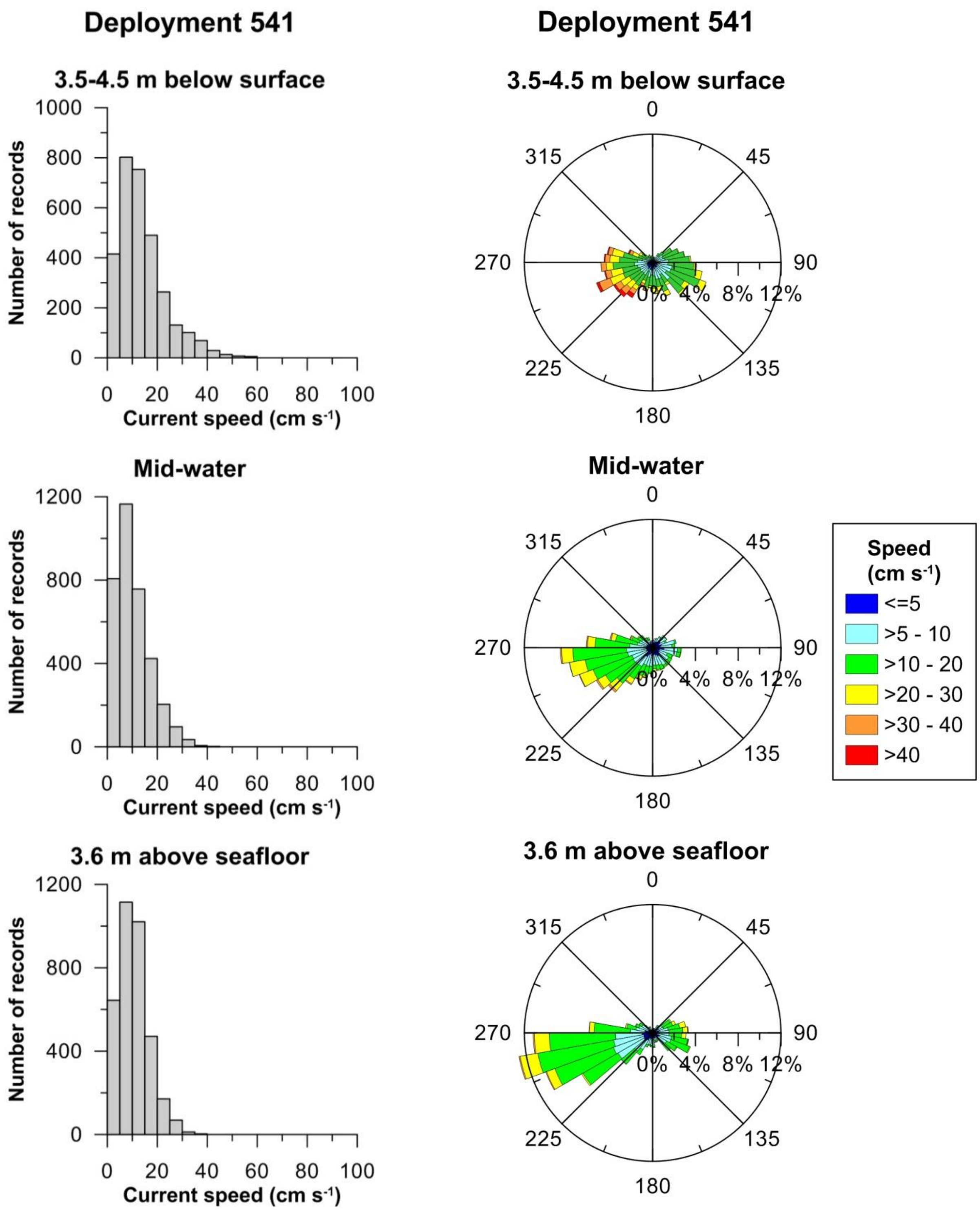

Fig. 10. Current speed histograms (left) and current velocity rose diagrams (right) for ADCP deployment 541 (Long Island Bay, 3 April to 22 May 2014). Data are presented for three depth levels: near surface (top), mid-water (middle), and near bottom (bottom).

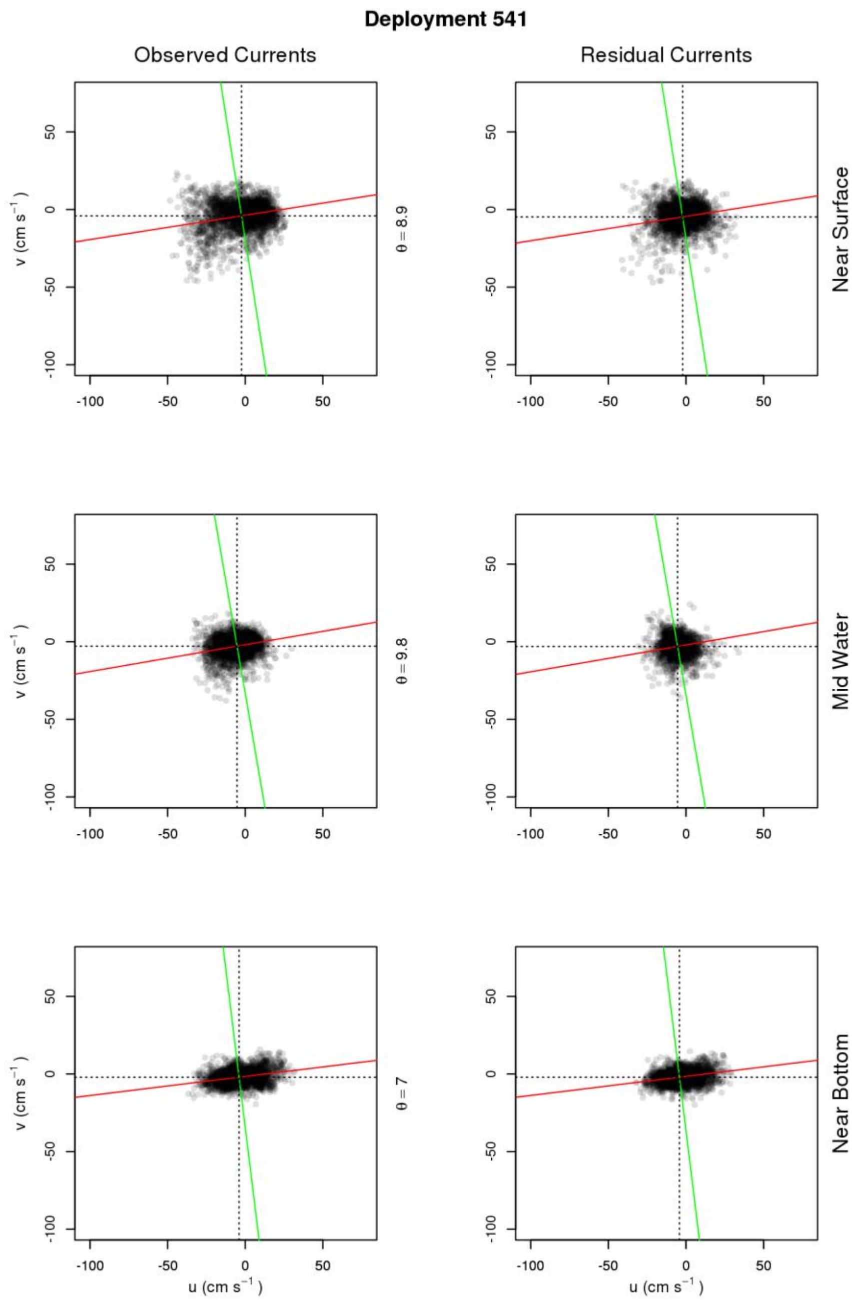

Fig. 11. Scatter plots of current velocities in ADCP deployment 541 (Long Island Bay, 3 April to 22 May 2014). Left: observed currents. Right: residual currents where residuals are obtained by removing the tidal signal from the original observation. Current velocity data in the east-west (u) and north-south (v) directions are presented for three depth levels: near surface (top), mid-water (middle), and near bottom (bottom). The red line is the major principal axis and the green line is the minor principal axis. θ = angle of the major axis (degrees from the east-west axis, in a counter-clockwise direction). The dotted lines indicate the mean currents in the east-west and north-south directions.

Table 11. Tidal analysis of water current velocities for ADCP deployment 541. Data are shown for the 5 main tidal constituents (M2, N2, S2, K1, O1). Z0 represents the mean flow in the direction of each principal axis at each depth level (near surface, mid-water, and near bottom). Amplitude = one-half of the range. Maj = in the direction of the major principal axis. Min = in the direction of the minor principal axis. * indicates that the constituent was not included in the 2nd pass of the tidal analysis program based on the value of the t-test. θ = angle of the major axis (degrees from the east-west axis, in a counter-clockwise direction). Time zone used in calculation of phases = UTC.

Deployment 541	Constituent		Amplitude	Phase (°)
Near surface currents (cm s^{-1}) θ = 8.9	Z0	Maj	-2.896	-
		Min	-4.413	-
	M2	Maj	12.053	190.2
		Min	1.374	268.1
	N2	Maj	2.312	122.7
		Min	2.099	145.0
	S2	Maj	0.913	118.5
		Min	*	*
	K1	Maj	1.607	156.1
		Min	1.275	38.8
	O1	Maj	1.036	94.9
	O1	Min	0.760	17.0
Mid-water currents (cm s^{-1}) θ = 9.8	Z0	Maj	-5.884	-
		Min	-2.097	-
	M2	Maj	8.766	199.4
		Min	1.002	234.7
	N2	Maj	1.338	105.9
		Min	*	*
	S2	Maj	1.387	206.2
		Min	0.529	25.9
	K1	Maj	0.680	291.0
		Min	0.454	17.5
	O1	Maj	*	*
		Min	*	*
Near bottom currents (cm s^{-1}) θ = 7.0	Z0	Z0	-4.459	-
		Min	-1.550	-
	M2	Maj	2.421	212.0
		Min	1.088	314.0
	N2	Maj	1.640	147.2
		Min	0.317	259.3
	S2	Maj	2.624	225.2
		Min	0.262	328.7
	K1	Maj	2.284	312.1
		Min	0.421	300.9
	O1	Maj	0.747	271.0
		Min	*	*

Table 12. Variance of observed water current velocity (cm s^{-1}) time series for ADCP deployment 541, with the percent contribution of the current in the major (Maj) and minor (Min) directions to the total variance of the currents, the percent contribution of the 5 main constituents (M2, N2, S2, K1, and O1) to the variances in the Maj and Min directions, and the percent contribution of the M2 constituent to the variances in the Maj and Min directions. The percent contribution was calculated by reconstructing the time series from the specified tidal constituents when they were included in the analysis, as well as any constituents that were inferred from these. The variance was then calculated for the reconstructed signal and used to calculate the percent contribution to the total signal. All variances were calculated using N degrees of freedom where N is the total number of observations in a given record. Maj = in the direction of the major principal axis. Min = in the direction of the minor principal axis.

Deployment 541		Variance	% of variance in Maj and Min directions	% of variance contributed by M2+N2+S2+K1+O1	% of variance contributed by M2 only
Near surface	Maj	184.947	71.3	42.7	41.9
	Min	74.470	28.7	<0.05	<0.05
Mid-water	Maj	83.130	69.9	49.7	49.6
	Min	35.783	30.1	<0.05	<0.05
Near bottom	Maj	112.480	86.9	8.3	2.8
	Min	17.013	13.1	<0.05	<0.05

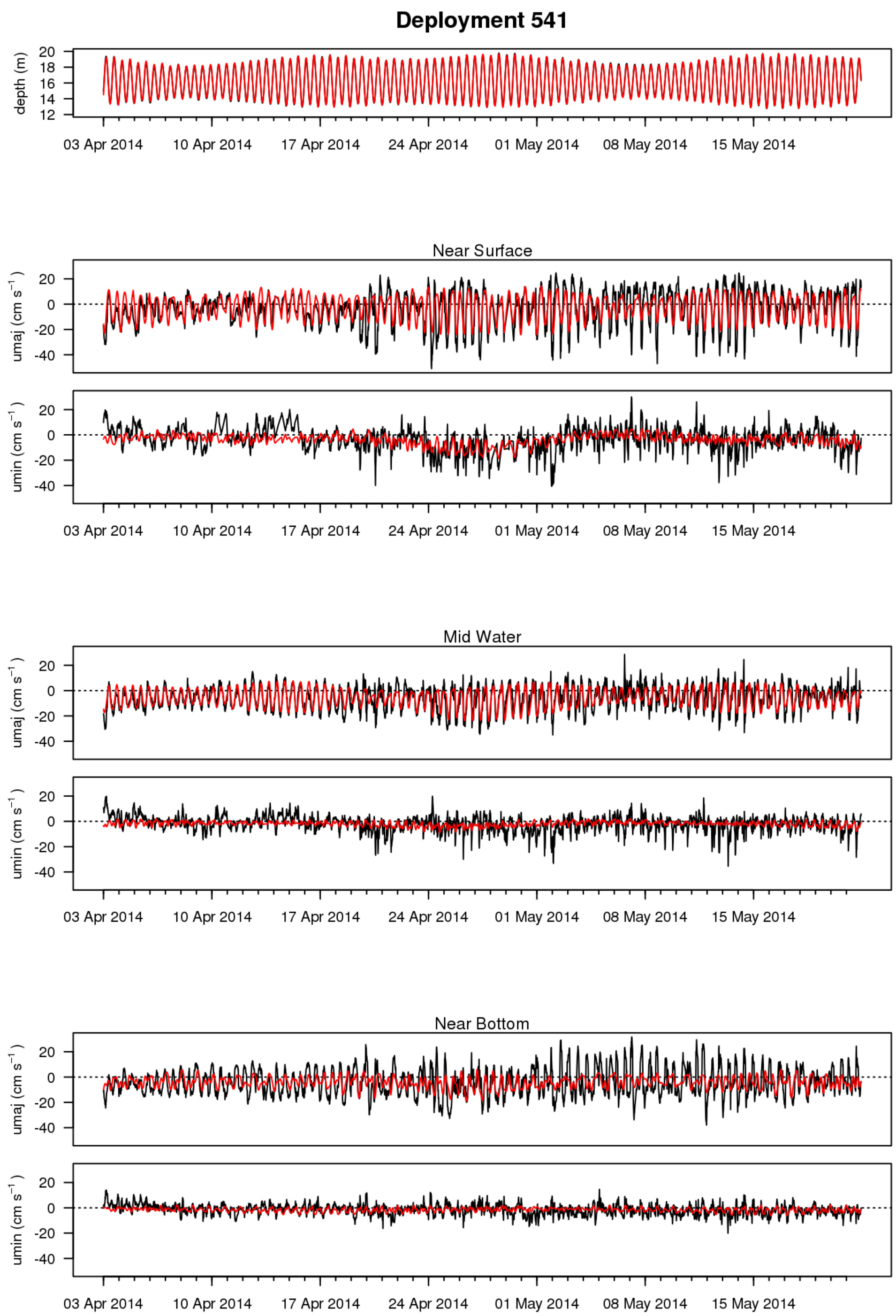

Fig. 12. Time series plots of water depth and current velocity for ADCP deployment 541 (Long Island Bay, 3 April to 22 May 2014). Current speeds are plotted in the major (umaj) and minor (umin) directions (as determined by the principal component analysis), for three depth levels (near surface, mid-water, and near bottom). Black lines are the observed currents; red lines are the reconstructed time series from the tidal analysis (tidal constituent).

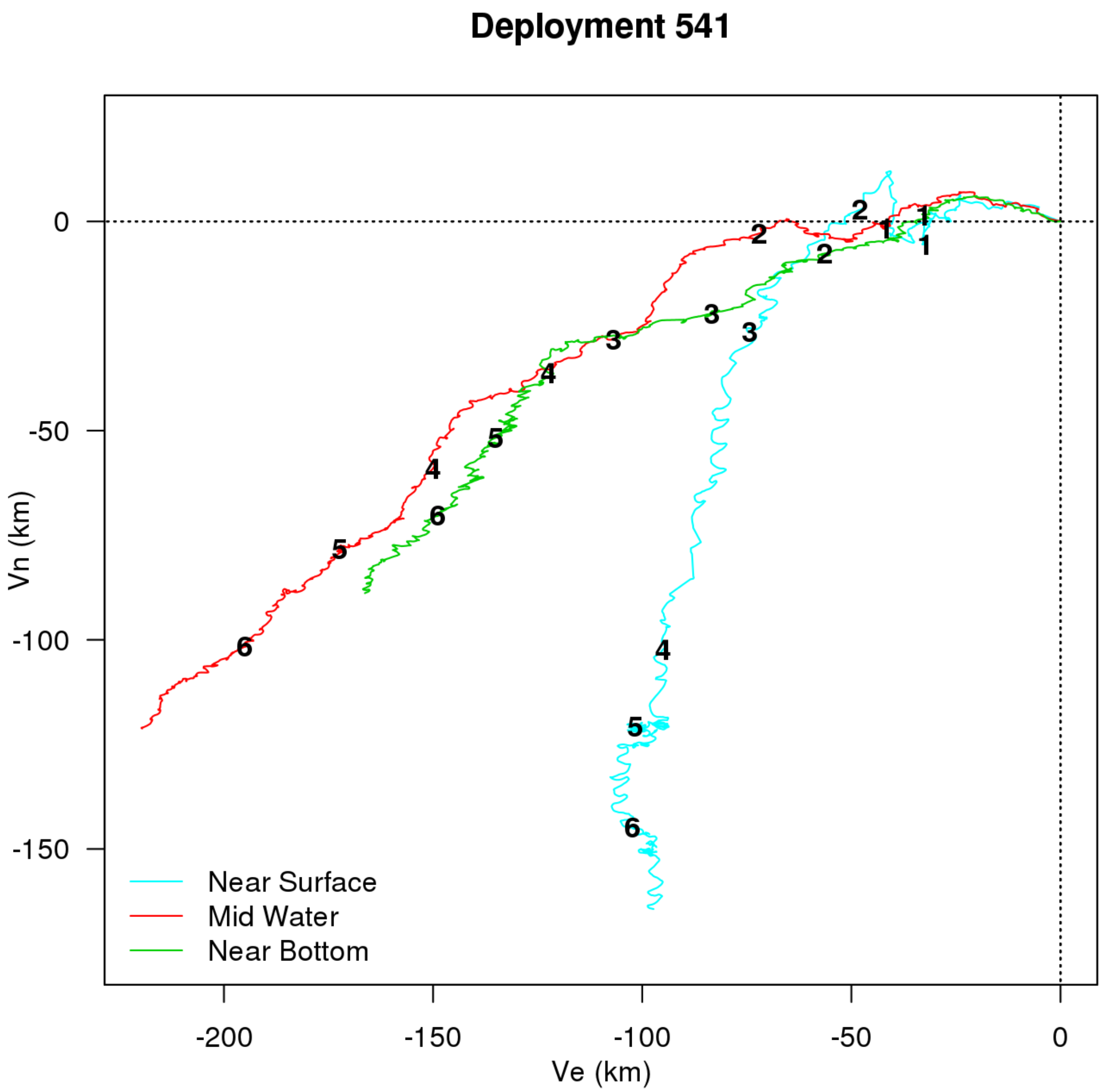

Fig. 13. Progressive vector plot for ADCP deployment 541 (Long Island Bay, 3 April to 22 May 2014). Successive movements of a particle are estimated using current velocities measured at 20-min intervals by the current meter. Ve = east-west direction; Vn = north-south direction. Data are presented for three depth levels: near surface (blue), mid-water (red), and near bottom (green). Numbers on the vectors indicate the number of weeks from the time of the first data record. Duration = 48.9 d (6.99 weeks).

Deployment 542 (mid-coast, south of Long Island)

The mean near surface current speed just south of Long Island (deployment 542) was slightly lower than at the entrances to Long Island Bay (deployments 540 and 541), while the mid-water and near bottom current speeds were much weaker (Table 8). Near the surface, the current direction and net movement were to the east and south (away from the Grand Manan shore), while there was no clear directionality and little net movement for the weak currents at mid-water and near the bottom (Figs. 14-16). Tidal analysis of current velocity amplitudes (Table 13 & Appendix D) indicated that M2 was the largest tidal constituent along the major and minor axes at all three depth levels. The major axis (from the principal components analysis) accounted for only 54-61% of the total variance (Table 14) and was in the northwest-southeast direction near the surface and primarily in the north-south direction at mid-water and near the bottom (Fig. 16). Tidal contribution to the currents' variance along the major axis was small, accounting for 37% near the surface but decreasing to 7% going down the water column, while the tides contributed ≤0.2% to the variation along the minor axis (Table 14 & Fig. 17).

The progressive vector plot (Fig. 18) indicated that the net displacement at the end of the data record (48.0 d) was ~130 km to the southeast near the surface, but <10 km at mid-water (to the east) and near the bottom (to the west).

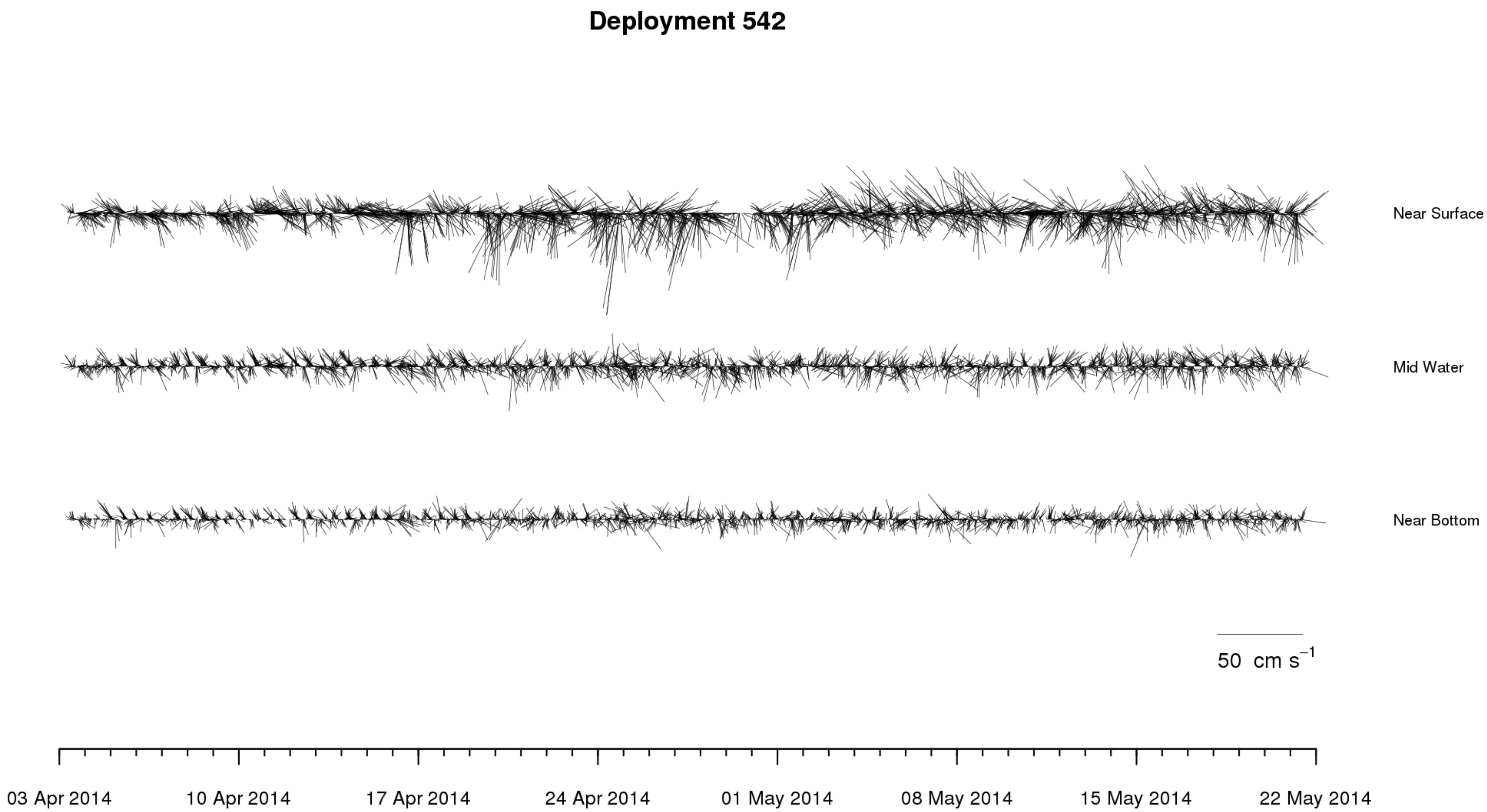

Fig. 14. Stick plots of current velocities in ADCP deployment 542 (south of Long Island, 3 April to 21 May 2014) at three depth levels (near surface, mid-water, and near bottom). The lines show the current direction (true north is straight up) and speed (see scale on graph) in each data segment (20-min intervals).

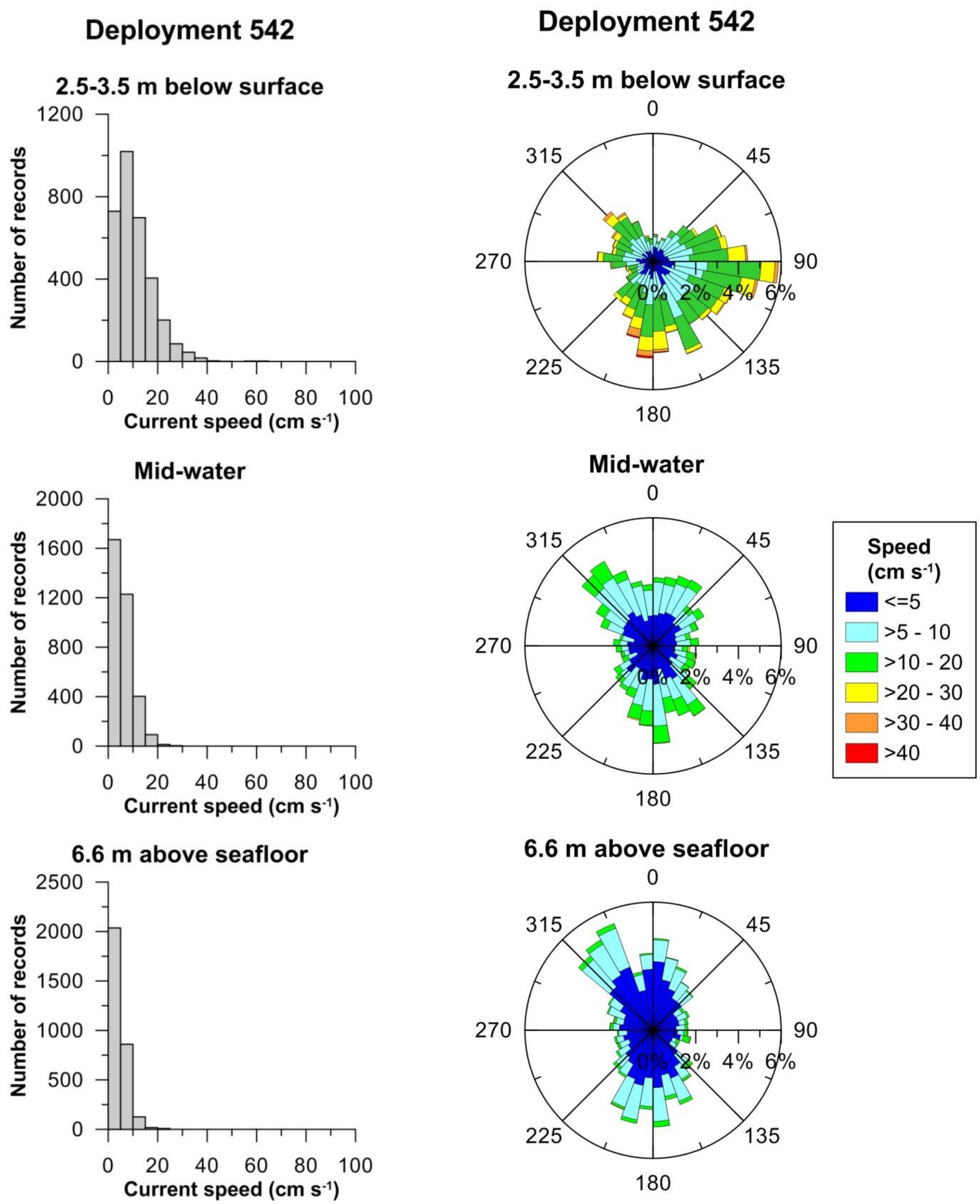

Fig. 15. Current speed histograms (left) and current velocity rose diagrams (right) for ADCP deployment 542 (south of Long Island, 3 April to 21 May 2014). Data are presented for three depth levels: near surface (top), mid-water (middle), and near bottom (bottom).

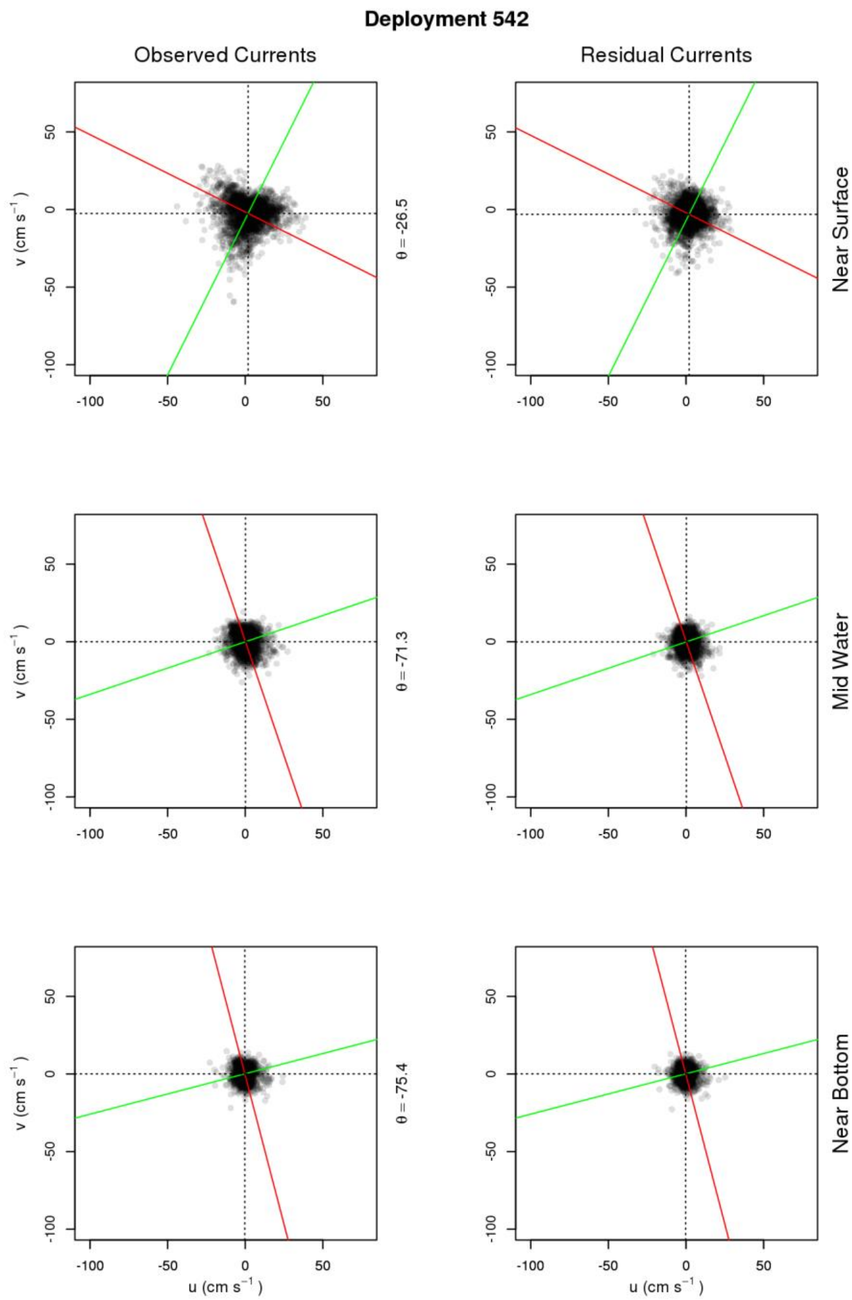

Fig. 16. Scatter plots for current velocities in ADCP deployment 542 (south of Long Island, 3 April to 21 May 2014). Left: observed currents. Right: residual currents where residuals are obtained by removing the tidal signal from the original observation. Current velocity data in the east-west (u) and north-south (v) directions are presented for three depth levels: near surface (top), mid-water (middle), and near bottom (bottom). The red line is the major principal axis and the green line is the minor principal axis. θ = angle of the major axis (degrees from the east-west axis, in a counter-clockwise direction). The dotted lines indicate the mean currents in the east-west and north-south directions.

Table 13. Tidal analysis of water current velocities for ADCP deployment 542. Data are shown for the 5 main tidal constituents (M2, N2, S2, K1, O1). Z0 represents the mean flow in the direction of each principal axis at each depth level (near surface, mid-water, and near bottom). Amplitude = one-half of the range. Maj = in the direction of the major principal axis. Min = in the direction of the minor principal axis. * indicates that the constituent was not included in the 2nd pass of the tidal analysis program based on the value of the t-test. θ = angle of the major axis (degrees from the east-west axis, in a counter-clockwise direction). Time zone used in calculation of phases = UTC.

Deployment 542	Constituent		Amplitude	Phase (°)
Near surface currents (cm s^{-1}) θ = -26.5	Z0	Maj	3.190	-
		Min	-1.888	-
	M2	Maj	7.525	174.3
		Min	4.937	246.6
	N2	Maj	*	*
		Min	3.083	207.7
	S2	Maj	0.954	257.2
		Min	1.025	198.9
	K1	Maj	1.259	185.3
		Min	0.776	110.8
	O1	Maj	*	*
		Min	1.041	41.1
Mid-water currents (cm s^{-1}) θ = -71.3	Z0	Maj	0.157	-
		Min	0.151	-
	M2	Maj	2.952	132.2
		Min	2.905	215.2
	N2	Maj	1.289	105.3
		Min	0.943	216.3
	S2	Maj	*	*
		Min	0.475	212.7
	K1	Maj	*	*
		Min	0.539	354.5
	O1	Maj	*	*
		Min	0.520	304.4
Near bottom currents (cm s^{-1}) θ = -75.4	Z0	Maj	-0.148	-
		Min	-0.192	-
	M2	Maj	1.435	167.9
		Min	1.165	213.2
	N2	Maj	0.680	118.4
		Min	0.468	146.7
	S2	Maj	*	*
		Min	*	*
	K1	Maj	*	*
		Min	0.546	337.9
	O1	Maj	*	*
		Min	0.318	283.5

Table 14. Variance of observed water current velocity (cm s^{-1}) time series for ADCP deployment 542, with the percent contribution of the current in the major (Maj) and minor (Min) directions to the total variance of the currents, the percent contribution of the 5 main constituents (M2, N2, S2, K1, and O1) to the variances in the Maj and Min directions, and the percent contribution of the M2 constituent to the variances in the Maj and Min directions. The percent contribution was calculated by reconstructing the time series from the specified tidal constituents when they were included in the analysis, as well as any constituents that were inferred from these. The variance was then calculated for the reconstructed signal and used to calculate the percent contribution to the total signal. All variances were calculated using N degrees of freedom where N is the total number of observations in a given record. Maj = in the direction of the major principal axis. Min = in the direction of the minor principal axis.

Deployment 542		Variance	% of variance in Maj and Min directions	% of variance contributed by M2+N2+S2+K1+O1	% of variance contributed by M2 only
Near surface	Maj	86.892	53.8	36.7	35.1
	Min	74.601	46.2	0.2	0.2
Mid-water	Maj	31.073	60.6	16.0	15.0
	Min	20.177	39.4	0.2	0.2
Near bottom	Maj	16.947	60.2	7.0	6.5
	Min	11.192	39.8	0.1	0.1

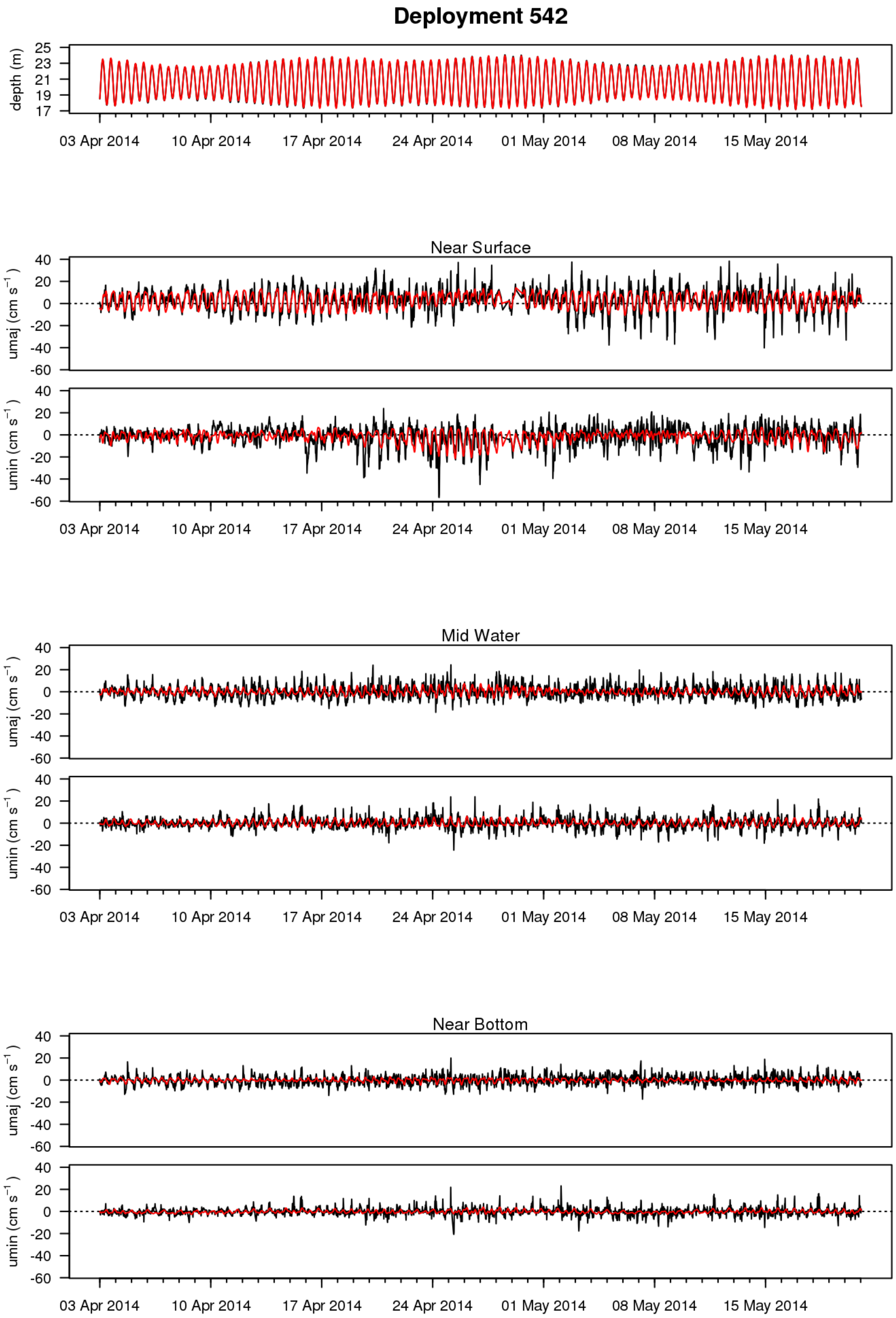

Fig. 17. Time series plots of water depth and current velocity for ADCP deployment 542 (south of Long Island, 3 April to 21 May 2014). Current speeds are plotted in the major (umaj) and minor (umin) directions (as determined by the principal component analysis), for three depth levels (near surface, mid-water, and near bottom). Black lines are the observed currents; red lines are the reconstructed time series from the tidal analysis (tidal constituent).

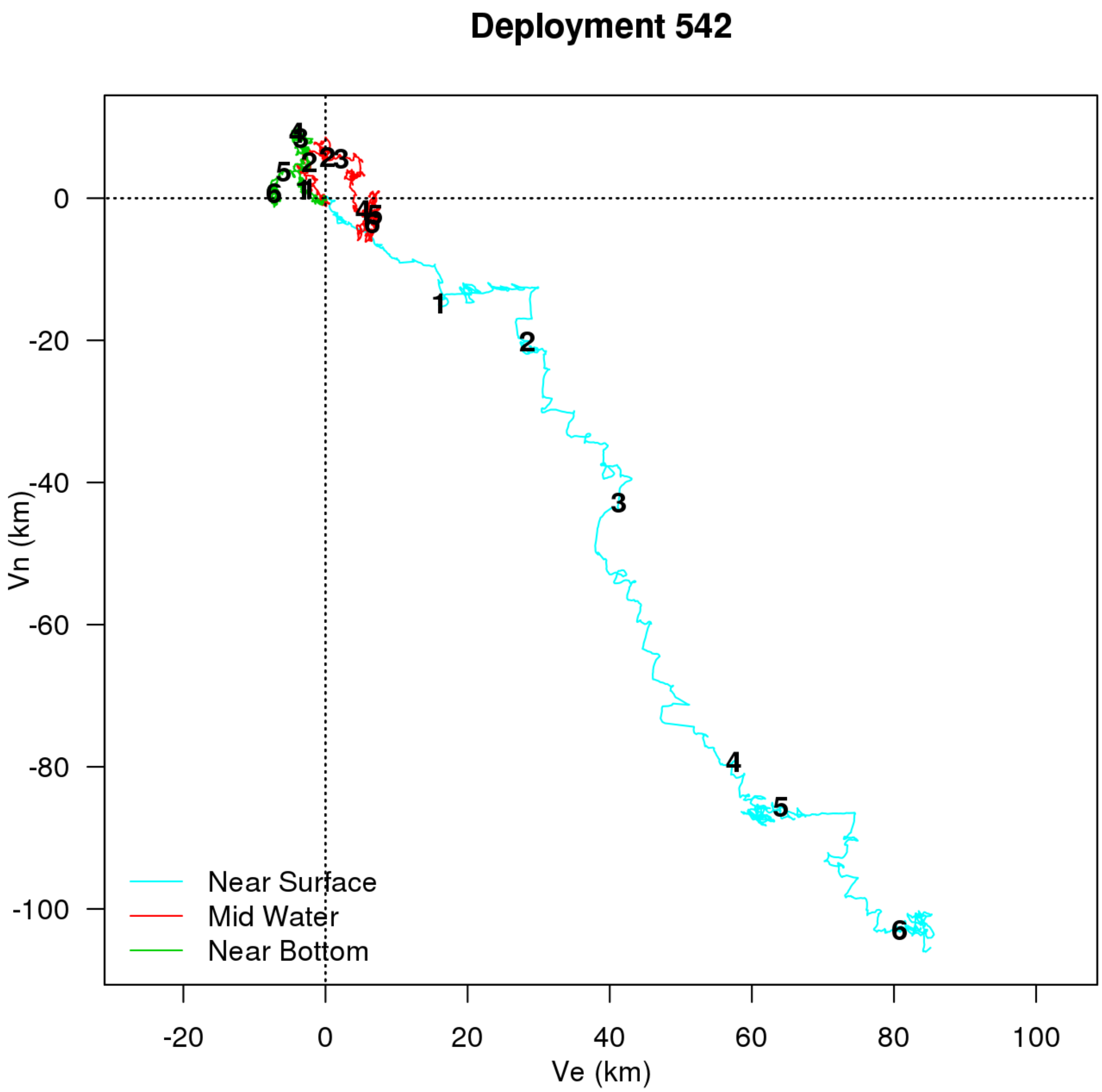

Fig. 18. Progressive vector plot for ADCP deployment 542 (south of Long Island, 3 April to 21 May 2014). Successive movements of a particle are estimated using current velocities measured at 20-min intervals by the current meter. Ve = east-west direction; Vn = north-south direction. Data are presented for three depth levels: near surface (blue), mid-water (red), and near bottom (green). Numbers on the vectors indicate the number of weeks from the time of the first data record. Duration = 48.0 d (6.9 weeks).

Deployment 543 (mid-coast, north of Great Duck Island)

Current velocities just north of Great Duck Island (deployment 543) were strong (Table 8), especially near the surface (the maximum near surface speed was 96.4 cm s^{-1}), and were mostly to the south (Figs. 19-21). Tidal analysis of current velocity amplitudes (Table 15 & Appendix D) indicated that M2 was by far the largest tidal constituent along the major axis at all three depth levels, and M2 was also the largest tidal constituent along the minor axis at all three depth levels. The major axis (from the principal components analysis) accounted for 78-87% of the total variance (Table 16) and was in the north-south direction at all three depth levels (Fig. 21). Tidal constituents dominated at this site at all three depth levels, accounting for 67-79% of the variance along the major axis, but ≤0.2% along the minor axis (Table 16 & Fig. 22).

The progressive vector plot (Fig. 23) showed considerable small-scale (tidal) movement. The net displacement at the end of the data record (48.0 d) was ~200 km to the south at all three depth levels.

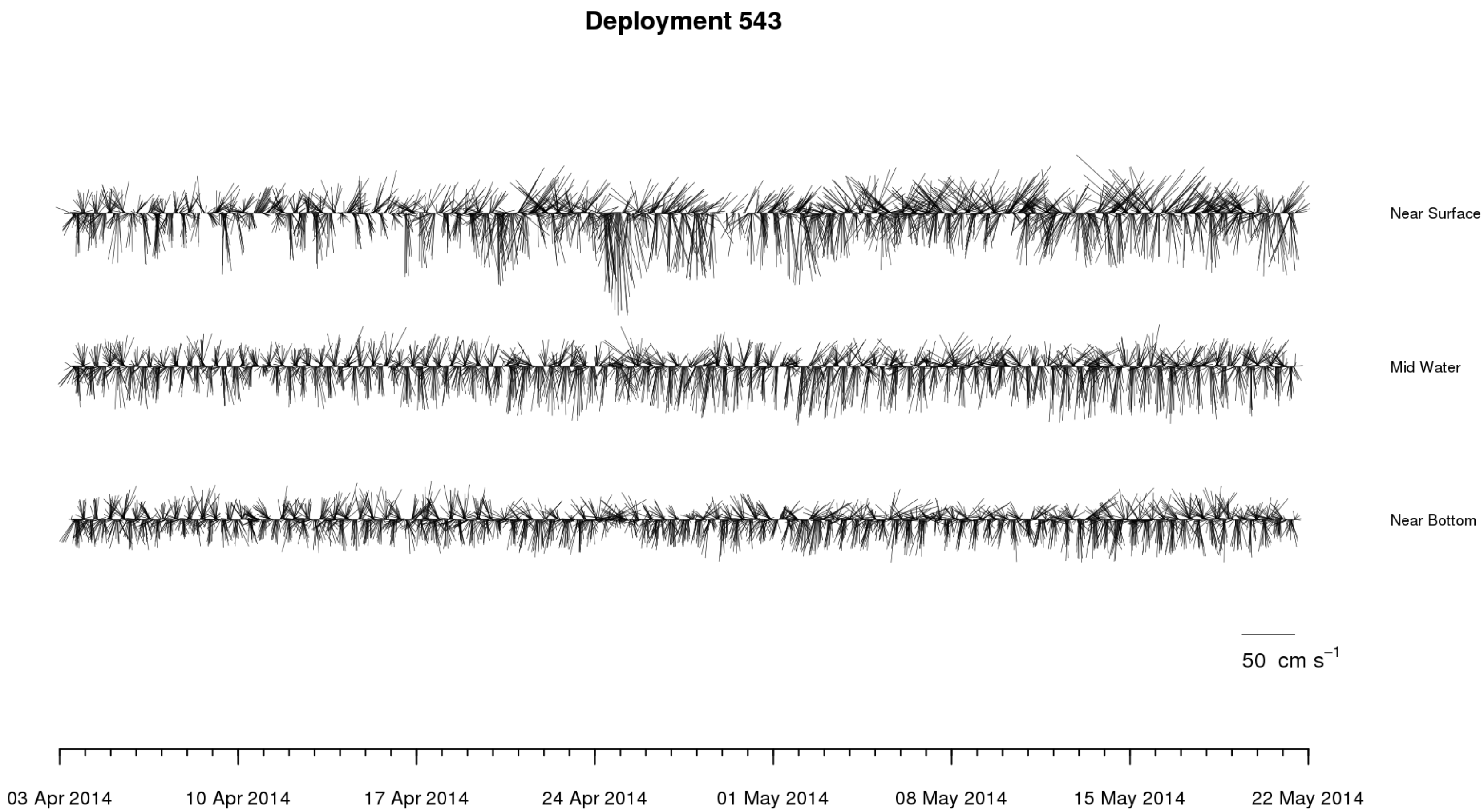

Fig. 19. Stick plots of current velocities in ADCP deployment 543 (north of Great Duck Island, 3 April to 21 May 2014) at three depth levels (near surface, mid-water, and near bottom). The lines show the current direction (true north is straight up) and speed (see scale on graph) in each data segment (20-min intervals).

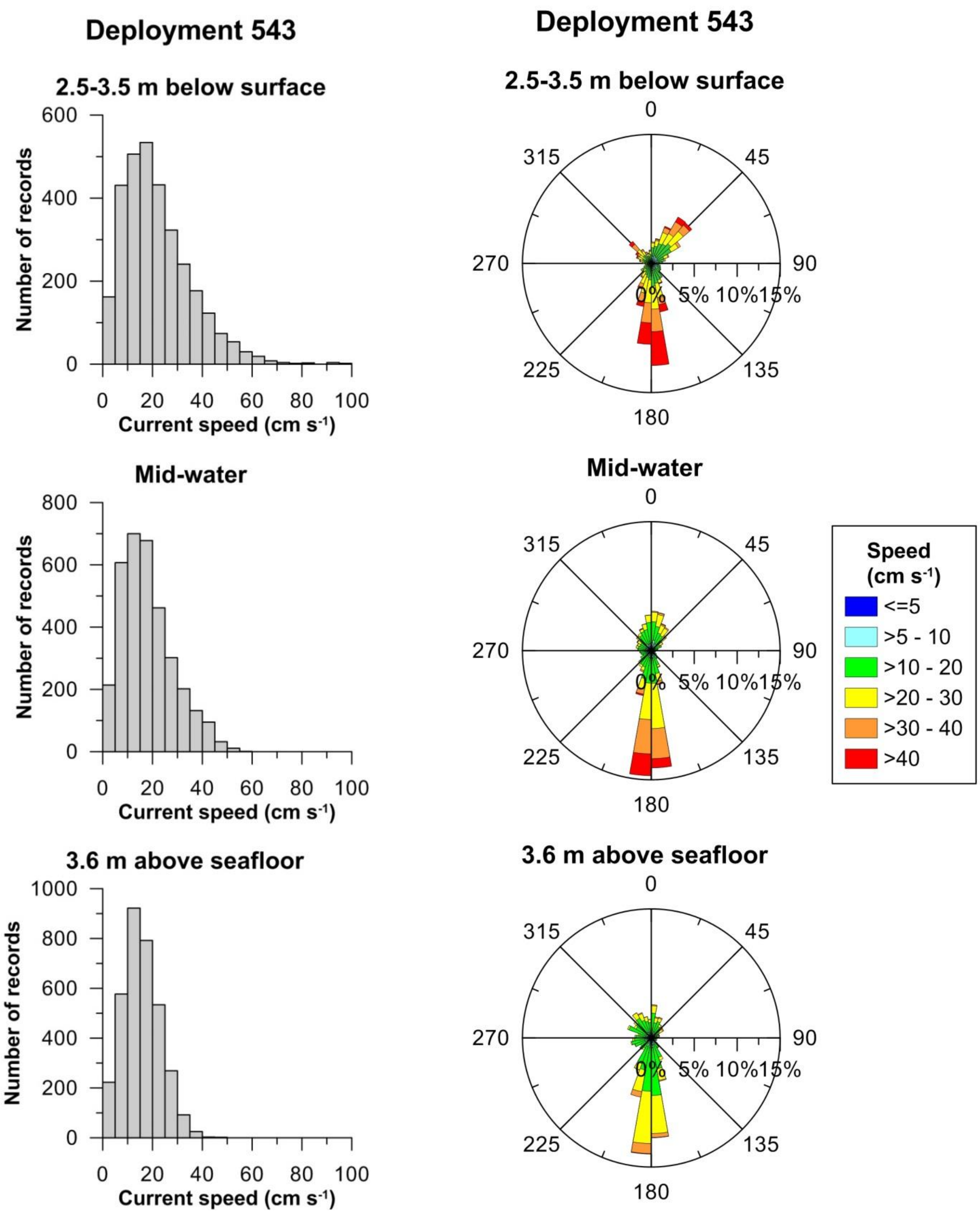

Fig. 20. Current speed histograms (left) and current velocity rose diagrams (right) for ADCP deployment 543 (north of Great Duck Island, 3 April to 21 May 2014). Data are presented for three depth levels: near surface (top), mid-water (middle), and near bottom (bottom).

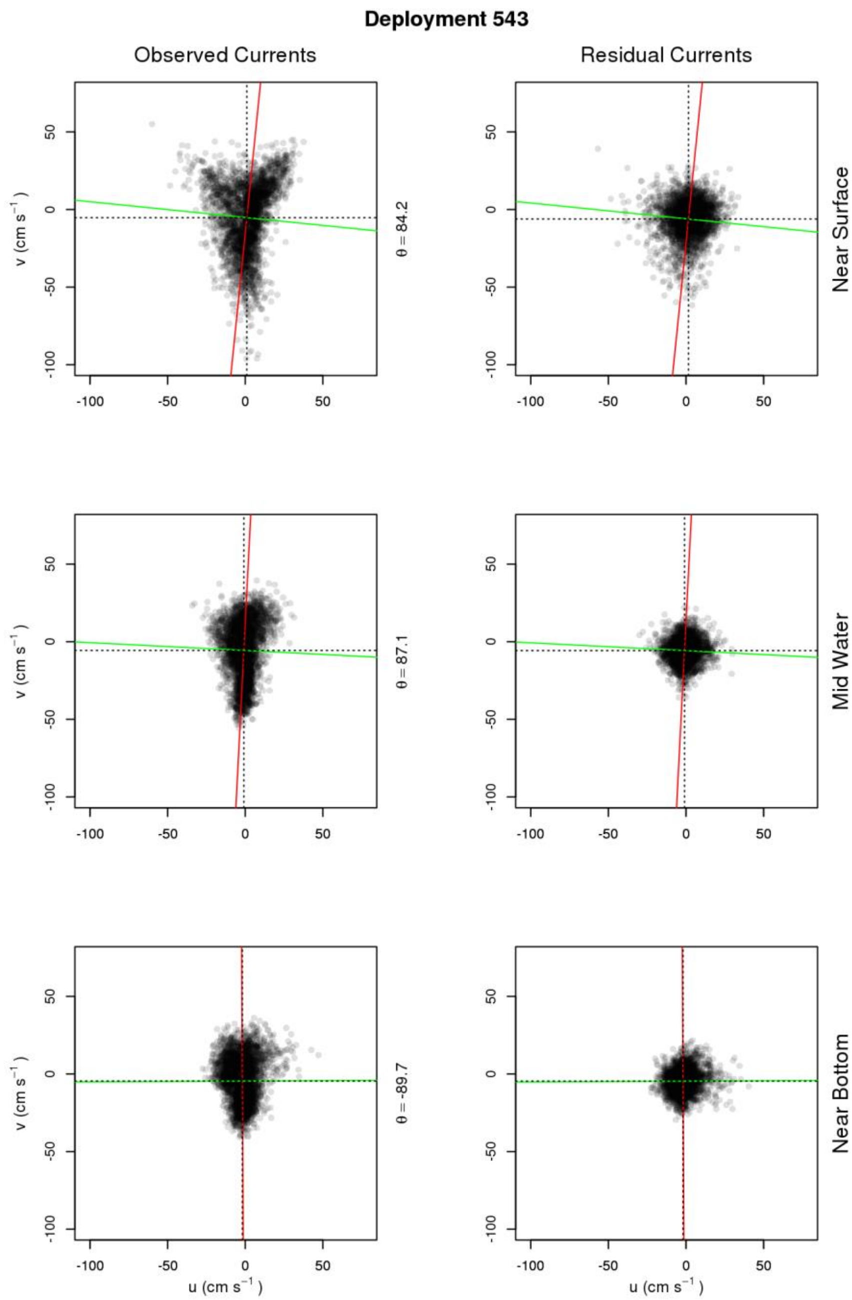

Fig. 21. Scatter plots for current velocities in ADCP deployment 543 (north of Great Duck Island, 3 April to 21 May 2014). Left: observed currents. Right: residual currents where residuals are obtained by removing the tidal signal from the original observation. Current velocity data in the east-west (u) and north-south (v) directions are presented for three depth levels: near surface (top), mid-water (middle), and near bottom (bottom). The red line is the major principal axis and the green line is the minor principal axis. θ = angle of the major axis (degrees from the east-west axis, in a counter-clockwise direction). The dotted lines indicate the mean currents in the east-west and north-south directions.

Table 15. Tidal analysis of water current velocities for ADCP deployment 543. Data are shown for the 5 main tidal constituents (M2, N2, S2, K1, O1). Z0 represents the mean flow in the direction of each principal axis at each depth level (near surface, mid-water, and near bottom). Amplitude = one-half of the range. Maj = in the direction of the major principal axis. Min = in the direction of the minor principal axis. * indicates that the constituent was not included in the 2nd pass of the tidal analysis program based on the value of the t-test. θ = angle of the major axis (degrees from the east-west axis, in a counter-clockwise direction). Time zone used in calculation of phases = UTC.

Deployment 543	Constituent		Amplitude	Phase (°)
Near surface currents ($cm\ s^{-1}$) θ = 84.2	Z0	Maj	-5.950	-
		Min	-2.161	-
	M2	Maj	25.652	313.2
		Min	4.775	46.0
	N2	Maj	4.923	252.9
		Min	1.717	100.0
	S2	Maj	2.781	305.9
		Min	0.915	178.7
	K1	Maj	1.951	136.1
		Min	1.389	14.3
	O1	Maj	1.763	114.2
		Min	*	*
Mid-water currents ($cm\ s^{-1}$) θ = 87.1	Z0	Maj	-5.747	-
		Min	0.690	-
	M2	Maj	22.720	319.2
		Min	4.334	47.5
	N2	Maj	3.086	271.5
		Min	1.000	352.9
	S2	Maj	3.185	335.6
		Min	*	*
	K1	Maj	*	*
		Min	0.846	178.4
	O1	Maj	1.572	268.4
		Min	0.582	152.5
Near bottom currents ($cm\ s^{-1}$) θ = -89.7	Z0	Maj	4.617	-
		Min	-1.955	-
	M2	Maj	16.475	138.1
		Min	3.654	210.1
	N2	Maj	1.550	75.1
		Min	1.575	140.4
	S2	Maj	2.757	177.3
		Min	*	*
	K1	Maj	0.827	135.1
		Min	0.914	337.3
	O1	Maj	1.125	100.0
		Min	*	*

Table 16. Variance of observed water current velocity (cm s^{-1}) time series for ADCP deployment 543, with the percent contribution of the current in the major (Maj) and minor (Min) directions to the total variance of the currents, the percent contribution of the 5 main constituents (M2, N2, S2, K1, and O1) to the variances in the Maj and Min directions, and the percent contribution of the M2 constituent to the variances in the Maj and Min directions. The percent contribution was calculated by reconstructing the time series from the specified tidal constituents when they were included in the analysis, as well as any constituents that were inferred from these. The variance was then calculated for the reconstructed signal and used to calculate the percent contribution to the total signal. All variances were calculated using N degrees of freedom where N is the total number of observations in a given record. Maj = in the direction of the major principal axis. Min = in the direction of the minor principal axis.

Deployment 543		Variance	% of variance in Maj and Min directions	% of variance contributed by M2+N2+S2+K1+O1	% of variance contributed by M2 only
Near surface	Maj	513.919	80.2	67.1	68.1
	Min	126.702	19.8	0.1	0.1
Mid-water	Maj	348.870	86.7	79.1	79.3
	Min	53.692	13.3	0.2	0.2
Near bottom	Maj	217.000	78.2	68.0	67.0
	Min	60.356	21.8	0.1	0.1

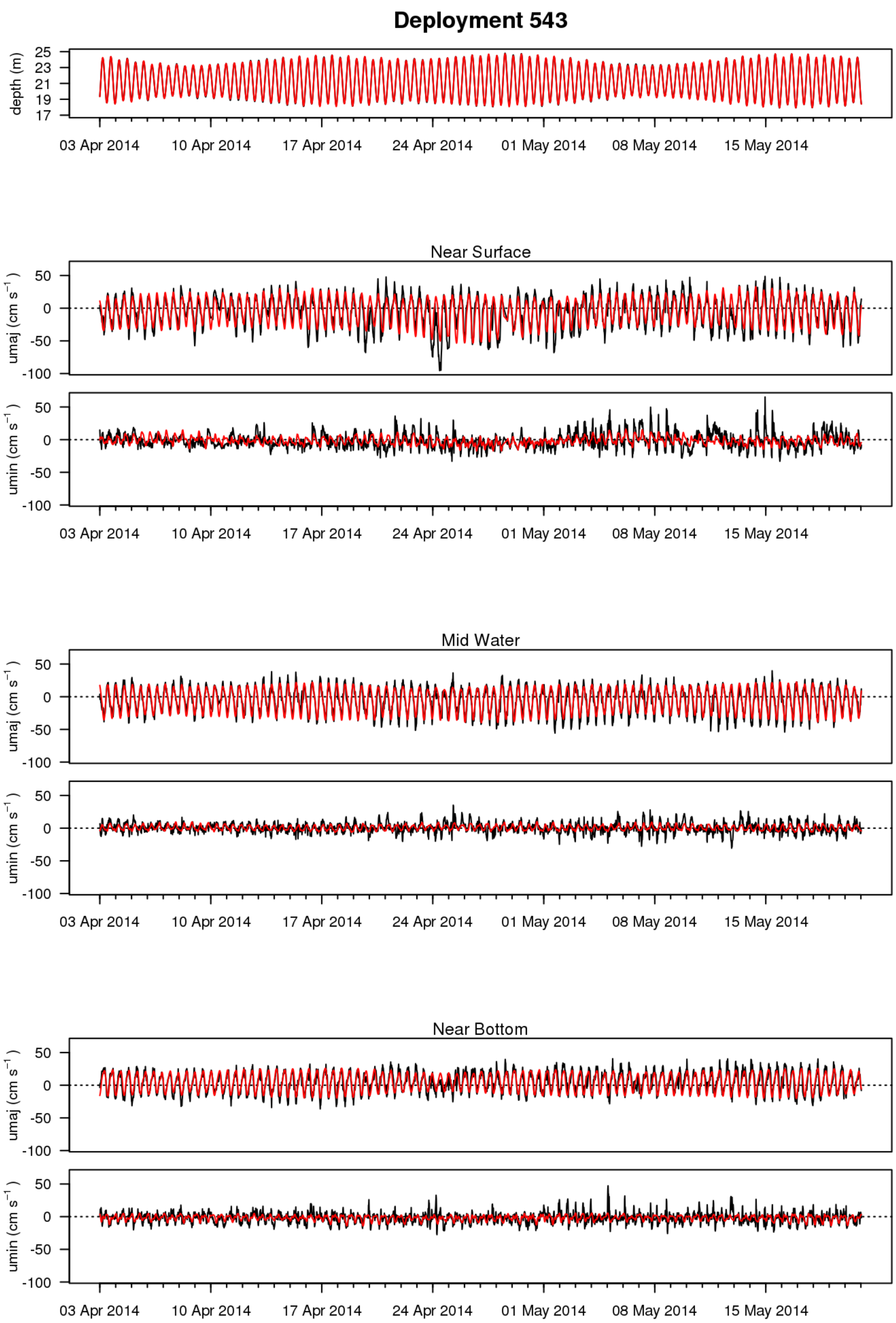

Fig. 22. Time series plots of water depth and current velocity for ADCP deployment 543 (north of Great Duck Island, 3 April to 21 May 2014). Current speeds are plotted in the major (umaj) and minor (umin) directions (as determined by the principal component analysis), for three depth levels (near surface, mid-water, and near bottom). Black lines are the observed currents; red lines are the reconstructed time series from the tidal analysis (tidal constituent).

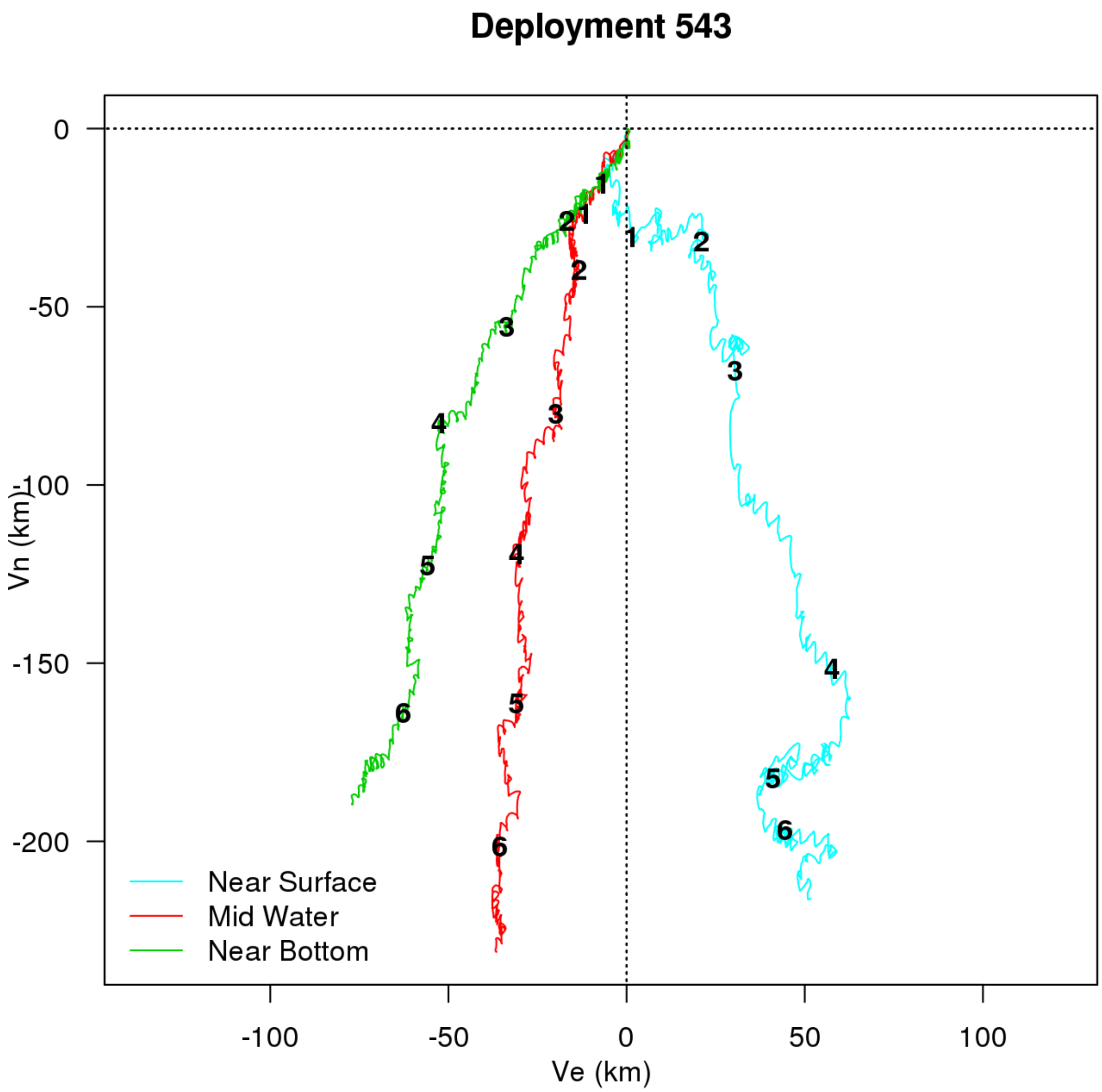

Fig. 23. Progressive vector plot for ADCP deployment 543 (north of Great Duck Island, 3 April to 21 May 2014). Successive movements of a particle are estimated using current velocities measured at 20-min intervals by the current meter. Ve = east-west direction; Vn = north-south direction. Data are presented for three depth levels: near surface (blue), mid-water (red), and near bottom (green). Numbers on the vectors indicate the number of weeks from the time of the first data record. Duration = 48.0 d (6.9 weeks).

Deployment 544 (northeast of White Head Island)

Current speeds northeast of White Head Island (deployment 544) were strong at all three depth levels (speeds at the three depth levels ranged from 0.2-88.0 cm s^{-1}, with means at the three depth levels ranging from 27.9-32.2 cm s^{-1}; Table 8). Current directions and the major axes (from the principal components analysis) were primarily to the northwest and southeast at all three depth levels (Figs. 24-26). Tidal analysis of current velocity amplitudes (Table 17 & Appendix D) indicated that M2 was by far the largest tidal constituent along the major axis at all three depth levels, and M2 was also the largest tidal constituent along the minor axis at all three depth levels. The major axis (from the principal components analysis) accounted for 87-96% of the total variance at the three depth levels (Table 18). The tidal contribution was responsible for over 80% of the total variance of currents along the major axis, but ≤0.2% along the minor axis (Table 18 & Fig. 27).

The progressive vector plot (Fig. 28) indicated considerable small-scale (tidal) movement. At mid-water and near the bottom, net movement was to the west (inshore), whereas near the surface it was initially to the northwest, then (after ~2 weeks) southward. The net displacement at the end of the data record (48.0 d) was ~200 km near the surface and near the bottom, and ~120 km mid-water.

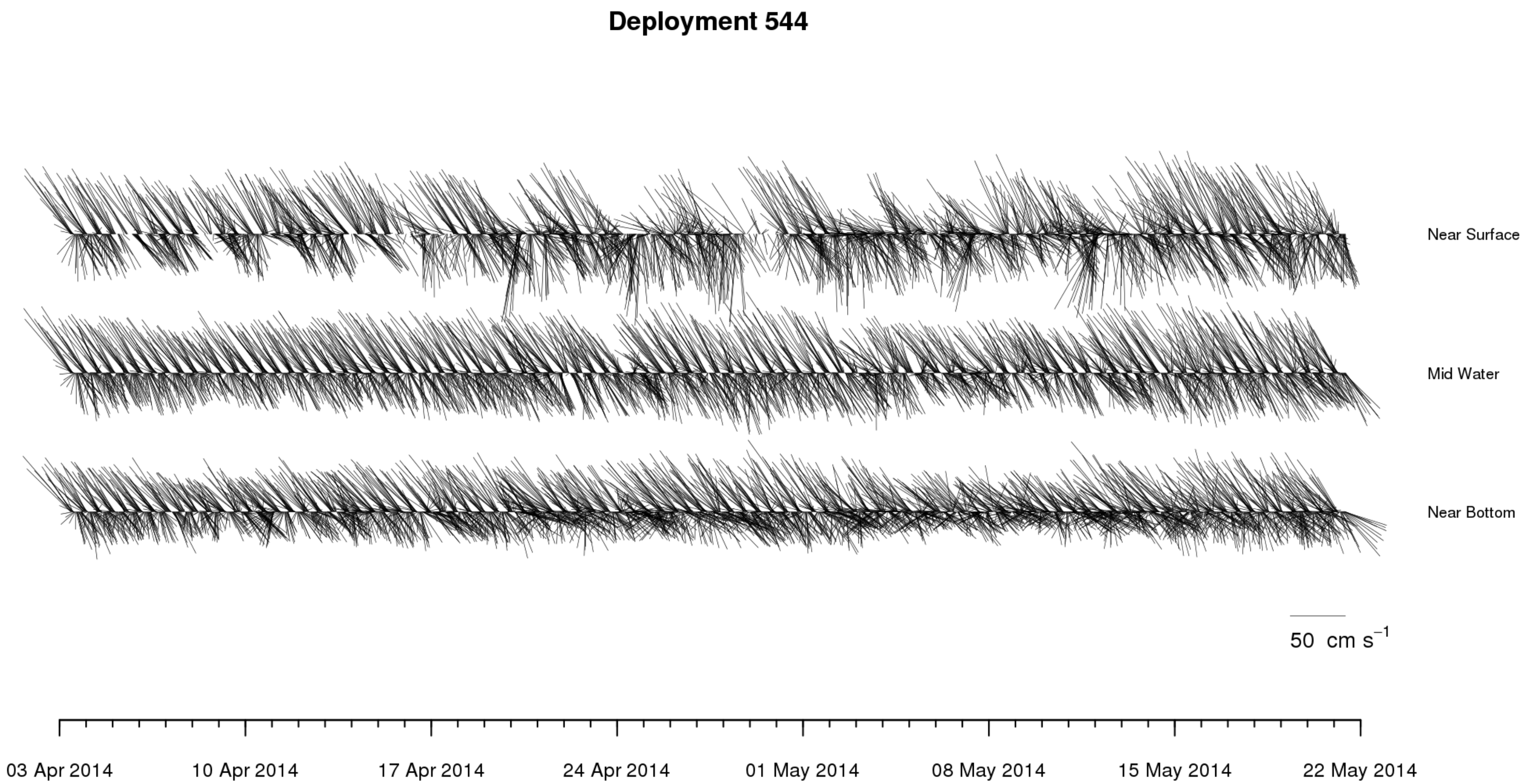

Fig. 24. Stick plots of current velocities in ADCP deployment 540 (Long Island Bay, 3 April to 21 May 2014) at three depth levels (near surface, mid-water, and near bottom). The lines show the current direction (true north is straight up) and speed (see scale on graph) in each data segment (20-min intervals).

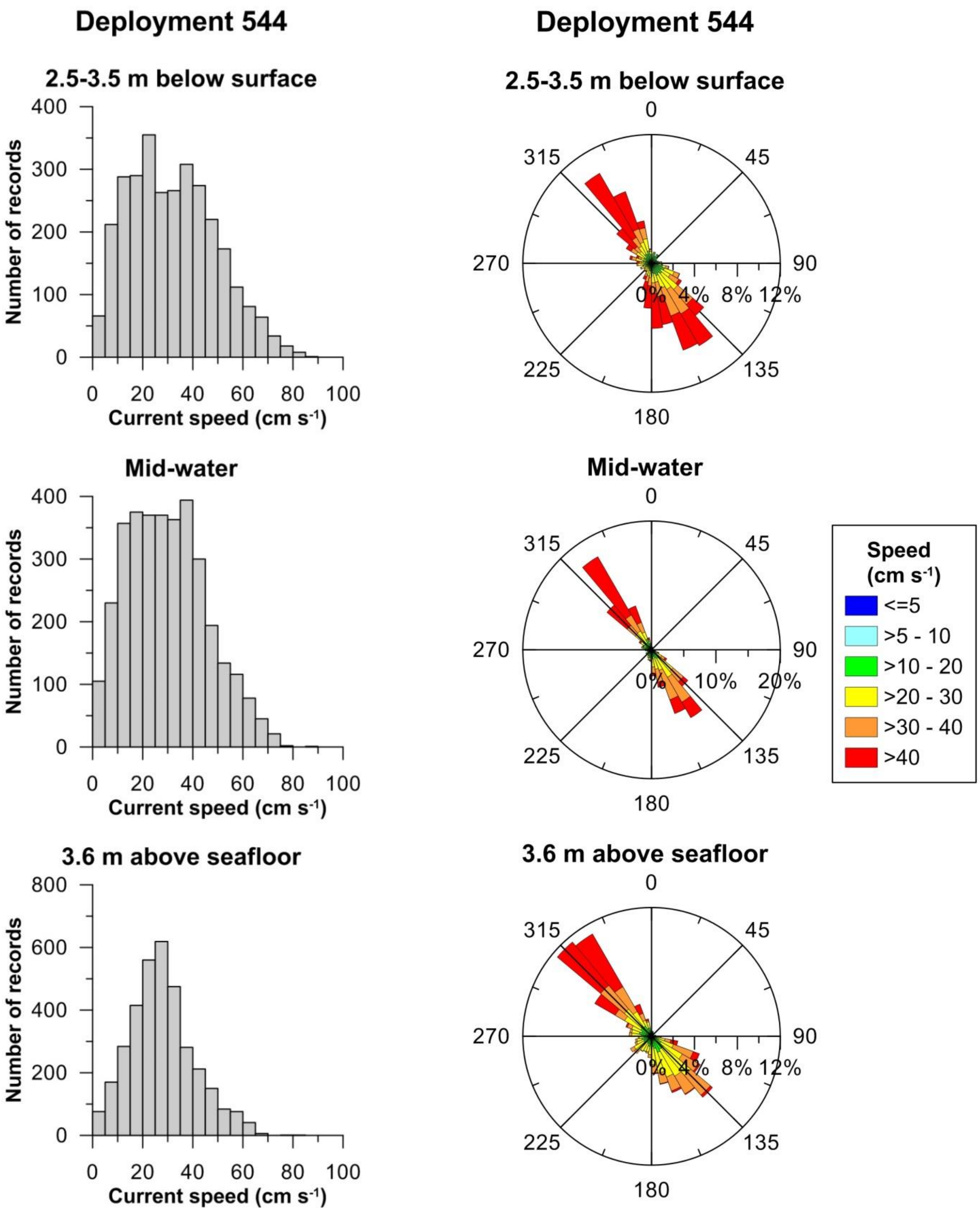

Fig. 25. Current speed histograms (left) and current velocity rose diagrams (right) for ADCP deployment 544 (northeast of White Head Island, 3 April to 21 May 2014). Data are presented for three depth levels: near surface (top), mid-water (middle), and near bottom (bottom).

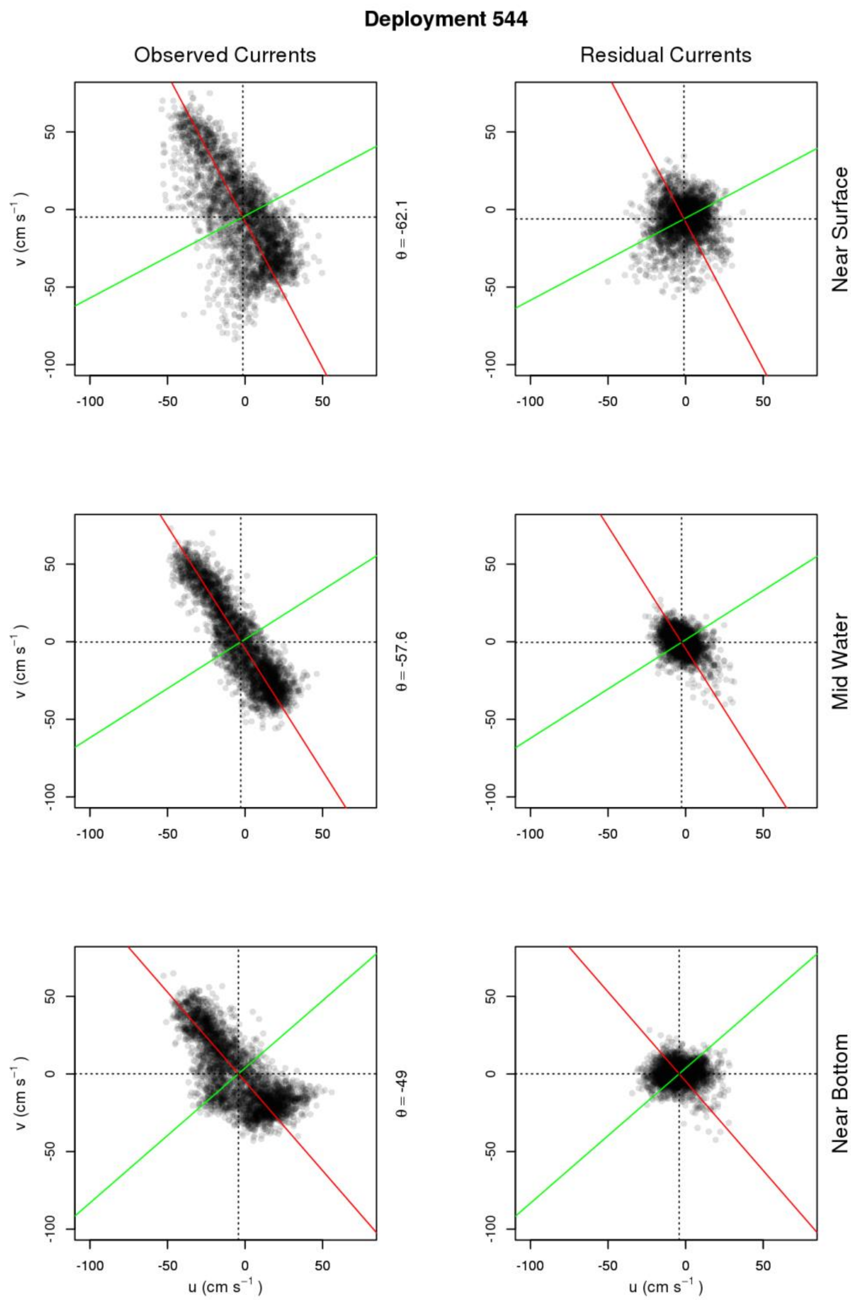

Fig. 26. Scatter plots for current velocities in ADCP deployment 544 (northeast of White Head Island, 3 April to 21 May 2014). Left: observed currents. Right: residual currents where residuals are obtained by removing the tidal signal from the original observation. Current velocity data in the east-west (u) and north-south (v) directions are presented for three depth levels: near surface (top), mid-water (middle), and near bottom (bottom). The red line is the major principal axis and the green line is the minor principal axis. θ = angle of the major axis (degrees from the east-west axis, in a counter-clockwise direction). The dotted lines indicate the mean currents in the east-west and north-south directions.

Table 17. Tidal analysis of water current velocities for ADCP deployment 544. Data are shown for the 5 main tidal constituents (M2, N2, S2, K1, O1). Z0 represents the mean flow in the direction of each principal axis at each depth level (near surface, mid-water, and near bottom). Amplitude = one-half of the range. Maj = in the direction of the major principal axis. Min = in the direction of the minor principal axis. * indicates that the constituent was not included in the 2nd pass of the tidal analysis program based on the value of the t-test. θ = angle of the major axis (degrees from the east-west axis, in a counter-clockwise direction). Time zone used in calculation of phases = UTC.

Deployment 544	Constituent		Amplitude	Phase (°)
Near surface currents (cm s^{-1}) θ = -62.1	Z0	Maj	4.895	-
		Min	-3.792	-
	M2	Maj	41.388	158.7
		Min	3.189	249.6
	N2	Maj	4.741	94.0
		Min	1.229	224.2
	S2	Maj	5.242	199.6
		Min	1.995	298.4
	K1	Maj	1.791	258.0
		Min	1.862	133.9
	O1	Maj	*	*
		Min	1.456	53.0
Mid-water currents (cm s^{-1}) θ = -57.6	Z0	Maj	-1.067	-
		Min	-2.435	-
	M2	Maj	42.368	158.1
		Min	4.151	259.9
	N2	Maj	6.261	112.2
		Min	1.279	208.3
	S2	Maj	5.727	189.0
		Min	1.122	314.3
	K1	Maj	2.232	341.4
		Min	0.742	343.8
	O1	Maj	1.394	291.0
		Min	1.052	265.0
Near bottom currents (cm s^{-1}) θ = -49.0	Z0	Maj	-2.781	-
		Min	-3.072	-
	M2	Maj	36.329	158.2
		Min	6.180	256.8
	N2	Maj	6.010	114.8
		Min	2.503	207.4
	S2	Maj	5.399	184.7
		Min	0.600	358.8
	K1	Maj	2.032	340.6
		Min	1.853	322.6
	O1	Maj	1.485	263.2
		Min	1.198	211.5

Table 18. Variance of observed water current velocity (cm s^{-1}) time series for ADCP deployment 544, with the percent contribution of the current in the major (Maj) and minor (Min) directions to the total variance of the currents, the percent contribution of the 5 main constituents (M2, N2, S2, K1, and O1) to the variances in the Maj and Min directions, and the percent contribution of the M2 constituent to the variances in the Maj and Min directions. The percent contribution was calculated by reconstructing the time series from the specified tidal constituents when they were included in the analysis, as well as any constituents that were inferred from these. The variance was then calculated for the reconstructed signal and used to calculate the percent contribution to the total signal. All variances were calculated using N degrees of freedom where N is the total number of observations in a given record. Maj = in the direction of the major principal axis. Min = in the direction of the minor principal axis.

Deployment 544		Variance	% of variance in Maj and Min directions	% of variance contributed by M2+N2+S2+K1+O1	% of variance contributed by M2 only
Near surface	Maj	1149.390	88.1	79.8	80.9
	Min	155.800	11.9	0.1	<0.05
Mid-water	Maj	1094.136	95.5	88.3	88.0
	Min	51.192	4.5	0.2	0.2
Near bottom	Maj	803.976	87.4	88.7	88.1
	Min	116.245	12.6	0.2	0.2

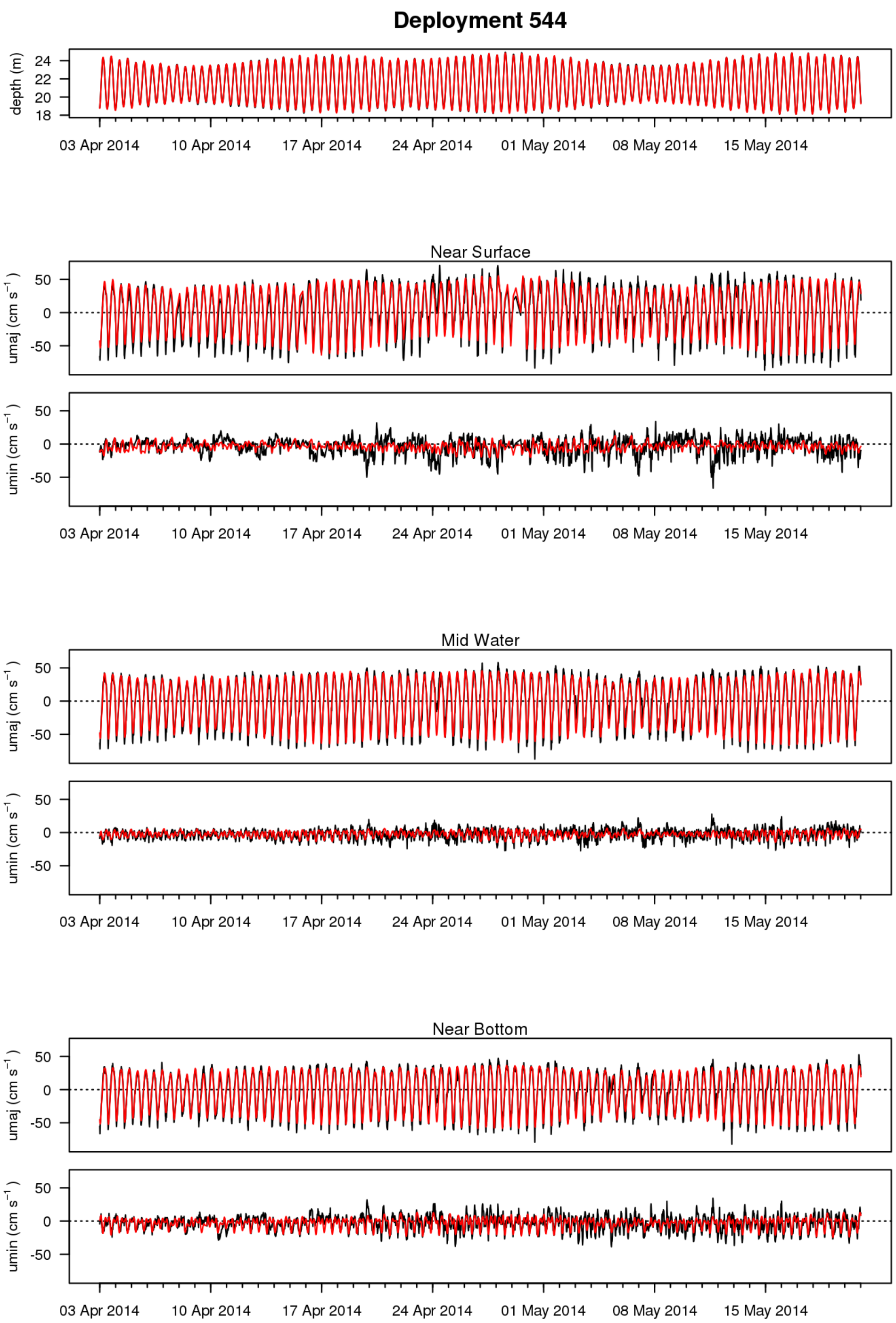

Fig. 27. Time series plots of water depth and current velocity for ADCP deployment 544 (northeast of White Head Island, 3 April to 21 May 2014). Current speeds are plotted in the major (umaj) and minor (umin) directions (as determined by the principal component analysis), for three depth levels (near surface, mid-water, and near bottom). Black lines are the observed currents; red lines are the reconstructed time series from the tidal analysis (tidal constituent).

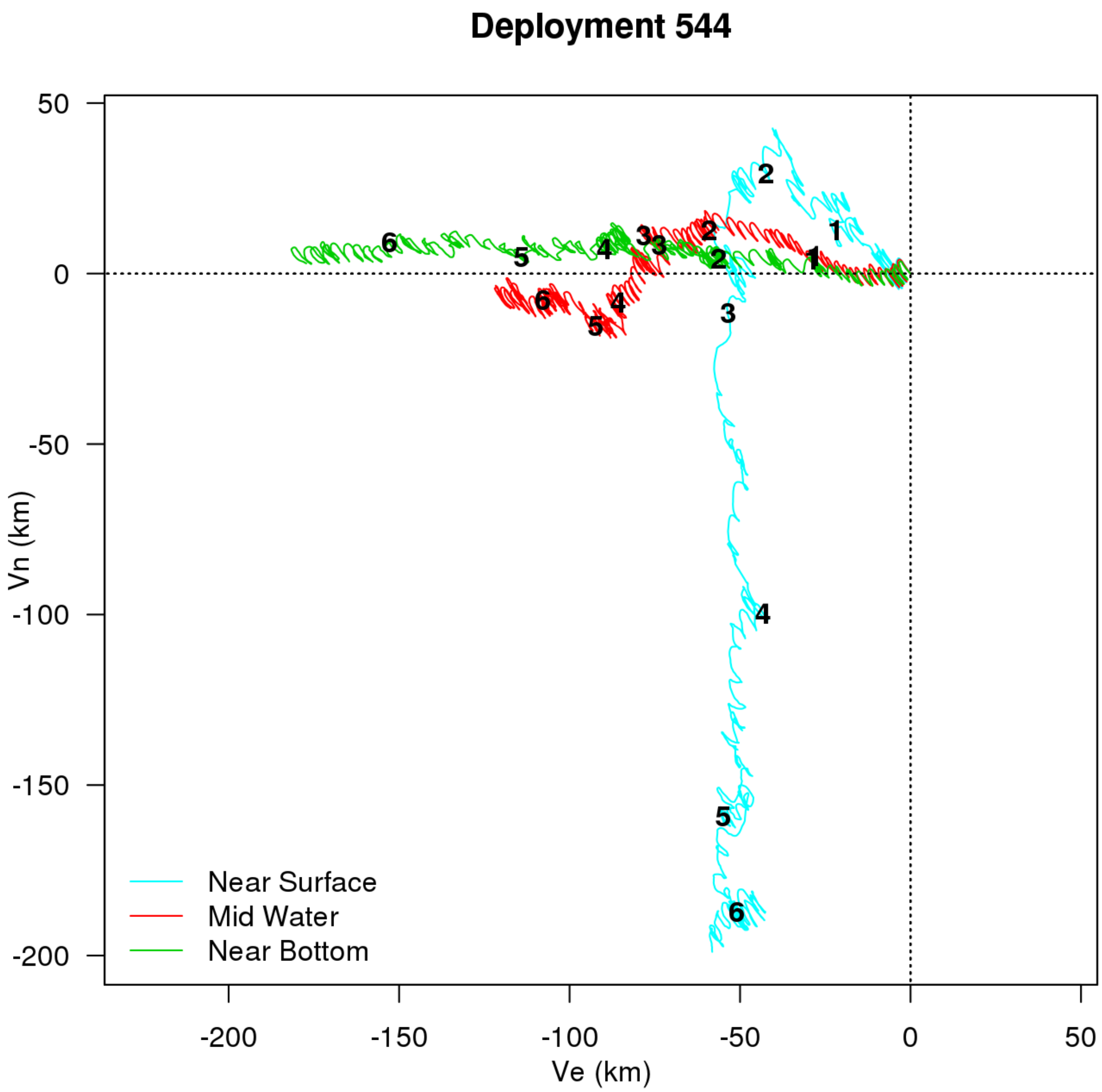

Fig. 28. Progressive vector plot for ADCP deployment 544 (northeast of White Head Island, 3 April to 21 May 2014). Successive movements of a particle are estimated using current velocities measured at 20-min intervals by the current meter. Ve = east-west direction; Vn = north-south direction. Data are presented for three depth levels: near surface (blue), mid-water (red), and near bottom (green). Numbers on the vectors indicate the number of weeks from the time of the first data record. Duration = 48.0 d (6.9 weeks).

Deployment 212 (Long Island Bay)

Deployment 212 (in 2000) was located between the locations of deployments 540 and 541. Current speeds in deployment 212 were similar to deployments 540 and 541: mean speeds at the three depth levels ranged from 8.8-11.4 cm s^{-1} and maxima were 25.4-48.4 cm s^{-1} (Table 8). The current direction and the major axis (from the principal components analysis) was predominantly east-west at all three depth levels (Figs. 29-31), as in deployments 540 and 541. Tidal analysis of current velocity amplitudes (Table 19 & Appendix D) indicated that M2 was by the dominant tidal constituent along the major axis at all three depth levels; along the minor axis, the amplitude of the M2 constituent was the largest but was of the same order of magnitude as those of other constituents. The major axis (from the principal components analysis) accounted for 75-82% of the total variance at the three depth levels (Table 20). As with deployments 540 and 541, non-tidal processes accounted for the majority of the variance in the currents; tidal constituents accounted for 32-35% of the variance along the major axis, but only ≤0.2% along the minor axis (Table 20 & Fig. 32).

The progressive vector plot (Fig. 33) indicated that the net movement was to the south, then southeast (out of the bay) near the surface, and to the west (into the bay) at mid-water and near the bottom. At all three levels, the net displacement at the end of the data record (46.2 d) was between 60 and 90 km.

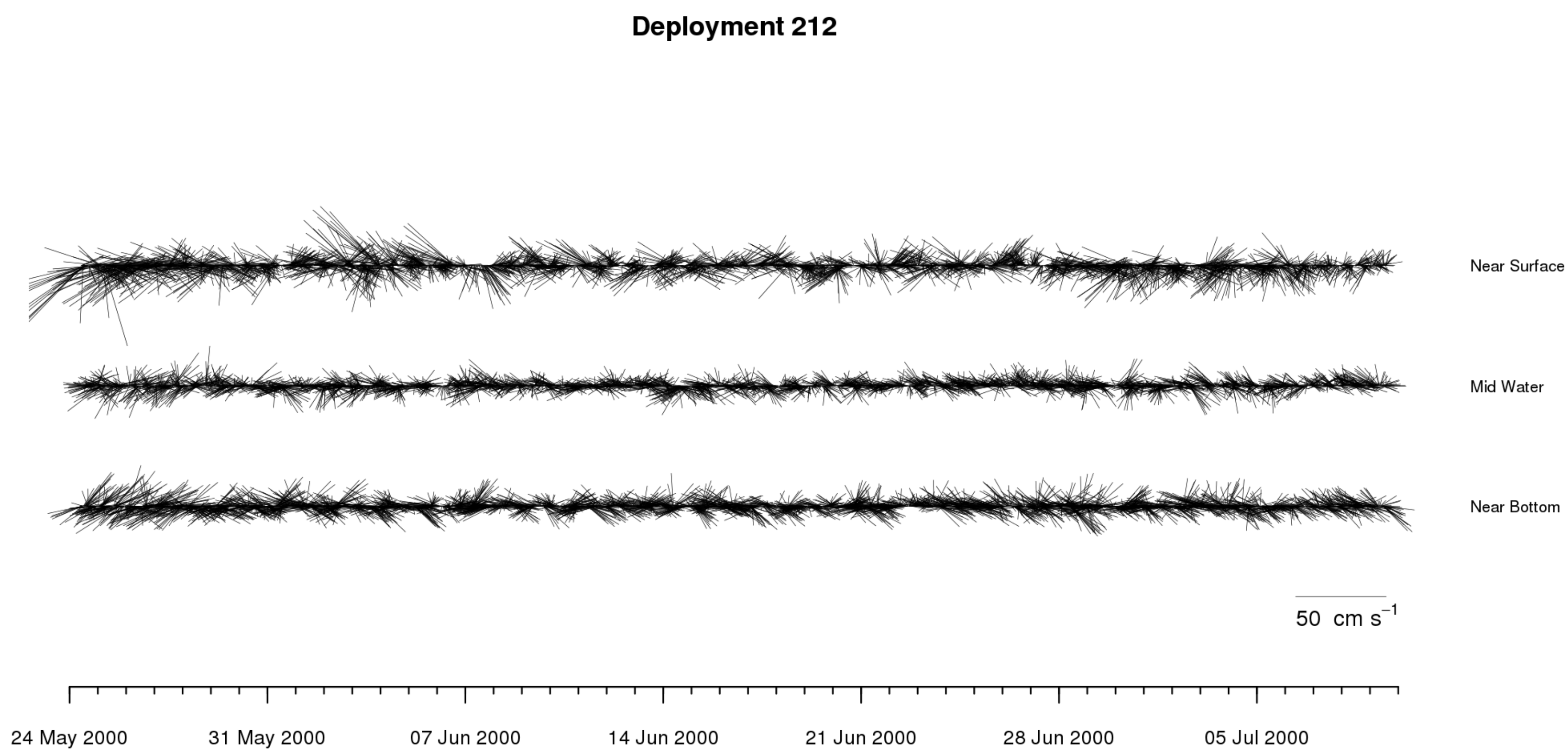

Fig. 29. Stick plots of current velocities in ADCP deployment 212 (Long Island Bay, 24 May to 9 July 2000) at three depth levels (near surface, mid-water, and near bottom). The lines show the current direction (true north is straight up) and speed (see scale on graph) in each data segment (15-min intervals).

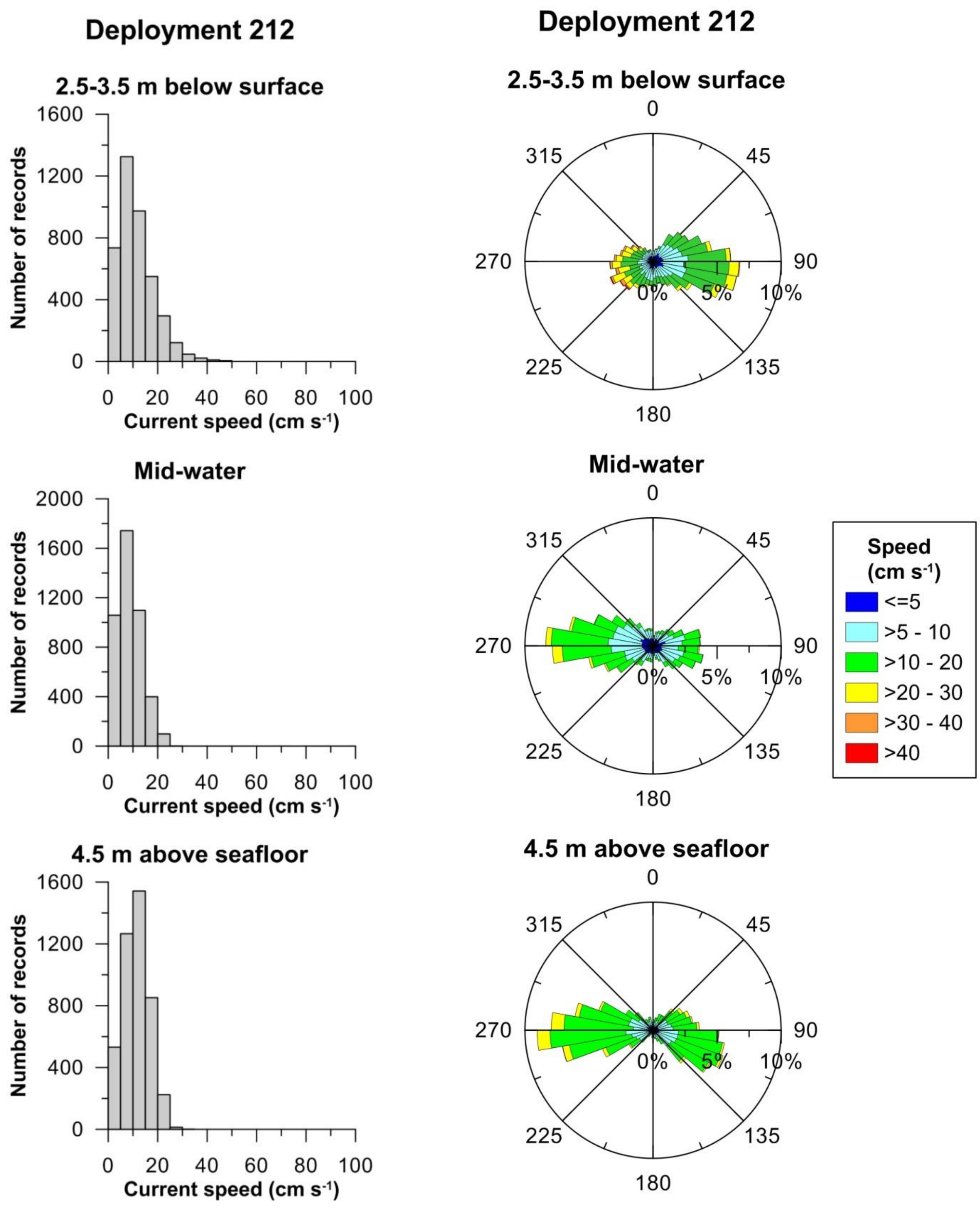

Fig. 30. Current speed histograms (left) and current velocity rose diagrams (right) for ADCP deployment 212 (Long Island Bay, 24 May to 9 July 2000). Data are presented for three depth levels: near surface (top), mid-water (middle), and near bottom (bottom).

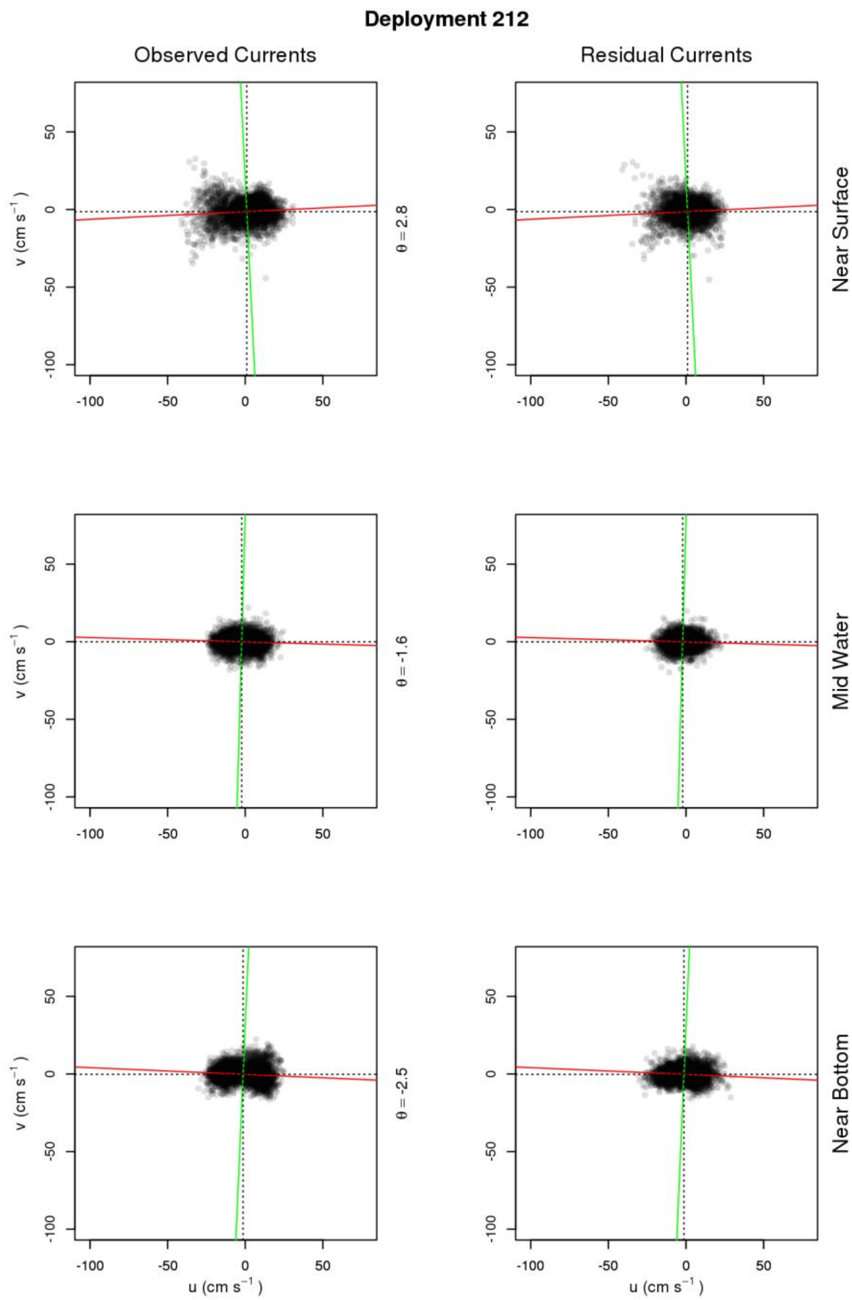

Fig. 31. Scatter plots for current velocities in ADCP deployment 212 (Long Island Bay, 24 May to 9 July 2000). Left: observed currents. Right: residual currents where residuals are obtained by removing the tidal signal from the original observation. Current velocity data in the east-west (u) and north-south (v) directions are presented for three depth levels: near surface (top), mid-water (middle), and near bottom (bottom). The red line is the major principal axis and the green line is the minor principal axis. θ = angle of the major axis (degrees from the east-west axis, in a counter-clockwise direction). The dotted lines indicate the mean currents in the east-west and north-south directions.

Table 19. Tidal analysis of water current velocities for ADCP deployment 212. Data are shown for the 5 main tidal constituents (M2, N2, S2, K1, O1). Z0 represents the mean flow in the direction of each principal axis at each depth level (near surface, mid-water, and near bottom). Amplitude = one-half of the range. Maj = in the direction of the major principal axis. Min = in the direction of the minor principal axis. * indicates that the constituent was not included in the 2nd pass of the tidal analysis program based on the value of the t-test. θ = angle of the major axis (degrees from the east-west axis, in a counter-clockwise direction). Time zone used in calculation of phases = UTC.

Deployment 212	Constituent		Amplitude	Phase (°)
Near surface currents (cm s^{-1}) $\theta = 2.8$	Z0	Maj	0.945	-
		Min	-1.421	-
	M2	Maj	7.303	239.1
		Min	1.337	325.3
	N2	Maj	2.947	239.3
		Min	0.937	295.1
	S2	Maj	1.696	274.3
		Min	0.539	313.0
	K1	Maj	2.217	169.2
		Min	0.559	192.6
	O1	Maj	3.395	180.6
		Min	*	*
Mid-water currents (cm s^{-1}) $\theta = -1.6$	Z0	Maj	-2.160	-
		Min	-0.147	-
	M2	Maj	4.879	177.5
		Min	1.291	349.1
	N2	Maj	1.819	131.5
		Min	*	*
	S2	Maj	1.146	93.8
		Min	1.073	324.4
	K1	Maj	2.904	352.6
		Min	0.647	279.5
	O1	Maj	3.054	23.2
		Min	0.242	246.2
Near bottom currents (cm s^{-1}) $\theta = -2.5$	Z0	Maj	-1.327	-
		Min	-0.294	-
	M2	Maj	6.838	139.9
		Min	2.761	3.8
	N2	Maj	3.253	100.7
		Min	0.863	8.6
	S2	Maj	1.540	143.0
		Min	0.786	304.2
	K1	Maj	2.036	335.7
		Min	0.265	7.9
	O1	Maj	2.713	1.2
		Min	0.756	29.5

Table 20. Variance of observed water current velocity (cm s^{-1}) time series for ADCP deployment 212, with the percent contribution of the current in the major (Maj) and minor (Min) directions to the total variance of the currents, the percent contribution of the 5 main constituents (M2, N2, S2, K1, and O1) to the variances in the Maj and Min directions, and the percent contribution of the M2 constituent to the variances in the Maj and Min directions. The percent contribution was calculated by reconstructing the time series from the specified tidal constituents when they were included in the analysis, as well as any constituents that were inferred from these. The variance was then calculated for the reconstructed signal and used to calculate the percent contribution to the total signal. All variances were calculated using N degrees of freedom where N is the total number of observations in a given record. Maj = in the direction of the major principal axis. Min = in the direction of the minor principal axis.

Deployment 212		Variance	% of variance in Maj and Min directions	% of variance contributed by M2+N2+S2+K1+O1	% of variance contributed by M2 only
Near surface	Maj	134.053	74.9	34.6	20.5
	Min	44.887	25.1	<0.05	<0.05
Mid-water	Maj	74.859	79.0	33.9	16.3
	Min	19.863	21.0	0.1	<0.05
Near bottom	Maj	127.399	82.3	31.5	18.9
	Min	27.314	17.7	0.2	0.1

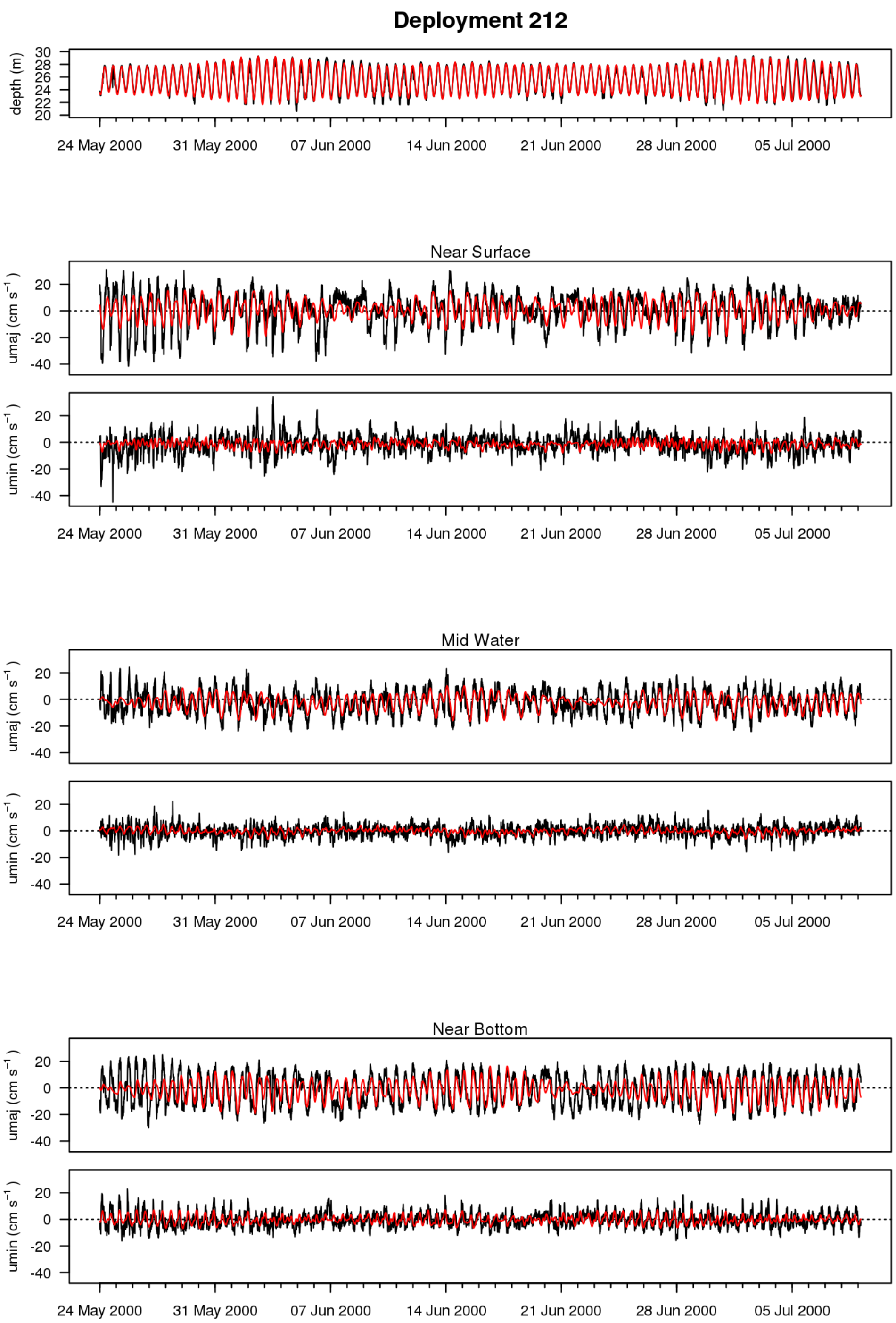

Fig. 32. Time series plots of water depth and current velocity for ADCP deployment 212 (Long Island Bay, 24 May to 9 July 2000). Current speeds are plotted in the major (umaj) and minor (umin) directions (as determined by the principal component analysis), for three depth levels (near surface, mid-water, and near bottom). Black lines are the observed currents; red lines are the reconstructed time series from the tidal analysis (tidal constituent).

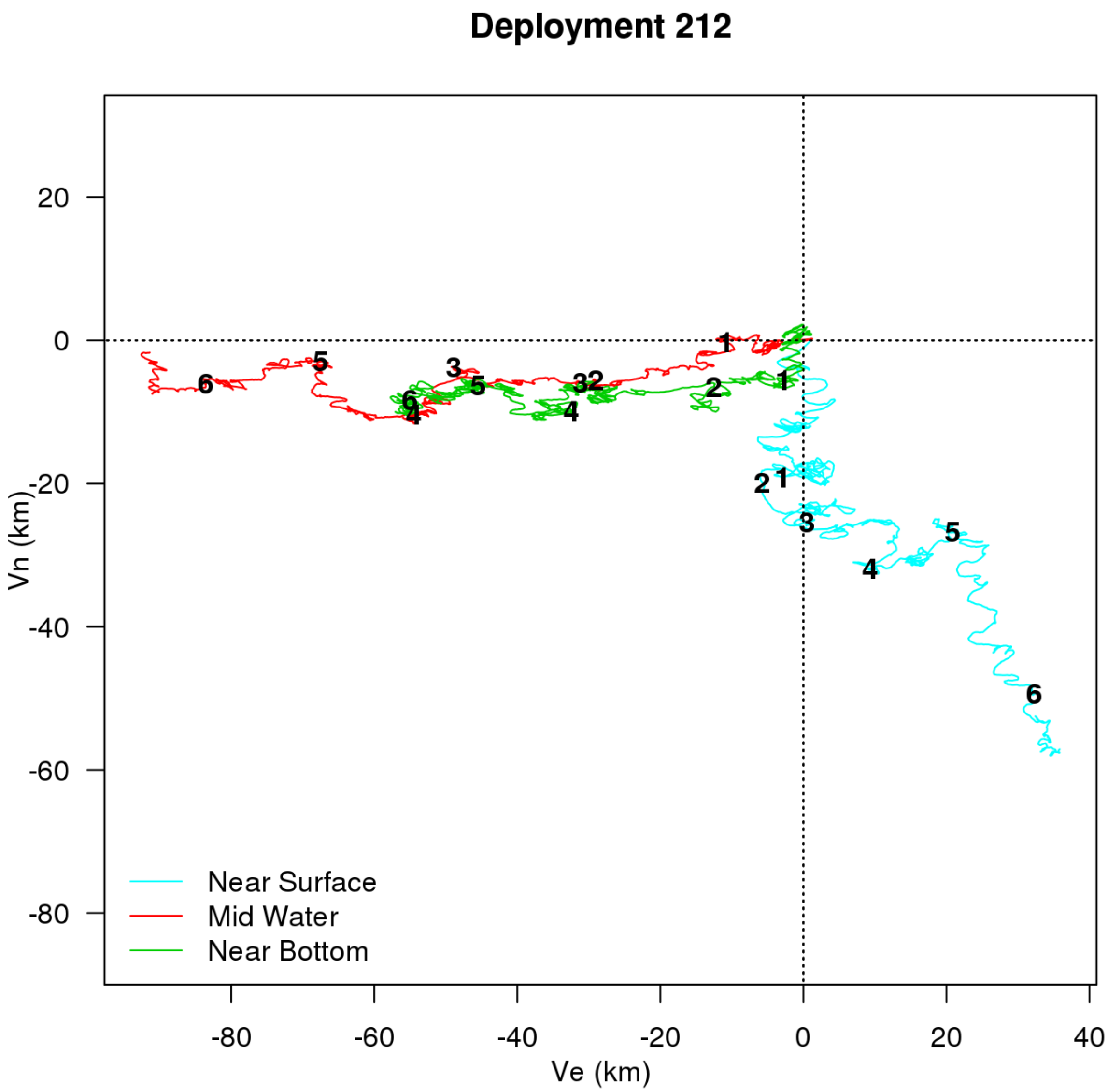

Fig. 33. Progressive vector plot for ADCP deployment 212 (Long Island Bay, 24 May to 9 July 2000). Successive movements of a particle are estimated using current velocities measured at 15-min intervals by the current meter. Ve = east-west direction; Vn = north-south direction. Data are presented for three depth levels: near surface (blue), mid-water (red), and near bottom (green). Numbers on the vectors indicate the number of weeks from the time of the first data record. Duration = 46.2 d (6.6 weeks).

Deployment 308 (Cow Passage)

The current speeds in deployment 308 (Cow Passage) were significantly slower than at deployment 544, which was located 1.5-2.0 km to the east, further offshore (Table 8), with both mean and maximum current speed being approximately half of those for deployment 544. Current direction was predominantly to the south at all three depth levels (Figs. 34-36). Tidal analysis of current velocity amplitudes (Table 21 & Appendix D) indicated that M2 was by far the largest tidal constituent along the major axis at all three depth levels; M2 was also the largest tidal constituent along the minor axis at all three depth levels. The major axis (from the principal components analysis) accounted for 92-94% of the total variance (Table 22) and was in the north-south direction at all three depth levels (Fig. 36). Tidal constituents dominated and accounted for 86% of the total variance along the major axis at all three depth levels, but only 0.1% along the minor axis (Table 22 & Fig. 37).

The progressive vector plot (Fig. 38) indicated that the net displacement at the end of the data record (40.9 d) was ~200-250 km to the south at all three depth levels. The current direction for this deployment was somewhat different than in deployment 544 (Figs. 24-26); deployment 308 was located much closer to the shore (Fig. 1), where the current directions were probably more influenced by the coastal topography.

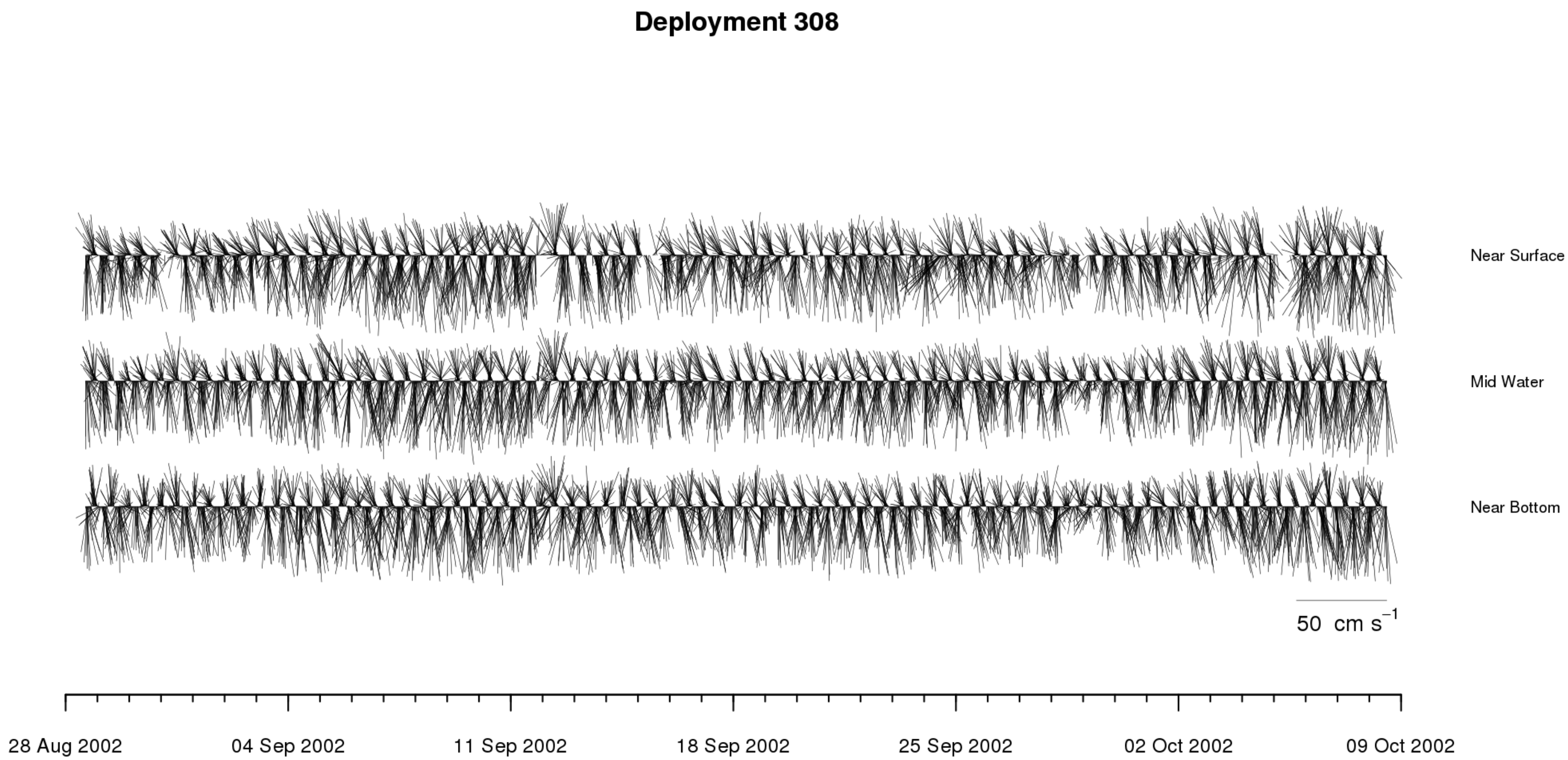

Fig. 34. Stick plots of current velocities in ADCP deployment 308 (Cow Passage, 28 August to 8 October 2002) at three depth levels (near surface, mid-water, and near bottom). The lines show the current direction (true north is straight up) and speed (see scale on graph) in each data segment (15-min intervals).

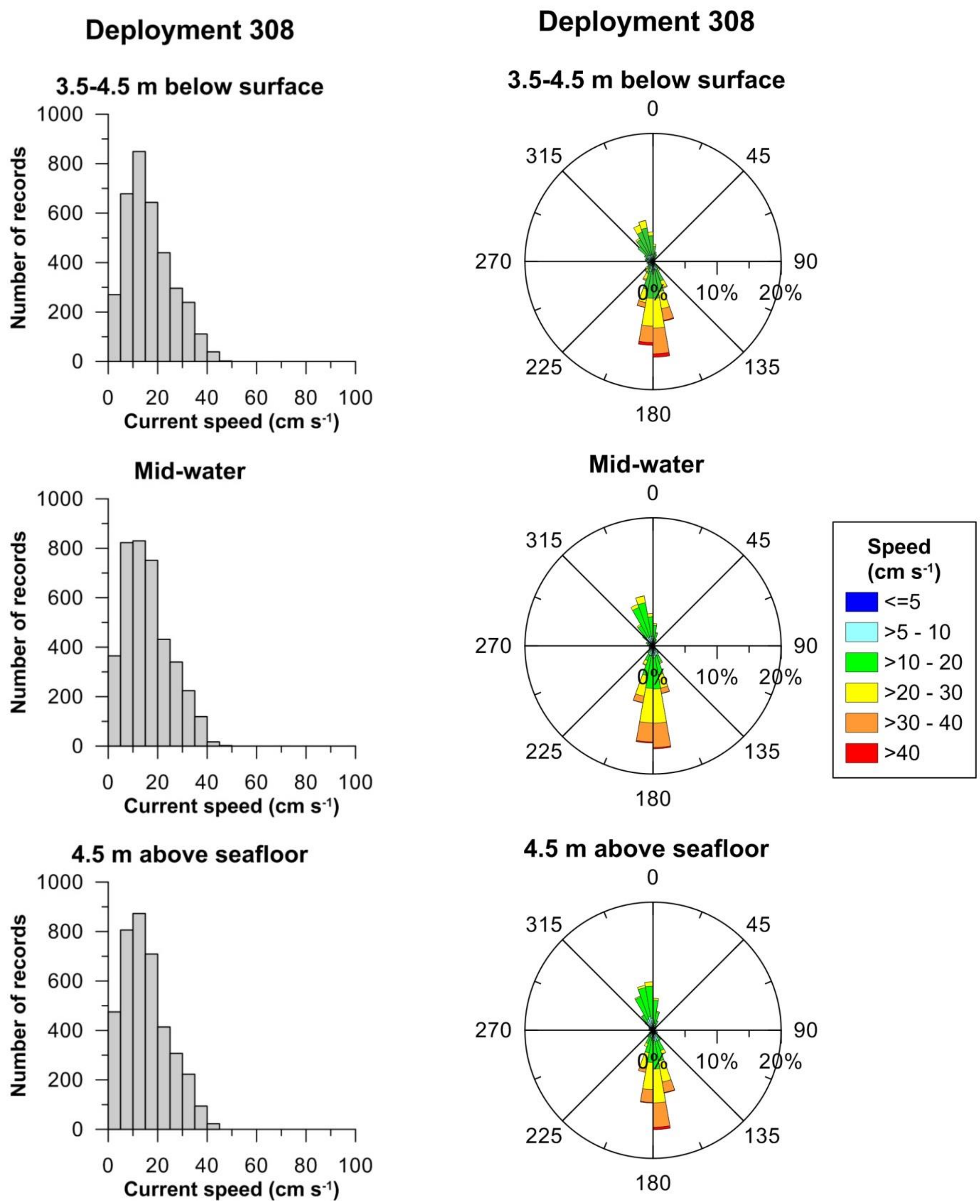

Fig. 35. Current speed histograms (left) and current velocity rose diagrams (right) for ADCP deployment 308 (Cow Passage, 28 August to 8 October 2002). Data are presented for three depth levels: near surface (top), mid-water (middle), and near bottom (bottom).

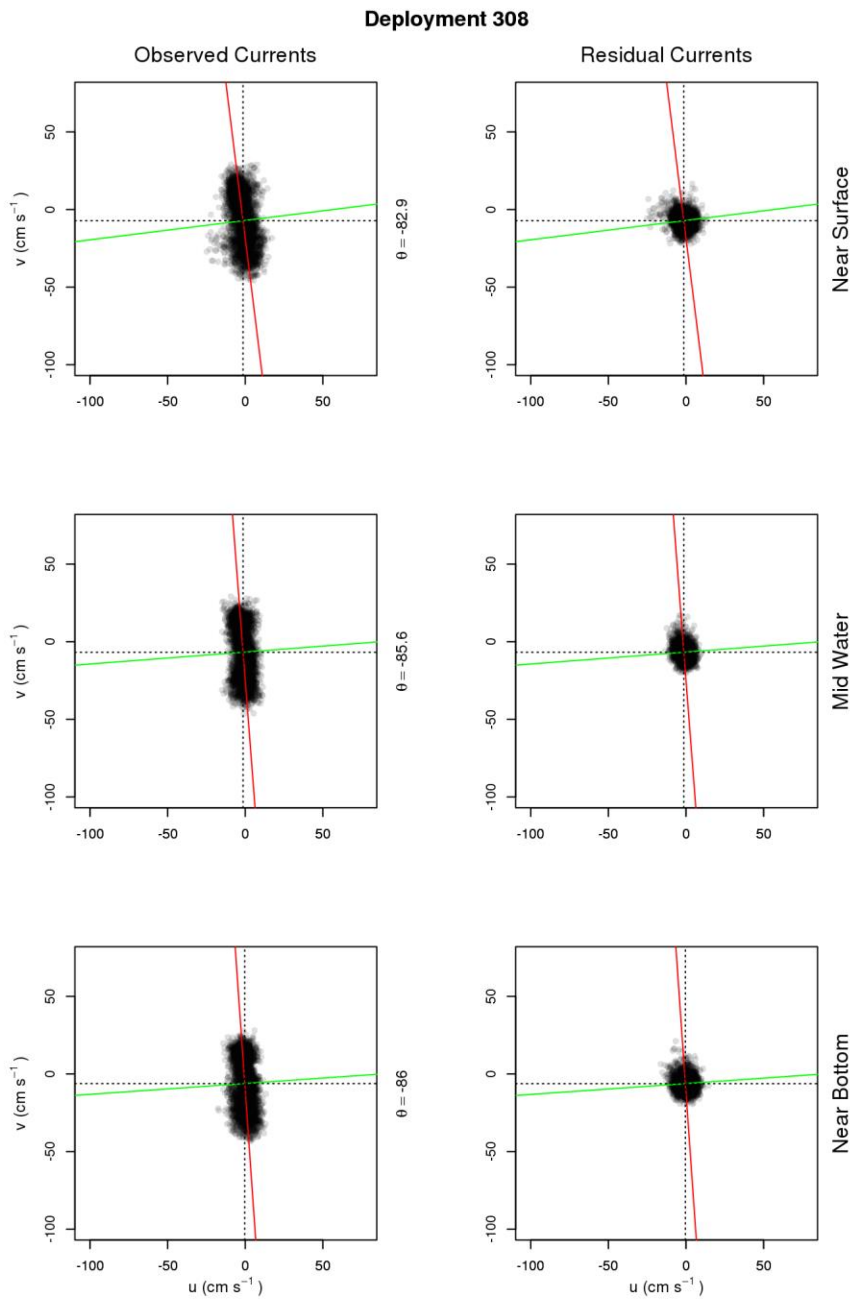

Fig. 36. Scatter plots for current velocities in ADCP deployment 308 (Cow Passage, 28 August to 8 October 2002). Left: observed currents. Right: residual currents where residuals are obtained by removing the tidal signal from the original observation. Current velocity data in the east-west (u) and north-south (v) directions are presented for three depth levels: near surface (top), mid-water (middle), and near bottom (bottom). The red line is the major principal axis and the green line is the minor principal axis. θ = angle of the major axis (degrees from the east-west axis, in a counter-clockwise direction). The dotted lines indicate the mean currents in the east-west and north-south directions.

Table 21. Tidal analysis of water current velocities for ADCP deployment 308. Data are shown for the 5 main tidal constituents (M2, N2, S2, K1, O1). Z0 represents the mean flow in the direction of each principal axis at each depth level (near surface, mid-water, and near bottom). Amplitude = one-half of the range. Maj = in the direction of the major principal axis. Min = in the direction of the minor principal axis. * indicates that the constituent was not included in the 2nd pass of the tidal analysis program based on the value of the t-test. θ = angle of the major axis (degrees from the east-west axis, in a counter-clockwise direction). Time zone used in calculation of phases = UTC.

Deployment 308	Constituent		Amplitude	Phase (°)
Near surface currents (cm s^{-1}) θ = -82.9	Z0	Maj	7.003	-
		Min	-2.291	-
	M2	Maj	21.595	85.5
		Min	1.231	213.8
	N2	Maj	4.090	52.1
		Min	0.567	207.0
	S2	Maj	2.573	115.4
		Min	0.768	280.0
	K1	Maj	0.844	313.4
		Min	0.706	330.2
	O1	Max	*	*
		Min	0.435	70.9
Mid-water currents (cm s^{-1}) θ = -85.6	Z0	Maj	6.645	-
		Min	-1.912	-
	M2	Maj	21.205	84.6
		Min	1.550	201.1
	N2	Maj	3.989	52.6
		Min	0.661	194.8
	S2	Maj	2.582	115.3
		Min	0.295	318.1
	K1	Maj	*	*
		Min	0.439	41.4
	O1	Maj	*	*
		Min	0.316	2.5
Near bottom currents (cm s^{-1}) θ = -86.0	Z0	Maj	6.185	-
		Min	-0.842	-
	M2	Maj	20.760	81.9
		Min	1.367	186.6
	N2	Maj	3.880	51.0
		Min	0.475	195.7
	S2	Maj	2.575	112.2
		Min	0.274	25.9
	K1	Maj	0.464	194.1
		Min	0.491	31.7
	O1	Maj	0.263	333.0
		Min	0.329	322.6

Table 22. Variance of observed water current velocity (cm s^{-1}) time series for ADCP deployment 308, with the percent contribution of the current in the major (Maj) and minor (Min) directions to the total variance of the currents, the percent contribution of the 5 main constituents (M2, N2, S2, K1, and O1) to the variances in the Maj and Min directions, and the percent contribution of the M2 constituent to the variances in the Maj and Min directions. The percent contribution was calculated by reconstructing the time series from the specified tidal constituents when they were included in the analysis, as well as any constituents that were inferred from these. The variance was then calculated for the reconstructed signal and used to calculate the percent contribution to the total signal. All variances were calculated using N degrees of freedom where N is the total number of observations in a given record. Maj = in the direction of the major principal axis. Min = in the direction of the minor principal axis.

Deployment 308		Variance	% of variance in Maj and Min directions	% of variance contributed by M2+N2+S2+K1+O1	% of variance contributed by M2 only
Near surface	Maj	282.276	91.8	86.2	80.6
	Min	25.319	8.2	0.1	<0.05
Mid-water	Maj	271.613	94.3	86.3	80.7
	Min	16.471	5.7	0.1	0.1
Near bottom	Maj	262.115	93.8	86.1	80.3
	Min	17.213	6.2	0.1	0.1

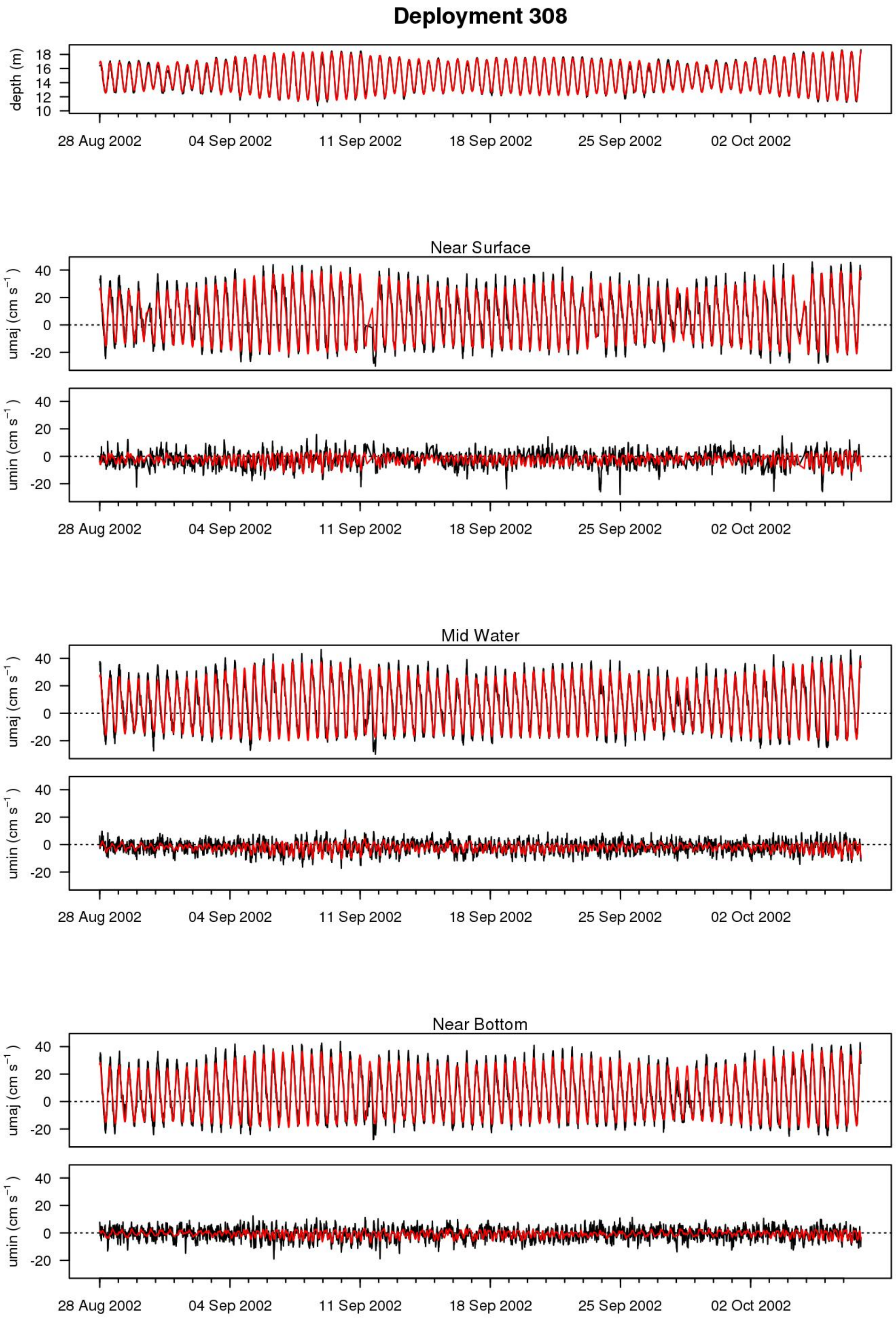

Fig. 37. Time series plots of water depth and current velocity for ADCP deployment 308 (Cow Passage, 28 August to 8 October 2002). Current speeds are plotted in the major (umaj) and minor (umin) directions (as determined by the principal component analysis), for three depth levels (near surface, mid-water, and near bottom). Black lines are the observed currents; red lines are the reconstructed time series from the tidal analysis (tidal constituent).

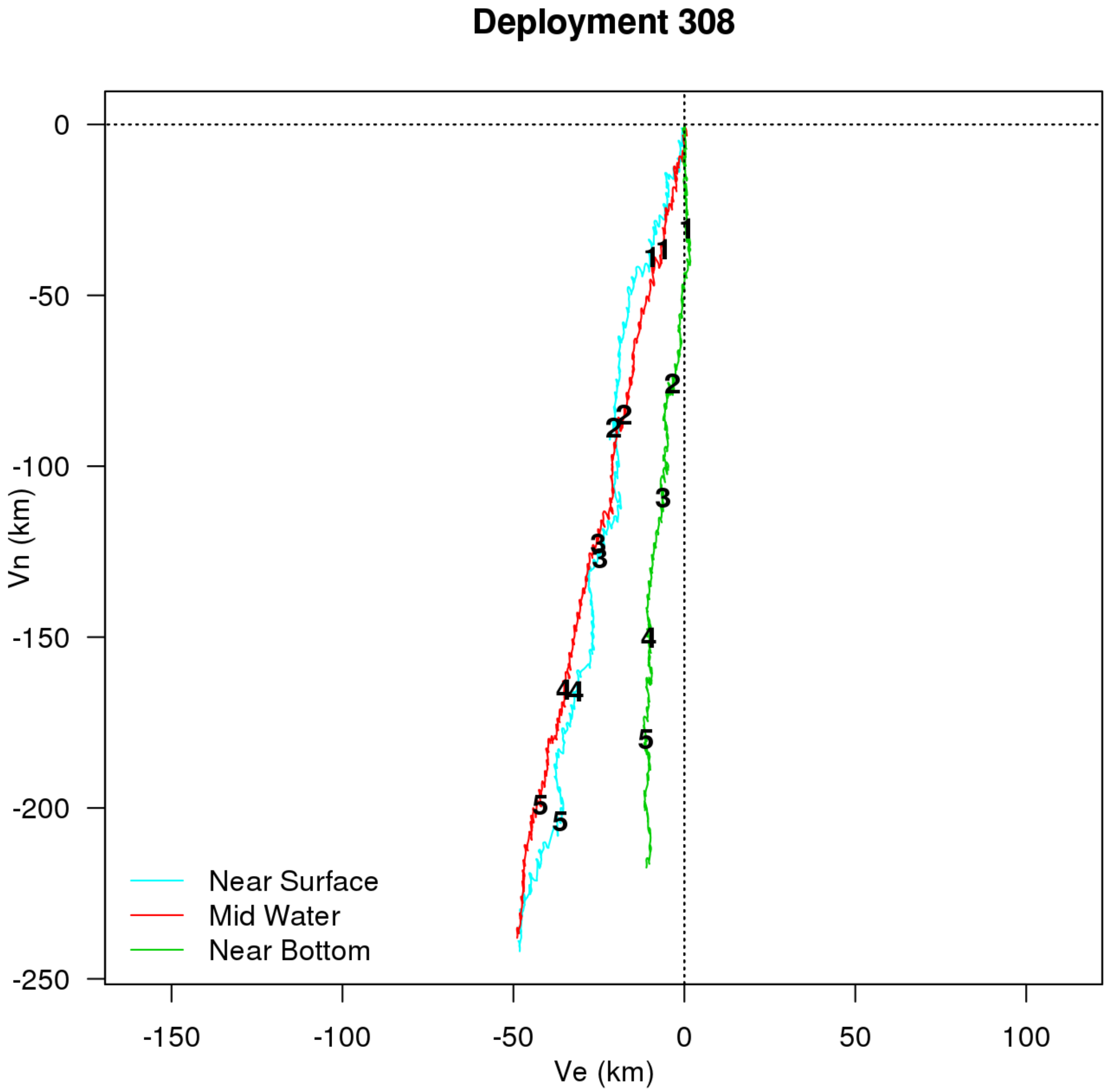

Fig. 38. Progressive vector plot for ADCP deployment 308 (Cow Passage, 28 August to 8 October 2002). Successive movements of a particle are estimated using current velocities measured at 15-min intervals by the current meter. Ve = east-west direction; Vn = north-south direction. Data are presented for three depth levels: near surface (blue), mid-water (red), and near bottom (green). Numbers on the vectors indicate the number of weeks from the time of the first data record. Duration = 40.9 d (5.8 weeks).

Deployment 309 (Cow Passage)

The mean and maximum current speeds in deployment 309 (Cow Passage) were 33-37% slower than those of deployment 308 (Table 8). Current direction was predominantly to the southeast at all three depth levels (Figs. 39-41). Tidal analysis of current velocity amplitudes (Table 23 & Appendix D) indicated that M2 was the largest tidal constituent along the major and minor axes at all three depth levels. The major axis (from the principal components analysis) accounted for 83-85% of the total variance (Table 24) and was in the northwest-southeast direction at all three depth levels (Fig. 41). The tides accounted for only 35-38% of the total variation along the major axis and ≤0.2% along the minor axis (Table 24 & Fig. 42).

The progressive vector plot (Fig. 43) indicated that the net displacement at the end of the data record (26.2 d) was ~120 km to the southeast at all three depth levels, considerably less than for deployment 308 (current speeds were slower in deployment 309; however, it also had the shortest data record). The current direction for deployment 309 was different from deployment 308, probably due to the influence of the coastal topography.

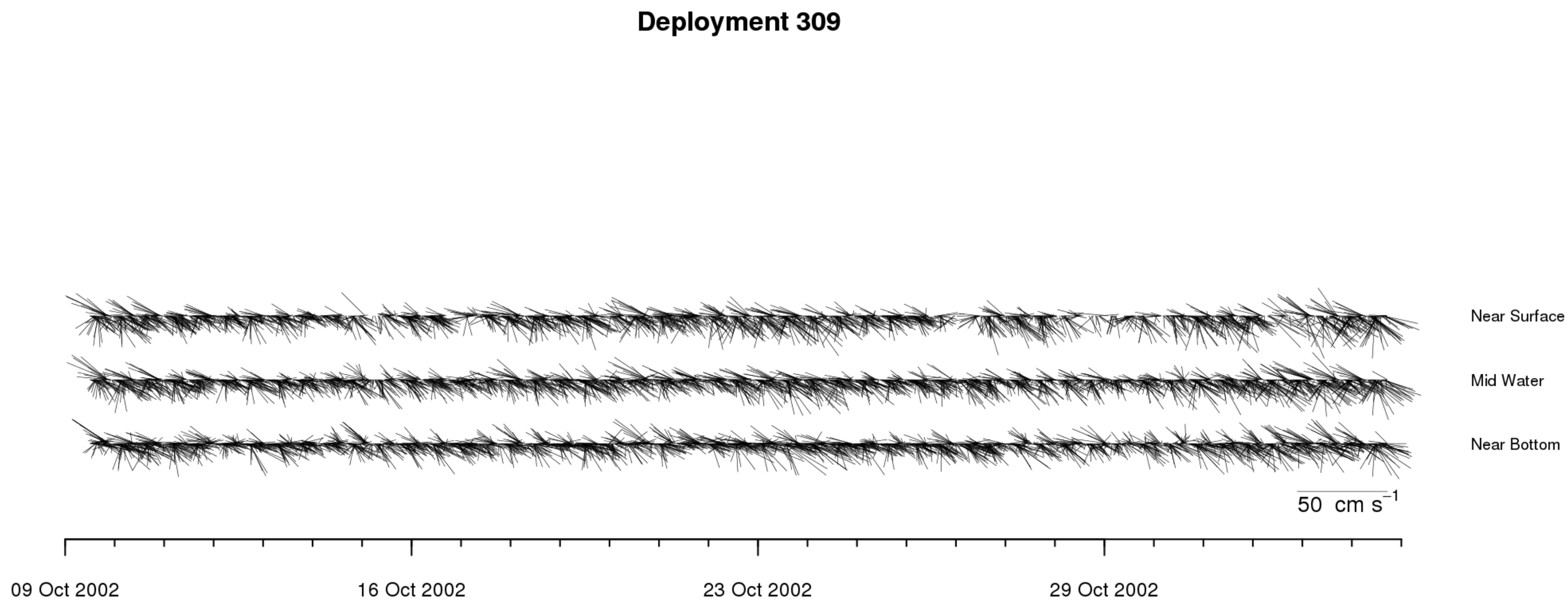

Fig. 39. Stick plots of current velocities in ADCP deployment 309 (Cow Passage, 9 October to 4 November 2002) at three depth levels (near surface, mid-water, and near bottom). The lines show the current direction (true north is straight up) and speed (see scale on graph) in each data segment (15-min intervals).

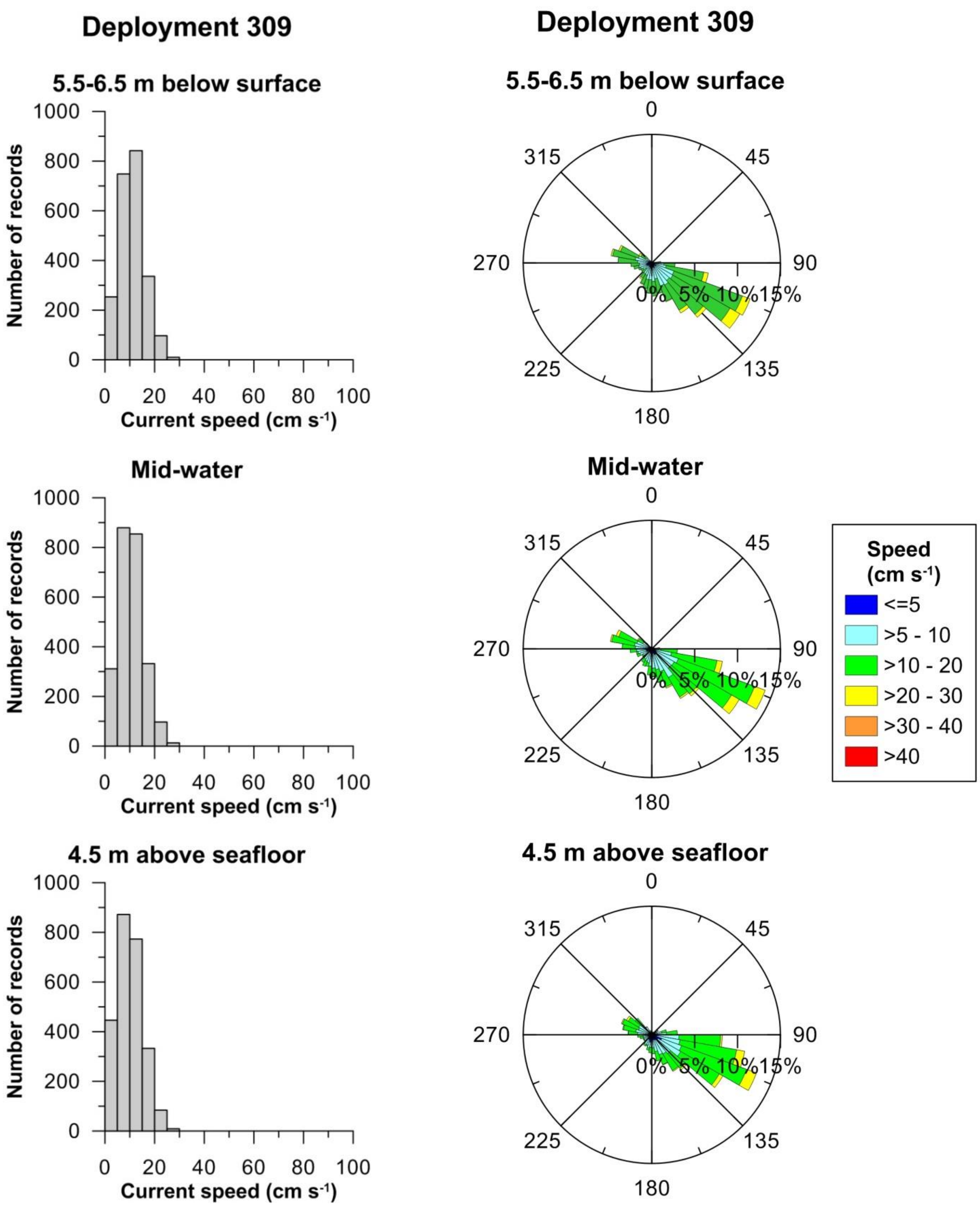

Fig. 40. Current speed histograms (left) and current velocity rose diagrams (right) for ADCP deployment 309 (Cow Passage, 9 October to 4 November 2002). Data are presented for three depth levels: near surface (top), mid-water (middle), and near bottom (bottom).

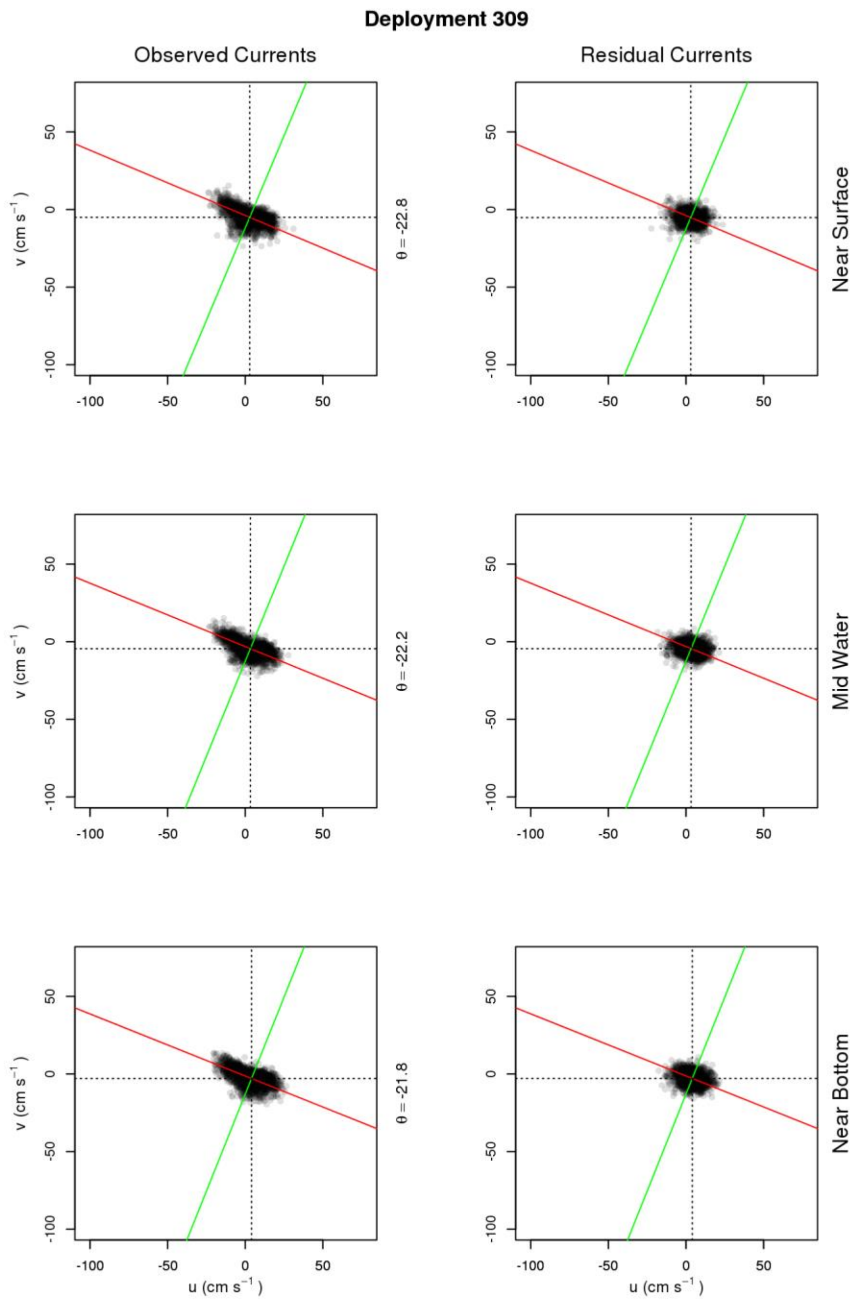

Fig. 41. Scatter plots for current velocities in ADCP deployment 309 (Cow Passage, 9 October to 4 November 2002). Left: observed currents. Right: residual currents where residuals are obtained by removing the tidal signal from the original observation. Current velocity data in the east-west (u) and north-south (v) directions are presented for three depth levels: near surface (top), mid-water (middle), and near bottom (bottom). The red line is the major principal axis and the green line is the minor principal axis. θ = angle of the major axis (degrees from the east-west axis, in a counter-clockwise direction). The dotted lines indicate the mean currents in the east-west and north-south directions.

Table 23. Tidal analysis of water current velocities for ADCP deployment 309. Data are shown for the 5 main tidal constituents (M2, N2, S2, K1, O1). Z0 represents the mean flow in the direction of each principal axis at each depth level (near surface, mid-water, and near bottom). Amplitude = one-half of the range. Maj = in the direction of the major principal axis. Min = in the direction of the minor principal axis. * indicates that the constituent was not included in the 2nd pass of the tidal analysis program based on the value of the t-test. θ = angle of the major axis (degrees from the east-west axis, in a counter-clockwise direction). Time zone used in calculation of phases = UTC.

Deployment 309	Constituent		Amplitude	Phase (°)
Near surface currents ($cm\ s^{-1}$) θ = -22.8	Z0	Maj	4.795	-
		Min	-3.639	-
	M2	Maj	8.217	89.4
		Min	2.138	286.8
	N2	Maj	1.896	55.1
		Min	1.235	273.1
	S2	Maj	1.817	119.0
		Min	0.761	321.9
	K1	Maj	*	*
		Min	*	*
	O1	Maj	0.501	97.5
		Min	*	*
Mid-water currents ($cm\ s^{-1}$) θ = -22.2	Z0	Maj	4.699	-
		Min	-2.873	-
	M2	Maj	7.931	87.8
		Min	1.918	280.1
	N2	Maj	1.711	41.5
		Min	1.217	272.0
	S2	Maj	1.763	123.7
		Min	0.341	348.2
	K1	Maj	0.493	113.5
		Min	*	*
	O1	Maj	0.541	120.1
		Min	*	*
Near bottom currents ($cm\ s^{-1}$) θ = -21.8	Z0	Maj	4.792	-
		Min	-1.188	-
	M2	Maj	7.729	87.0
		Min	1.524	277.1
	N2	Maj	1.633	42.9
		Min	0.926	271.2
	S2	Maj	1.681	126.3
		Min	*	*
	K1	Maj	0.375	119.3
		Min	*	*
	O1	Maj	0.478	129.0
		Min	*	*

Table 24. Variance of observed water current velocity (cm s^{-1}) time series for ADCP deployment 309, with the percent contribution of the current in the major (Maj) and minor (Min) directions to the total variance of the currents, the percent contribution of the 5 main constituents (M2, N2, S2, K1, and O1) to the variances in the Maj and Min directions, and the percent contribution of the M2 constituent to the variances in the Maj and Min directions. The percent contribution was calculated by reconstructing the time series from the specified tidal constituents when they were included in the analysis, as well as any constituents that were inferred from these. The variance was then calculated for the reconstructed signal and used to calculate the percent contribution to the total signal. All variances were calculated using N degrees of freedom where N is the total number of observations in a given record. Maj = in the direction of the major principal axis. Min = in the direction of the minor principal axis.

Deployment 309		Variance	% of variance in Maj and Min directions	% of variance contributed by M2+N2+S2+K1+O1	% of variance contributed by M2 only
Near surface	Maj	94.478	83.1	37.2	34.6
	Min	19.173	16.9	0.2	0.1
Mid-water	Maj	90.781	85.4	35.1	33.7
	Min	15.544	14.6	0.2	0.1
Near bottom	Maj	85.555	83.8	35.2	34.0
	Min	16.525	16.2	0.1	0.1

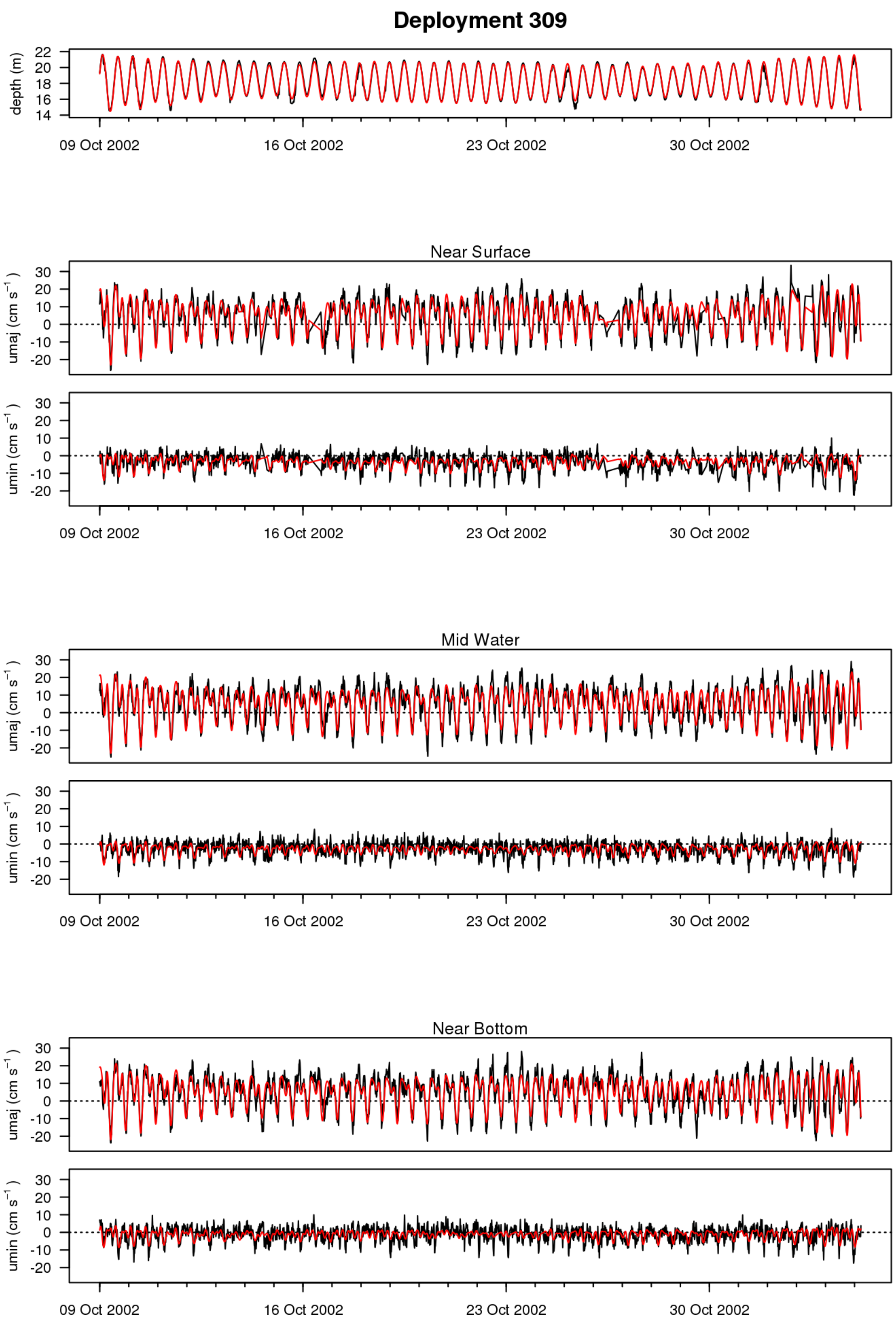

Fig. 42. Time series plots of water depth and current velocity for ADCP deployment 309 (Cow Passage, 9 October to 4 November 2002). Current speeds are plotted in the major (umaj) and minor (umin) directions (as determined by the principal component analysis), for three depth levels (near surface, mid-water, and near bottom). Black lines are the observed currents; red lines are the reconstructed time series from the tidal analysis (tidal constituent).

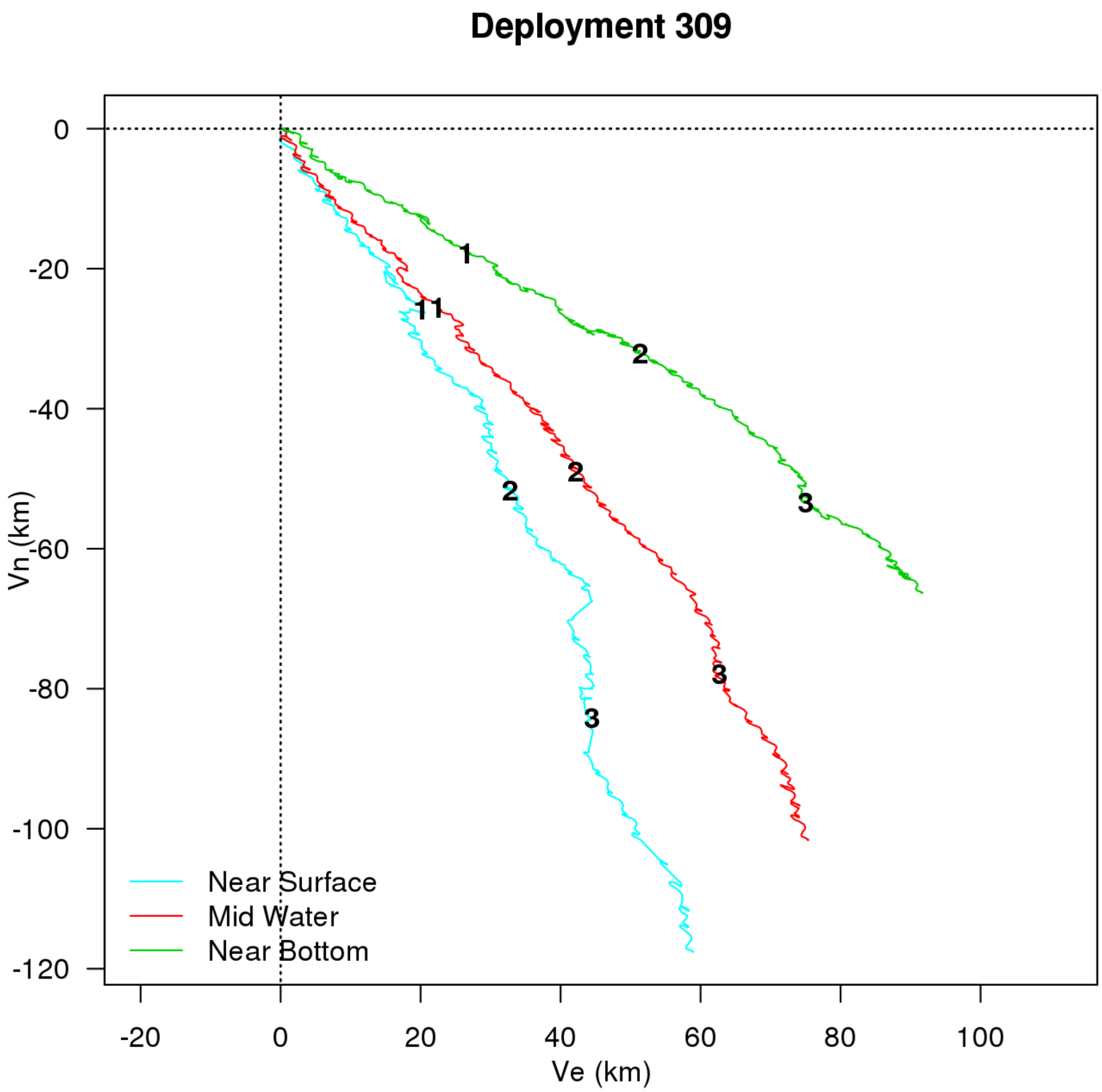

Fig. 43. Progressive vector plot for ADCP deployment 309 (Cow Passage, 9 October to 4 November 2002). Successive movements of a particle are estimated using current velocities measured at 15-min intervals by the current meter. Ve = east-west direction; Vn = north-south direction. Data are presented for three depth levels: near surface (blue), mid-water (red), and near bottom (green). Numbers on the vectors indicate the number of weeks from the time of the first data record. Duration = 26.2 d (3.7 weeks).

SUMMARY AND CONCLUSIONS

Data were collected during 5 ADCP deployments along the eastern coast of Grand Manan Island in 2014. Data were also available from three previous ADCP deployments in the area in 2000 and 2002. Tidal constituents accounted for most of the variance in water depth in all deployments (≥95% for the 5 main tidal constituents and ≥82% for M2 alone). By contrast, the tides accounted for much less of the currents' variations. Furthermore, tidal contributions to the variation in currents varied not only from location to location but also with depth. Common to all deployments, however, the tides contributed very little to the variation of the currents along the minor axis from the principle components analysis.

In the northern part of the study area (Long Island Bay; deployments 540, 541, and 212), mean current speeds were moderate (8.8-16.5 cm s^{-1}), and the flow was mainly east and west. Immediately south of Long Island (deployment 542), currents were weak, especially at mid-water (mean speed 5.9 cm s^{-1}) and near bottom (mean speed 4.3 cm s^{-1}), with no clear directionality; the major axes (from the principal components analysis) accounted for just over half of the total variance (the smallest of all the deployments reported in this study). Just north of Great Duck Island (deployment 543), mean current speeds were slightly stronger than in Long Island Bay (15.7-22.0 cm s^{-1}), with flow mainly to the south. Further south, in Cow Passage (deployments 308 and 309), mean current speeds were moderate (10.1-16.6 cm s^{-1}), the flow directions appeared to be influenced by the nearby shorelines, and the major axes accounted for high portions of the total variance. Further offshore to the east, just northeast of White Head Island (deployment 544), mean current speeds were strongest (27.9-32.2 cm s^{-1}) and the flow was mainly to the northwest and southeast; at this site and at deployment 308, the major axes accounted for the highest portion of the total variance (of all the deployments reported in this study).

Non-tidal constituents were important contributors to the observed variances in current velocity in the northernmost deployments (in Long Island Bay and near Long Island, deployments 212, 540, 541 and 542). Tidal constituents dominated in the southernmost deployments (deployments 308, 543 and 544), except in deployment 309 (which had the slowest current speeds of the deployments in the White Head Island area).

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Watson and K. Coombs (NBDAAF) and B. House (ACFFA) for assisting in project planning. We also thank K. Coombs and F.J. Fife for reviewing a draft of this report.

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ADCP COMPASS CALIBRATION DATA, JULY 2014

New batteries were degaussed and placed in every ADCP. Each ADCP was then initialized on a compass table (at the Bedford Institute of Oceanography, Dartmouth, NS) by pointing the instrument (beam 3) to magnetic north. The instrument was then rotated and recorded every 20°. The instrument was then swung to look for offsets. Measurements before and after calibration are presented in the tables below. Residuals are the absolute values of the differences between nominal values and measurements (before and after calibration). The overall error in compass swing is generated by the ADCP calibration software; values <2° are considered to be acceptable. The following tables present calibration data for ADCPs used in the 2014 deployments; data were not available for the 2000 and 2002 deployments.

Deployment 540 (ADCP Ser. No. 12627)

Nominal (°)	Before (°)	Before residual (°)	After (°)	After residual (°)
0	0.02	0.02	359.80	0.20
20	20.71	0.71	20.05	0.02
40	41.21	1.21	40.26	0.26
60	60.77	0.77	59.80	0.20
80	80.78	0.78	79.76	0.24
100	99.60	0.40	99.30	0.70
120	118.76	1.24	118.91	1.09
140	138.09	1.91	138.49	1.51
160	156.49	3.51	158.13	1.87
180	175.31	4.69	177.90	2.10
200	194.66	5.34	197.75	2.25
220	214.12	5.88	218.05	1.95
240	234.24	5.76	238.17	1.83
260	254.45	5.55	258.17	1.83
280	275.38	4.62	278.69	1.31
300	296.66	3.34	299.10	0.90
320	318.58	1.42	319.21	0.79
340	339.28	0.72	339.71	1.29
360	359.92	0.08	359.88	1.42
Mean		2.52		1.04
Min		0.02		0.02
Max		5.88		2.25
SD		2.10		0.74

Overall error in compass swing after calibration = 0.7°

Deployment 541 (ADCP Ser. No. 12570)

Nominal (°)	Before (°)	Before residual (°)	After (°)	After residual (°)
0	359.94	0.06	0.68	0.68
20	20.74	0.74	20.77	0.77
40	41.56	1.56	40.63	0.63
60	61.57	1.57	59.94	0.06
80	81.33	1.33	79.63	0.37
100	101.81	1.81	98.94	1.06
120	119.95	0.05	119.24	0.76
140	139.21	0.79	138.80	1.20
160	158.11	1.89	158.71	1.29
180	176.82	3.18	178.74	1.26
200	195.95	4.05	198.92	1.08
220	215.76	4.24	218.74	1.26
240	235.34	4.66	238.63	1.37
260	255.76	4.24	258.37	1.63
280	276.16	3.84	278.63	1.37
300	296.93	3.07	298.79	1.21
320	318.22	1.78	319.56	0.44
340	339.02	0.98	340.37	0.37
360	0.03	0.03	0.85	0.85
Mean		2.10		0.93
Min		0.03		0.06
Max		4.66		1.63
SD		1.51		0.41

Overall error in compass swing after calibration = 1.8°

Deployment 542 (ADCP Ser. No. 12610)

Nominal (°)	Before (°)	Before residual (°)	After (°)	After residual (°)
0	359.20	0.80	0.05	0.05
20	19.33	0.67	19.79	0.21
40	39.47	0.53	40.04	0.04
60	58.65	1.35	60.53	0.53
80	78.19	1.81	80.29	0.29
100	97.32	2.68	100.47	0.47
120	116.40	3.60	120.62	0.62
140	135.01	4.99	140.33	0.33
160	154.18	5.82	160.08	0.08
180	173.54	6.46	179.43	0.57
200	193.19	6.81	198.84	1.16
220	213.59	6.41	218.35	1.65
240	233.91	6.09	238.26	1.74
260	254.90	5.10	258.22	1.78
280	275.66	4.34	278.58	1.42
300	297.26	2.74	298.89	1.11
320	318.25	1.75	319.32	0.68
340	339.20	0.80	339.62	0.38
360	359.64	0.36	359.78	0.22
Mean		3.32		0.70
Min		0.36		0.04
Max		6.81		1.78
SD		2.27		0.57

Overall error in compass swing after calibration = 1.0°

Deployment 543 (ADCP Ser. No. 12605)

Nominal (°)	Before (°)	Before residual (°)	After (°)	After residual (°)
0	359.50	0.50	0.24	0.24
20	19.23	0.77	20.02	0.02
40	39.11	0.89	40.01	0.01
60	59.93	0.07	59.54	0.46
80	79.36	0.64	79.57	0.43
100	99.32	0.68	99.62	0.38
120	119.58	0.42	119.84	0.16
140	140.19	0.19	140.22	0.22
160	160.28	0.28	160.99	0.99
180	180.83	0.83	181.48	1.48
200	200.97	0.97	201.36	1.36
220	221.18	1.18	221.14	1.14
240	240.99	0.99	240.52	0.52
260	260.84	0.84	260.18	0.18
280	280.55	0.55	279.90	0.10
300	299.99	0.01	300.06	0.06
320	319.80	0.20	319.81	0.19
340	339.58	0.42	340.09	0.09
360	359.62	0.38	0.23	0.23
Mean		0.57		0.43
Min		0.01		0.01
Max		1.18		1.48
SD		0.33		0.45

Overall error in compass swing after calibration = 1.4°

Deployment 544 (ADCP Ser. No. 12608)

Nominal (°)	Before (°)	Before residual (°)	After (°)	After residual (°)
0	0.60	0.60	359.09	0.91
20	21.18	1.18	19.38	0.62
40	42.04	2.04	39.58	0.42
60	62.54	2.54	59.80	0.20
80	82.40	2.40	80.51	0.51
100	101.73	1.73	99.88	0.12
120	121.60	1.60	120.06	0.06
140	140.63	0.63	139.62	0.38
160	160.23	0.23	159.17	0.83
180	179.40	0.60	179.00	1.00
200	198.29	1.71	198.70	1.30
220	218.31	1.69	218.75	1.25
240	237.99	2.01	238.56	1.44
260	257.58	2.42	258.51	1.49
280	277.34	2.66	278.79	1.21
300	297.67	2.33	298.33	1.67
320	318.29	1.71	318.54	1.46
340	339.57	0.43	338.76	1.24
360	0.59	0.59	359.19	0.81
Mean		1.53		0.89
Min		0.23		0.06
Max		2.66		1.67
SD		0.78		0.49

Overall error in compass swing after calibration = 1.2°

SET UP PARAMETERS FOR ADCP DEPLOYMENTS

Set up parameters for ADCPs deployed off the east coast of Grand Manan Island in 2014 and 2000-2002. Bin size = vertical distance over which measurements are averaged. Segment interval = time between the start of consecutive segments. Segment length = time duration of each segment. Ping interval = time between consecutive acoustic pings within a segment. Standard deviation = estimated standard deviation of current velocity measurements (see the Methods section in the main report for further details).

Deploy-ment	ADCP frequency (kHz)	Bin size (m)	Segment interval (min)	Segment length (min)	Ping interval (s)	Number of pings per segment	Standard deviation (cm s^{-1})
2014 deployments							
540	600	1	20	4	1.0	240	0.45
541	600	1	20	4	1.0	240	0.45
542	600	1	20	4	1.0	240	0.45
543	600	1	20	4	1.0	240	0.45
544	600	1	20	4	1.0	240	0.45
2000 & 2002 deployments							
212	300	1	15	5	3.0	100	1.36
308	300	1	15	5	3.0	100	1.36
309	300	1	15	5	3.0	100	1.36

SIGNAL INTENSITY PER DEPTH INTERVAL FOR ADCP DEPLOYMENTS

Box and whisker plots of signal intensity at 1-m depth intervals for ADCP deployments off the east coast of Grand Manan Island. Thick vertical lines represent medians. Boxes extend from the 1st to 3rd quartiles (= the interquartile range). Thin vertical lines (at the ends of the dashed horizontal lines) represent the ranges, excluding outliers. Small circles represent outliers; outliers are values that are at least 1.5 interquartile ranges below the 1st quartile or at least 1.5 interquartile ranges above the 3rd quartile. Also shown are the percentages of current velocity data records at 1-m depth intervals (red diamonds); 100% indicates that data were obtained in every 20-min segment throughout the deployment.

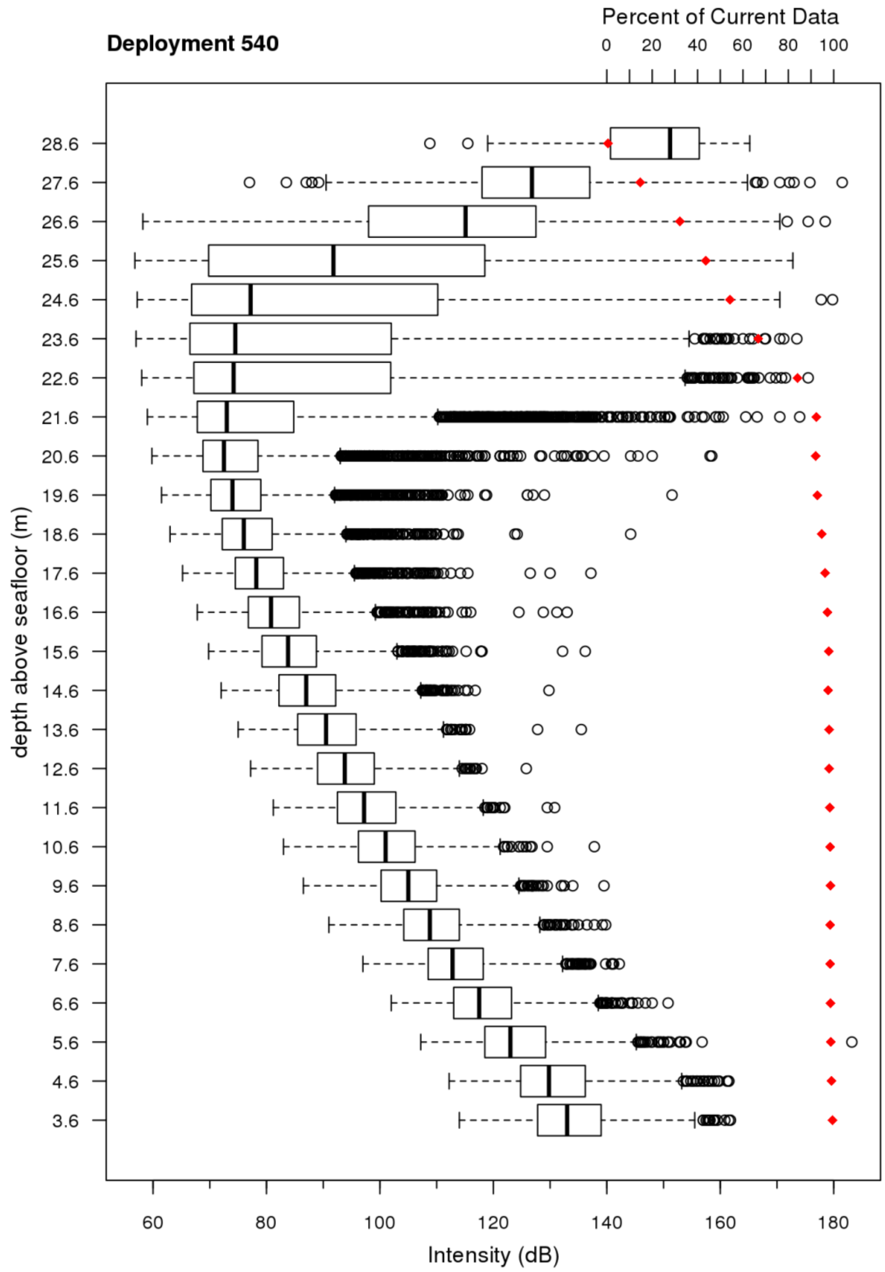

Fig. C1. Box and whisker plots of signal intensity at 1-m depth intervals for ADCP deployment 540 (Long Island Bay, 3 April to 25 May 2014). Mean water depth = 26.8 m.

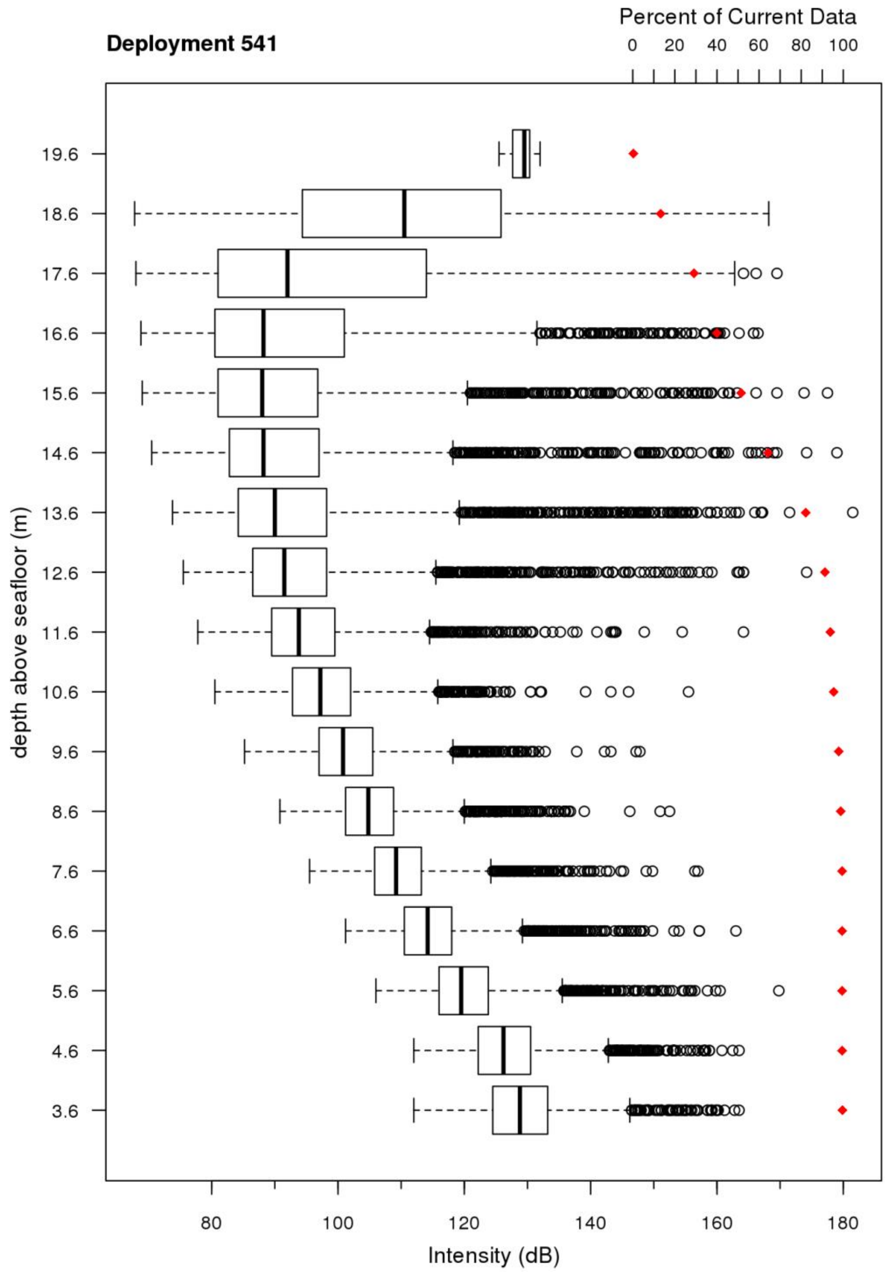

Fig. C2. Box and whisker plots of signal intensity at 1-m depth intervals for ADCP deployment 541 (Long Island Bay, 3 April to 22 May 2014). Mean water depth = 17.7 m.

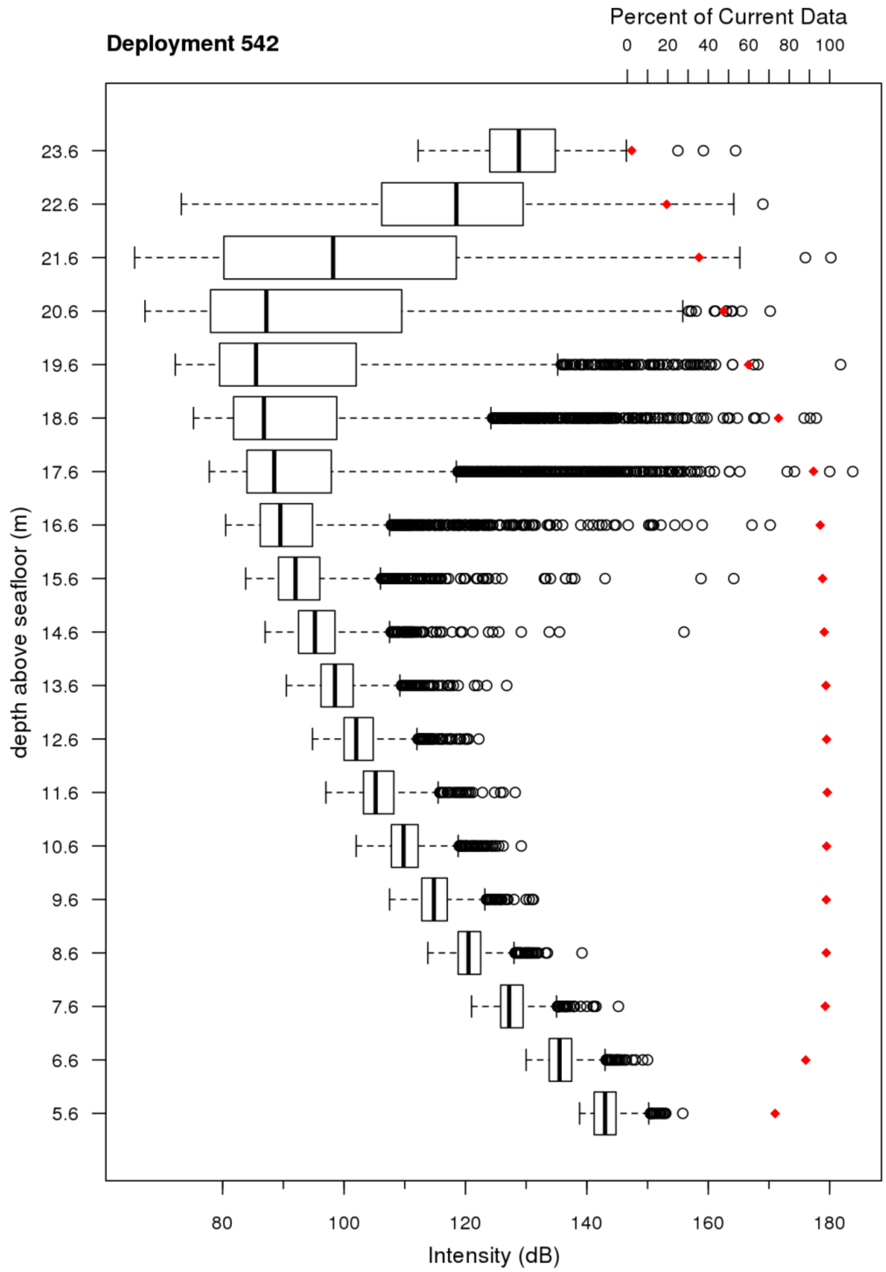

Fig. C3. Box and whisker plots of signal intensity at 1-m depth intervals for ADCP deployment 542 (south of Long Island, 3 April to 21 May 2014). Mean water depth = 22.1 m.

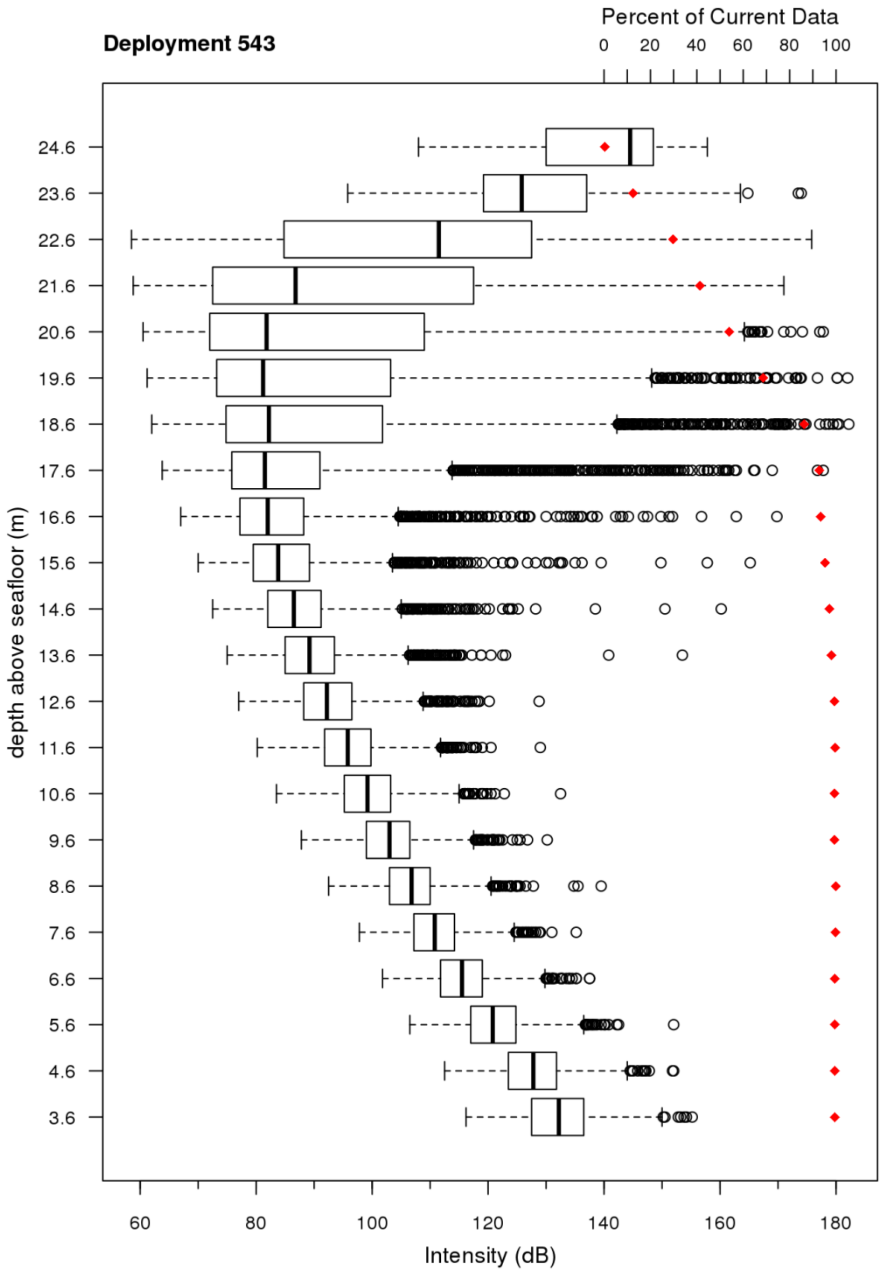

Fig. C4. Box and whisker plots of signal intensity at 1-m depth intervals for ADCP deployment 543 (north of Great Duck Island, 3 April to 21 May 2014). Mean water depth = 22.8 m.

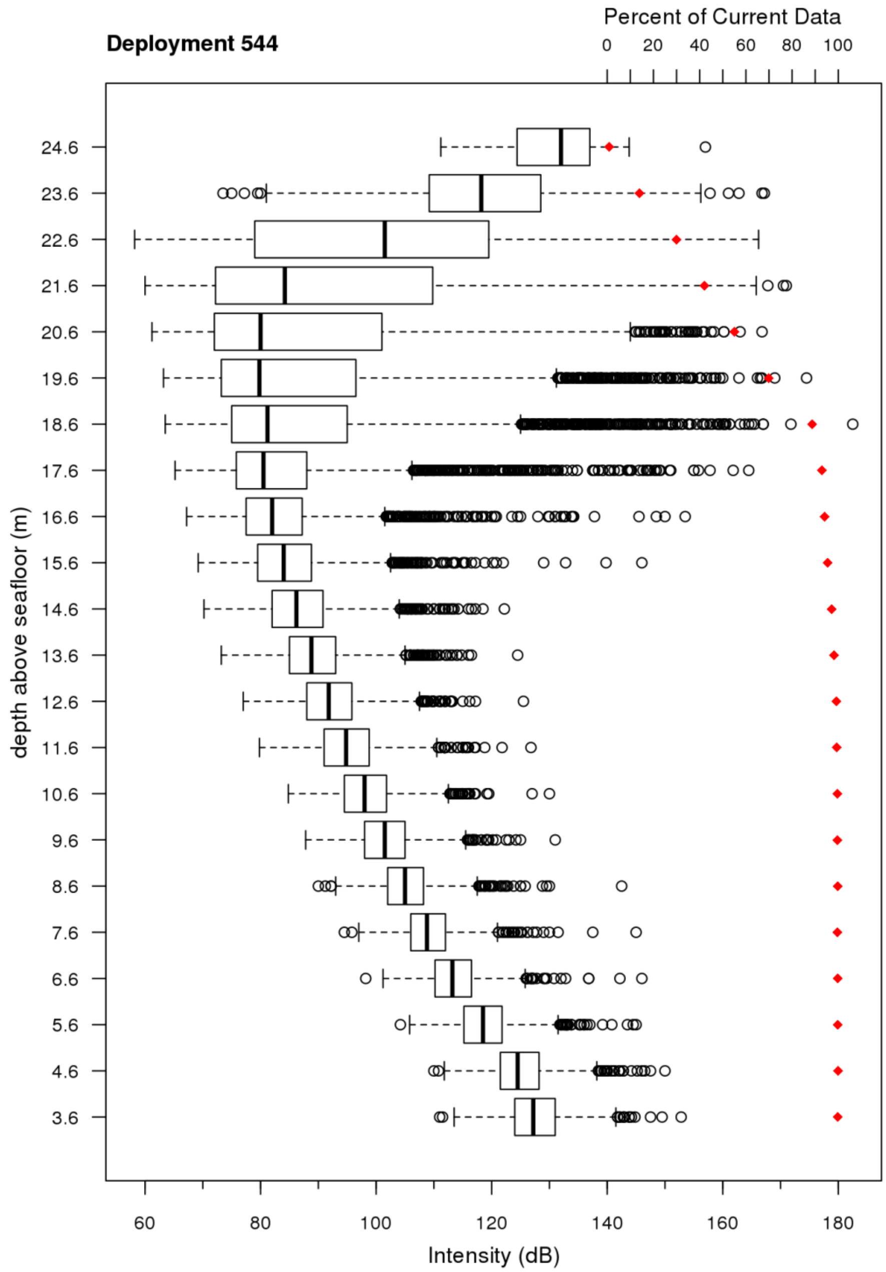

Fig. C5. Box and whisker plots of signal intensity at 1-m depth intervals for ADCP deployment 544 (northeast of White Head Island, 3 April to 21 May 2014. Mean water depth = 23.0 m.

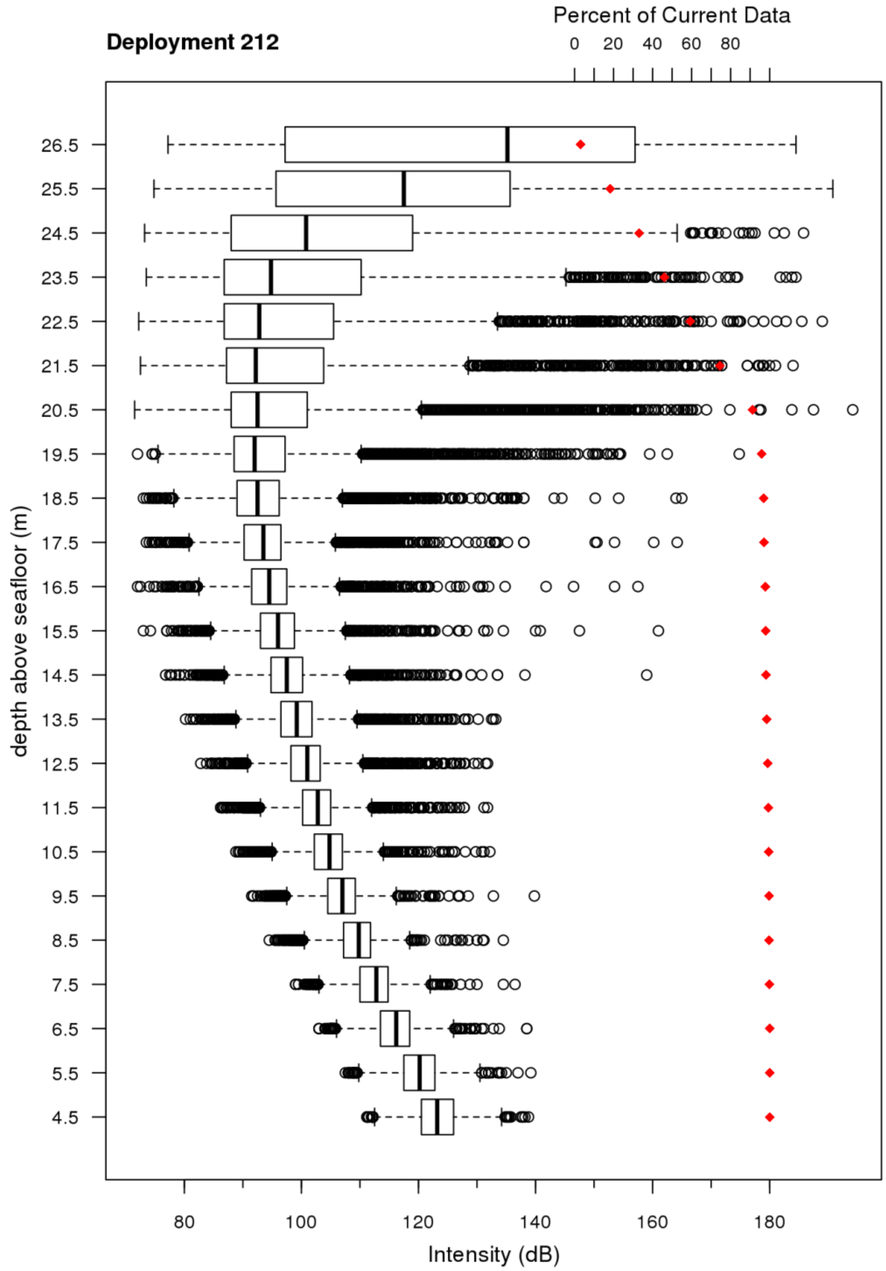

Fig. C6. Box and whisker plots of signal intensity at 1-m depth intervals for ADCP deployment 212 (Long Island Bay, 24 May to 9 July 2000). Mean water depth = 25.5 m.

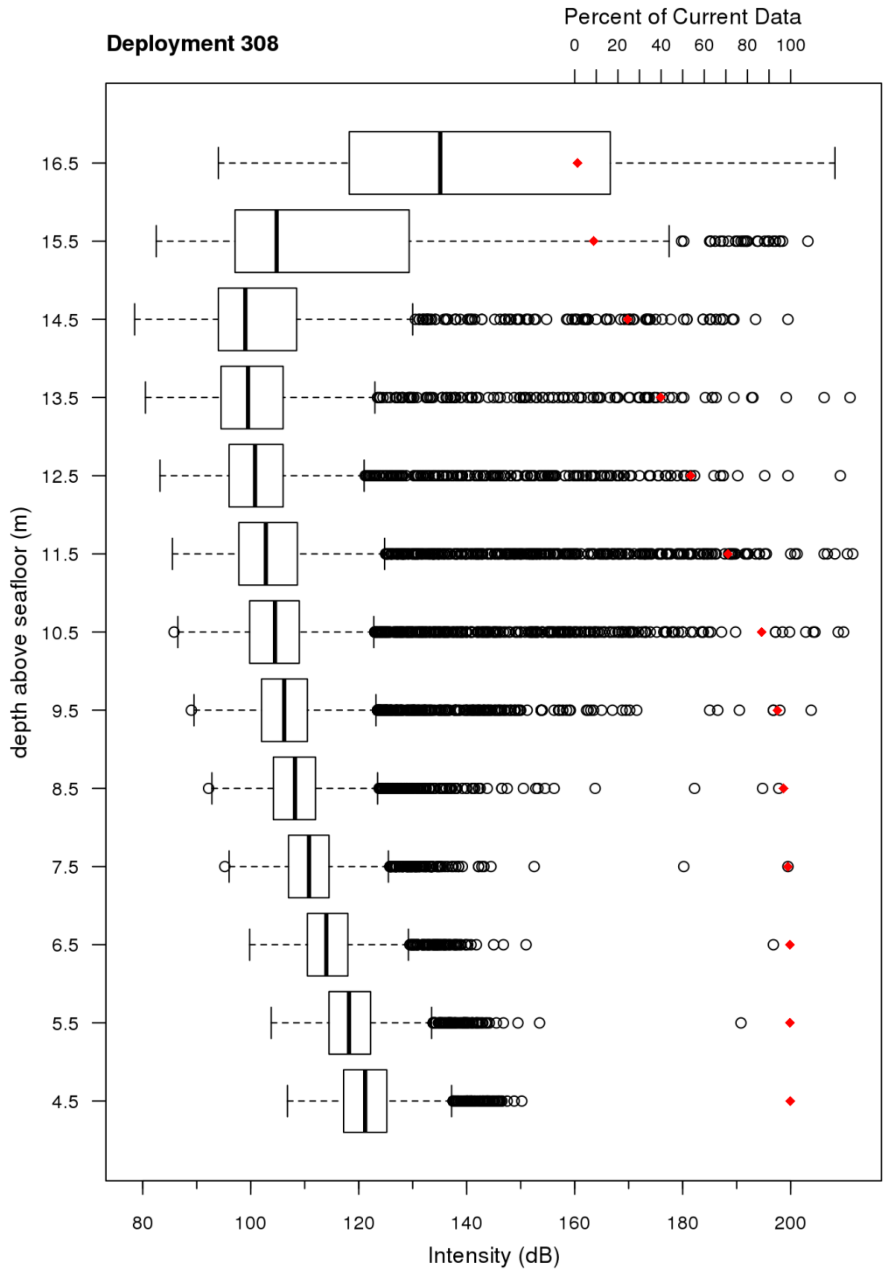

Fig. C7. Box and whisker plots of signal intensity at 1-m depth intervals for ADCP deployment 308 (Cow Passage, 28 August to 8 October 2002). Mean water depth = 14.9 m.

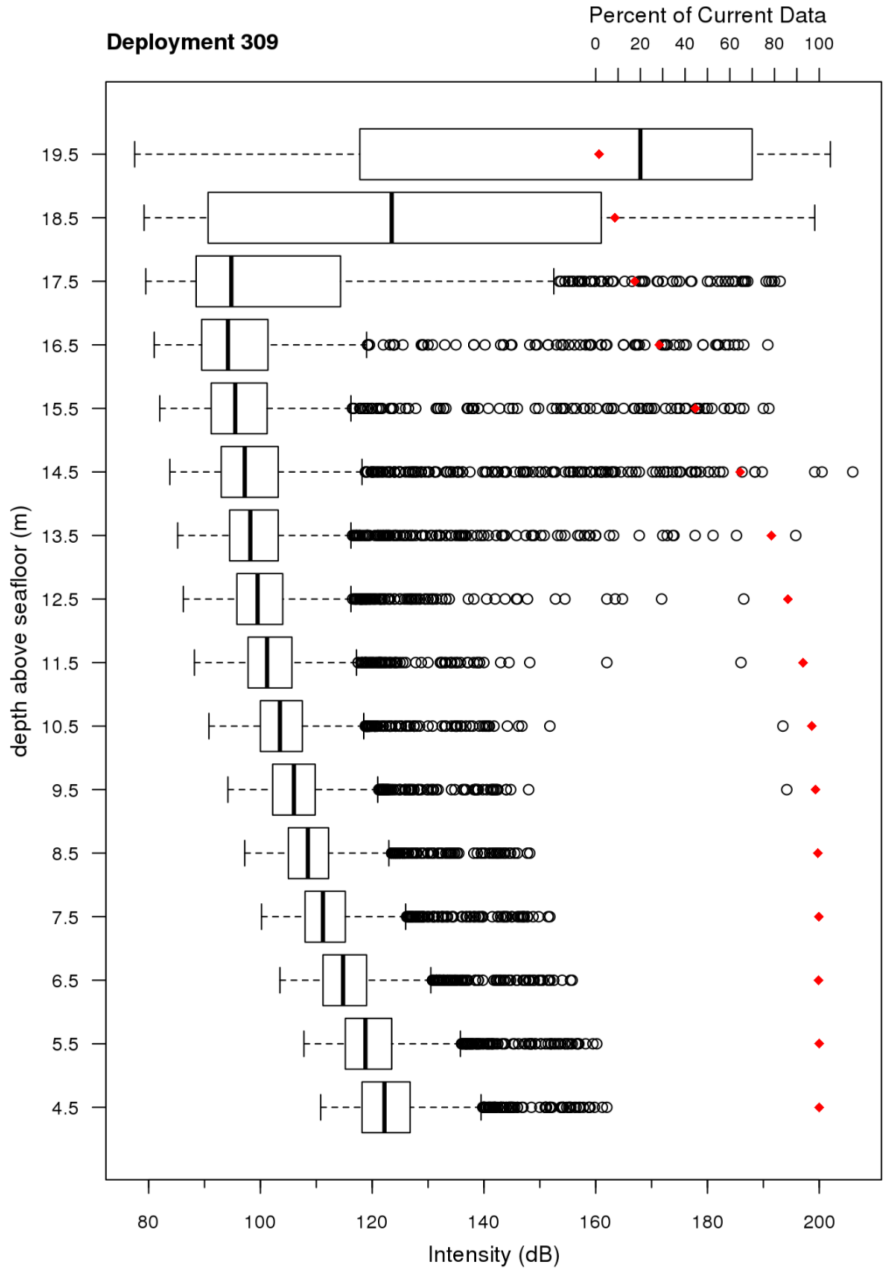

Fig. C8. Box and whisker plots of signal intensity at 1-m depth intervals for ADCP deployment 309 (Cow Passage, 9 October to 4 November 2002). Mean water depth = 18.3 m.

TIDAL ANALYSIS OF ADCP CURRENT DATA

Results of tidal analysis of ADCP current velocity data from the east coast of Grand Manan Island. The data have been decomposed into major and minor axes using principal component analysis. Data shown include: θ (angle of the major principal components axis, in degrees from the east-west axis in a counter-clockwise direction; blue dots), and amplitude (A) and phase (P) for the 5 main tidal constituents (M2, N2, S2, K1, and O1). For amplitude and phase, red/green dots are for the results of tidal analysis along the major/minor axes. Data are presented using three depth axes: σ (10 equal depth bins, from the sea surface [0.0] to the seafloor [-1.0]), depth above the seafloor, and depth below the surface. Data are shown for depth levels where current measurements were obtained in ≥80% of all segments during the deployment. See the Methods section in the main report for further details.

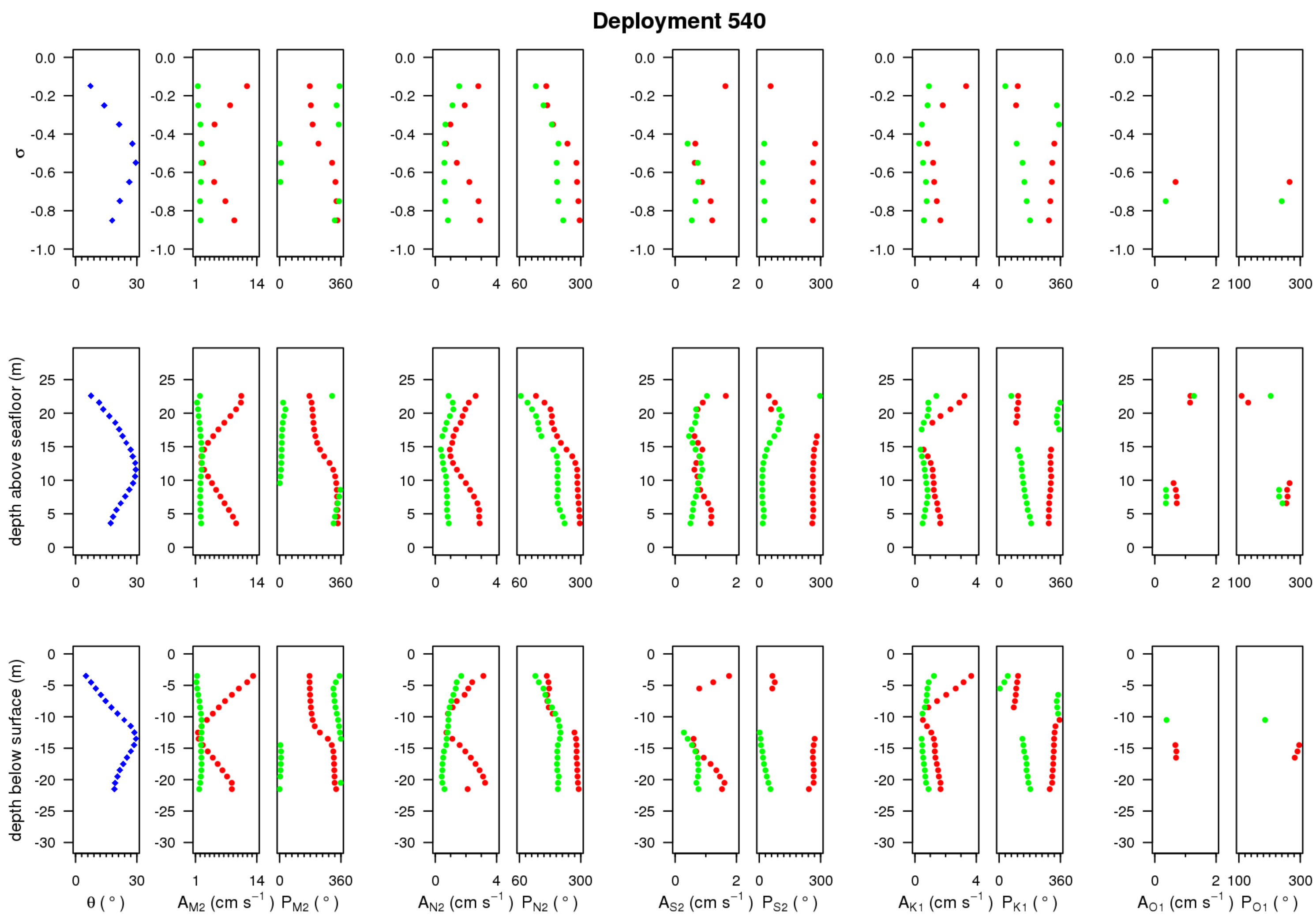

Fig. D1. Results of tidal analyses for ADCP deployment 540 (Long Island Bay, 3 April to 25 May 2014). Amplitude (A) and phase (P) of the 5 main tidal constituents (M2, N2, S2, K1, O1) along the major (red dots) and minor (green dots) axes (determined using principal components analysis) are plotted against depth (using three depth scales). θ = angle of major axis (blue dots).

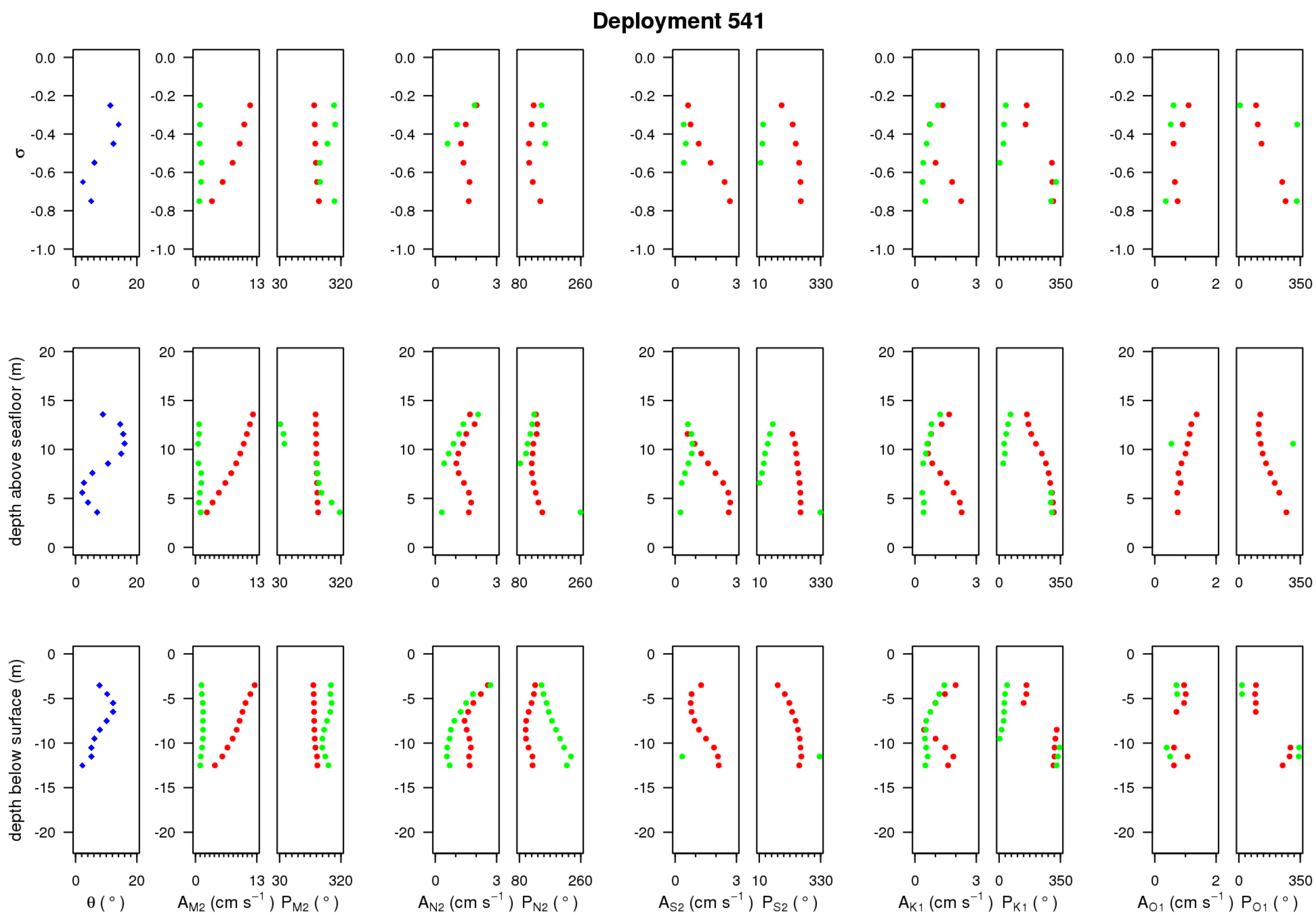

Fig. D2. Results of tidal analyses for ADCP deployment 541 (Long Island Bay, 3 April to 22 May 2014). Amplitude (A) and phase (P) of the 5 main tidal constituents (M2, N2, S2, K1, O1) along the major (red dots) and minor (green dots) axes (determined using principal components analysis) are plotted against depth (using three depth scales). θ = angle of major axis (blue dots).

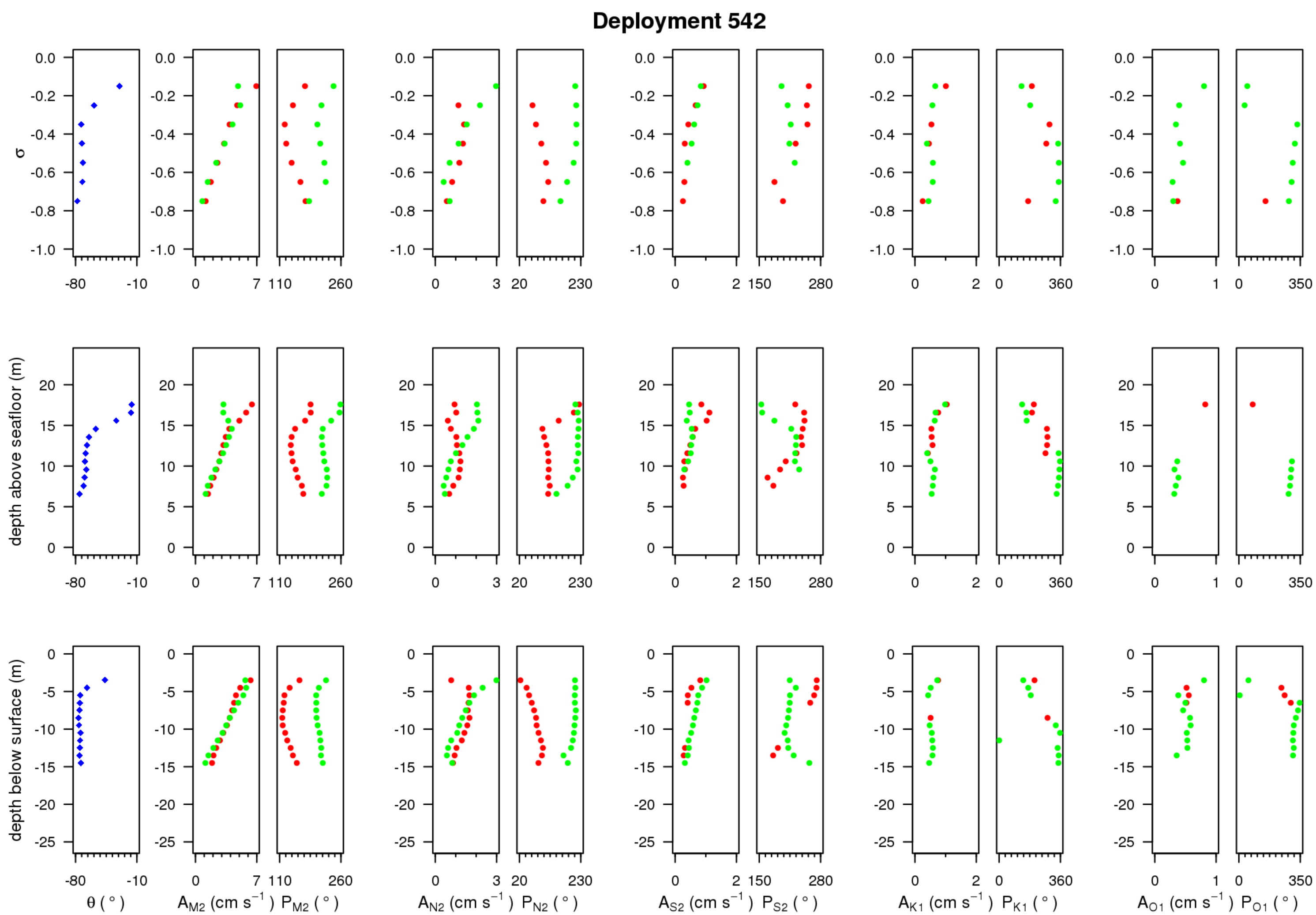

Fig. D3. Results of tidal analyses for ADCP deployment 542 (south of Long Island, 3 April to 21 May 2014). Amplitude (A) and phase (P) of the 5 main tidal constituents (M2, N2, S2, K1, O1) along the major (red dots) and minor (green dots) axes (determined using principal components analysis) are plotted against depth (using three depth scales). θ = angle of major axis (blue dots).

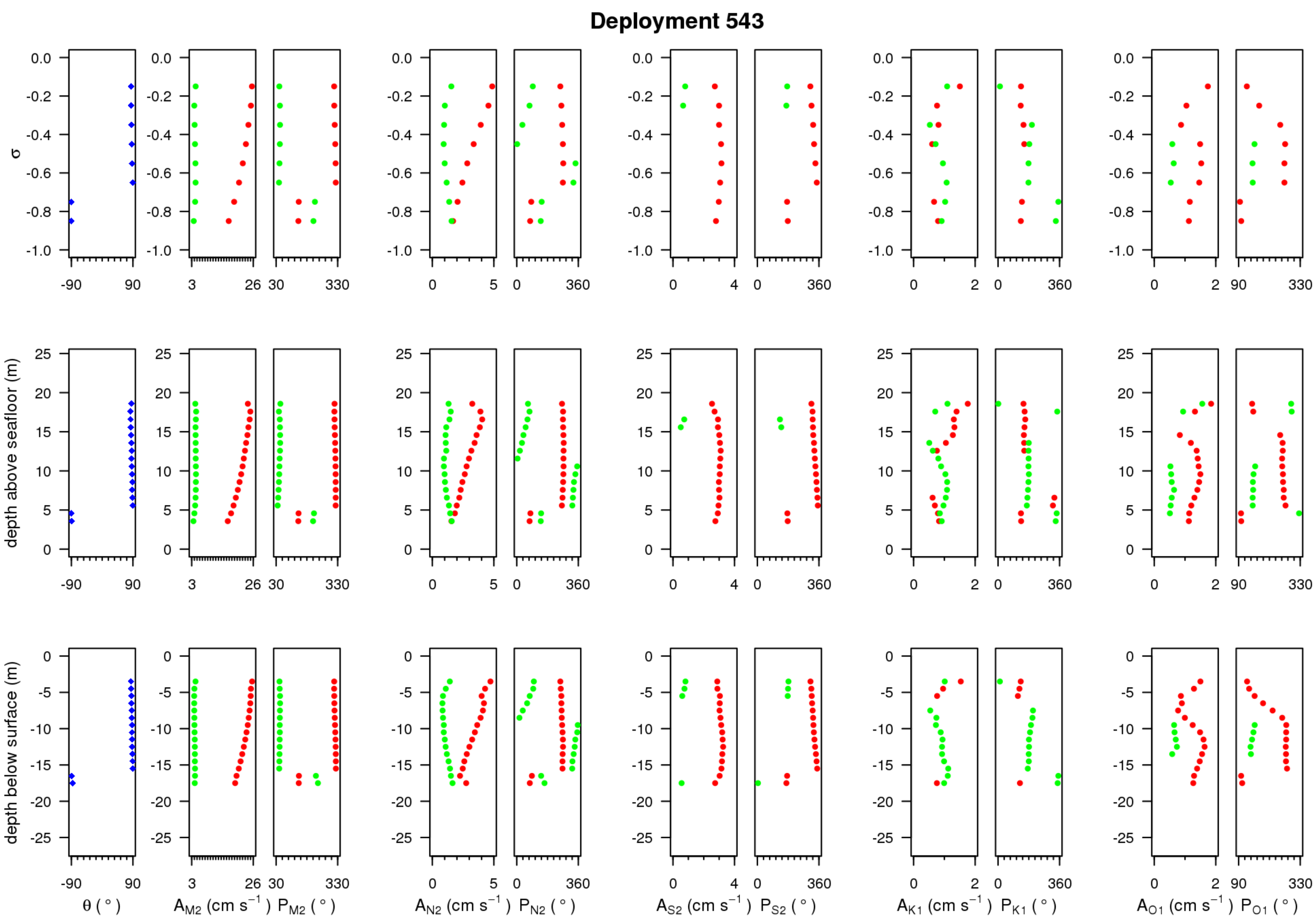

Fig. D4. Results of tidal analyses for ADCP deployment 543 (north of Great Duck Island, 3 April to 21 May 2014). Amplitude (A) and phase (P) of the 5 main tidal constituents (M2, N2, S2, K1, O1) along the major (red dots) and minor (green dots) axes (determined using principal components analysis) are plotted against depth (using three depth scales). θ = angle of major axis (blue dots).

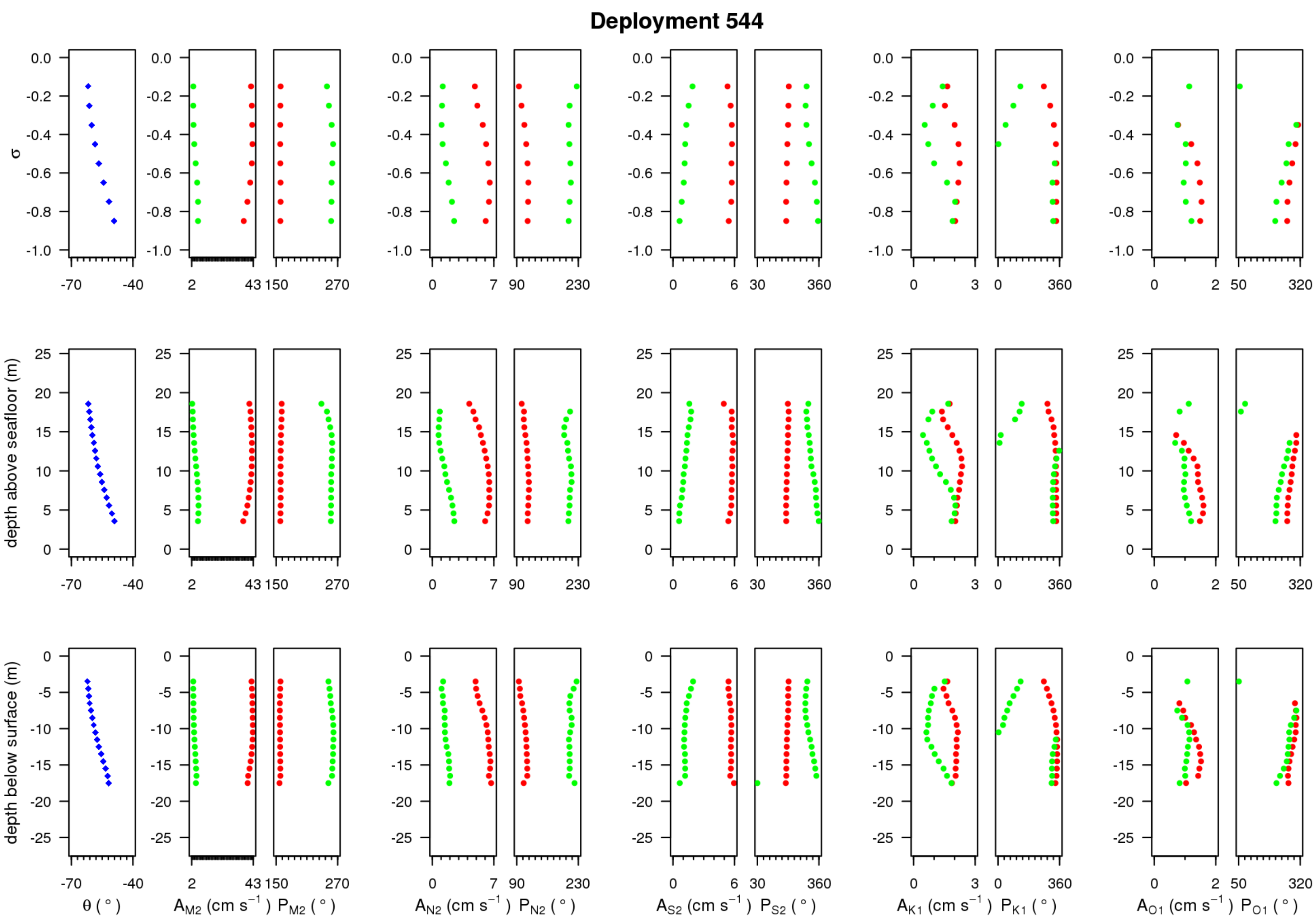

Fig. D5. Results of tidal analyses for ADCP deployment 544 (northeast of White Head Island, 3 April to 21 May 2014). Amplitude (A) and phase (P) of the 5 main tidal constituents (M2, N2, S2, K1, O1) along the major (red dots) and minor (green dots) axes (determined using principal components analysis) are plotted against depth (using three depth scales). θ = angle of major axis (blue dots).

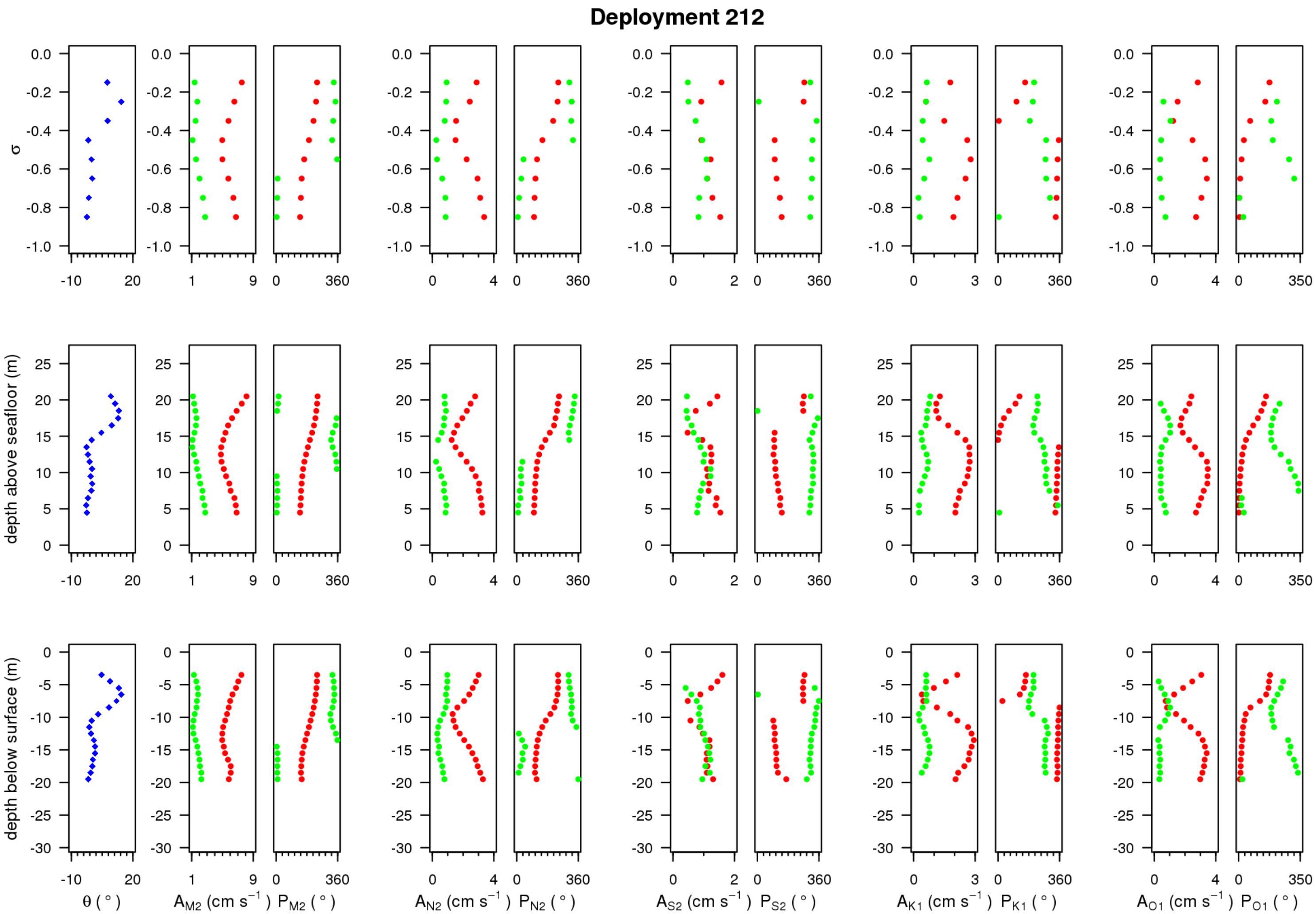

Fig. D6. Results of tidal analyses for ADCP deployment 212 (Long Island Bay, 24 May to 9 July 2000). Amplitude (A) and phase (P) of the 5 main tidal constituents (M2, N2, S2, K1, O1) along the major (red dots) and minor (green dots) axes (determined using principal components analysis) are plotted against depth (using three depth scales). θ = angle of major axis (blue dots).

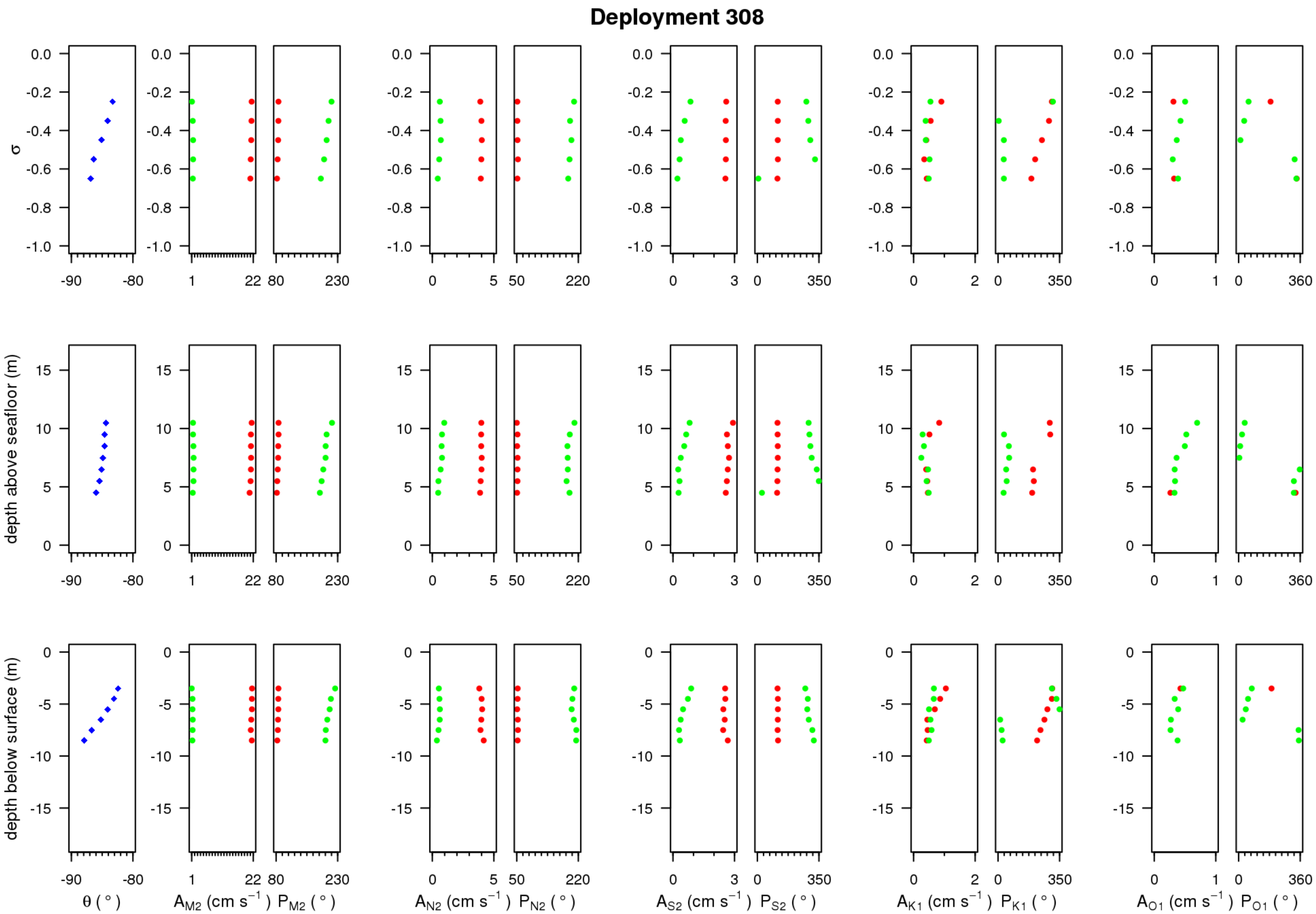

Fig. D7. Results of tidal analyses for ADCP deployment 308 (Cow Passage, 28 August to 8 October 2002). Amplitude (A) and phase (P) of the 5 main tidal constituents (M2, N2, S2, K1, O1) along the major (red dots) and minor (green dots) axes (determined using principal components analysis) are plotted against depth (using three depth scales). θ = angle of major axis (blue dots).

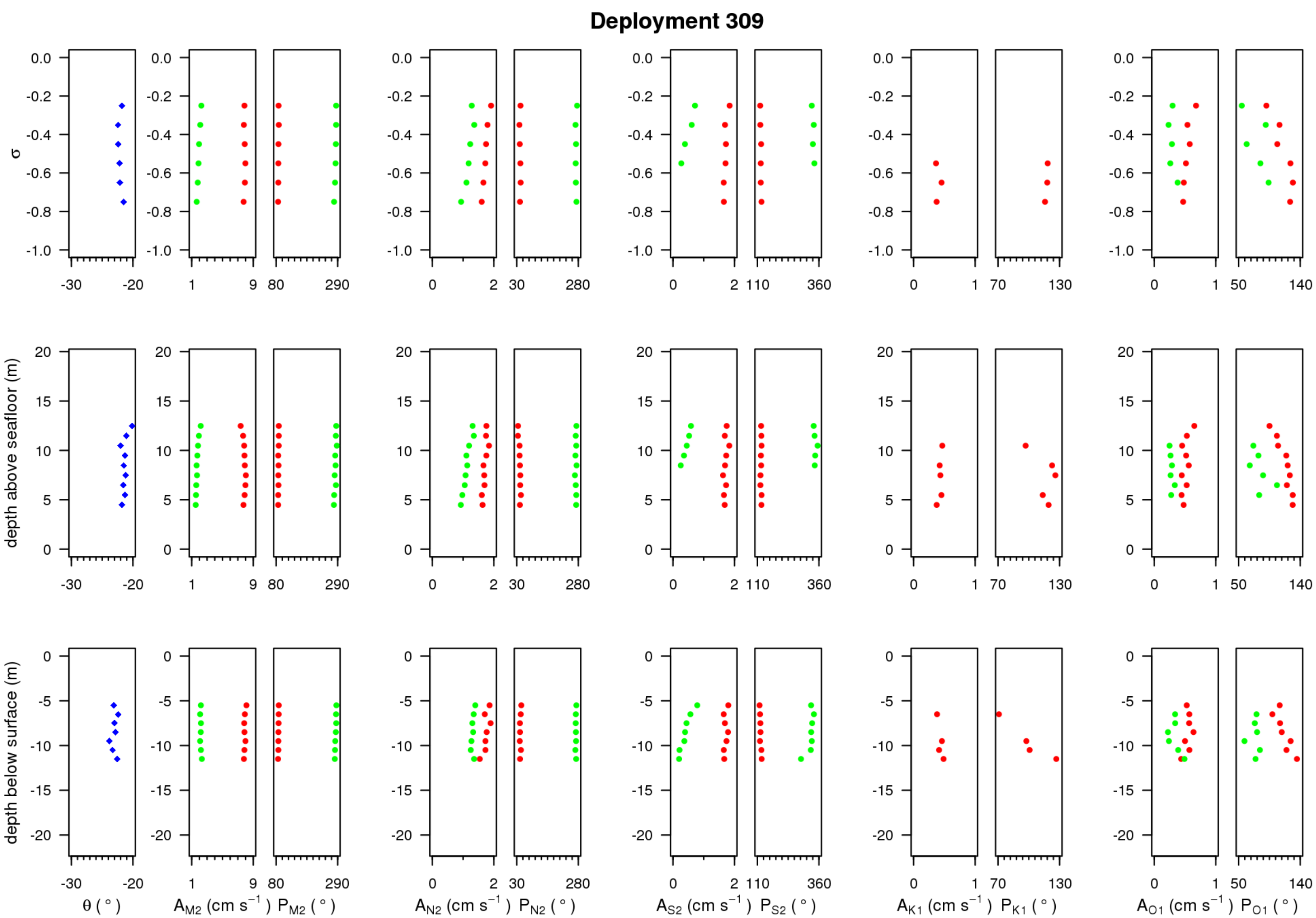

Fig. D8. Results of tidal analyses for ADCP deployment 309 (Cow Passage, 9 October to 4 November 2002). Amplitude (A) and phase (P) of the 5 main tidal constituents (M2, N2, S2, K1, O1) along the major (red dots) and minor (green dots) axes (determined using principal components analysis) are plotted against depth (using three depth scales). θ = angle of major axis (blue dots).