ADCP Data Quality Control

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06/12/2011

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NATURAL ENVIRONMENT RESEARCH COUNCIL

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Introduction

Liverpool Bay ADCP Measurements

Liverpool Bay (Figure 1) is a semi-enclosed shallow subsection of the eastern Irish Sea. Liverpool Bay is a coastal sea system with strong tidal mixing, occasional large storm surges and waves, freshwater input from the rivers Mersey, Dee, Ribble, Clwyd and Conwy, and stable and unstable stratification. The three dominant physical processes are the semi-diurnal tides, near-shore density gradients, and vertical stratification (Polton *et al., 2011*).

Three near-shore *in situ* moorings have been continually maintained in Liverpool Bay. Site A, close to the mouth of the river Mersey at 53° 32' N, 3° 21.8' W was established in August 2002, with a mean water depth of 23.5 m. A second site, Site B, (later referred to as 'old site B'), was established at 53° 27' N, 3° 38.6' W in April 2005, where the mean water depth is 25.0 m. In January 2010, Site B was moved to 53° 32.3' N, 3° 38.4' W, (later referred to as 'new site B'), where the mean water depth is 36.8 m.

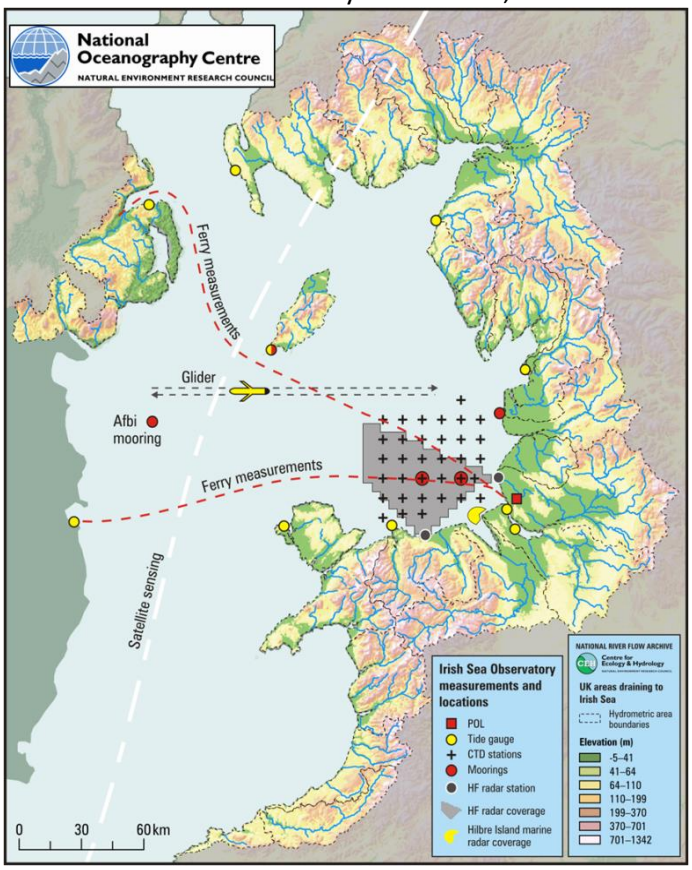

Figure 1: Liverpool Bay Monitoring System
yellow Dots= tide gauges; red dots with cross= moorings; dotted lined= possible ferry routes; shaded area= HF radar coverage; crosses= CTD stations, SPM, nutrients survey points; square= met station.

Aim

To assess the quality of all COBS ADCP data from 2002- present and where required, make corrections for magnetic declination errors, remove above surface bins and side lobe contamination as well as correct for compass errors.

ADCP (Acoustic Doppler Current Profiler)

The ADCPs (Acoustic Doppler Current Profiler) (Lu & Lueck, 1998) used in Liverpool Bay recorded along beam velocities at a 10 min resolution. The water column was divided into uniform segments (bins) of 1m and the velocities were averaged over each bin.

Quality control method

A quality control was required to correct the data for magnetic declination errors, remove bins above the surface and contaminated near surface bins as well as correct for compass errors. Any changes made to the data during the quality control are noted as comments in the header of each file and are also remarked in the COBS_ADCP_Data_Catalogue.xls.

1. Corrections

a) Correction for magnetic declination errors

Magnetic declination is the angle between magnetic and true north. It varies spatially and with time due to the change of earth's magnetic field. Since the previous correction was a fixed value for the start of the observing period the variation over time was needed.
For each site declinations were calculated using Geomag 7.0 (International Association of Geomagnetism and Aeronomy, Working Group V-MOD, 2010). The declinations calculated using this software can be found in the accompanying documentation.

b) Remove bins above the surface

The sea surface was calculated using CSIRO seawater toolbox ver.3.2 (Morgans, 2006) from the pressure. The ADCP pressure record was used for most files, however sometimes this was not available or faulty then pressure of an alongside ADCP or of a different pressure recording instrument on the same frame was used. The bins above the surface were blanked with non values (NaN).

(i) Using backscatter intensity

If no pressure records were available or it could not be used the intensity backscatter was used to calculate the surface. Backscatter data are collected for each beam thus the average of the four data sets was used. The sea surface is a relatively hard surface hence it can be detected looking for the strongest backscatter signal in the upper water column. After comparing the running mean of the backscatter deduced sea surface height with the running mean of the sea surface height based on the pressure record the index point was found from which the backscatter intensity was used (Figure 2) instead of the pressure signal. Thereafter the pressure record was blanked with non values (NaN).

Side lobe contamination

While ADCP sound signals are sent out in all directions at the same time, the strength is direction dependent. Whereas the largest amount of the energy passes through the main lobe, the side lobes, which are on an angle relative to the main lobes, are generally suppressed at a certain frequency in relation to the main lobe (Teledyne RD Instruments, 2006). Side lobes can be a major source of error particularly close to the sea surface. After the sea surface was calculated significant side lobe contamination was found in the three near surface bins (Figure 3, Figure 4), which were then blanked with non values (NaN). From the fourth bin away from the surface (light blue and purple graph in Figure 3, light blue and purple dots in Figure 4) the data appear noise free.

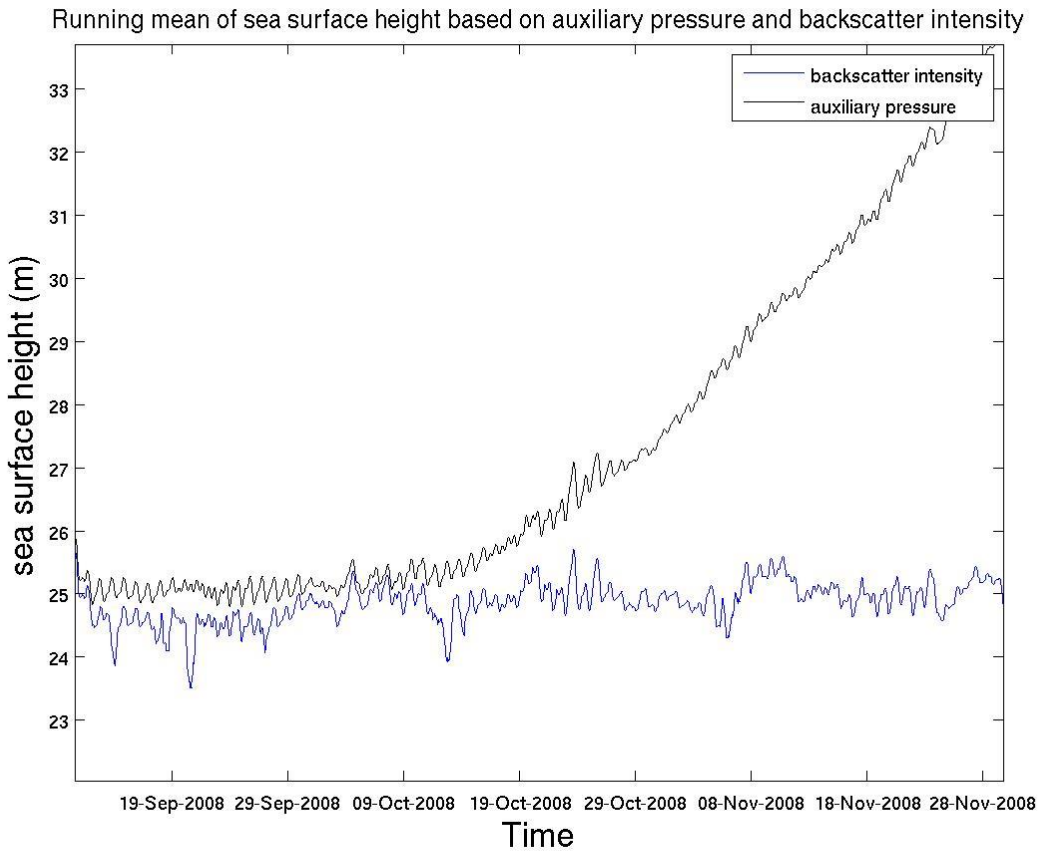

Figure 2 Running mean of sea surface height based on backscatter intensity (blue) and auxiliary pressure record (black). In this particular example the pressure significantly deviates from the backscatter intensity from the 9th of October 2008 onwards.

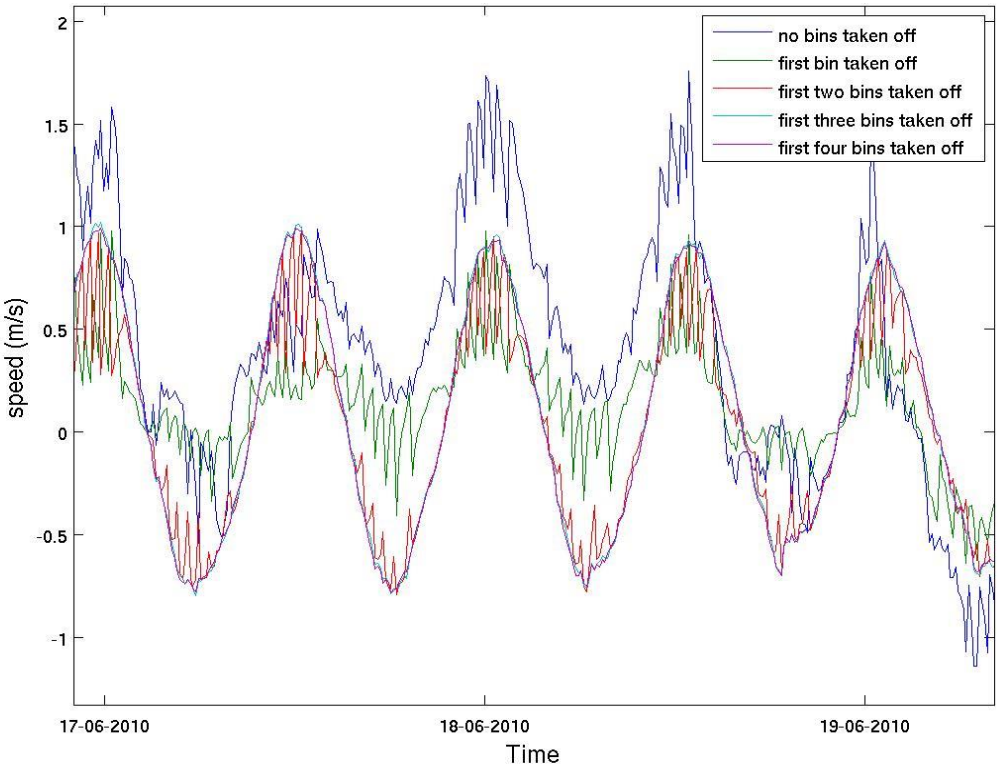

Figure 3 Eastward velocities of the five near surface bins. The side lobe contamination is clearly evident in the first three near surface bins (dark blue, green and red graph) as a deviation from the lower bins (light blue and purple graph).

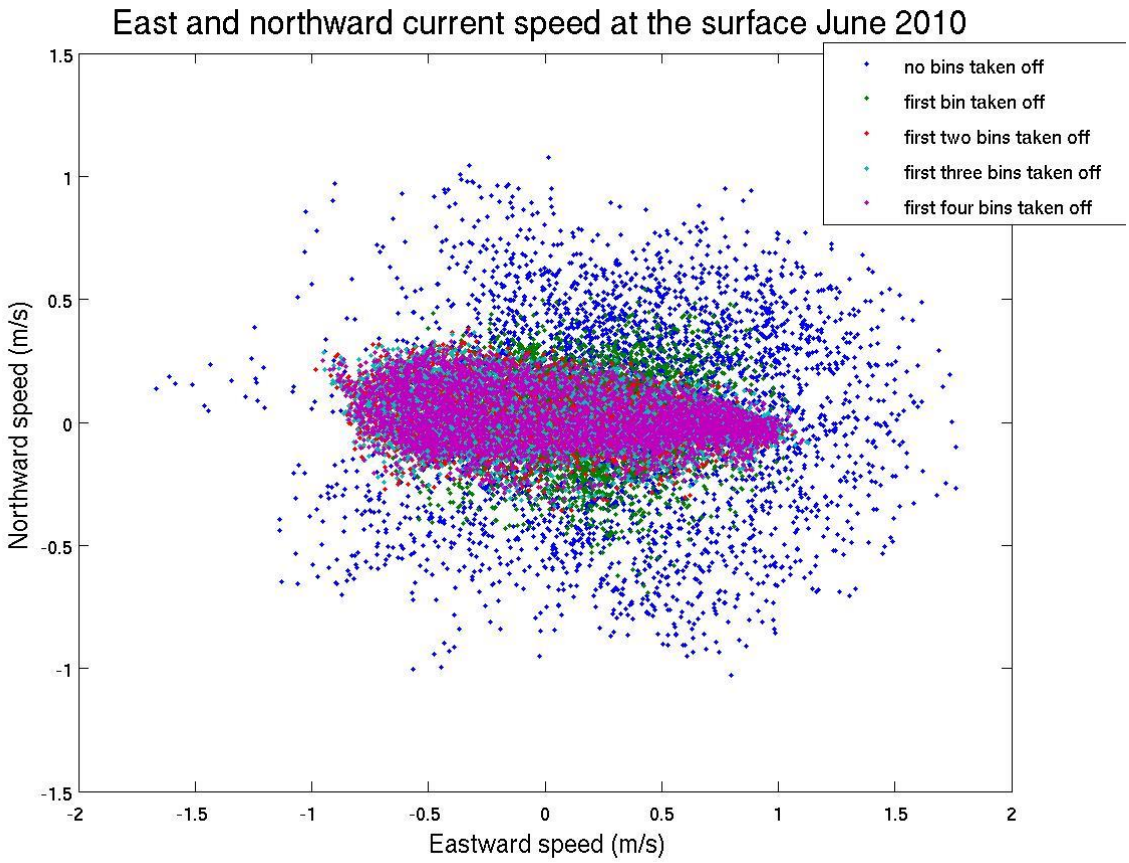

Figure 4 Current ellipse of near surface bins. First three near surface bins (dark blue, green and red dots) are scattered over the whole profile and show side lobe noise. The current ellipse shows the expected east-west direction only from the fourth bin away from the surface (light blue and purple dots).

c) Correct for compass errors

The ADCP is affected by local magnetic fields of batteries, other instruments and the frame it is mounted on. The data were corrected using measurements that were free of such errors. These data were available from the HF Radar system (WERA), which observes sea surface currents and waves in the Liverpool Bay and is also part of the Liverpool Bay Coastal Observatory. Two sites point out on Liverpool Bay and have a maximum range of nearly 100 km and the resolution for sea surface currents is 2 km. One site is located at Llanddulas/Abergele, North Wales pointing northwards, whereas the second site is located at Formby, Merseyside pointing approximately west-south-west. Sound pulses are sent out and the response is measured every 20 min. Using data from these two sites enough information is available to calculate sea surface currents and their direction.

A tidal harmonic analysis (T-tide, Pawlowicz *et al.*, 2002) was used to calculate the ellipse characteristics of the major tidal current constituent in the radar data. In Liverpool Bay this is the M2 component, which is the principal lunar semi-diurnal tidal constituent. Although the inclination increases over a period of five years (2006 - 2011) at all three sites this variation is within one standard deviation (Figure 5, Figure 6, Figure 7), and therefore smaller than the compass accuracy of 2 ° (Teledyne RD Instruments, 2008), which justifies using a mean value as reference for each site.

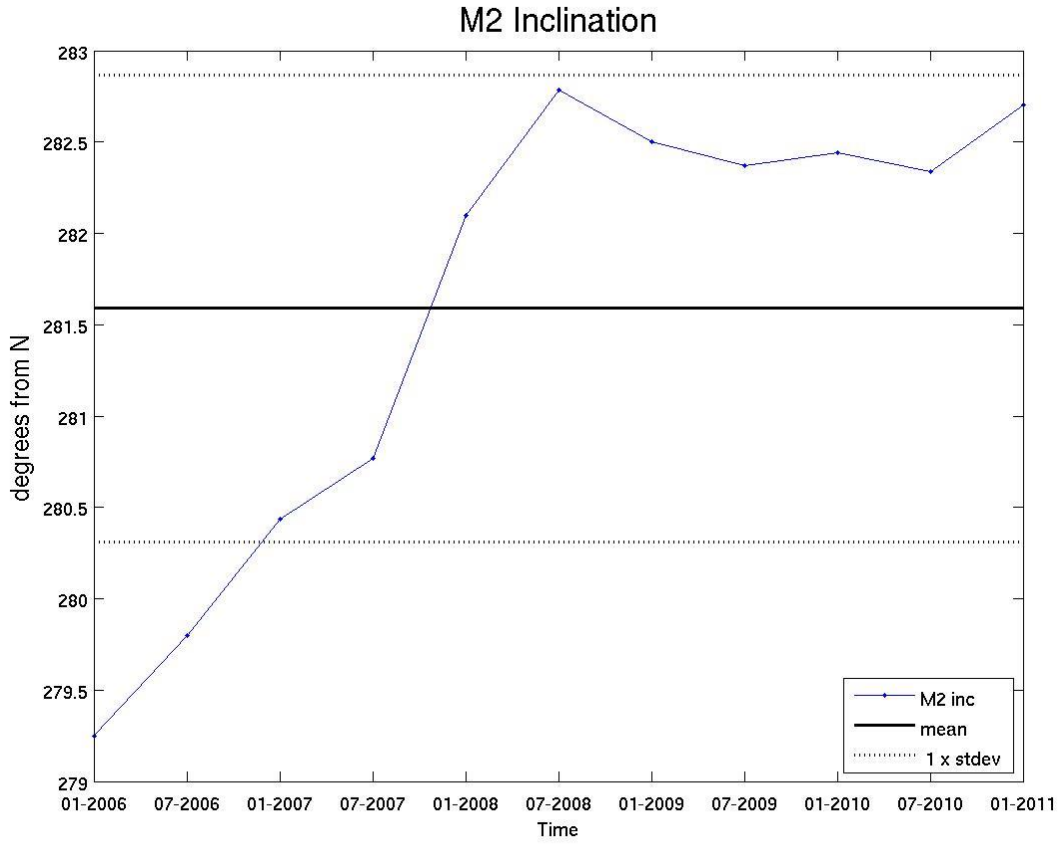

Figure 5: Change of mean M2 inclination over time at site A.

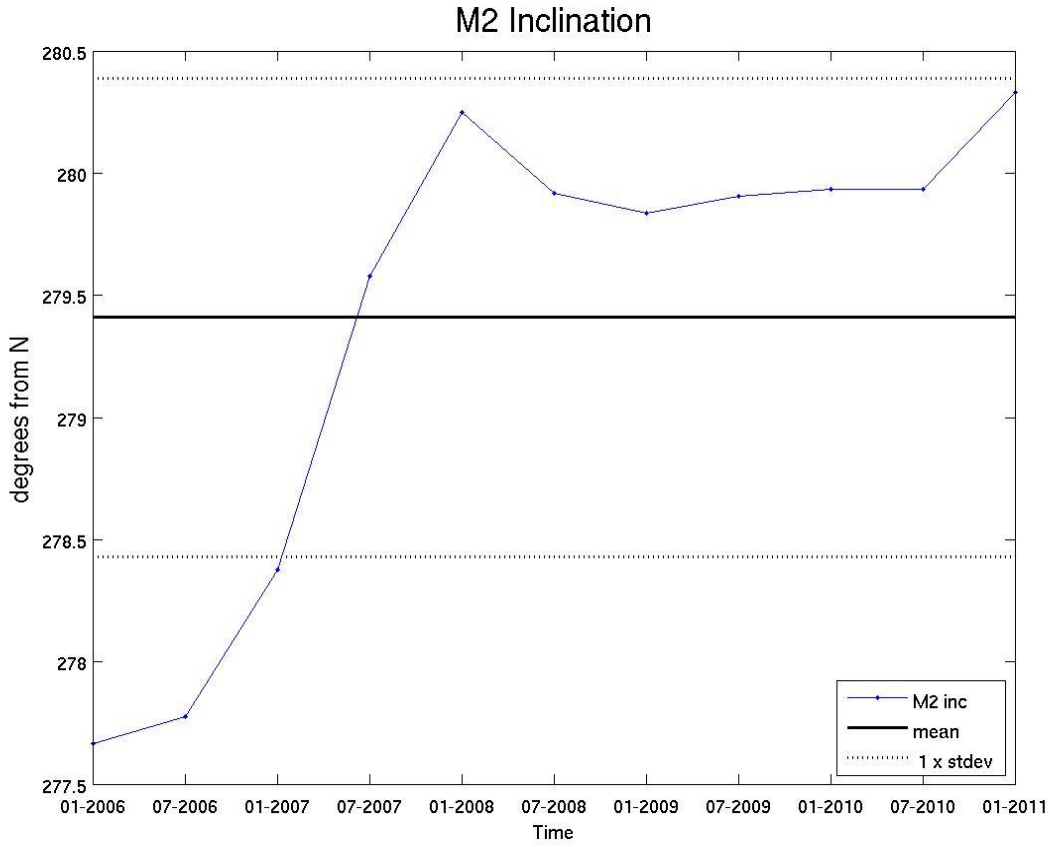

Figure 6: Change of mean M2 inclination over time at site old B.

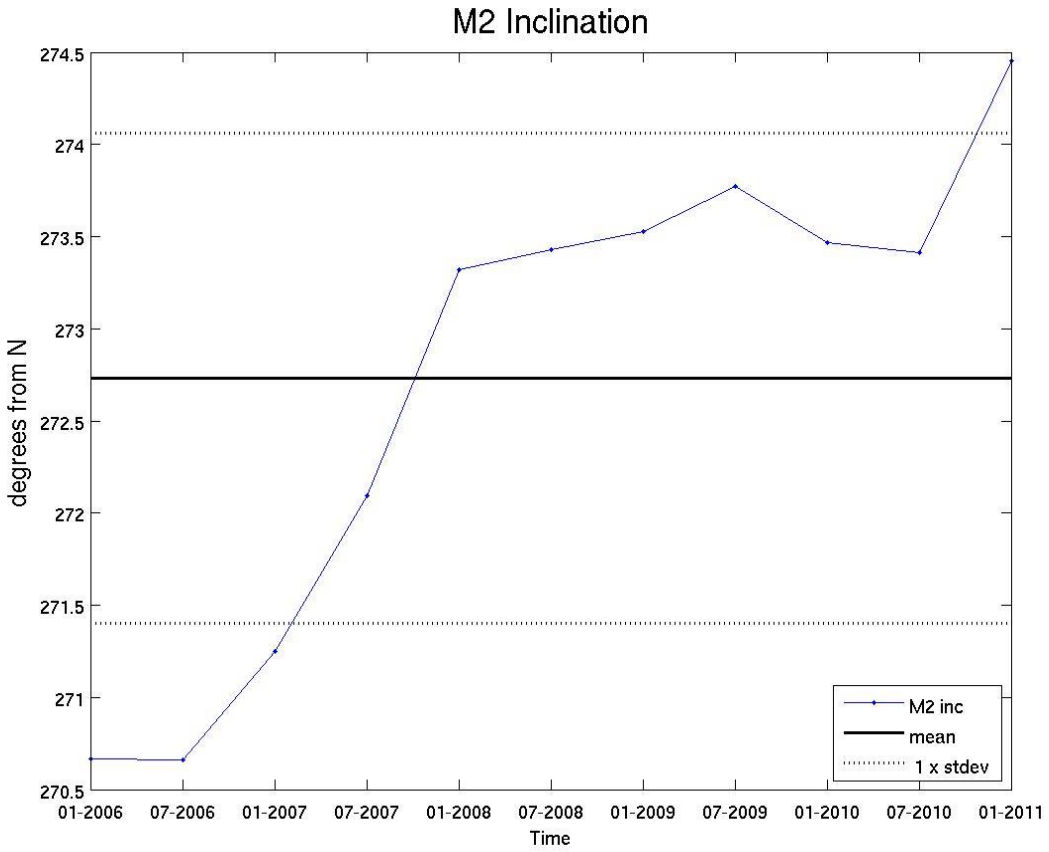

Figure 7: Change of mean M2 inclination over time at site new B.

The M2 inclination of all three sites was calculated as a mean value of all five individual yearly means where cell 234, 134 and 136 correspond to site A, new B and old B, respectively of the HF Radar data grid.

After the above surface and contaminated near surface bins had been removed only the topmost bin was used to calculate the M2 inclination for each ADCP file, which represented the surface layer as the typical inclination variation within the three near surface bins was within one degree (blue, green and pink graph in Figure 8).

i) Correction for mean error offset

Since the ADCP compass error can be considered a random error we would expect the long term mean of the error to be around zero. At site A a mean error of 5.3 degrees indicates that there are likely other factors influencing changes in elliptical orientation between the surface data as observed with the HF radar and the uppermost ADCP data 3m below the sea surface. These factors are likely true i.e. due to the dynamic physical environment of site A particularly due to the influence of the river Mersey plume. The mean offset of ~5.3 degrees was therefore applied to ADCP data. For consistency the same corrections were applied to the ADCP data from stations oB (0.42 degrees) and nB (0.73 degrees), which may be due to physical factors.

A summary of all compass corrections can be found in the accompanying COBS_ADCP_Data_Catalogue.xls.

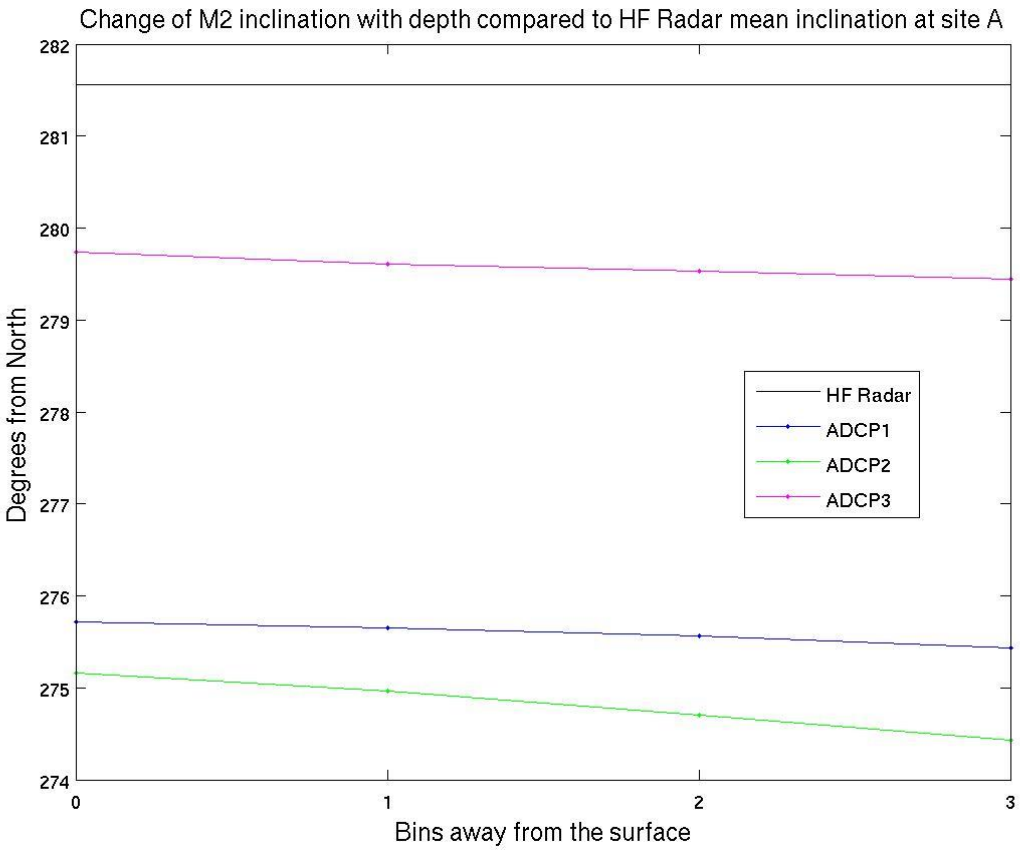

Figure 8 Change of M2 inclination of three different ADCP data sets (dark blue, green and pink graph) compared to the mean inclination calculated using HF Radar data (black graph) from site A. Each dot of the coloured lines corresponds to a bin below the surface.

d) Move of mooring (site B)

In January 2010 the mooring at 53° 27' N, 3° 38.6' W (old site B) was moved to a 53° 32.3' N, 3° 38.4' W (new site B). The mean water depth for this mooring increased to 36.8 m. During the first two moorings after the move the bin number of the ADCP had not been correctly adjusted hence not the full extent of the water column was sampled and so the data were cut short before reaching the surface. This problem only occurred during cruise MA0210 and MA0510.

2. Visual check

After the corrections had been made the data underwent a visual check to spot any obvious errors, which had not been picked up during the initial quality control to ensure the data represent real observations.

A pseudo colour plot of the east-west component of the velocity was plotted for each file (Figure 9). These plots gave information about range of the eastward velocity (expected to be ~ -1 m/s – 1 m/s), if the eastward (positive) and westward (negative) velocities were in phase with ingoing and outgoing tide and if the surface height follows the pressure signal. The current ellipse was also checked by looking if the dots were arranged along a west-east axis and not scattered (Figure 10).

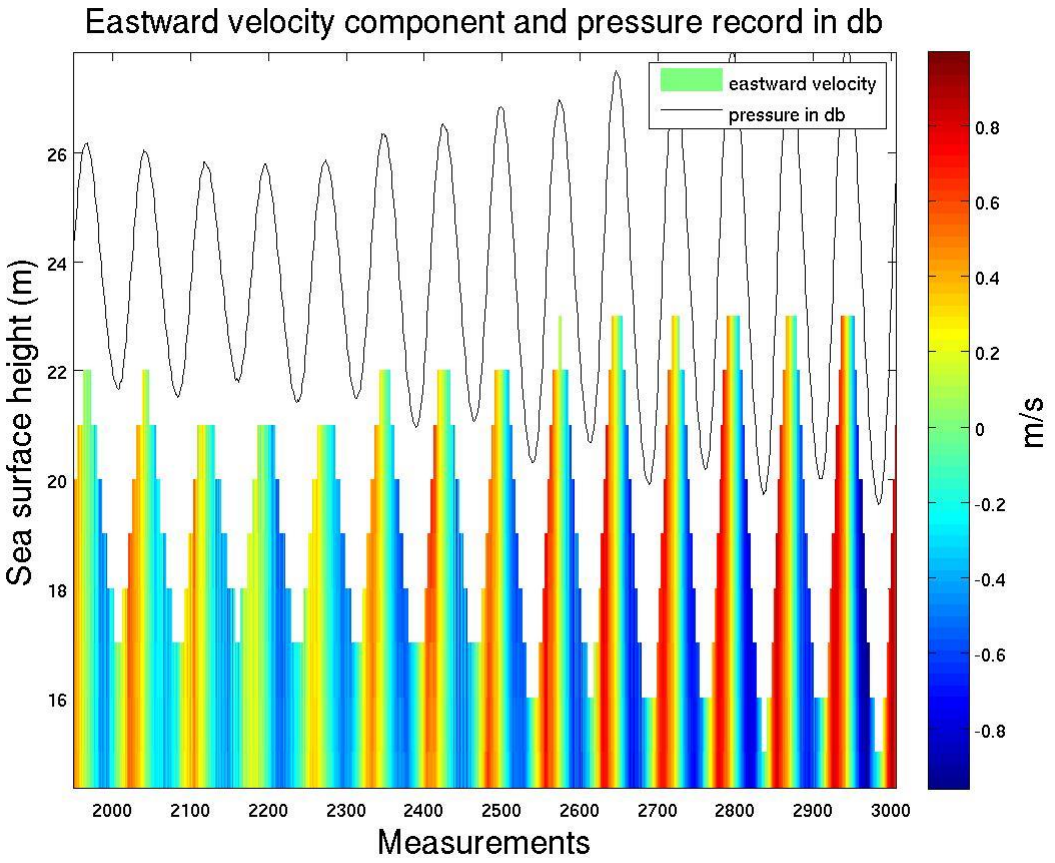

Figure 9: Eastward velocity component and pressure record in db.

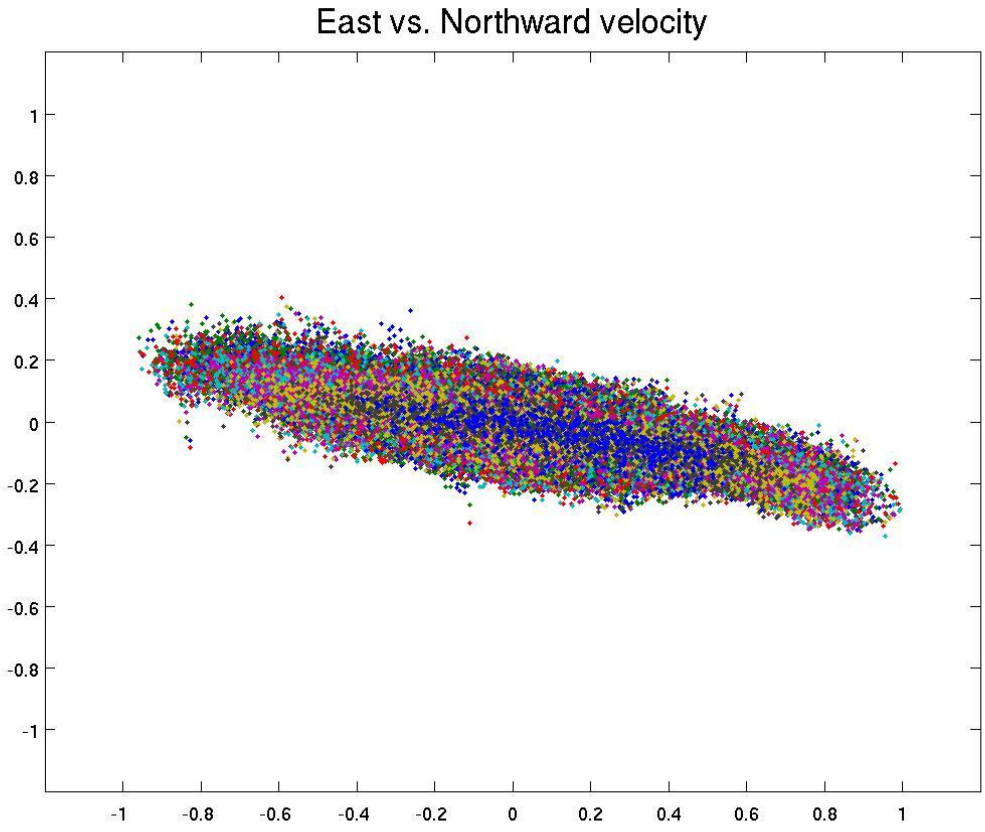

Figure 10: Current ellipse of the ADCP data. Same coloured dots are data points from the same bin. All dots are arranged along a west-east axis.

Cataloguing

When a new set of cruise data is available on the Coastal Observatory Website, it is quality controlled and added to the COBS_ADCP_Data_Catalogue.xls.
The model output of Geomag 7.0 that calculated the declinations can be found in Declinations.doc.

1. COBS ADCP Data Catalogue

This document was created to catalogue all recorded and quality controlled ADCP data from 2002 to present cruises.

Liverpool Bay Coastal observatory: available ADCP data 2002-present

Cruise #	Cruise ID	file	Station index	applied magnetic declination in degrees North	correction for compass error in degrees North	three beam corrected	auxiliary pressure used	source of replacement pressure, if necessary	comments
75	MA0711	bb12241_01121		-3.0747	0.919	not necessary	yes		
		bb02390_01123		-3.1987	1.3046	not necessary	yes		
74	MA0111	bb03644_01117		-3.0959	5.1865	not necessary	no	alongside Sea Bird 16 +	pressure data too small b
		bb05807_01118		-3.2203	10.3944	not necessary	yes		
73	MA4910	bb02390_01113		-3.1178	2.2943	not necessary	yes		
		bb05806_01115		-3.2427	1.6783	not necessary	no	alongside Sea Bird 16 +	
72	MA3610	bb12239_01109		-3.1412	14.5956	not necessary	yes		
		bb05807_01111		-3.2662	1.9013	not necessary	yes		
71	MA2910	bb05806_01106		-3.1673	7.9862	not necessary	yes		
		bb02390_01107		-3.2922	0.7023	not necessary	yes		
70	MA2110	bb12239_01102		-3.1856	-7.5339	not necessary	yes		
		bb05807_01104		-3.3106	3.8121	not necessary	yes		
69	MA1710	bb02390_01098		-3.1995	8.887	not necessary	yes		
		bb05806_01100		-3.3246	1.8173	not necessary	yes		
68	MA1010	bb05807_01094		-3.2149	8.9103	not necessary	yes		
		bb12239_01096		-3.3403	7.6981	not necessary	yes		
67	MA0510	bb05806_01090		-3.2335	10.5758	not necessary	yes		
		bb02390_01092		-3.3592	1.0346	not necessary	yes		Mooring had previously b
66	MA0210	bb05807_01086		-3.2545	8.4666	not necessary	yes		
		bb05803_01088		-3.3797	0.8598	not necessary	yes		Mooring had previously b
65	MA4709	bb02390_01082		-3.2783	7.7656	not necessary	yes		
		bb05806_01084		-3.3863	-7.9551	not necessary	yes		
64	MA3809	bb12239_01078		-3.3064	6.3198	not necessary	yes		
		bb05807_01080		-3.4157	1.4312	not necessary	yes		
63	MA3309	bb05806_01074		-3.3331	-2.2604	not necessary	yes		
		bb02390_01076		-3.4426	-2.0535	not necessary	yes		

Figure 11: ADCP Data Catalogue. Header and some quality controlled ADCP data from 2009-2011.

The table is designed to show the meta data of ADCP data collected from 2002 – present.

For each ADCP file, the table shows:

- Cruise number and ID
- Location of mooring by using the station colour code (Figure 11).
- Applied magnetic declination in °N
- Applied correction for compass error in °N
- If the data have been three beam corrected

Station colour code	
A	53º 32´ N 3º 21.8´ W,
old' B	53º 27´ N 3º 38.6´ W
new' B	53° 32.3' N, 3° 38.4' W

Figure 2: Station colour code.

- If the auxiliary pressure was used to detect the surface
    - And if not what was the source of the replacement pressure or signal to indentify the surface.
- Comments regarding problems that were encountered during the quality control, or why certain corrections could not be made.

The first sheet is a summary of all processed data from 2002 - present and the following sheets are yearly summaries.

2. Declinations

This document was created to record the full output of Geomag 7.0, which was used to determine the declinations at site A, old B and new B from 2002 to 2011.

Declinations

SITE A
Model: DGRF2000
Latitude: 53 deg, 32 min, 0 sec North Longitude: -3 deg, 21 min, 8 sec East
Altitude: 0.00 km
Range of Interest: 2002-1-1 to 2011-4-18 (yyyy-mm-dd), step 1.00 (years)

Date (yr)	D (deg min)	I (deg min)	H (nT)	X (nT)	Y (nT)	Z (nT)	F (nT)
2002.00	-4d 34m	68d 3m	18278.4	18220.2	-1457.7	45353.2	48898.0
2003.00	-4d 25m	68d 3m	18289.5	18235.3	-1406.9	45380.0	48926.9
2004.00	-4d 15m	68d 3m	18300.7	18250.4	-1356.2	45406.7	48956.0
2005.00	-4d 5m	68d	18312.1	18265.5	-	45433.5	48985.0

Figure 12: Screenshot of Declinations document.

The output of the model shows the model coefficients used, the position in degrees, minutes, seconds, the altitude, the range of interest and the time steps used. The parameters are:

D: Declination
I: Inclination
H: Horizontal field strength
X: North component
Y: East component
Z: Vertical component
F: Total field strength
dD,dI, change per year of

The results are listed for the chosen starting time increasing with the time steps to the end of the period of interest (Figure 12).The yearly change is also given at the end of the table.

References

International Association of Geomagnetism and Aeronomy, Working Group V-MOD. Participating members: Finlay, C.C., Maus, S., Beggan, C.D., Bondar, T.N., Chambodut, A., Chernova, T.A., Chulliat, A., Golovkov, V.P., Hamilton, B., Hamoudi, M., Holme, R., Hulot, G., Kuang, W Langlais, B. Lesur, V., Lowes, F.J., Luhr, H., Macmillan, S., Mandea, M., McLean, S., Manoj, C., Menvielle, M., Michaelis, I., Olsen, N., Rauberg, J., Rother, M., Sabaka, T.J., Tangborn, A., Toffner-Clausen, L., Thebault, E., Thomson, A.W.P., Wardinski, I., Wei, Z., T. I. Zvereva, T.I., (2010). International Geomagnetic Reference Field: the eleventh generation, *Geophys. J. Int*., 183, 3, 1216-1230. DOI: 10.1111/j.1365-246X.2010.04804.x.

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