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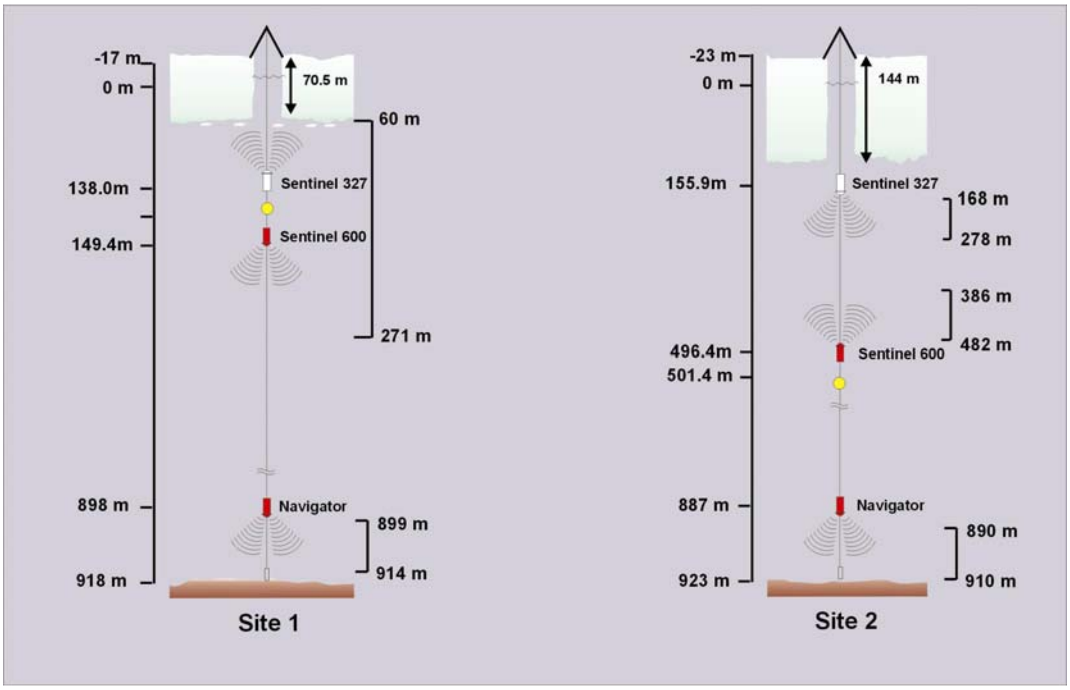
N. Robinson and A. Pyne



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Water Column Current Profile Analysis from beneath the McMurdo Ice Shelf at Windless Bight and under the sea ice in Granite Harbour, Antarctica

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November 3, 2003

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This analysis and report has been prepared primarily for engineering modelling of the sea riser casing for the ANDRILL (McMurdo portfolio) drilling operation.

1 McMurdo Ice Shelf: Water Current Velocity Profiles from S4 and ADCP data

1.1 Background

In January 2003, two Hot Water Drill (HWD) holes were made through the McMurdo Ice Shelf approximately 6 and 12 km from Scott Base, Antarctica (See figure 1). Water samples were taken from different depths beneath the Ice Shelf in addition to the deployment of various instruments through the holes in the ice shelf. Profiling the water column beneath the ice shelf was achieved with casts of a current meter (Inter-Ocean S4) and a Seabird CTD (Conductivity-Temperature-Depth).

Longer term current data was obtained with a mooring of 3 Acoustic Doppler Current Profilers (ADCPs) deployed for a few diurnal tidal cycles, approximately covering the spring periods, figure 2. Two of the ADCPs were Sentinels, (Sentinel 327, Sentinel 600), used for observing large sections of the water column at once, while the third was a Navigator, used for observing the benthic boundary layer, especially for understanding sediment transport near the seafloor. (See figure 3 for diagram of mooring array.)

The two sites were located on seismic lines that will be used to define ANDRILL drilling targets, to be drilled from the ice shelf platform and coring 1000m into the sea floor.

This report details analysis of the measurements completed with the aim of deriving water column profiles during periods of maximum flow. The maximum flow profiles will be used for modelling and engineering for a steel sea riser, which will be the initial drill casing from the ice shelf surface to the sea floor.

1.2 The Data Sets

The maximum flow profiles are created from 3 basic data sets for each of the two sites.

Site 1

Location	77^{o}53.308'S, 167^{o}05.067'E
Ice Thickness	70.5 m
Water Depth	918 m
Freeboard	17 m

12 x S4 current meter casts run every 2 - 2 $\frac{1}{2}$ hours over a 30 hour period and 3 x Acoustic Doppler Current Profiler (ADCP) mooring of 86 hours.

Site 2

Location	77^{o}50.111'S, 167^{o}20.209'E
Ice Thickness	144 m
Water Depth	923 m
Freeboard	23 m

10 x S4 current meter casts run every 2 - 2 $\frac{1}{2}$ hours over a 24 hour period and S4 mooring + ADCP mooring of 47 hours.

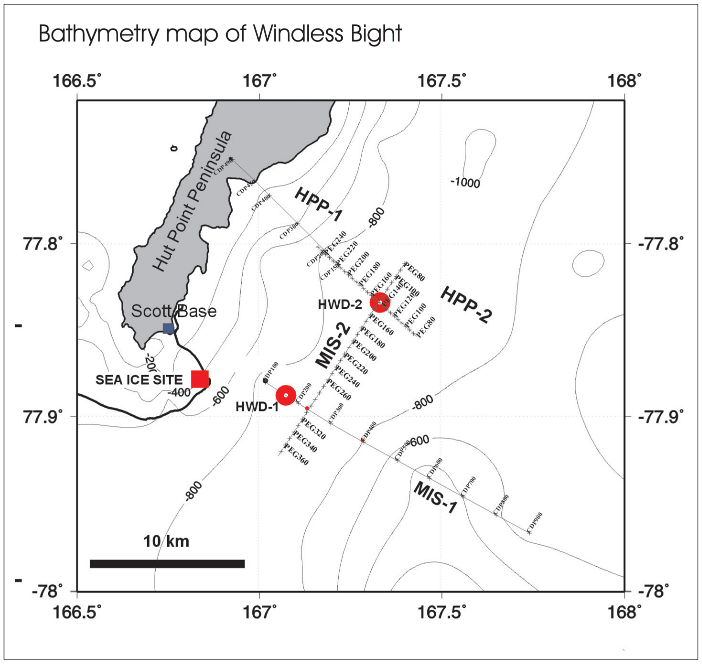


Figure 1: Bathymetry map of Windless Bight area showing location of seismic lines MIS-1,MIS-2,HPP-1,HPP-2. Also shown are the locations of moorings set in sea ice - Sea Ice Site - and shelf ice - HWD-1, HWD-2.

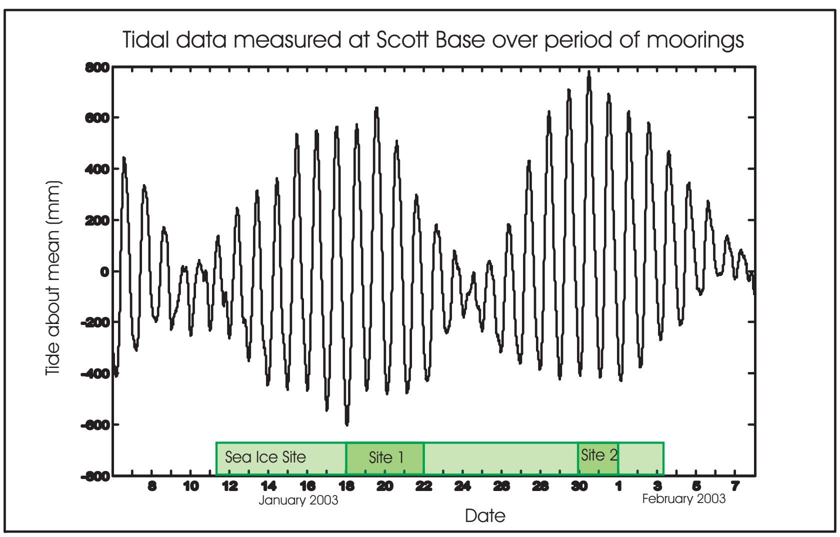


Figure 2: Tidal data measured at Scott Base (*Goring, personal communication 2003*). Tides corresponding to the timing of the moorings are shown. The two ice shelf moorings were timed to coincide with the maximum spring tides.

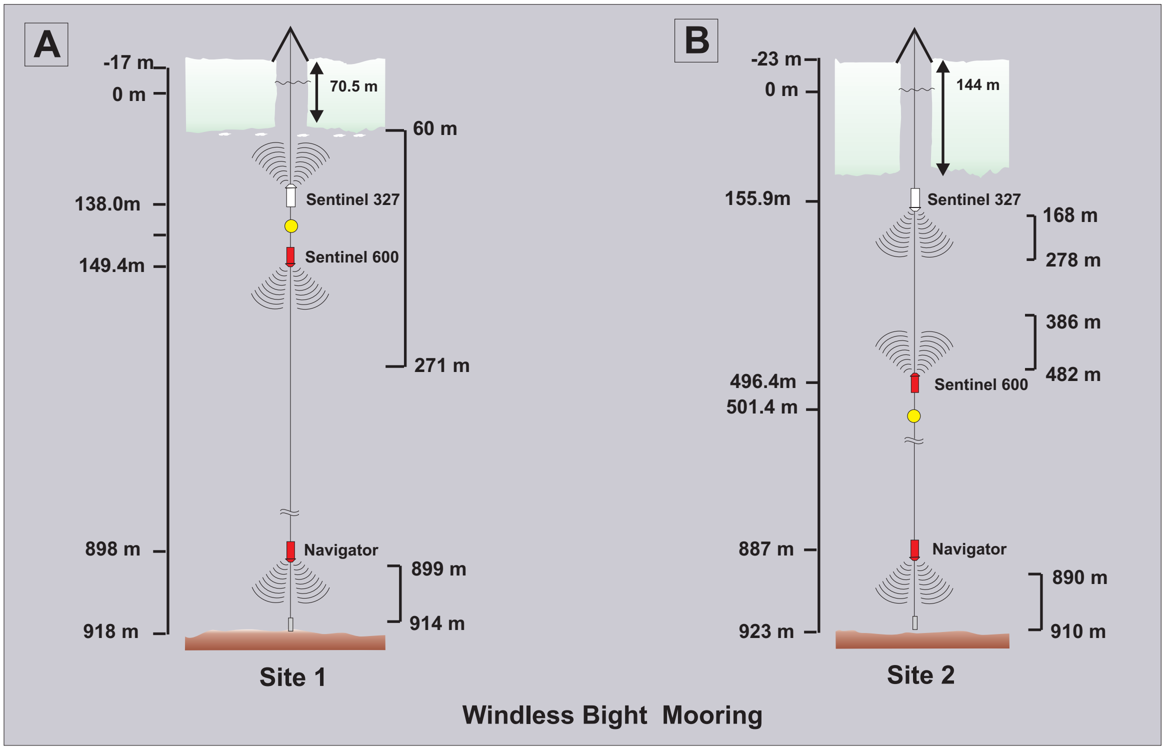


Figure 3: Diagram showing the mooring array at (A), HWD-1 and (B), HWD-2. The scale to the left indicates the depth below sea level at which each instrument was deployed. The ranges to the right indicate the sections of the water column observed by the ADCPs.

ADCP instruments measure currents (speed and direction) by sending out a burst of sound at a fixed frequency, periodically (every 2 seconds) and measuring the Doppler shift on the return signal after the sound is reflected from particulate in the water column. The instrument receives this return signal in a continuous stream, but can be set up to integrate over short time periods, relating directly to different depths (bins), effectively surveying a large depth range simultaneously. The S4 instrument measures currents (speed and direction) by creating a magnetic field and sensing the voltage induced by the movement of water through the field. When this instrument is used in profiling mode it is moved vertically through the water column.

In general, the data from the ADCPs are more reliable than that from the S4 for several reasons:

- The technology and instruments are newer;
- Measurements are taken at a number of depths simultaneously rather than just a single fixed point;
- Every measurement is an average of four instantaneous measurements separated spatially;

- The S4 profiles are obtained by "towing" the instrument vertically through the water column ('down' and 'up' casts), and although it measures current velocity in the horizontal plane, this vertical movement creates turbulence which has horizontal as well as vertical components. The data indicates that the S4 records current velocities higher that actual during profiling at the vertical speeds used, see tables 6 and 7.

- The S4 was the first of two instruments plus two water sampling bottles on the line being cast at the same time, so that, especially for up casts, there is potential for extraneous disturbance in the water column due to these other objects.

However, the combined ADCP data sets cover less than half of the available water column, and because of this, the S4 profiling data sets were used to 'fill the gaps', with the simultaneous mooring alongside the ADCP used as a reference for correlation.

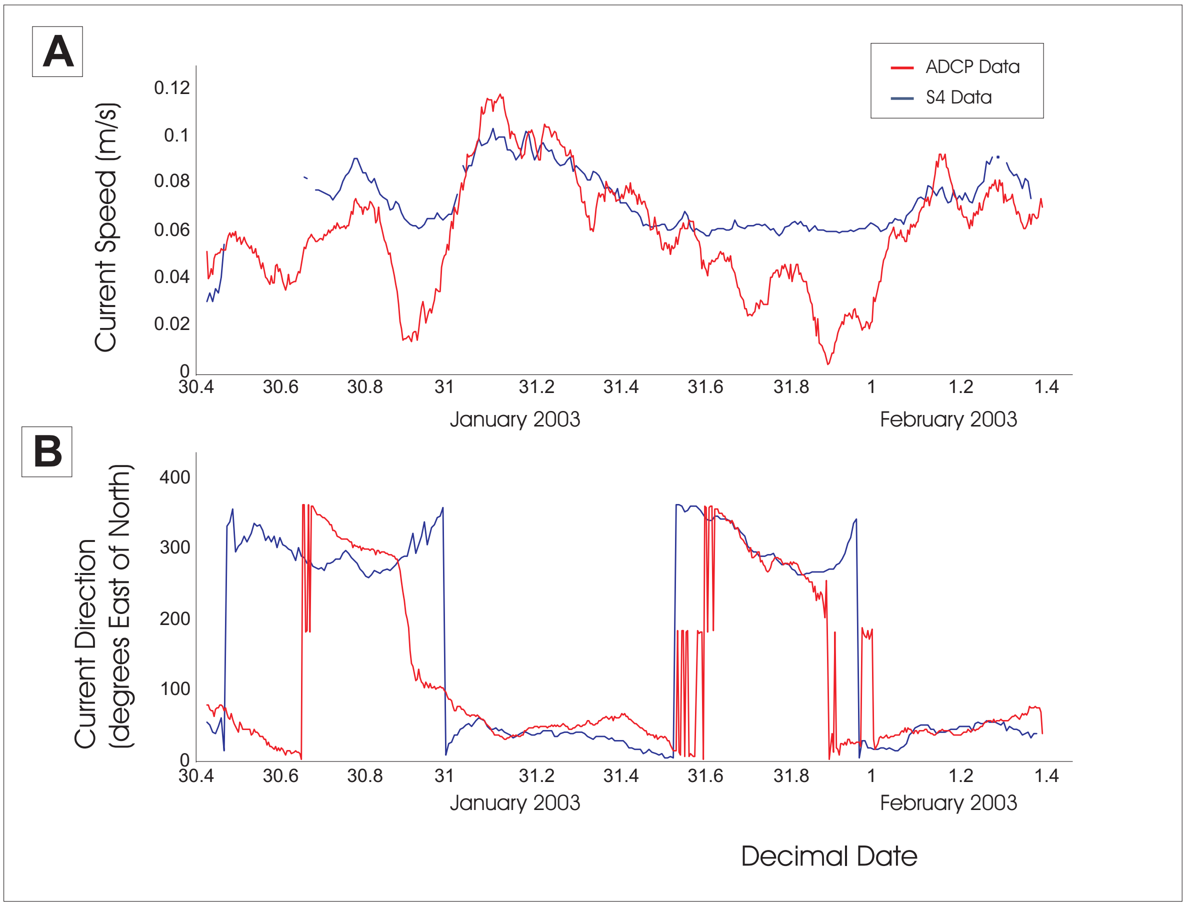


Figure 4: Comparison of (A), current speed and (B), current direction data from ADCP moored at 496.4m and S4. Good correspondence between the two instruments is seen for current speeds above $\sim 0.06ms^{-1}$. Below this value, the S4 data plateaus, indicating insufficient response from the instrument.

1.3 How Profiles Were Created

1.3.1 Mooring Data - ADCPs + S4

The S4 mooring data was taken every $\frac{1}{2}$ second for one minute at the start of every 10 minutes. For purposes of comparison with ADCP data, these 120 samples were averaged into a single measurement at the start of every 10 minute interval.

Initially, the S4 mooring speed data was directly compared with an average of ADCP data from the two bins closest to the S4. (For comparison of these two instruments, see figure 4.) This showed good correlation between the two instruments where high velocities ($> 10cms^{-1}$) were recorded by the ADCP, but the S4 did not record velocities less than $\sim 6cms^{-1}$, and consequently there were long periods where the instruments did not agree.

In preparation for creating the maximum flow profiles, the periods of maximum current speed, as seen in the ADCP record were identified - 2 periods in each record. The vertical stripes, seen in figures 5 and 6, represent these periods of maximum flow, which are nearly simultaneous through the water column. These sub-sets of data were then extracted from the whole record, and plotted as a function of depth, figure 8. The black dots represent the first period, with red for the second period. The one set of green data is from a third period selected from Sn327 record (site 1), and was included because the other regions did not capture the highest currents immediately below the ice shelf.

1.3.2 S4 Casts

The S4 profiles are acknowledged to be less accurate than the ADCP data, but can be considered to represent the 'shape' of the water column profile, and are used here to show that current speed and direction are probably reasonably consistent in the depth intervals of the water column not surveyed by the ADCP instruments. Each cast was separated into up and down casts, and considered separately. The up casts were smoother, even though velocity of the instrument through the water column was lower on the down casts. It was decided that the up casts seemed to provide more consistent profiles, so representative casts were all 'up casts', figure 7.

Again, for each site, all up casts were considered side by side in order to determine which was the 'most representative' cast, in terms of general shape through the water column. Since data had been collected every $\frac{1}{2}$ second for the duration of each cast, a 10 second 'running mean' was applied before the comparison, in order to reveal the trend of the data, and to remove outlying points.
For Site 1 Cast ♯6 was selected.
For Site 2 Cast ♯2 and ♯4 were selected.

To produce a realistic profile, the chosen casts were then superimposed onto the data from the ADCPs at the previously determined periods of maximum current speeds. Overlaying the data sets showed that the S4 and ADCP data reveal the same general shape for the velocity profiles, but also that the S4 recorded much higher velocities. It is not likely that this difference results from the timing - the ADCP mooring followed the S4 casts - and so an appropriate offset was applied to the S4 data.

No offset was applied to the S4 data for Cast ♯6 data from Site 1, while offsets of 0.17 ms^{-1} and 0.04 cms^{-1} were applied to Cast ♯2 and Cast ♯4 respectively from Site 2. All three sets of data are shown on figure 8.

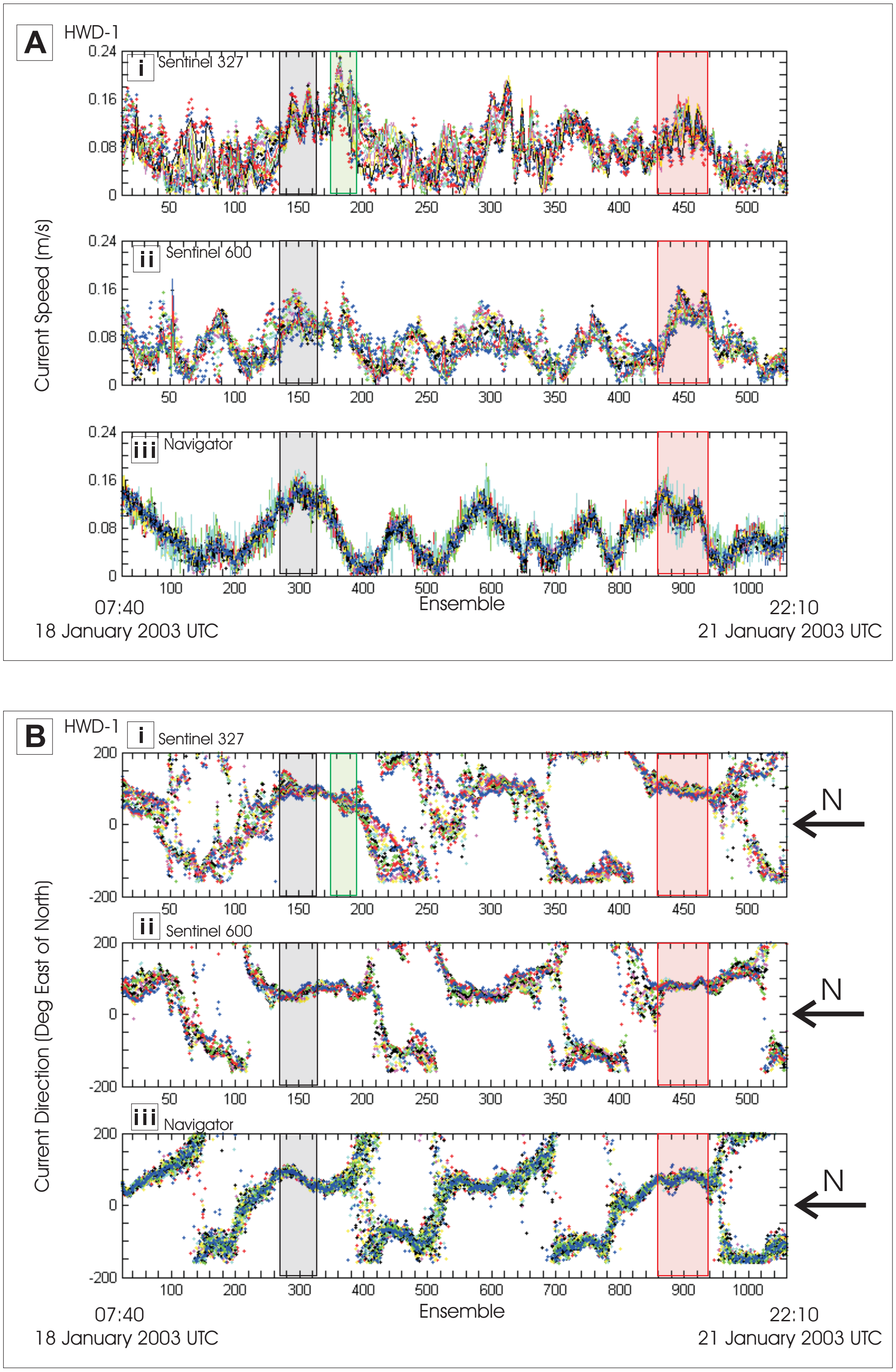
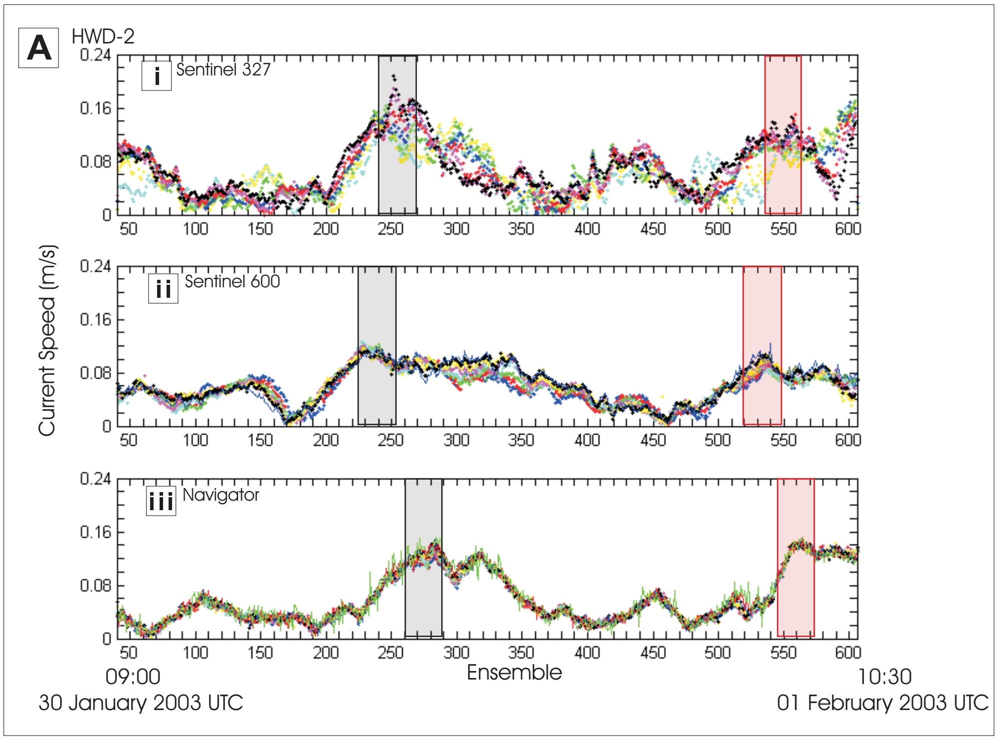


Figure 5: (A) Current speed and (B) current direction data from the three ADCP instruments at HWD-1. Time series (i) is from the Sentinel 327, (ii) Sentinel 600 and (iii) Navigator. Also shown are the short periods from which data were extracted for constuction of maximum current profiles - Black, region 1, Green, region 1b, Red, region 2. The maximum current speed at each depth were captured, so the regions were not quite synchronous through the water column.



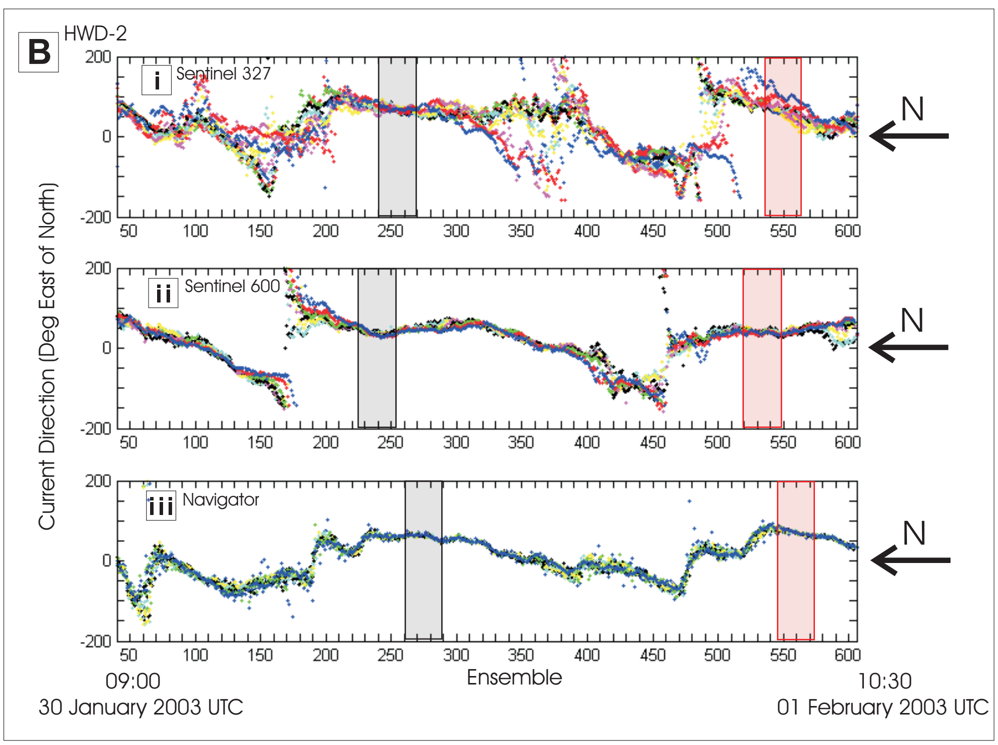


Figure 6: (A) Current speed and (B) current direction data from the three ADCP instruments at HWD-2. Time series (i) is from the Sentinel 327, (ii) Sentinel 600 and (iii) Navigator. Also shown are the short periods from which data were extracted for constuction of maximum current profiles - Black, region 1, Green, region 1b, Red, region 2. The maximum current speed at each depth were captured, so the regions were not quite synchronous through the water column.

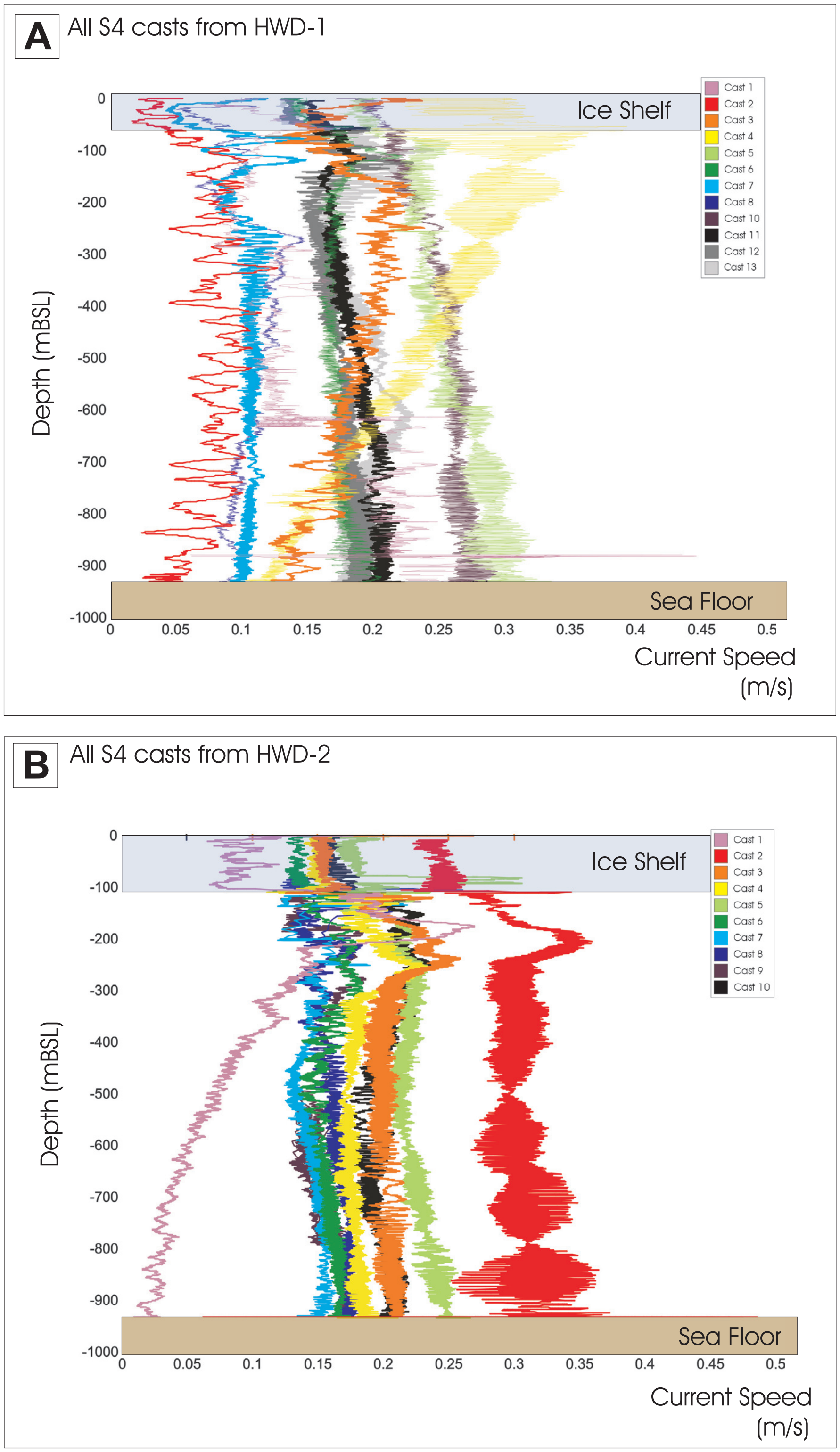


Figure 7: Current speed data from every cast at (A) HWD-1 and (B) HWD-2. This demonstrates that the selected casts, Cast 6 at Site 1 and Casts 2 and 4 at Site 2 are representative of the shape of the velocity profile as recorded by the S4 casts.

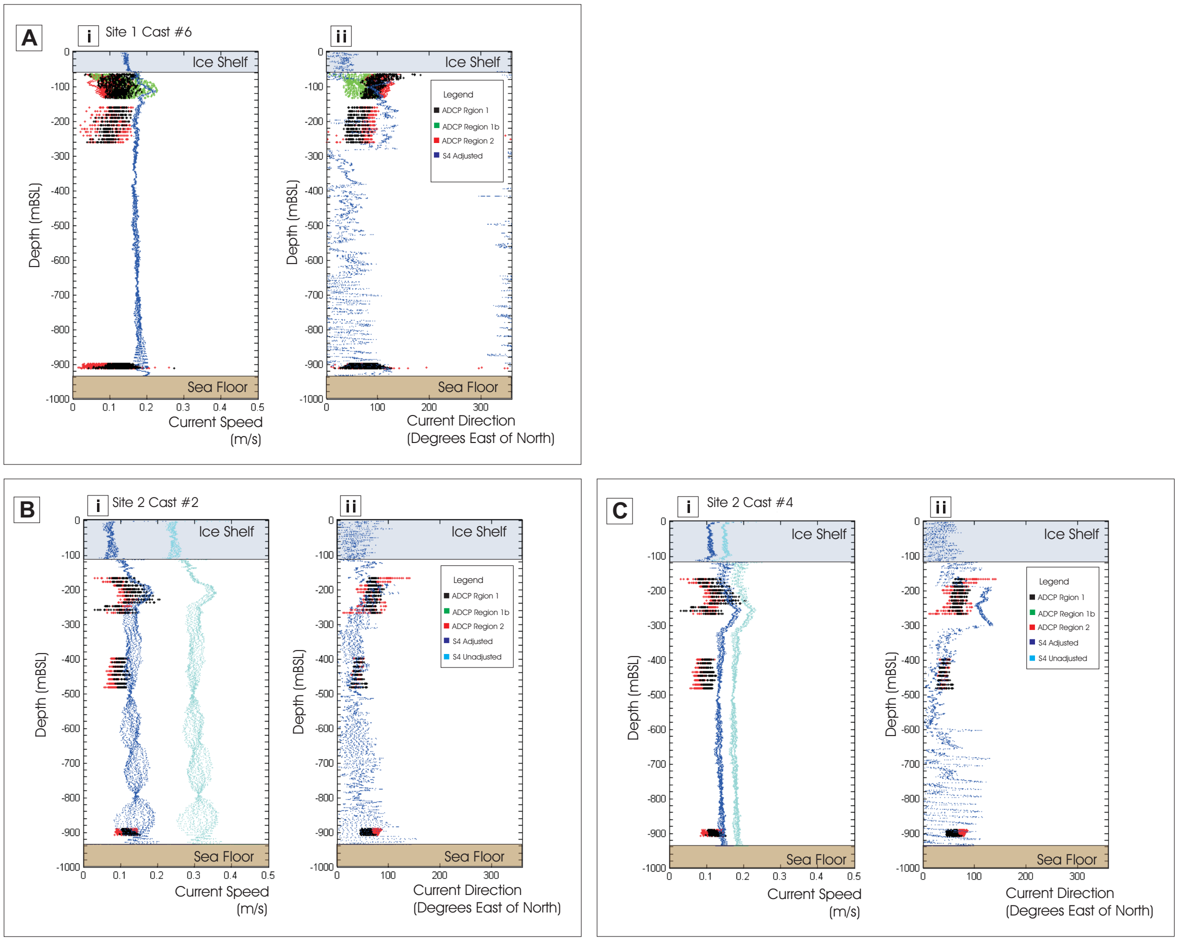


Figure 8: (i) Current speed and (ii) current direction data from representative S4 casts used to create maximum speed profiles. These data are overlaid with the appropriate ADCP data from the selected regions. Where necessary, an offset has been applied to the S4 current speed data in order to make it consistent with the more reliable ADCP data. No offset has been applied to (A) Site 1, Cast 6 while offsets of 0.17 ms^{-1} and 0.04 ms^{-1} were applied to (B) Site 2, Cast 2 and (C) Site 2, Cast 4 respectively.

1.4 Discussion of Data

The ADCP instruments were programmed for a magnetic declination correction of 155^o east of north prior to deployment and the S4 data corrected during post processing by subtracting 145^o from each data point in the resultant series after averaging the 120 measurements taken in the first minute of every 10. When the direction data were compared in the manner described above for speed, acceptable agreement between the instruments were observed for the whole period of the mooring.

1.5 Resultant Profiles

To create a synthetic velocity profile, the 'representative' S4 casts with the appropriate speed offset applied were plotted, and a smoothed curve constructed encompassing the maximum speeds at each depth. These were then read off every 10 metres of depth, creating a series of well-spaced data points.

1.6 Acknowledgement

The data collection and analysis was funded by NZ FORST Paleoclimate grant to Prof. Peter Barrett, Antarctic research centre, Victoria University of Wellington: K042 Antarctic field program 2002/2003, (Natalie Robinson, part of an MSc scholarship) and Antarctica NZ contract with VUW (Alex Pyne, ANDRILL Drilling Science Coordinator).

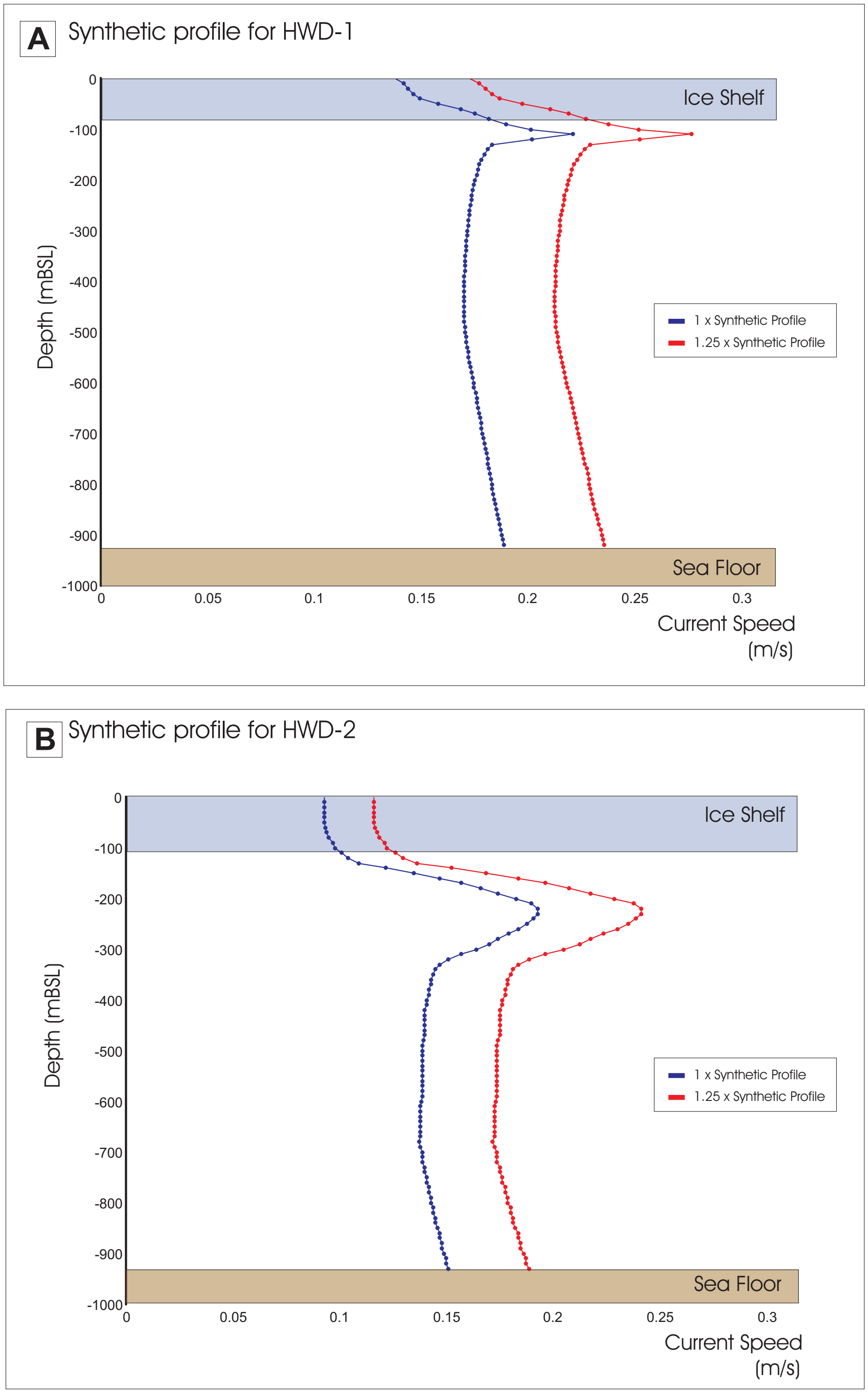


Figure 9: Synthetic maximum speed profiles created for (A) HWD-1 and (B) HWD-2 from ADCP and S4 data. x 1 profiles are shown in blue, with x 1.25 in red.

2 Granite Harbour: Water Current Velocity Profiles from ADCP data

2.1 Background

Current velocity survey has been undertaken on behalf of Dr Ross Powell (Northern Illinois University) by McMurdo Station Crary Lab staff in the 2000/2001 season as part of site survey preparation for ANDRILL. Moorings were deployed at two sites in Granite Harbour from the sea ice during the period 5 December 2000 to 4 January 2001, figure 10. The GH-1 site is approximately 5 km north of Couloir Cliffs in approximately 800 m of water. The GH-2 site is in the mid-outer harbour in approximately 900 to 950 m of water.

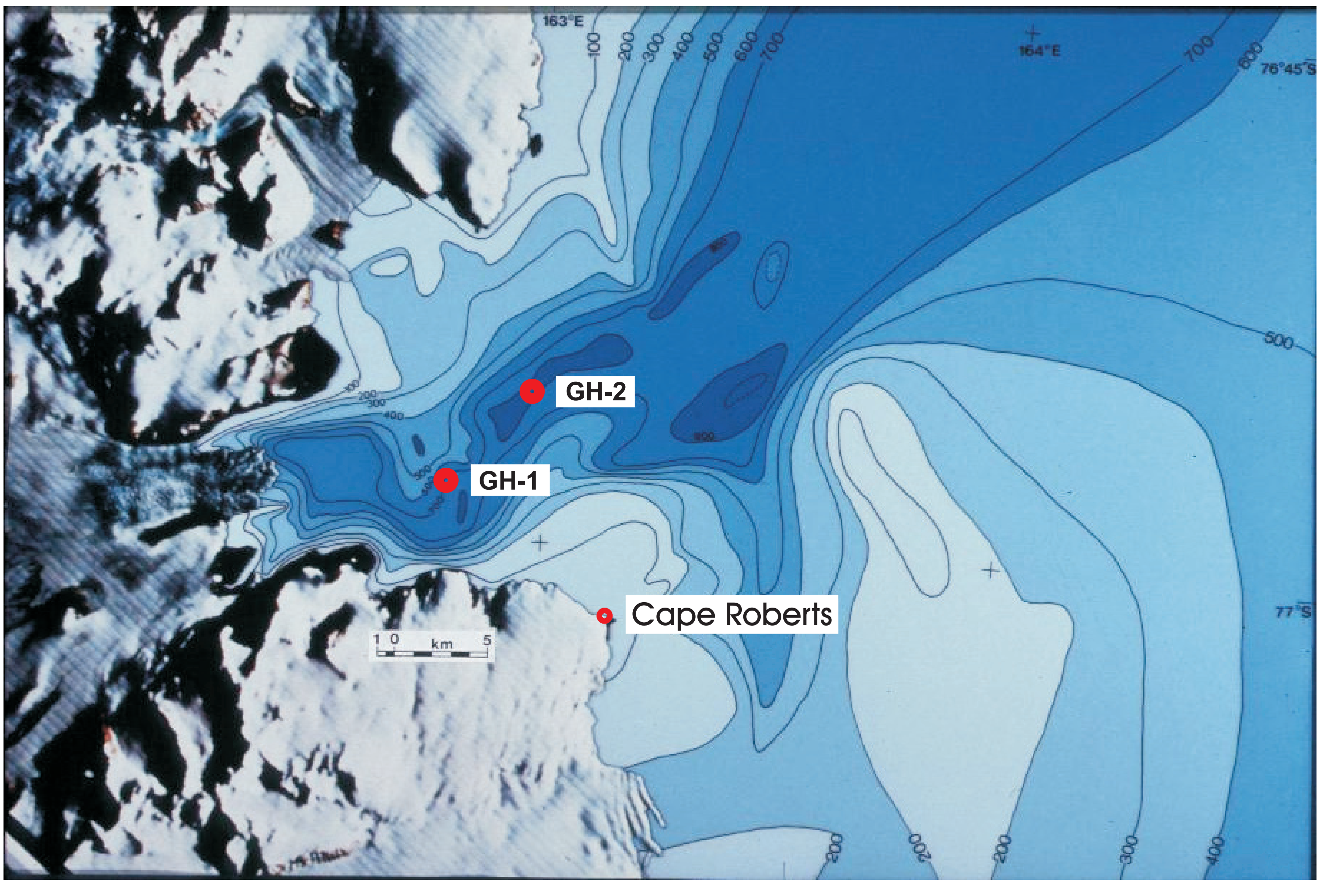


Figure 10: Bathymetry map of Granite Harbour area (*Pyne unpublished*) showing locations of moorings set in sea ice at GH-1, GH-2.

2.2 Moorings

Each mooring (GH-1 and GH-2) was in the water for approximately 15 and 14 days respectively and consisted of three downward looking ADCP RDI sentinels instruments set just

STATION	LATITUDE*	LONGITUDE*	GEOID ELEVATION+	CORR-ECTION	MSL
ROB-0	77.0356590 S	163.1782096 E	−53.643	−55.310	1.667
GH1-339 (12 – 05 – 00)	76.9750482 S	162.7503070 E	−55.274	−55.461	0.187
GH1-354 12 – 20 – 00	76.9750252 S	162.7505520 E	−57.236	−55.462	−1.774
GH2-355 12 – 21 – 00	76.9338021 S	162.9506571 E	−57.260	−55.693	−1.567
GH2-004 01 – 04 – 01	76.9338086 S	162.9506676 E	−54.871	−55.693	0.822

Table 1: MACKAY SEA VALLEY SEA ICE MOTION STUDY - The sea ice positions of the two different sites (GH-1 and GH-2) were checked at two different times to determine lateral sea ice motion: GH1-339, GH1-354 and GH2-355, GH2-004 where -xxx is day of the year.
* Coordinates are in decimal degrees, WGS-84
+ Elevations are 40-70 cm too high. (Source: Chuck Kurnik, UNAVCO, 03 – 13 – 01)

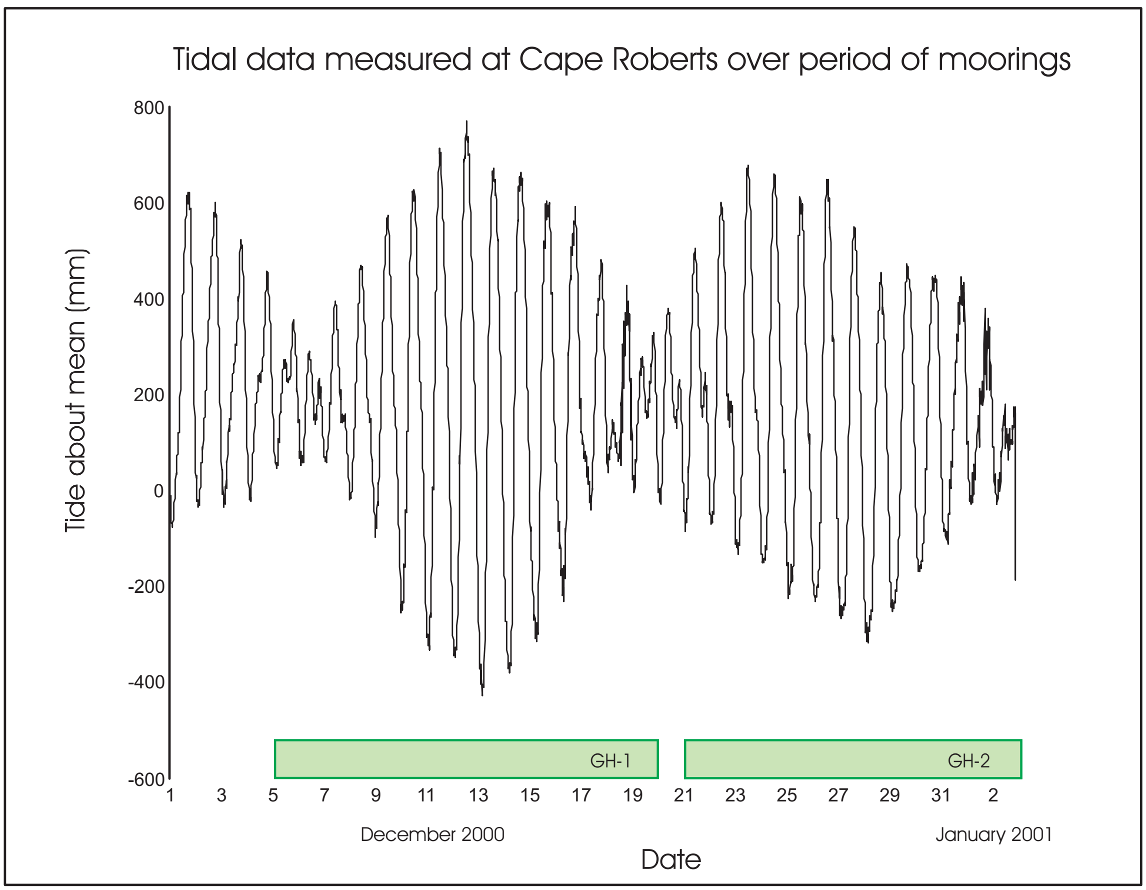


Figure 11: Tidal data measured at Cape Roberts (*Pyne personal communication*). Tides corresponding to the timing of the moorings are shown.

below the sea ice, at 250 m and at 500m depth. An S4 instrument was also set on the mooring just above the ADCP at 250 m, figure 12.

The period of each mooring encompasses the maximum tidal period range as indicated in figure 11, from the tide gauge at Cape Roberts 10 - 13 km away.

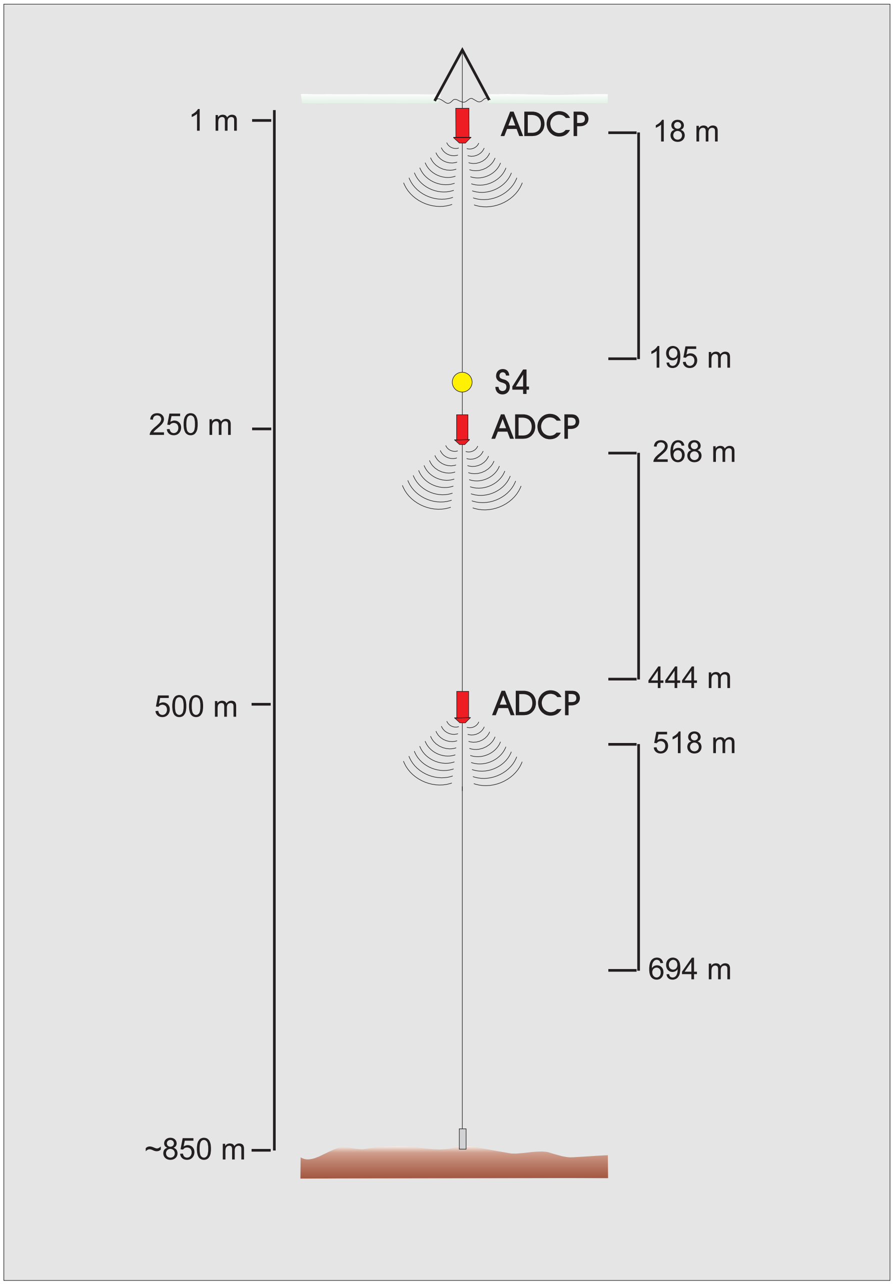


Figure 12: Diagram showing the mooring array at both GH-1 and GH-2 with 3 ADCPs and one S4 instrument. The scale to the left indicates the depth below sea level at which each instrument was deployed. The ranges to the right indicate the sections of the water column observed by the ADCPs.

The analysis of the mooring data generally follows the methodology detailed in section one for the McMurdo ice Shelf except that no S4 casts are available to “fill in the gaps” between the ADCP data. The setup data for three sentinel instruments and two S4 are shown in Appendix 2, Tables 12 and 13.

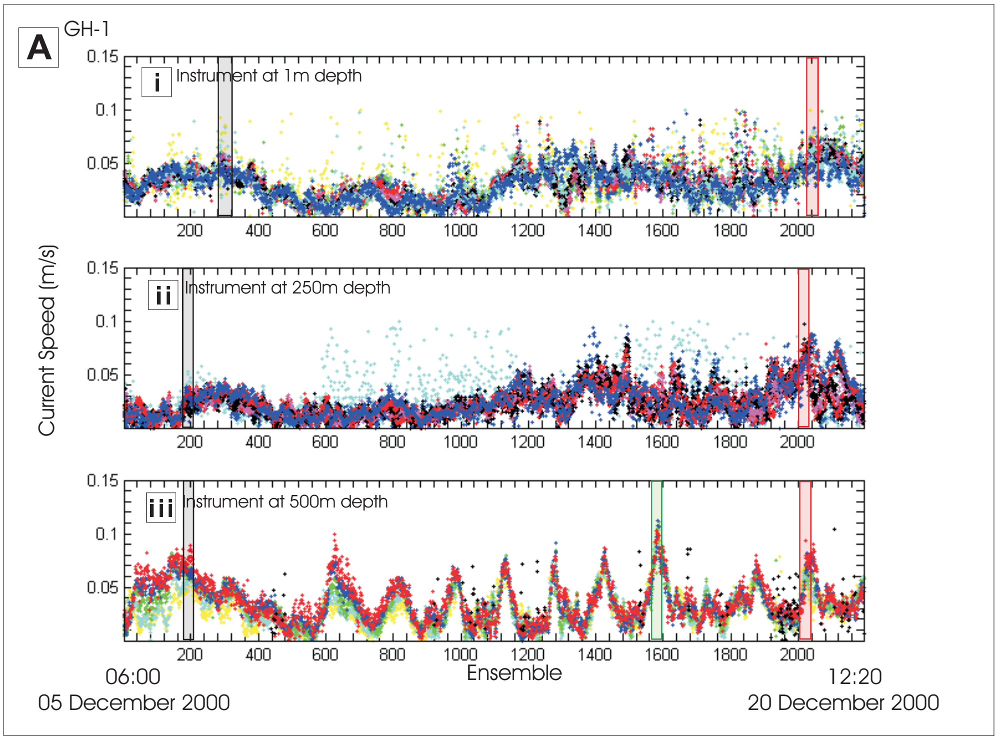
2.2.1 Magnetic deviation

Both the ADCP and S4 data were recorded without any correction for the magnetic deviation in the area. A value of $+150^o$ (east of North) has been applied to the processed directional data for all instruments to correct magnetic azimuth to true azimuth. The resulting current direction measured by the S4s and the uppermost data bin of the ADCP moored at 250 m depth agree within $\pm$ 10 degrees at both sites.

For each site the ADCP speed and directions are shown in figure 13 and figure 14. To develop the synthetic maximum current profile, two periods of maximum flow for each instrument were selected and plotted against depth for the two sites, see figure 15. The synthetic water profiles were then constructed and are shown in figure 16. The calculated data is shown in Appendix 2, tables 10 and 11.

2.3 Acknowledgement

The data collection was funded by NSF grant OPP-0003607 to Prof. Ross Powell, Northern Illinois University. The data analysis was funded by NZ FORST Paleoclimate grant to Prof. Peter Barrett, Victoria University of Wellington, (Natalie Robinson, part of an MSc scholarship) and Antarctica NZ contract with VUW (Alex Pyne, ANDRILL Drilling Science Coordinator).



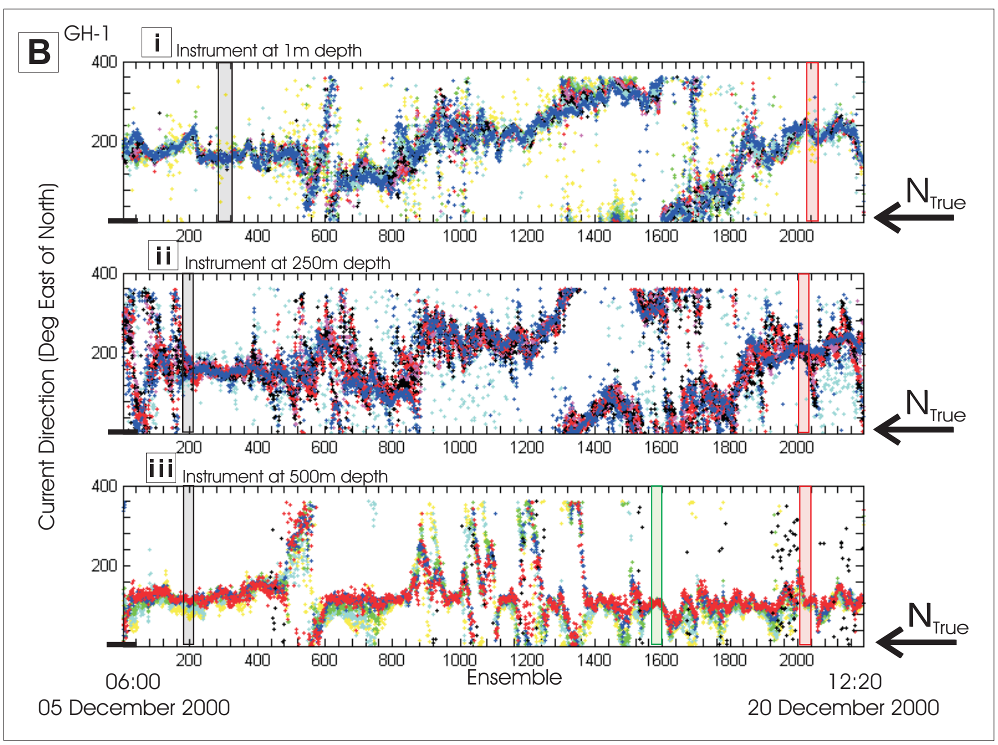


Figure 13: (A) Current speed and (B) current direction data from the three ADCP instruments at GH-1. Time series (i) is from the instrument at 1m BSL, (ii) 250m BSL and (iii) 500m BSL. Also shown are the short periods from which data was extracted for construction of maximum current profiles - Black, region 1, Green, region 1b, Red, region 2. The maximum current speeds at each depth were captured, so the regions were not quite synchronous through the water column.

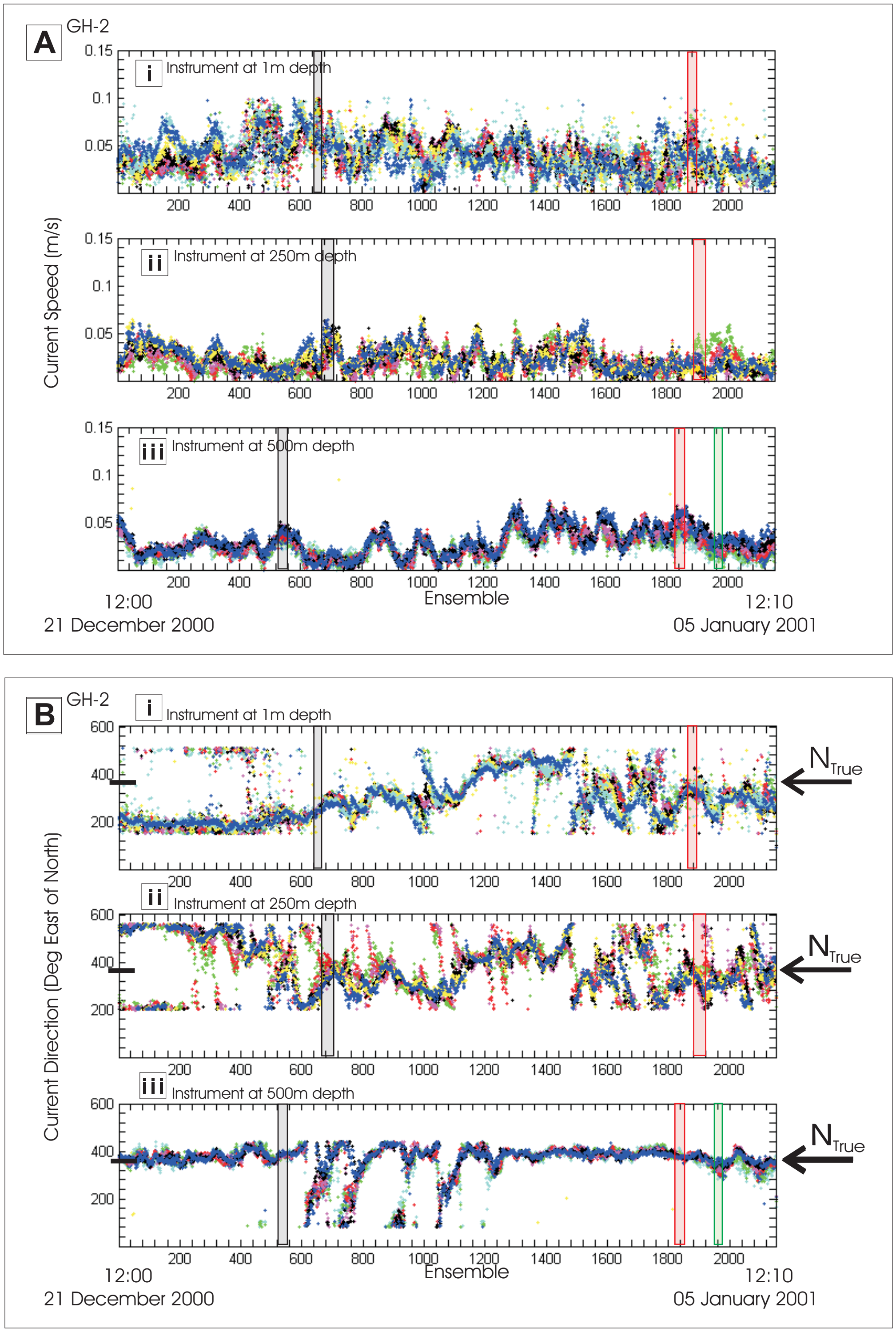
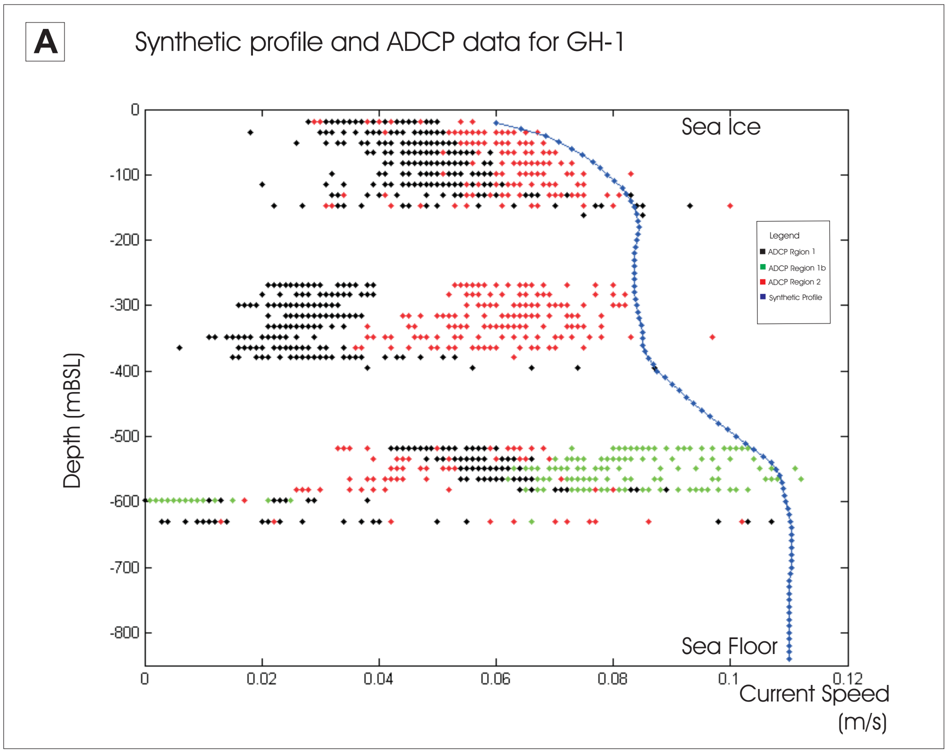


Figure 14: (A) Current speed and (B) current direction data from the three ADCP instruments at GH-2. Time series (i) is from the instrument at 1m BSL, (ii) 250m BSL and (iii) 500m BSL. Also shown are the short periods from which data was extracted for construction of maximum current profiles - Black, region 1, Red, region 2, Green, region 2b. The maximum current speeds at each depth were captured, so the regions were not quite synchronous through the water column.



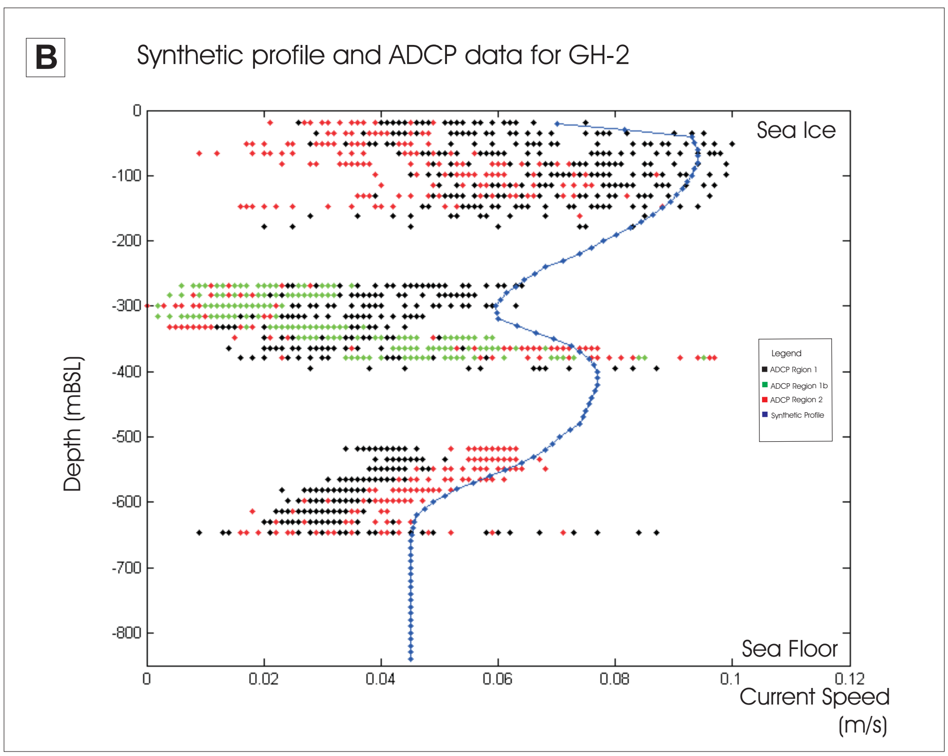


Figure 15: Synthetic maximum speed profiles created for (A) GH-1 and (B) GH-2 shown overlaid with the ADCP data.

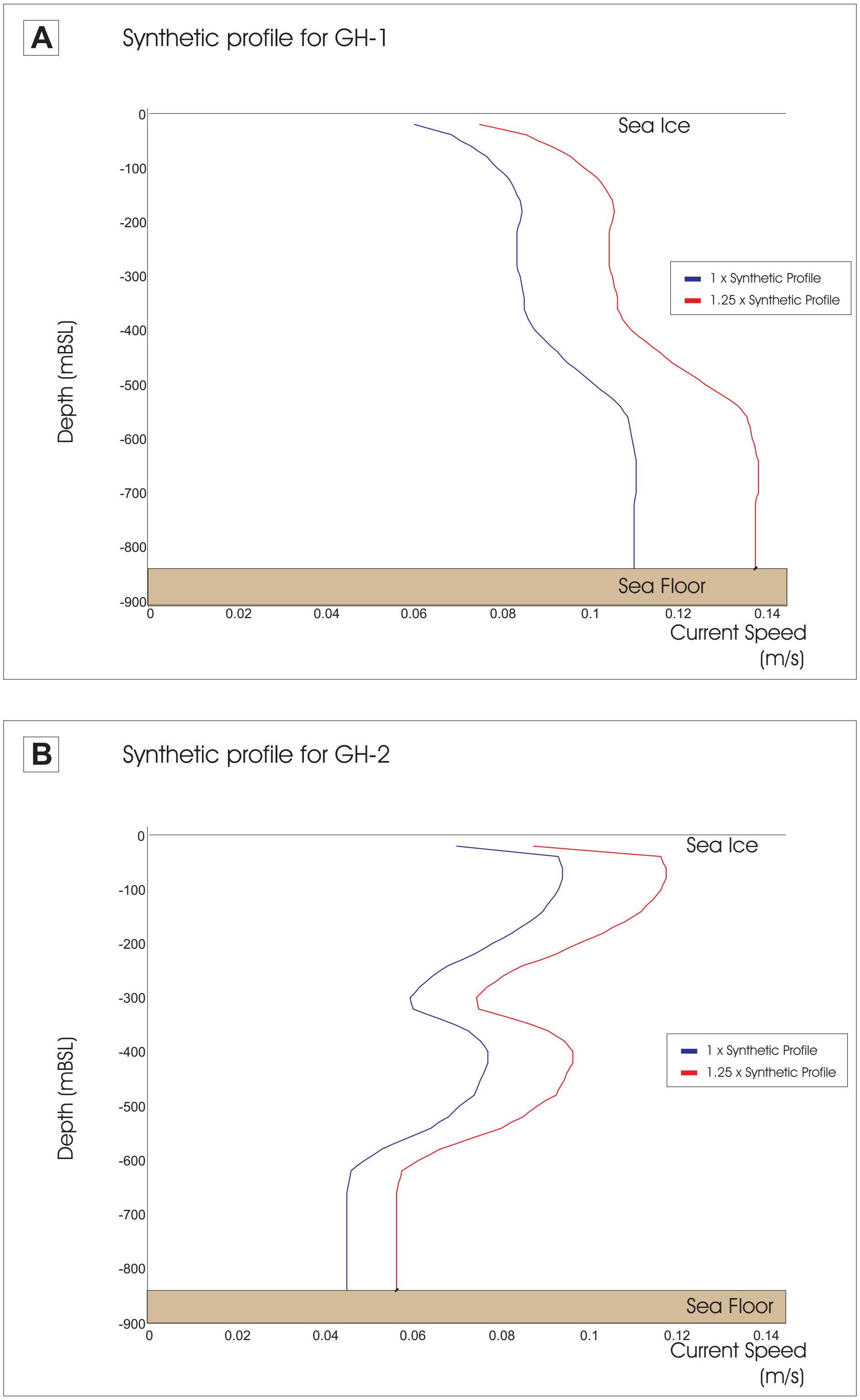


Figure 16: Synthetic maximum speed profiles created for (A) GH-1 and (B) GH-2 from ADCP data. x 1 profiles are shown in blue, with x 1.25 in red.

3 Appendices

3.1 Appendix 1 - Windless Bight

HWD-1 **Instrument**	RDI Sentinel 327	InterOcean S4 SN 04911042	RDI Sentinel 600	RDI Navigator
Water Depth	138.0m	143.0m	149.4m	898m
System Frequency	307.2 kHz		307.2 kHz	614.4 kHz
1st Bin Below Instrument	+6.03m		-12.05m	-1.44m
Bin Size	4.00m		10.00m	0.5m
No. of bins	30		13	90
Time per Ping	3.00 sec		3.00 sec	0.62 sec
Time (S4)		0.5 sec		
Pings per ensemble	200		200	175
Average Count (S4)		Did not Operate		
On Time (S4)				
Cycle Time (S4)				
Average Ensemble Interval	00 : 10 : 00.00		00 : 10 : 00.00	00 : 05 : 00.00
Start Date (Ensemble)	18-01-2003		18-01-2003	18-01-2003
Time	06 : 00 : 00.00		06 : 00 : 00.00	06 : 00 : 00.00
End Date (Ensemble)	22-01-2003		22-01-2003	22-01-2003
Time	02 : 10 : 00.00		02 : 10 : 00.00	2 : 05 : 00.00

Table 2: Windless Bight Site HWD-1; ADCP and S4 setup data

HWD-2 Instrument	RDI Sentinel 327	RDI Sentinel 600	InterOcean S4 SN 08291863	RDI Navigator
Water Depth	155.9m	496.4m	501.4m	887m
System Frequency	307.2 kHz	307.2kHz		614.4 kHz
1st Bin Below Instrument	-12.09m	14.13m		-2.99m
Bin Size	10.00m	12.00m		2.00m
No. of bins	14	13		20
Time per Ping	2.00 sec	2.00 sec		0.62 sec
Time (S4)			0.5 sec	
Pings per ensemble	150	150		130
Average Count (S4)			120	
On Time (S4)			00 : 01 : 00	
Cycle Time (S4)			00 : 10 : 00	
Average Ensemble Interval	00 : 05 : 00.00	00 : 05 : 00.00		00 : 05 : 00.00
Start Date (Ensemble)	30-01-2003	30-01-2003	30-01-2003	30-01-2003
Time	07 : 00 : 00.00	07 : 00 : 00.00	07 : 00 : 00.00	07 : 00 : 00.00
End Date (Ensemble)	01-02-2003	01-02-2003	01-02-2003	01-02-2003
Time	11 : 10 : 00.00	10 : 55 : 00.00	11 : 30 : 00.00	10 : 50 : 00.00

Table 3: Windless Bight Site HWD-2; ADCP and S4 setup data

Cast No.	Start	Mid	End
1	3607	12680	38878
2	2092	5389	8654
3	2130	8511	10530
4	1909	5974	11996
5	1397	9526	15035
6	1161	7574	11620
7	2775	9355	13308
8	3053	9650	13832
9	DID	NOT	OPERATE
10	1572	8343	12834
11	2153	8761	13408
12	2302	9330	13631
13	1226	7786	12017

Table 4: Sample numbers defining ‘Up’ and ‘Down’ casts at HWD-1

Cast No.	**Start**	**Mid**	**End**
1	2800	11375	15422
2	1836	10230	14807
3	1461	10290	15147
4	1492	9441	14036
5	2010	10447	15090
6	1885	9738	14363
7	1576	9228	13948
8	2225	9581	14614
9	1787	10083	15044
10	1409	9745	13866

Table 5: Sample numbers defining 'Up' and 'Down' casts at HWD-2

Site 1 **Cast No.**	Down (min)	Depth = 933m Av Vel Down ms^{-1}	Up)min)	Av Vel Up ms^{-1}
2	26	0.598	17	0.915
3	50	0.311	16	0.972
4	33	0.471	49	0.317
5	55	0.283	45	0.346
6	51	0.305	33	0.471
7	52	0.299	32	0.486
8	51	0.305	32	0.486
10	54	0.288	33	0.471
11	52	0.305	33	0.471
12	52	0.305	33	0.471
13	52	0.305	32	0.486

Table 6: Vertical velocity of S4 instrument through the water column at HWD-1

Site 2 **Cast No.**	Down (min)	Depth = 870m Av Vel Down ms^{-1}	Up)min)	Av Vel Up ms^{-1}
1	62	0.234	30	0.483
2	60	0.242	31	0.468
3	64	0.227	37	0.392
4	59	0.246	32	0.453
5	61	0.238	34	0.426
6	58	0.250	32	0.453
7	58	0.250	32	0.453
8	55	0.264	32	0.453
9	62	0.234	32	0.453
10	60	0.242	32	0.453

Table 7: Vertical velocity of S4 instrument through the water column at HWD-2

Depth m	**Speed ms^{-1}**	**Depth m**	**Speed ms^{-1}**	**Depth m**	**Speed ms^{-1}**	**Depth m**	**Speed ms^{-1}**
0	0.1385	240	0.1735	480	0.1704	720	0.1797
10	0.1418	250	0.1732	490	0.1706	730	0.1801
20	0.1442	260	0.1728	500	0.1708	740	0.1806
30	0.1466	270	0.1725	510	0.1711	750	0.1811
40	0.1495	280	0.1722	520	0.1714	760	0.1815
50	0.1580	290	0.1721	530	0.1717	770	0.1820
60	0.1685	300	0.1719	540	0.1721	780	0.1825
70	0.1753	310	0.1717	550	0.1724	790	0.1828
80	0.1817	320	0.1714	560	0.1728	800	0.1831
90	0.1900	330	0.1712	570	0.1732	810	0.1833
100	0.2014	340	0.1711	580	0.1737	820	0.1837
110	0.2212	350	0.1709	590	0.1741	830	0.1842
120	0.2017	360	0.1708	600	0.1745	840	0.1847
130	0.1833	370	0.1706	610	0.1749	850	0.1851
140	0.1813	380	0.1705	620	0.1755	860	0.1857
150	0.1797	390	0.1704	630	0.1760	870	0.1862
160	0.1784	400	0.1703	640	0.1764	880	0.1867
170	0.1774	410	0.1703	650	0.1768	890	0.1872
180	0.1766	420	0.1702	660	0.1772	900	0.1876
190	0.1760	430	0.1702	670	0.1777	910	0.1881
200	0.1753	440	0.1701	680	0.1780	920	0.1887
210	0.1747	450	0.1701	690	0.1783		
220	0.1743	460	0.1702	700	0.1788		
230	0.1738	470	0.1703	710	0.1792		

Table 8: Synthetic Profile for Windless Bight site HWD-1

Depth m	**Speed ms^{-1}**	**Depth m**	**Speed ms^{-1}**	**Depth m**	**Speed ms^{-1}**	**Depth m**	**Speed ms^{-1}**
0	0.0930	240	0.1910	480	0.1395	720	0.1390
10	0.0930	250	0.1880	490	0.1390	730	0.1400
20	0.0930	260	0.1840	500	0.1390	740	0.1400
30	0.0930	270	0.1790	510	0.1390	750	0.1410
40	0.0930	280	0.1740	520	0.1390	760	0.1410
50	0.0930	290	0.1700	530	0.1390	770	0.1420
60	0.0935	300	0.1640	540	0.1390	780	0.1420
70	0.0940	310	0.1570	550	0.1390	790	0.1430
80	0.0950	320	0.1510	560	0.1390	800	0.1430
90	0.0970	330	0.1470	570	0.1390	810	0.1440
100	0.0980	340	0.1450	580	0.1390	820	0.1440
110	0.1010	350	0.1440	590	0.1390	830	0.1450
120	0.1040	360	0.1430	600	0.1385	840	0.1450
130	0.1090	370	0.1430	610	0.1380	850	0.1460
140	0.1220	380	0.1420	620	0.1380	860	0.1470
150	0.1350	390	0.1420	630	0.1380	870	0.1470
160	0.1470	400	0.1410	640	0.1380	880	0.1480
170	0.1570	410	0.1410	650	0.1380	890	0.1480
180	0.1660	420	0.1400	660	0.1380	900	0.1490
190	0.1740	430	0.1400	670	0.1380	910	0.1500
200	0.1830	440	0.1400	680	0.1375	920	0.1500
210	0.1900	450	0.1400	690	0.1380	930	0.1510
220	0.1930	460	0.1400	700	0.1390		
230	0.1930	470	0.1400	710	0.1390		

Table 9: Synthetic Profile for Windless Bight site HWD-2

Depth m	**Speed cms^{-1}**	**Depth m**	**Speed cms^{-1}**	**Depth m**	**Speed cms^{-1}**	**Depth m**	**Speed cms^{-1}**
		220	0.0835	430	0.0913	640	0.1105
20	0.0600	230	0.0835	440	0.0925	650	0.1105
30	0.0643	240	0.0835	450	0.0938	660	0.1105
40	0.0685	250	0.0835	460	0.0950	670	0.1105
50	0.0708	260	0.0835	470	0.0965	680	0.1105
60	0.0730	270	0.0835	480	0.0980	690	0.1105
70	0.0748	280	0.0835	490	0.0995	700	0.1105
80	0.0765	290	0.0838	500	0.1010	710	0.1103
90	0.0778	300	0.0840	510	0.1025	720	0.1100
100	0.0790	310	0.0843	520	0.1040	730	0.1100
110	0.0803	320	0.0845	530	0.1055	740	0.1100
120	0.0815	330	0.0848	540	0.1070	750	0.1100
130	0.0823	340	0.0850	550	0.1078	760	0.1100
140	0.0830	350	0.0850	560	0.1085	770	0.1100
150	0.0835	360	0.0850	570	0.1088	780	0.1100
160	0.0840	370	0.0855	580	0.1090	790	0.1100
170	0.0843	380	0.0860	590	0.1093	800	0.1100
180	0.0845	390	0.0868	600	0.1095	810	0.1100
190	0.0843	400	0.0875	610	0.1098	820	0.1100
200	0.0840	410	0.0888	620	0.1100	830	0.1100
210	0.0838	420	0.0900	630	0.1103	840	0.1100

Table 10: Synthetic Profile for site GH-1

Depth m	**Speed cms^{-1}**	**Depth m**	**Speed cms^{-1}**	**Depth m**	**Speed cms^{-1}**	**Depth m**	**Speed cms^{-1}**
		220	7.400	430	7.650	640	4.550
20	7.000	230	7.100	440	7.600	650	4.525
30	8.150	240	6.800	450	7.550	660	4.525
40	9.300	250	6.625	460	7.500	670	4.500
50	9.350	260	6.450	470	7.450	680	4.500
60	9.400	270	6.300	480	7.400	690	4.500
70	9.400	280	6.150	490	7.225	700	4.500
80	9.400	290	6.050	500	7.050	710	4.500
90	9.350	300	5.950	510	6.925	720	4.500
100	9.300	310	5.975	520	6.800	730	4.500
110	9.225	320	6.000	530	6.600	740	4.500
120	9.150	330	6.325	540	6.400	750	4.500
130	9.050	340	6.650	550	6.125	760	4.500
140	8.950	350	6.950	560	5.850	770	4.500
150	8.800	360	7.250	570	5.575	780	4.500
160	8.650	370	7.400	580	5.300	790	4.500
170	8.450	380	7.550	590	5.100	800	4.500
180	8.250	390	7.625	600	4.900	810	4.500
190	8.025	400	7.700	610	4.750	820	4.500
200	7.800	410	7.700	620	4.600	830	4.500
210	7.600	420	7.700	630	4.575	840	4.500

Table 11: Synthetic Profile for site GH-2

3.2 Appendix 2 - Granite Harbour

GH-1 **Instrument**	76.9750482 S RDI Sentinel	 InterOcean S4 SN 08291863	162.7503070E RDI Sentinel	 RDI Sentinel
Water Depth	1m	250m	250m	500m
System Frequency	307.2 kHz		307.2kHz	307.2KHz
1st Bin Below Instrument	-17.76m		-17.75m	-17.74m
Bin Size	16.00m		16.00m	16.00m
No. of bins	11		11	11
Time per Ping	9.23 sec		9.23 sec	9.23 sec
Time (S4)		0.5 sec		
Pings per ensemble	65		65	65
Average Count (S4)		120		
On Time (S4)		00 : 03 : 00		
Cycle Time (S4)		00 : 12 : 00		
Average Ensemble Interval	00 : 10 : 00.00		00 : 10 : 00.00	00 : 10 : 00.00
Start Date (Ensemble)	5-12-2000	5-12-2000	5-12-2000	5-12-2000
Time	06 : 00 : 00.00	06 : 00 : 00.00	06 : 00 : 00.00	06 : 00 : 00.00
End Date (Ensemble)	20-12-2000	22-12-2000	20-12-2000	20-12-2000
Time	14 : 20 : 00.00	07 : 39 : 00.00	15 : 10 : 00.00	17 : 20 : 00.00

Table 12: Granite Harbour Site GH-1; ADCP and S4 setup data

GH-1	76.9750482 S		162.7503070E	
Instrument	RDI Sentinel	InterOcean S4 SN 08291863	RDI Sentinel	RDI Sentinel
Water Depth	1m	250m	250m	500m
System Frequency	307.2 kHz		307.2kHz	307.2KHz
1st Bin Below Instrument	-17.76m		-17.75m	-17.74m
Bin Size	16.00m		16.00m	16.00m
No. of bins	11		11	11
Time per Ping	9.23 sec		9.23 sec	9.23 sec
Time (S4)		0.5 sec		
Pings per ensemble	65		65	65
Average Count (S4)		120		
On Time (S4)		00 : 03 : 00		
Cycle Time (S4)		00 : 12 : 00		
Average Ensemble Interval	00 : 10 : 00.00		00 : 10 : 00.00	00 : 10 : 00.00
Start Date (Ensemble)	21-12-2000	21-12-2000	21-12-2000	21-12-2000
Time	12 : 00 : 00.00	12 : 00 : 00.00	12 : 00 : 00.00	12 : 00 : 00.00
End Date (Ensemble)	5-01-2001	5-01-2001	5-01-2001	5-01-2001
Time	15 : 20 : 00.00	16 : 51 : 00.00	15 : 30 : 00.00	15 : 40 : 00.00

Table 13: Granite Harbour Site GH-2; ADCP and S4 setup data