Two-Rocks moorings data report

C. B. Fandry, D. Slawinski and L. Pender

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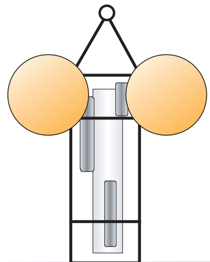

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Enquiries should be addressed to:

Dr Chris Fandry
CSIRO Marine and Atmospheric Research
Private Bag No. 5
WEMBLEY WESTERN AUSTRALIA 6913
Phone 08 9333 6570

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Introduction

As part of the Strategic Research Fund for the Marine Environment (SRFME), a marine research project jointly supported by CSIRO and the WA State Government, a set of moorings were deployed at three sites off Two Rocks, Western Australia (Fig. 1) during the period July 2004 to July 2005. The field program consisted of four separate deployments that were made during this period and the data collected included ocean currents, temperature, salinity, pressure (sea level), oxygen and fluorescence.

The sites were chosen to coincide with three sites where monthly biogeochemical measurements were being made. Being relatively close to shore the data will be limited in their application to describing features of the Leeuwin Current and the eddies, which are persistent features of the circulation off WA. Nevertheless they are complementing the biogeochemical data, and are providing the basis for conceptual physical models of the near shore circulation as well as vital observational data for the validation of numerical models.

This report summarises all of the valid data collected during this field program.

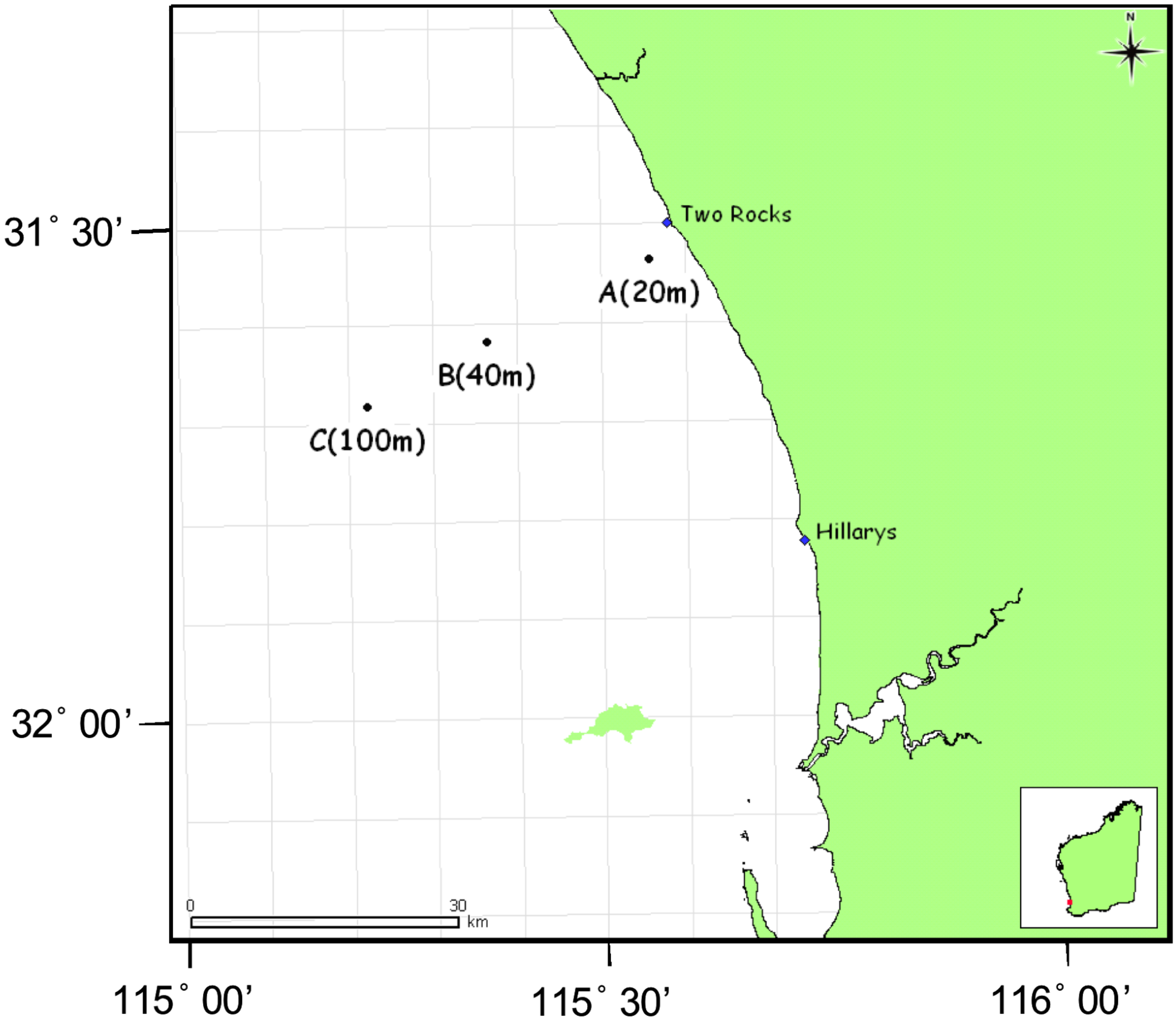

Figure1: Mooring locations A, B, C and water depths.

Mooring Summary

Mooring	Position	Water Depth	1st deployment	2nd deployment	3rd deployment	4th deployment
A	31º 32.2S, 115º 33.5E	20m	30/6/04 to 10/10/04	13/10/04 to 20/1/05	8/2/05 to 16/4/05	18/4/05 to 16/7/05
B	31º 37.1S, 115º 21.9E	40m	30/06/04 to 7/10/04	8/10/04 to 6/1/05	8/2/05 to 16/4/05	No data
C	31º 40.9S, 115º 13.3E	100m	30/06/04 to 7/10/04	8/10/04 to 6/1/05	12/1/05 to 19/4/05	20/6/05 to 16/7/05

Table 1: Summary of mooring positions, depth and deployment periods

First Deployment

Mooring A

Instrument	Serial no.	Nominal Depth	Description
SBE 19-plus	4534	10m	Multi-sensor – CTD, Oxygen, PAR and Fluorescence
SBE 37	3125	20m	Microcat – CT (conductivity and temperature)
SBE 26	0409	20m	Tide/wave gauge
RBR XR-420-TG	010095	20m	Tide gauge with temperature sensor.
Aquadopp	1036	20m	ADCP

Commentary

With the exception of the Microcat (3125) conductivity data and SBE 19 Plus multi-sensor (4534) auxiliary data, all instruments were working properly. Very early in the deployment, the conductivity sensor of the Microcat filled with sand rendering the data useless. The SBE 26 (0409) tide gauge also filled with sand, however the data is okay. The batteries in the SBE 19 Plus multi-sensor went flat around 1 Sept. and thus auxiliary data (oxygen, PAR and fluorescence) are not valid after this time. There appears to be valid CTD data up until 15 Sept.

The Brankner tide gauge (RBR XR-420-TG) was incorrectly configured to sample every 15 hours (instead of 15 minutes), and the data are therefore not included in this report.

Mooring B

Instrument	Serial no.	Nominal Depth	Description
SBE 37	2972	20m	Microcat – CTD (conductivity, temperature and pressure)
SBE 26	0408	40m	Tide/wave gauge
RDI Workhorse	3712	40m	300khz ADCP – lost and later recovered

Commentary

The ADCP was lost sometime during this deployment and later recovered using a commercial ROV. From the state of the ADCP cage upon recovery, it is evident that the cage was upside-down for at least some of the deployment. No data was recovered from this ADCP. The SBE 26 (0408) tide gauge underwent a slow failure from about 22 July, 2004 and no data is included here. The Microcat (2972) data appears to be okay.

Mooring C

Instrument	Serial no.	Nominal Depth	Description
SBE 19-plus	4536	10m	Multi-sensor – CTD, Oxygen, PAR and Fluorescence
SBE 37	3050	50m	Microcat – CT (conductivity and temperature)
SBE 37	3027	100m	Microcat – CTD (conductivity, temperature and depth)
RDI Workhorse	3713	100m	300 khz ADCP

Commentary

There appeared to be a problem with the deployment of the ADCP cage on this mooring. There is no valid ADCP data until late on 24 Aug. when the ADCP pitch and roll sensors indicated that the ADCP flipped from pointing down to pointing up. There was a storm event on the 24 Aug which probably caused the instrument to right itself. The Microcat (3027)mounted on the ADCP cage had valid temperature data; however, the salinity data indicates fouling of the conductivity cell up until the same time that the ADCP began to work, although the salinity data is still noisy after this time

The batteries in the SBE 19 Plus multi-sensor (4536) went flat around 19 Sept. and thus auxiliary data (oxygen, PAR and fluorescence) are not valid after this time. There appears to be valid CTD data up until the mooring was recovered. The fluorometer data becomes noisy from around 1 Sept. Data from the second Microcat (3050) appears to be okay.

Second Deployment

Mooring A

Instrument	Serial no.	Nominal Depth	Description
SBE 19-plus	4534	10m	Multi-sensor – CTD, Oxygen, PAR and Fluorescence
SBE 37	3125	20m	Microcat – CT (conductivity and temperature)
SBE 26	0409	20m	Tide/wave gauge
RBR XR-420-TG	010095	20m	Tide gauge with temperature sensor.
Aquadopp	1036	20m	ADCP

Commentary

The SBE 26 tide gauge (0409) failed to store any data. Fortunately the Brankner tide gauge (010095) worked well. The PAR sensor on the SBE 19 Multisensor failed on 31 Oct after a calibration drift which started around 25 Oct. As in the first deployment, the conductivity cell on the SBE 37 Microcat (3125) filled with sand on 8 Dec despite being mounted vertically. Thus the conductivity and salinity data are of little value. There is also evidence that the conductivity cell was partially blocked on occasions before this date.

Data from the Microcat temperature sensor and all sensors on the SBE 19 Multisensor (4534) with the exception of PAR as noted above appeared to be of good quality.

Mooring B

Instrument	Serial no.	Nominal Depth	Description
SBE 37	2972	20m	Microcat – CTD (conductivity, temperature and pressure)

Commentary
Good quality data was measured by the Microcat (2972).

Mooring C

Instrument	Serial no.	Nominal Depth	Description
SBE 19-plus	4536	10m	Multi-sensor – CTD, Oxygen, PAR and Fluorescence
SBE 37	3027	20m	Microcat – CTD (conductivity, temperature and depth)
SBE 37	3050	100m	Microcat – CTD (conductivity and temperature)

Commentary
With the exception of the SBE 19 Multisensor 4536) PAR sensor, which was not operational for the duration of the deployment, all instruments provided good quality data.

Third Deployment

Mooring A

Instrument	Serial no.	Nominal Depth	Description
SBE 19-plus	4534	10m	Multi-sensor – CTD, Oxygen, PAR and Fluorescence
SBE 37	3125	20m	Microcat – CT (conductivity and temperature)
SBE 26	0409	20m	Seabird Tide/wave gauge
RBR XR-420-TG	010095	20m	Tide gauge with temperature sensor.
Aquadopp	1484	11m	Single point acoustic doppler current meter.

Commentary
All instruments provided good quality data except for the SBE 19 plus (4534). As with the previous deployments the geochemical sensors malfunctioned and none of the data is useful.

Mooring B

Instrument	Serial no.	Nominal Depth	Description
SBE 37	2972	25m	Microcat – CTD (conductivity, temperature and pressure).
Aquadopp	1414	26m	Single point acoustic doppler current meter.

Commentary
The Aquadopp (1414) gave a full record for the deployment period and the data appears to be good. The SBE37 (2972) was deployed, but unfortunately was not turned on to log data.

Mooring C

Instrument	Serial no.	Nominal Depth	Description
SBE 19-plus	4536	15m	Multi-sensor – CTD, Oxygen, PAR and Fluorescence.
SBE 37	3050	50m	Microcat – CTD (conductivity, temperature).
SBE 37	3027	100m	Microcat – CTD (conductivity, temperature and depth).
SBE 26	0408	100m	Seabird Tide/wave gauge.
RDI Workhorse	3712	100m	300khz ADCP.

Commentary
The Seabird SBE37's (3027 and 3050) provided good data for the full deployment period. SBE 26 (0408) developed a leak in its pressure sensor and the data slowly drifted off during the deployment. The SBE19-plus (4536) recorded data from 12th Jan until it ran out of batteries on 30th March. The temperature, pressure and conductivity/salinity records all appears to give good data, however the data from the geochemical sensors are once again unreliable. The RDI ADCP (3712) recorded data from 12th Jan until a fault developed in the unit on 19th Feb. The data for that 5 week period appears to be good.

Fourth Deployment

Mooring A

Instrument	Serial no.	Nominal Depth	Description
SBE 19-plus	4534	10m	Multi-sensor – CTD, Oxygen, PAR and Fluorescence
SBE 37	3125	20m	Microcat – CT (conductivity and temperature)
SBE 26	0409	20m	Seabird Tide/wave gauge
RBR XR-420-TG	010095	20m	Tide gauge with temperature sensor.
Aquapro	AQP1036	20m	Nortek 600khz ADCP

Commentary
Data from all instruments appear of good quality with the exception noted below. The SBE19 (4534) recorded from the start of the deployment until 23rd June when it ran out of batteries. The temperature, pressure, and conductivity/salinity sensor records all appear to give good data, however the data from the geochemical sensors are unreliable.

Mooring B

Instrument	Serial no.	Nominal Depth	Description
SBE 37	2972	25m	Microcat – CTD (conductivity, temperature and pressure).
RDI ADCP	3713	45m	300khz Workhorse ADCP

Commentary

No data is available from this mooring at the time of publication of this report because the mooring was not recovered until mid January 2006. If the data is found to be good, it will be available via the link on p11.

Mooring C

Instrument	Serial no.	Nominal Depth	Description
SBE 19-plus	4536	15m	Multi-sensor – CTD, Oxygen, PAR and Fluorescence.
SBE 37	3027	50m	Microcat – CTD (conductivity, temperature and pressure).
SBE 37	3050	100m	Microcat – CTD (conductivity and temperature).
RDI Workhorse	3712	100m	300khz ADCP.

Commentary

This mooring was not deployed until 20th June. All the data records therefore are of approximately 4 weeks duration only. All instruments recorded for the full 4 weeks duration, and all appear to have good data, except the geochemical sensors on the SBE (4536).

Data Files

The instruments were configured to provide a time-series of raw data at 15 minute intervals. A simple moving average over five point samples (1.25hours) was applied to the time-series which was then sampled at hourly intervals on the hour. For each mooring and oceanic variable the hourly data from all the instruments were combined to form data files covering one full year (Table 3). In some cases data from different instruments were used to construct the full year data files. There are data gaps where instrument failures occurred and during deployment change overs. Hourly wind data from an automatic weather station at a nearby coastal town, Ocean Reef, is also available on this site. The data files can be accessed with approval at http://www.marine.csiro.au/marlin/search contents.html

Mooring	Variable	Instrument (s)	Depth	File Name
A	T	SBE 4534	10m	Temperature_A_SBE4534_ July04-July05.xls
A	T	SBE 3125	20m	Temperature_A_SBE3125_ July04-July05.xls
B	T	SBE 2972	25m	Temperature_B_SBE2972_ July04-Dec04.xls
C	T	SBE 3027/3050	50m	Temperature_C_SBE3027_ 3050_50m_July04-July05.xls
C	T	SBE 3027/3050	100m	Temperature_C_SBE3027_ 3050_July04-July05.xls
C	T	SBE 2972	10-50m	Temperature_C_SBE2972_ July04-July05.xls
A	S	SBE 3125	20m	Salinity_A_SBE3125_July04-June05.xls
A	S	SBE 4534	10m	Salinity_A_SBE4534_July04-June05.xls
C	S	SBE 3050/3027	50m	Salinity_C_SBE3050-3027_50m_July04-June05.xls
C	S	SBE3050/3027	100m	Salinity_C_SBE3050-3027_July04-June05.xls
C	S	SBE 4536	10m	Salinity_C_SBE4536_July04-June05.xls
A	P	AQD1036/ RBR010095	20m	Pressure_A_AQD1036_RBR0 10095_July04-July05.xls
C	P	SBE 3037/RDI 3712	100m	Pressure_C_SBE3027_RDI 3712_July04-July05.xls
A	Currents	AQD1036/AQD1484	5-20m	Currents_A_AQD1036_AQD 1484_July04-July05.xls
B	Currents	AQD1414	28m	Currents_B_AQD1414_Feb05-April05.xls
C	Currents	RDI 3712/3713	11-97m	Currents_C_RDI3713_3712_ July04-June05.xls

Table 3: Listing of data files (T is temperature, S is salinity and P is pressure). The currents are resolved as long-shore and cross-shore components where the positive longshore direction is defined as 31^0 to the west of North, and positive cross-shore direction is 31^0 to the north of East.

Data Figures

Temperature

Figures 2-6 show time-series of temperature based on hourly data derived from the raw 15 minute data using a running 5 point (1.25 hour) average.

Salinity

Figures 7-11 show time-series of salinity based on hourly data derived from the raw 15 minute data using a running 5 point (1.25 hour) average. While there has been a quality check on the salinity data, and bad data eliminated, some data may still be questionable (eg. Fig. 10)

Pressure

Figures 12-13 show time-series of pressure based on hourly data derived from the raw 15 minute data using a running 5 point (1.25 hour) average. The spring and neap cycles of the (diurnal) tides are clearly evident.

Long-shore Currents

Figures 14 and 15 show time-series of long-shore currents based on hourly data derived from the raw 15 minute data using a running 5 point (1.25 hour) average. The depth-averaged currents shown in Fig.14 are based on ADCP data, and the currents at 28m shown in Fig.15 are based on a fixed depth current meter.

Long-shore Currents, Winds and Pressure

Figure 16 compares time-series of 24 hour averaged long-shore bottom stress with long-shore wind stress at site A. Bottom stress is based on the depth-averaged current and given by the quadratic form $\tau^B = \rho_{water} C_D V(U^2+V^2)^{1/2}$ where C_D = 0.003 is the bottom drag coefficient, ρ_{water} =1024kgm^{-3} , and (U, V) the cross-shore and longshore components of depth-averaged current respectively. A linear regression analysis confirms the strong correlation between the two variables with a correlation coefficient of 0.79. The relationship is similar for other periods which shows that the coastal long-shore currents are essentially wind –driven.

Figure 17 compares the 48 hour averaged residual pressure (mean sea-level atmospheric pressure removed) with the long-shore wind stress. Clearly evident is the strong negative correlation between the two due to the Ekman effect ie. a northward wind stress causes, a northward flow with a corresponding offshore Ekman flow and hence a fall in sea-level, and a southward wind stress has the reverse effect.

Figure 18 shows monthly averaged long-shore current profiles at Sites C and A. At Site A the currents are on average northwards in the months October to April and southwards in the months May to September. This is a response to the prevailing winds during these periods. At Site C the currents are northwards in January and February, and southwards in May to October. The southward flow is much stronger than that at Site A and is probably due to the influence of the southward flowing Leeuwin current.

Figures 19 and 20 compare the monthly averaged near surface long-shore currents with 3% of the long-shore wind speed (this is a sometimes used rule of thumb law). The relationship is reasonable at Site A for all months and at Site C during January and February.

Temperature Comparisons

Temperatures at all sites are compared for the entire mooring perid 1 July 2004 to 15 July 2005 in Figure 21. At the shallow Site A, the waters are well mixed throughout the year, while at Site C there is some stratification in the summer months. During the winter months the inshore waters at Site A are cooler than the offshore waters at Site C by as much as 5^0C. The warmer offshore water is due to the influence of the Leeuwin current. In summer the inshore waters are warmer than the offshore waters by up to 2^0C, due to local surface heating having a greater effect in the near-shore shallow waters than in the offshore waters.

Monthly-averaged temperatures at all sites are shown in Figure 22. The trend for offshore waters to be warmer than inshore waters during winter and cooler in summer is clearly evident.

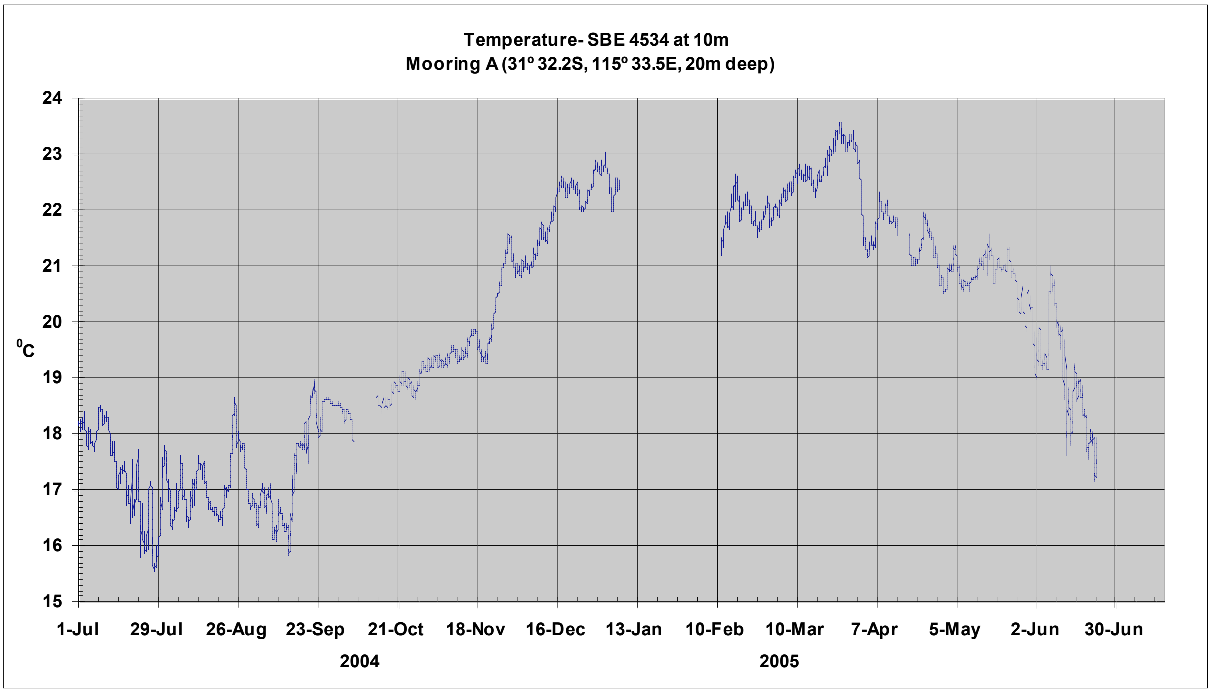

Figure 2: Temperature at 10m depth at Site A based on hourly time-series

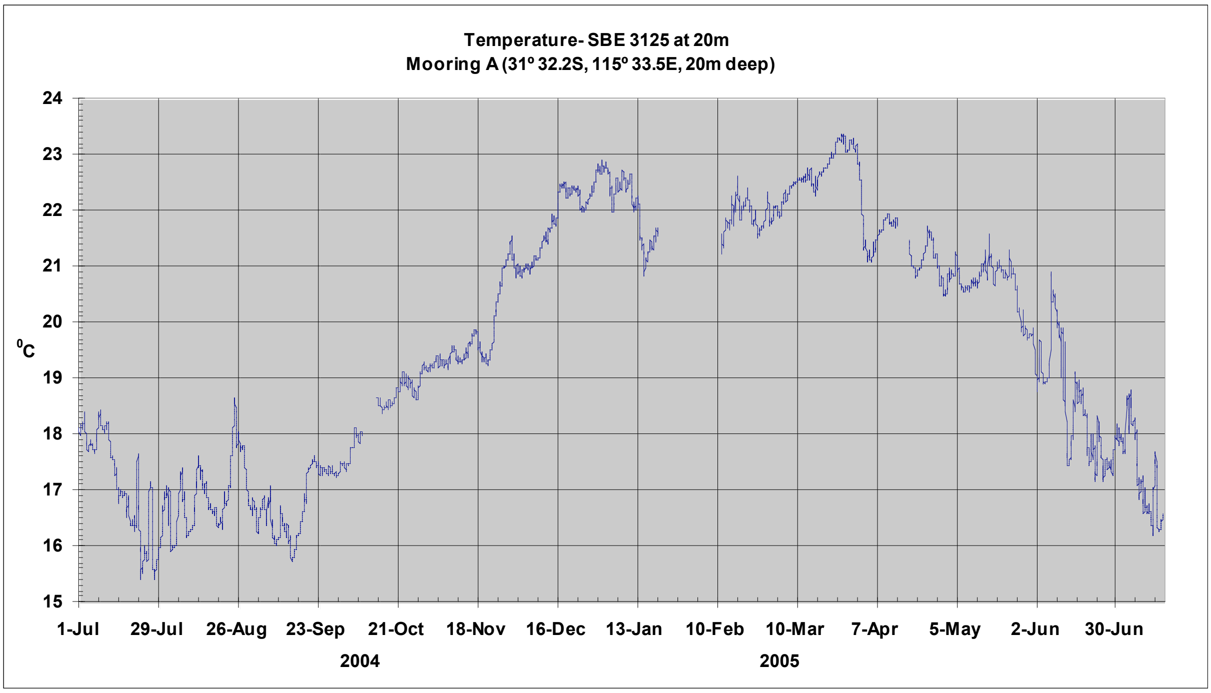

Figure 3: Temperature at 20m depth at Site A based on hourly time-series

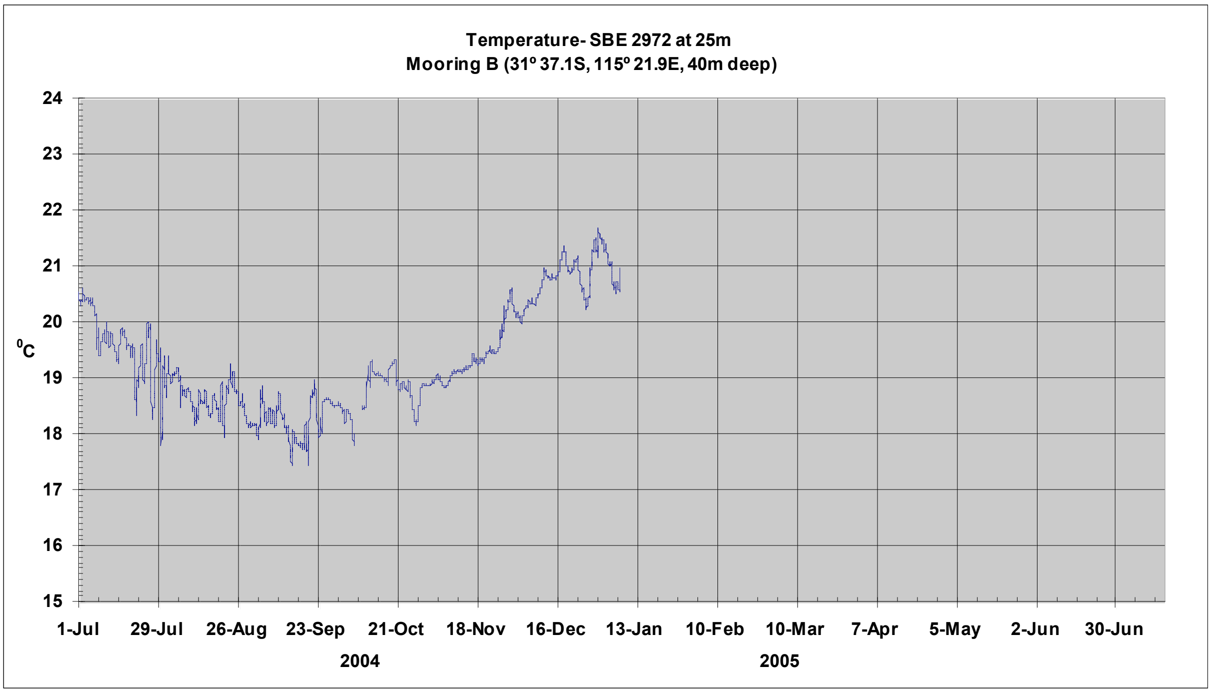

Figure 4: Temperature at 25m depth at Site B based on hourly time-series

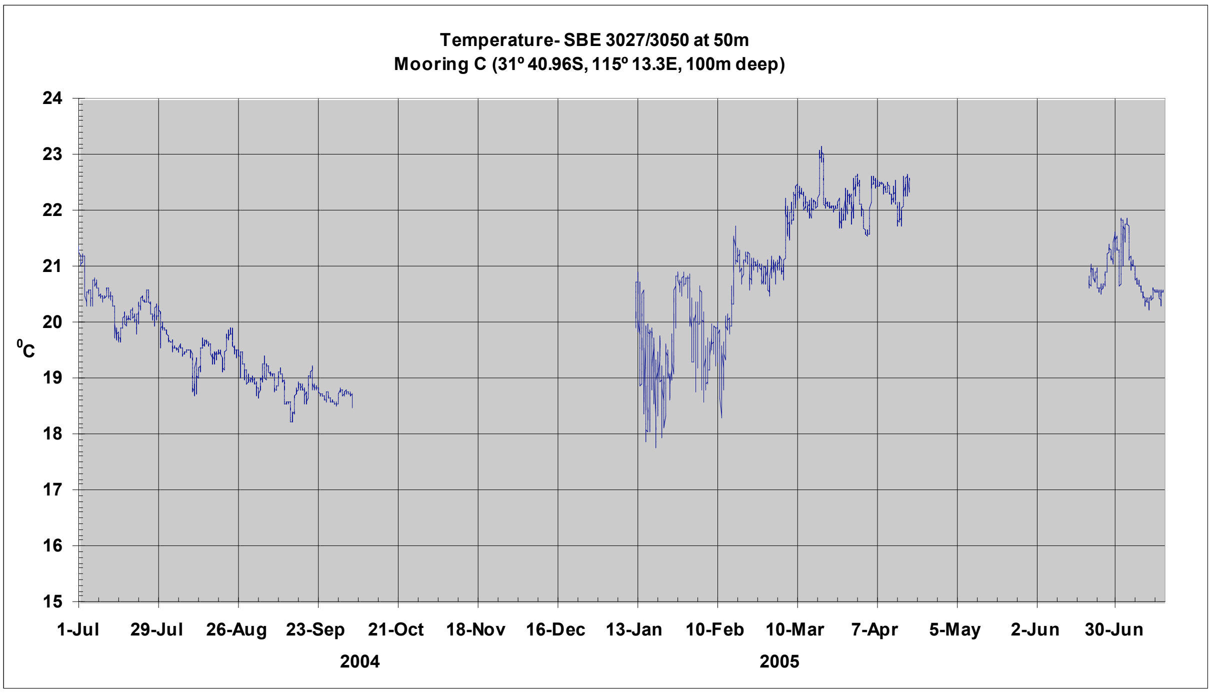

Figure 5: Temperature at 50m depth at Site C based on hourly time-series

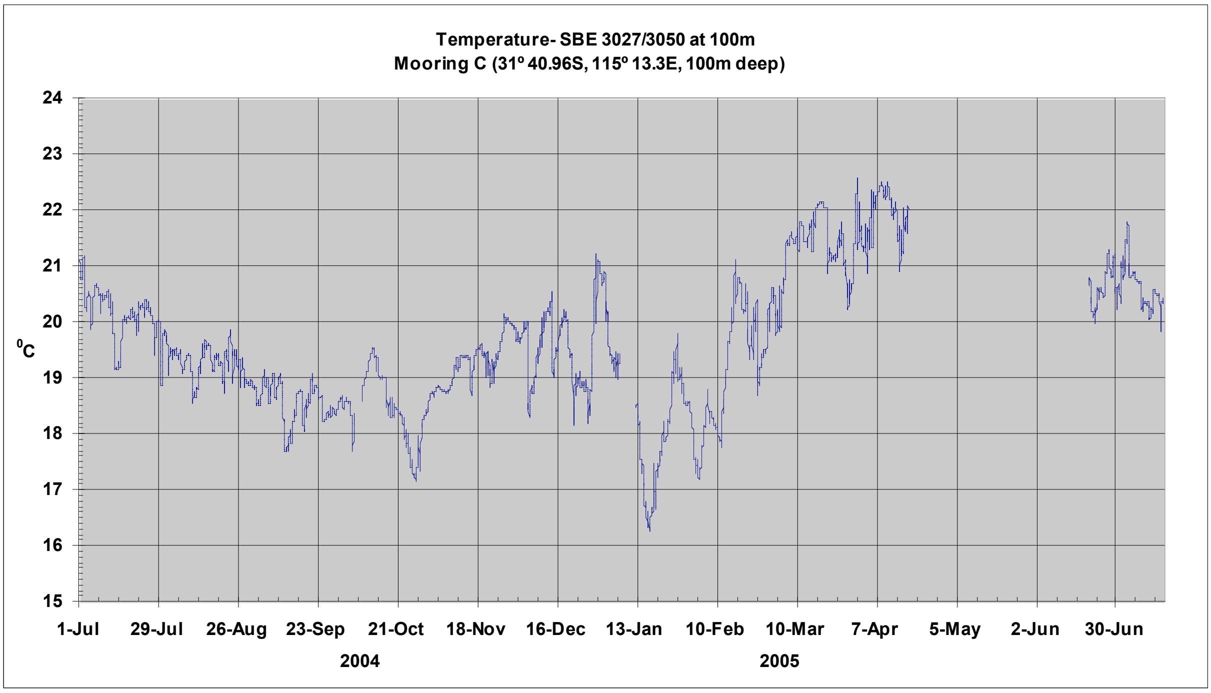

Figure 6: Temperature at 100m depth at Site C based on hourly time-series

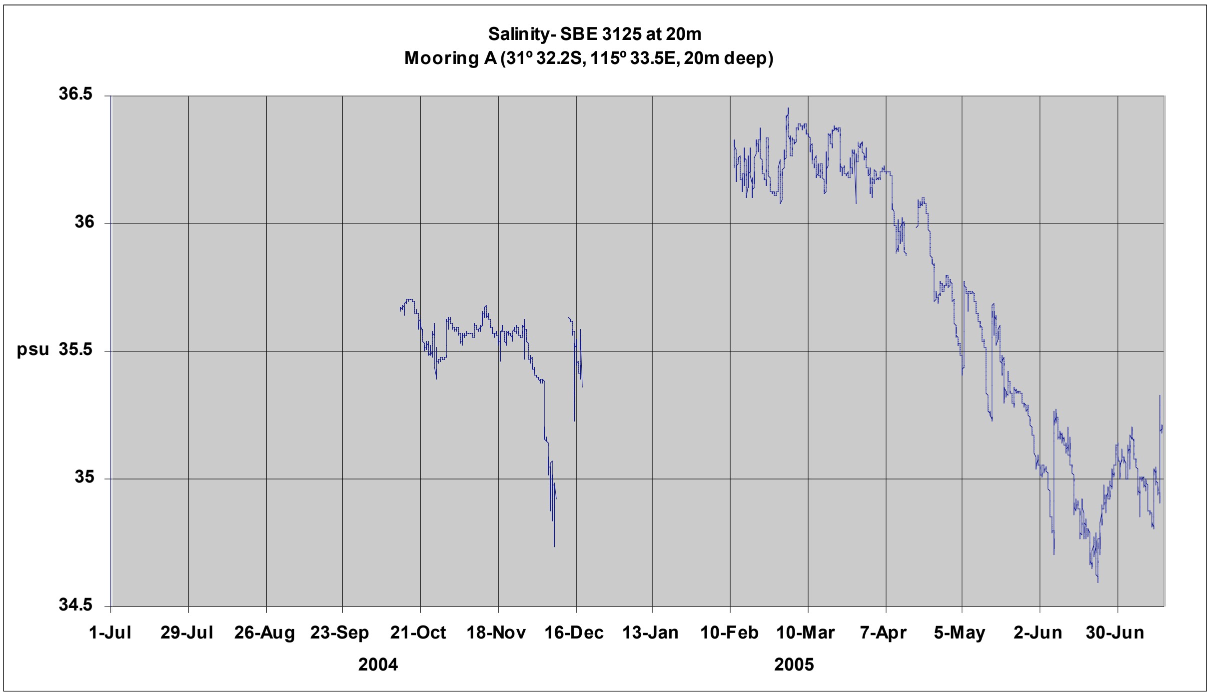

Figure 7: Salinity at 20m depth at Site A based on hourly time-series

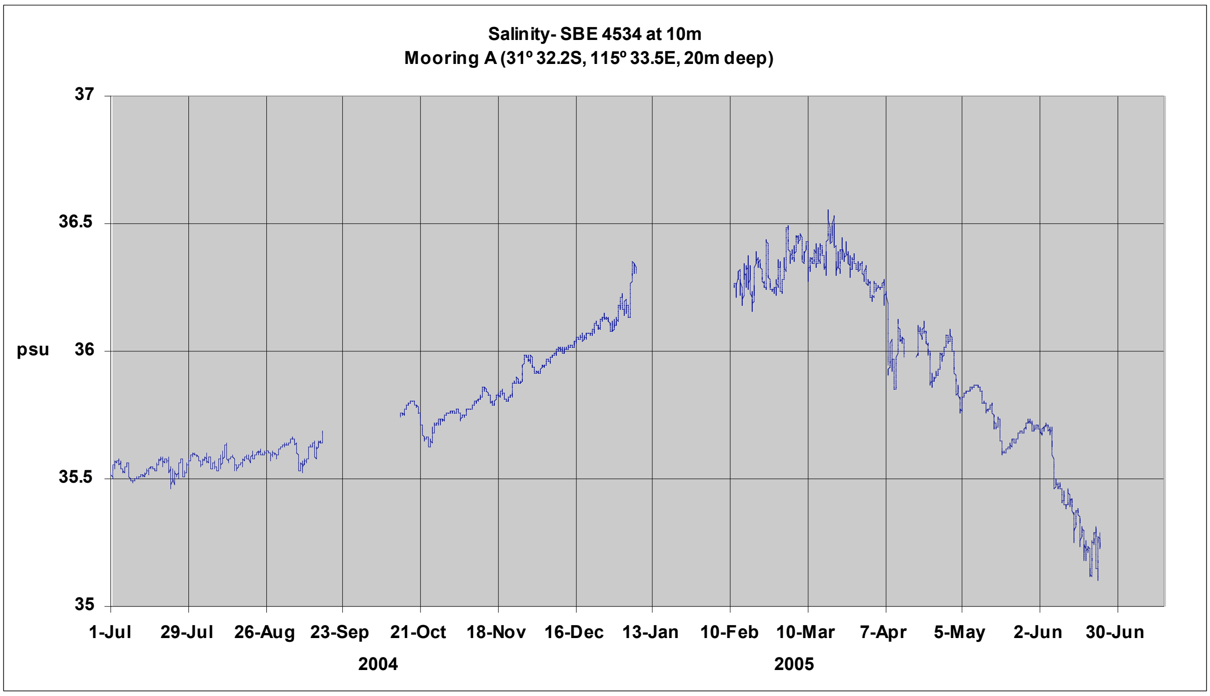

Figure 8: Salinity at 10m depth at Site A based on hourly time-series

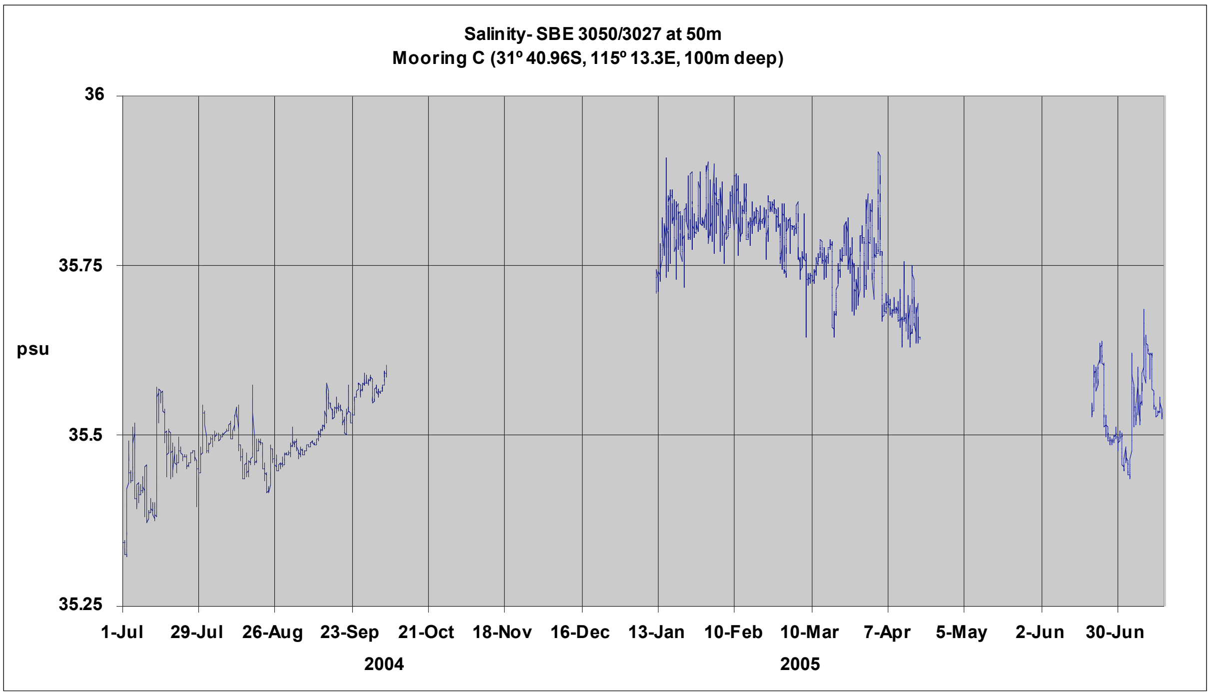

Figure 9: Salinity at 50m depth at Site C based on hourly time-series

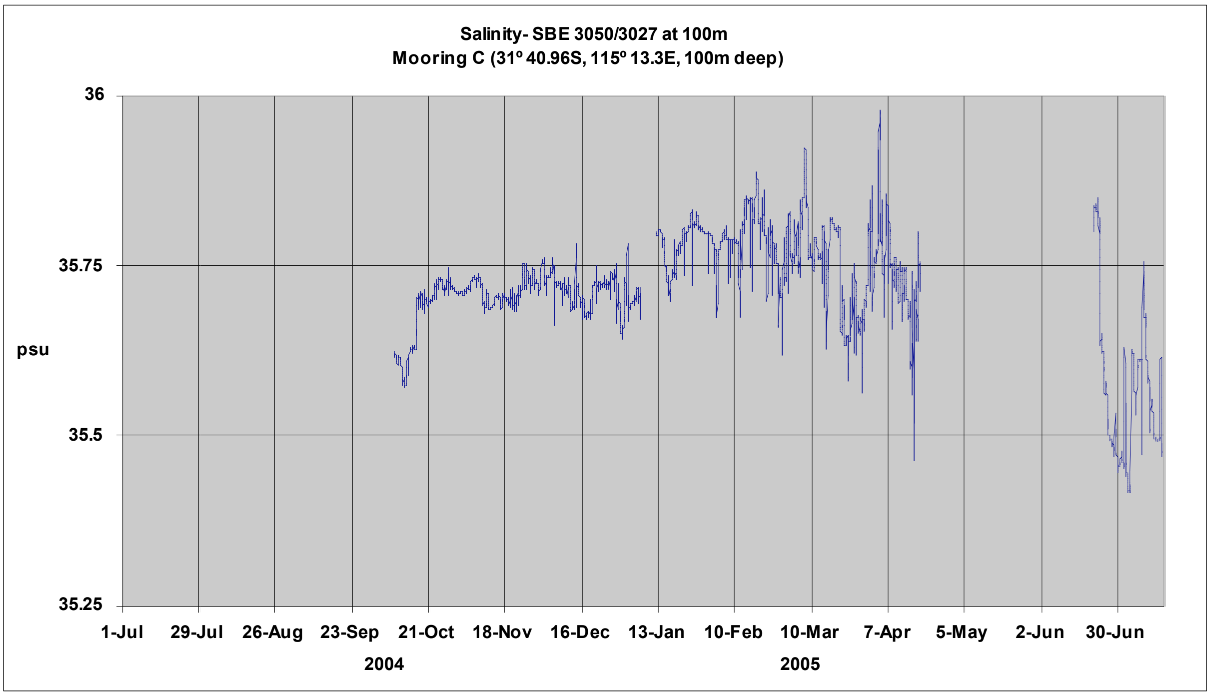

Figure 10: Salinity at 100m depth at Site C based on hourly time-series

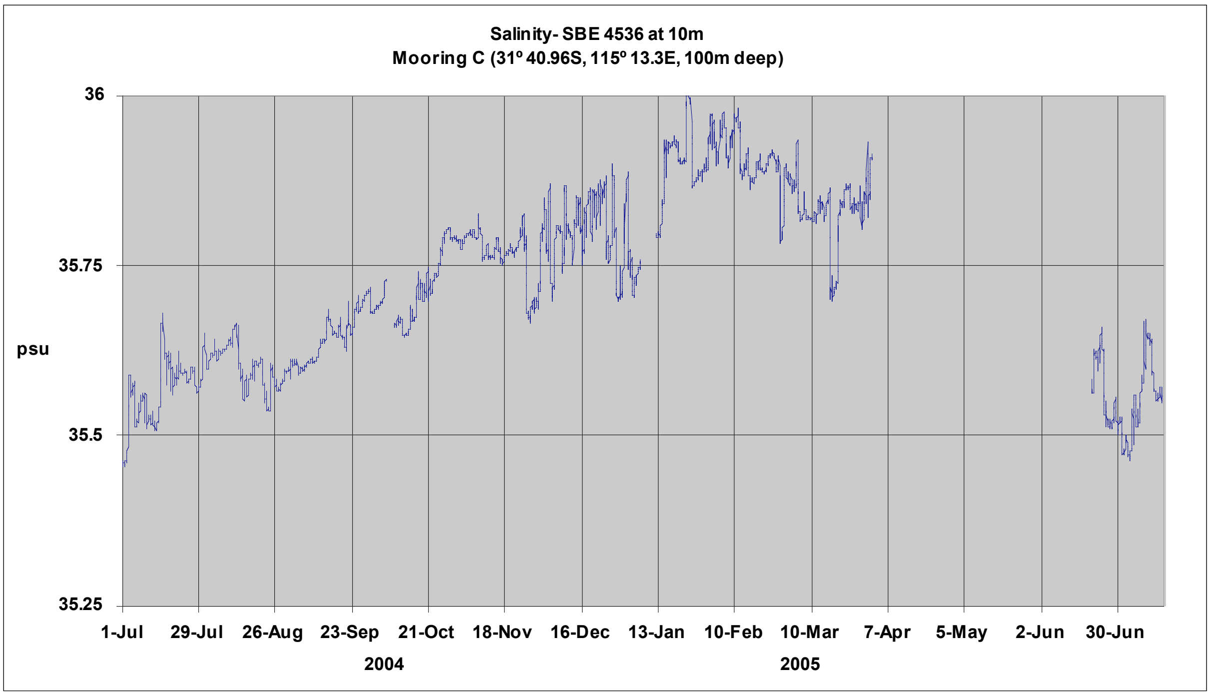

Figure 11: Salinity at 10m depth at Site C based on hourly time-series

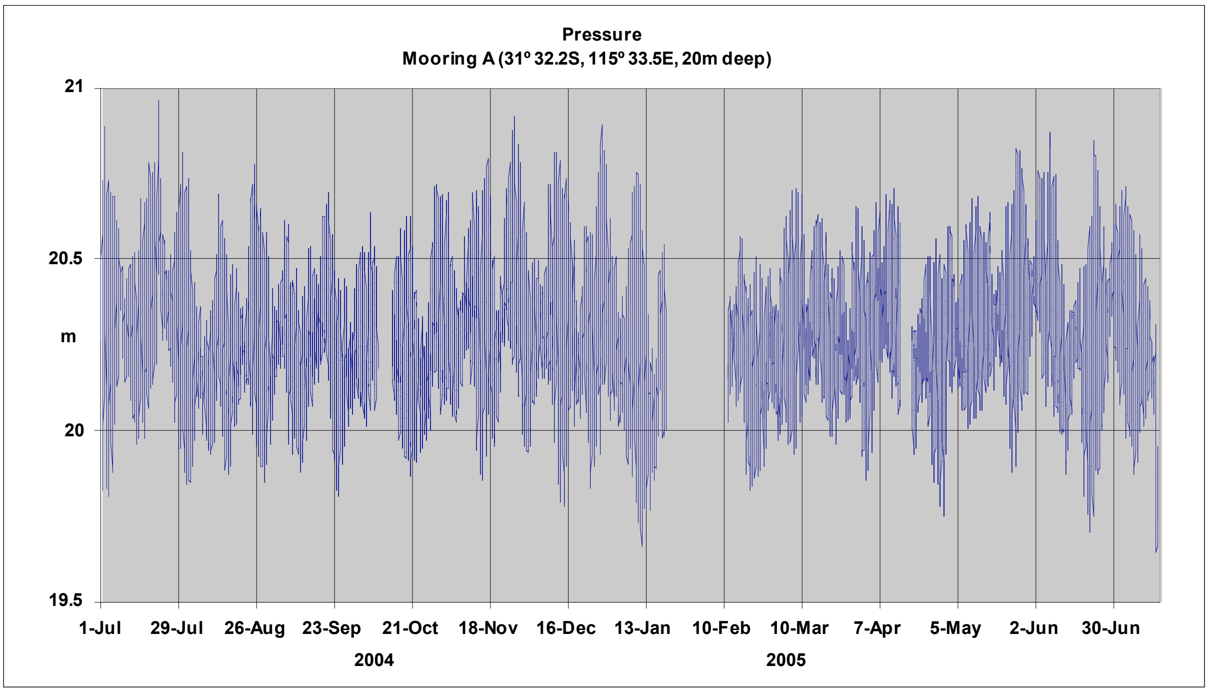

Figure 12: Pressure at the ocean bottom at Site A based on hourly time-series

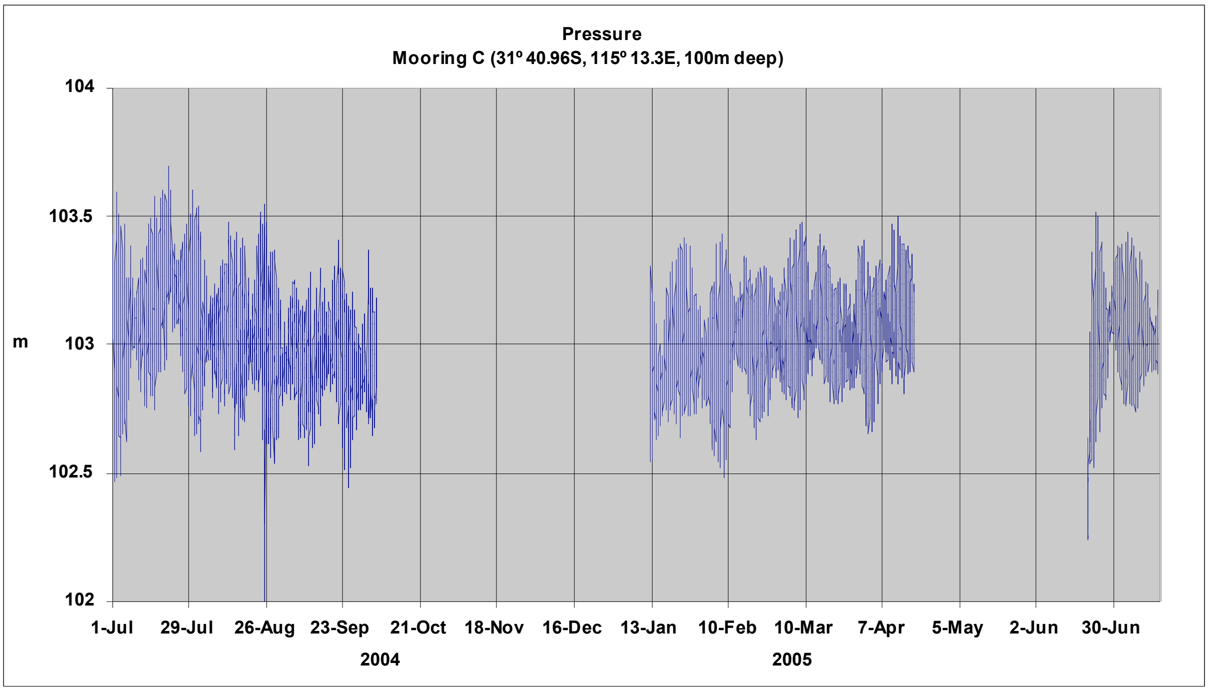

Figure 13: Pressure at the ocean bottom at Site C based on hourly time-series

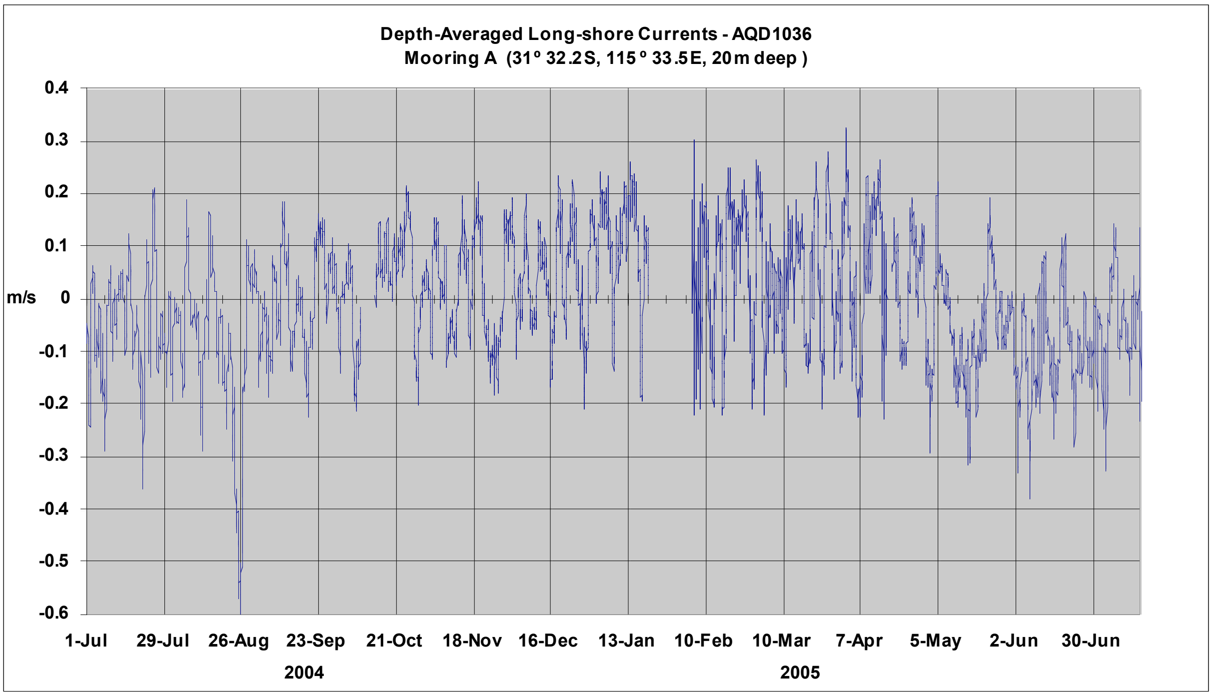

Figure 14: Depth-Averaged long-shore current at Site A based on hourly time-series

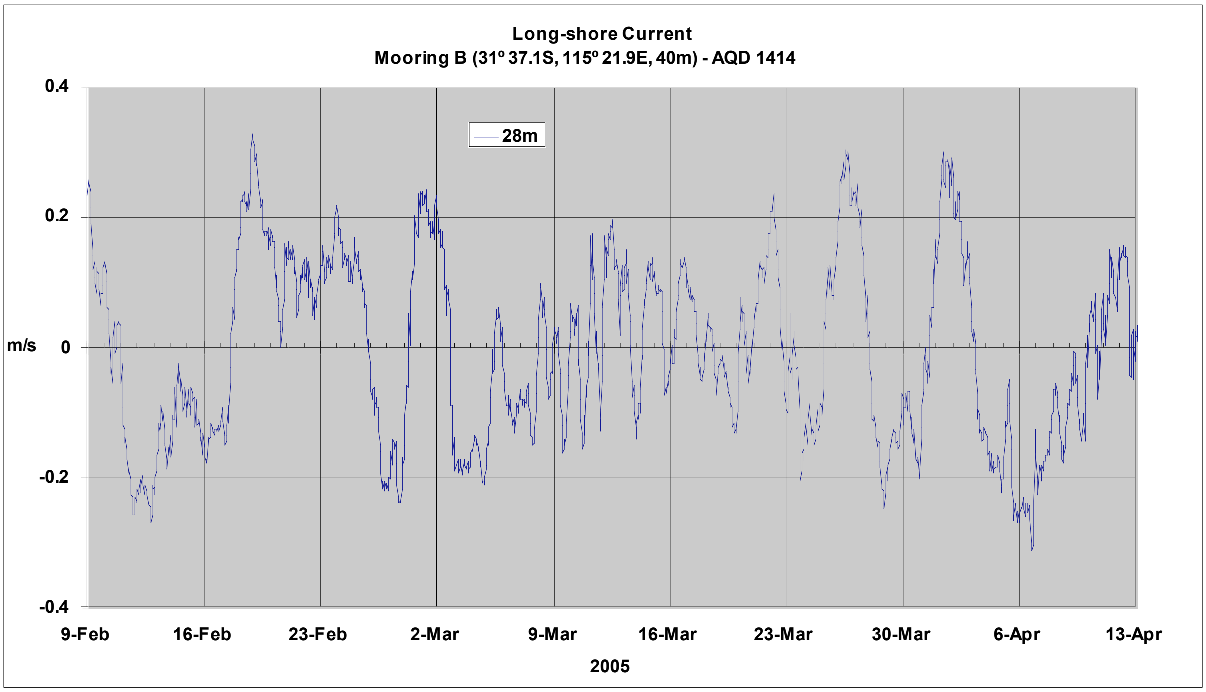

Figure 15: Long-shore current at 28m depth at Site B based on hourly time-series

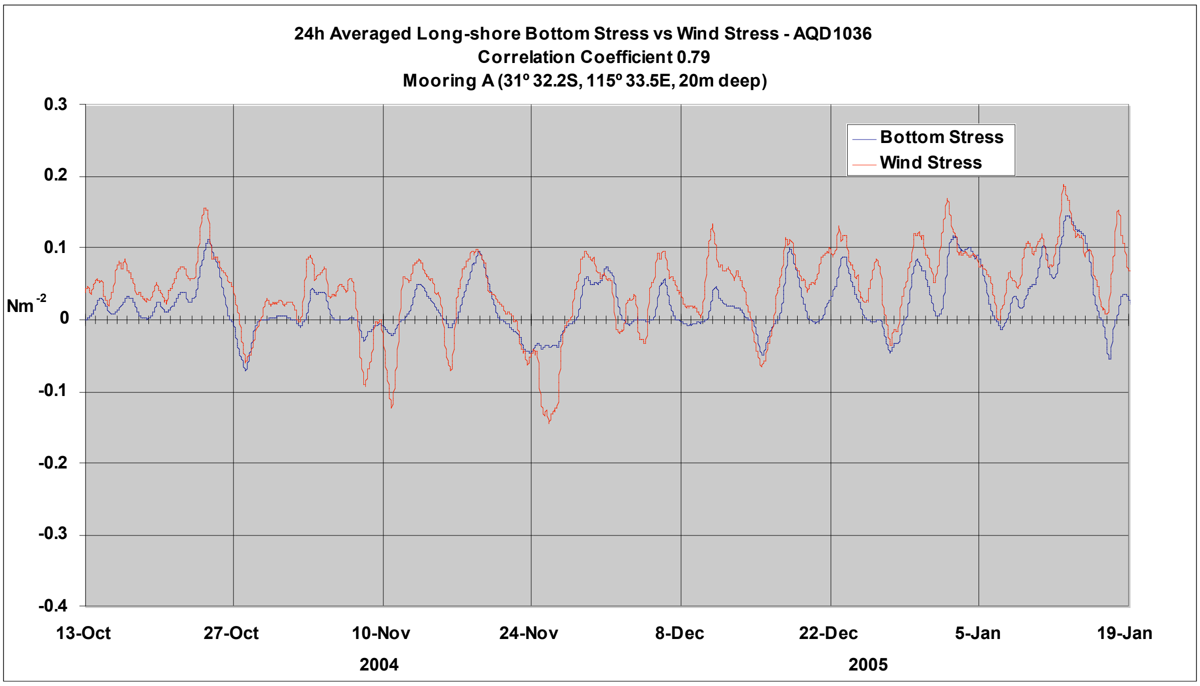

Figure 16: 24hr-averaged long-shore quadratic bottom stress (based on depth averaged current) vs long-shore wind stress at Site A from 13 Oct 2004 to 19 Jan 2005

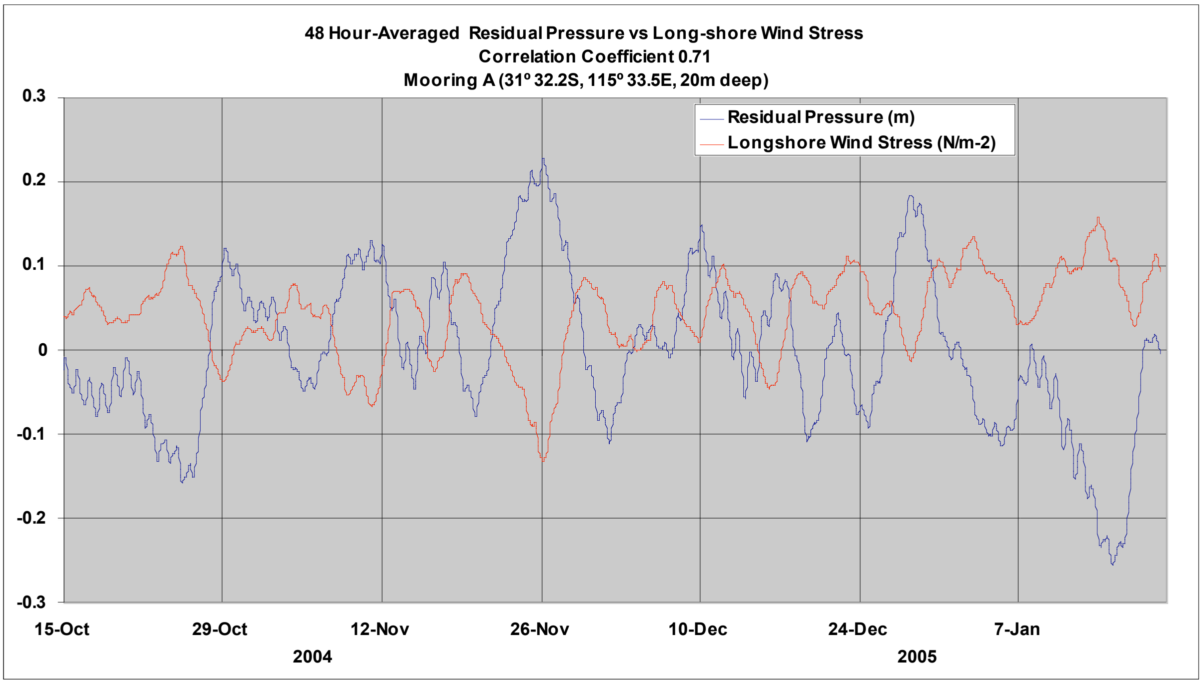

Figure 17: 48hr-averaged residual pressure vs long-shore wind stress at Site A from 15 Oct 2004 to 19 Jan 2005

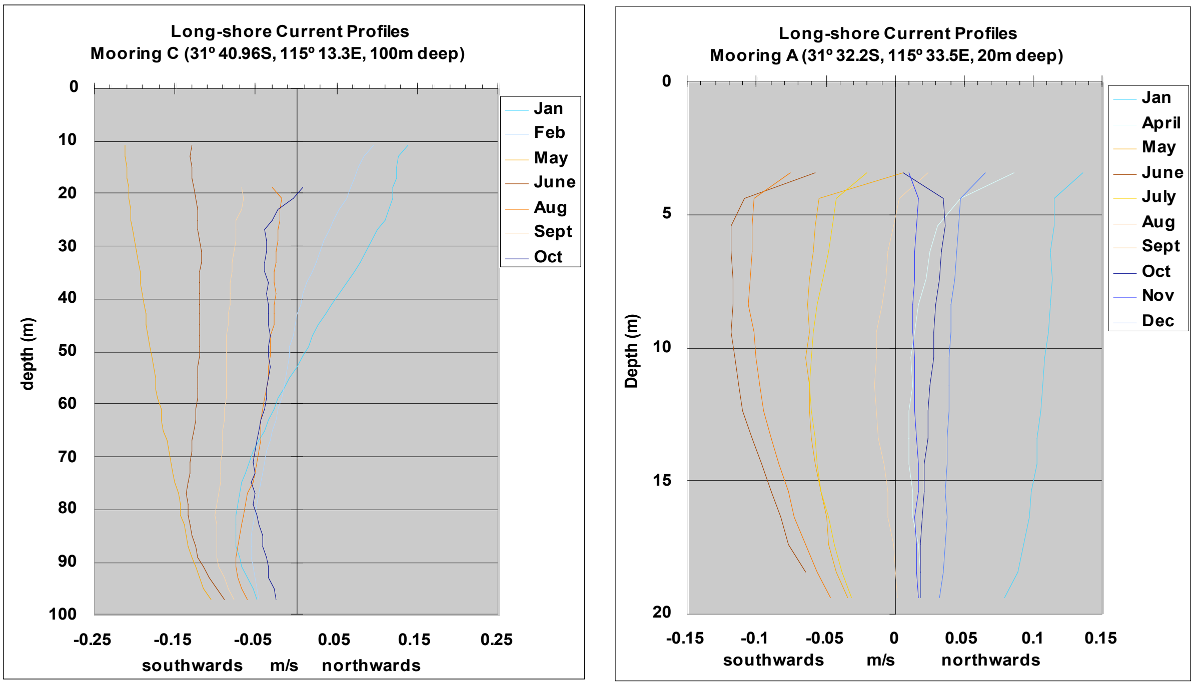

Figure 18: Monthly-averaged long-shore current profiles at Sites C and A

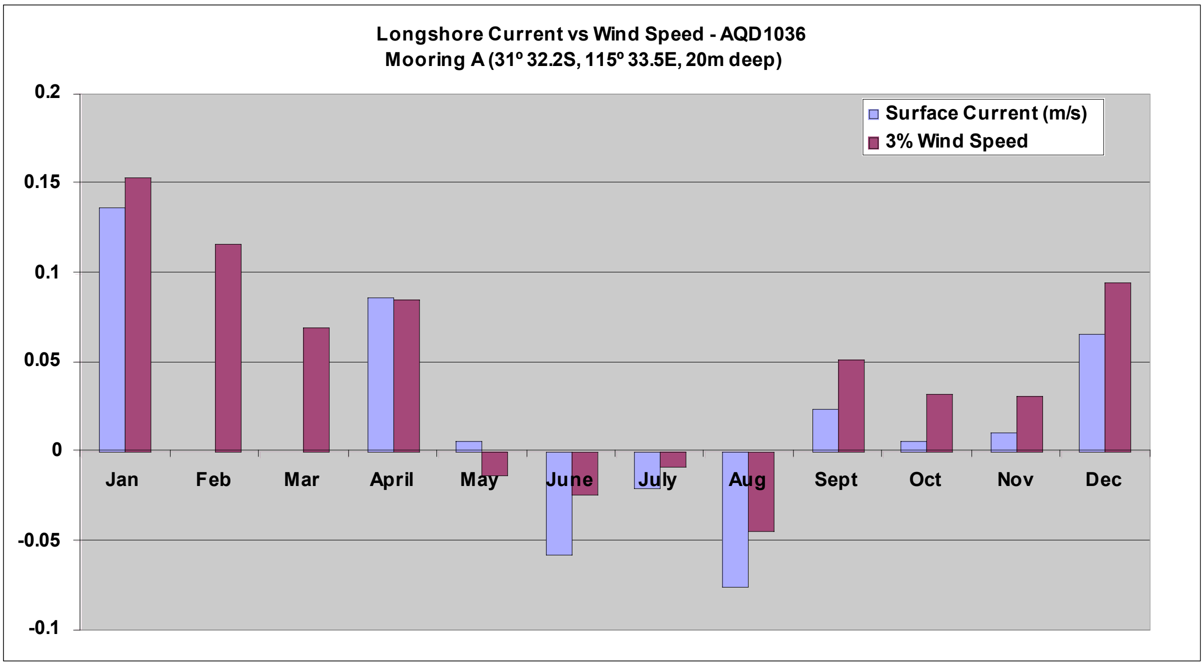

Figure 19: Long-shore current near the surface vs 3% of the long-shore component of wind speed at Site A.

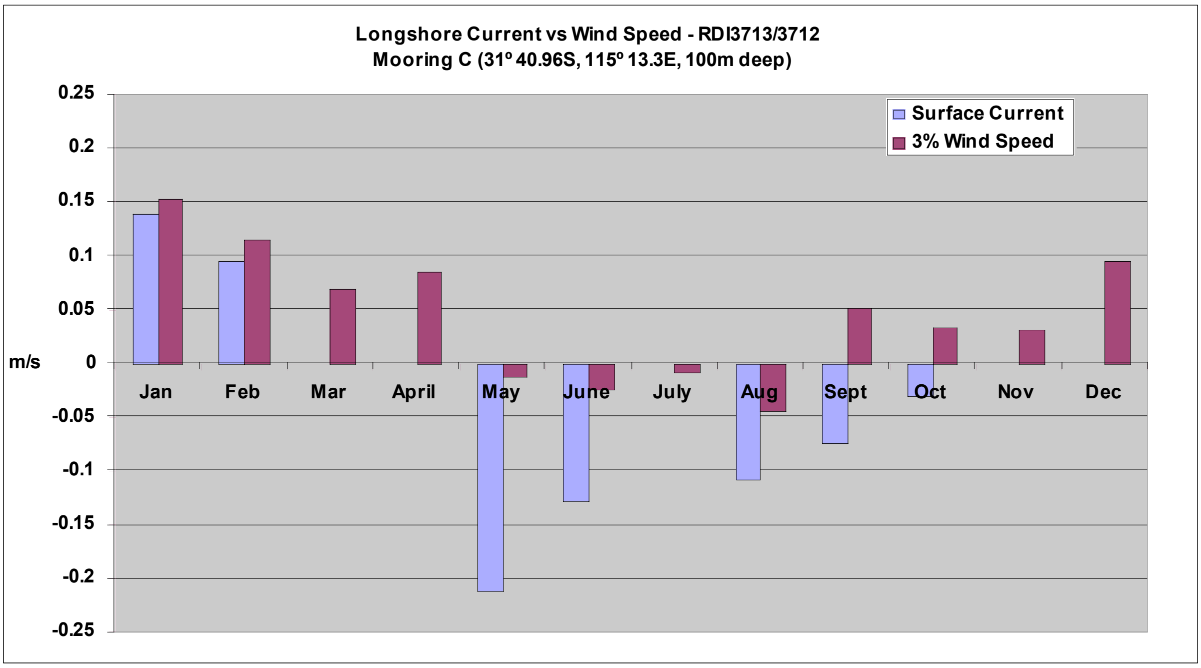

Figure 20: Long-shore current near the surface vs 3% of the long-shore component of wind speed at Site C

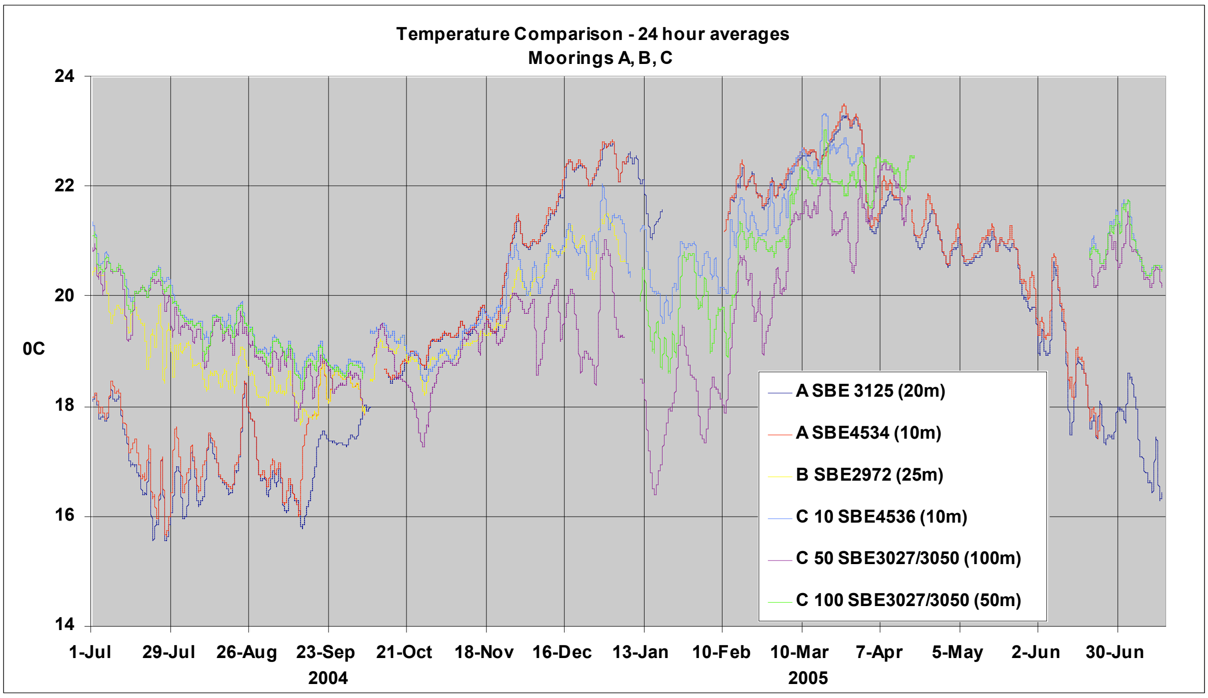

Figure 21: Comparison of temperatures at all sites

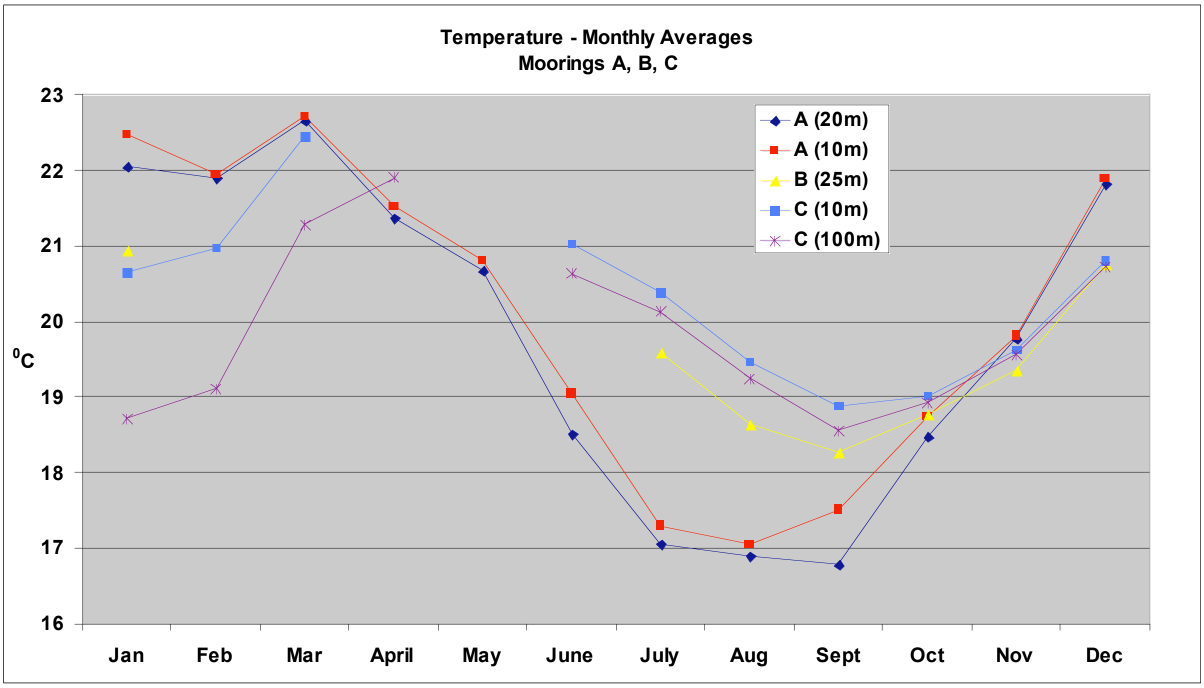

Figure22: Monthly-averaged temperatures from all sites

Mooring Design

The following three diagrams depict the basic mooring design for each of the moorings. There were some variations on these for different deployments.

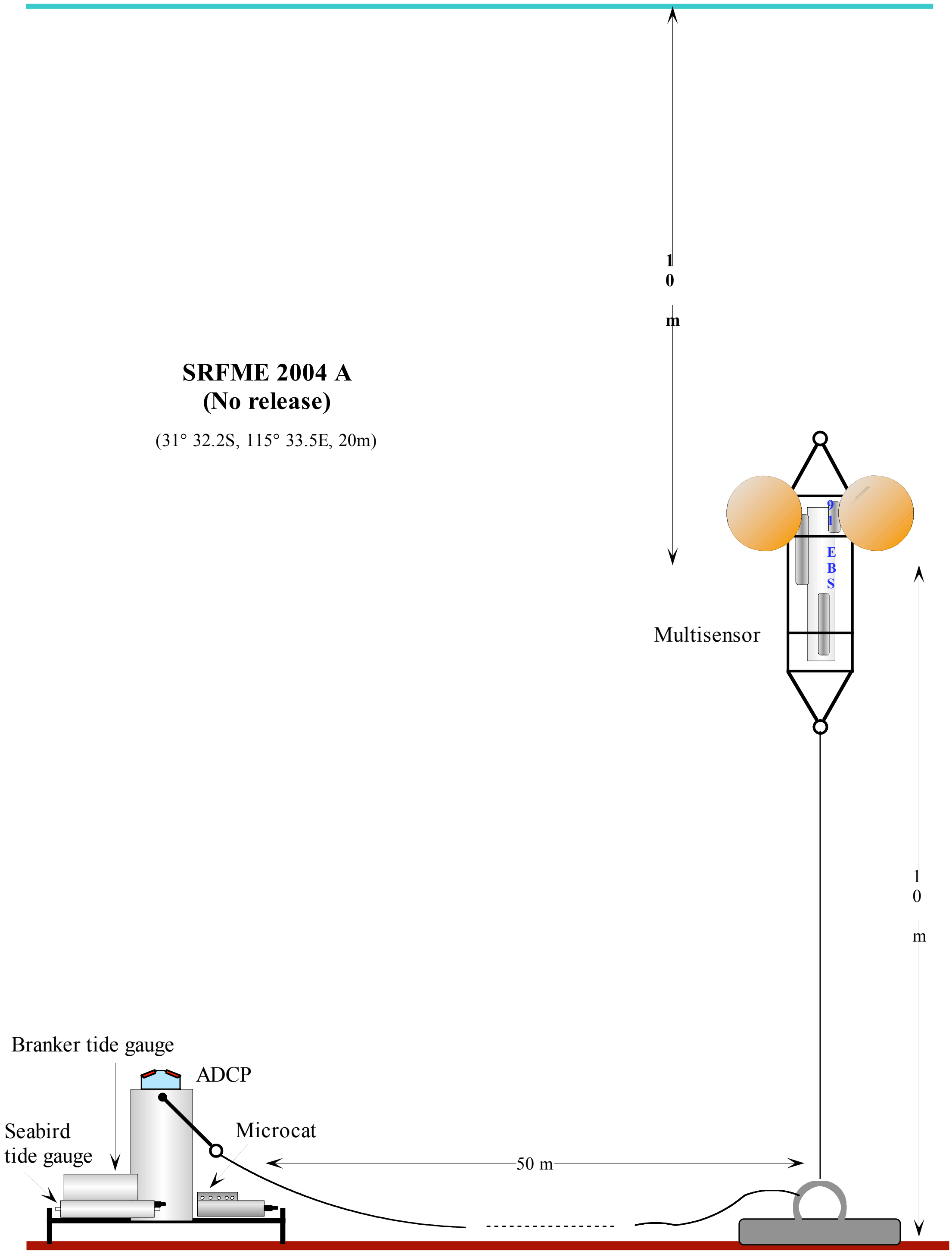

Figure 24: Mooring A, where the Multisensor is SBE 4534, Microcat is SBE 3125 and ADCP is AQD 1036. No data was collected by the Branker tide gauge.

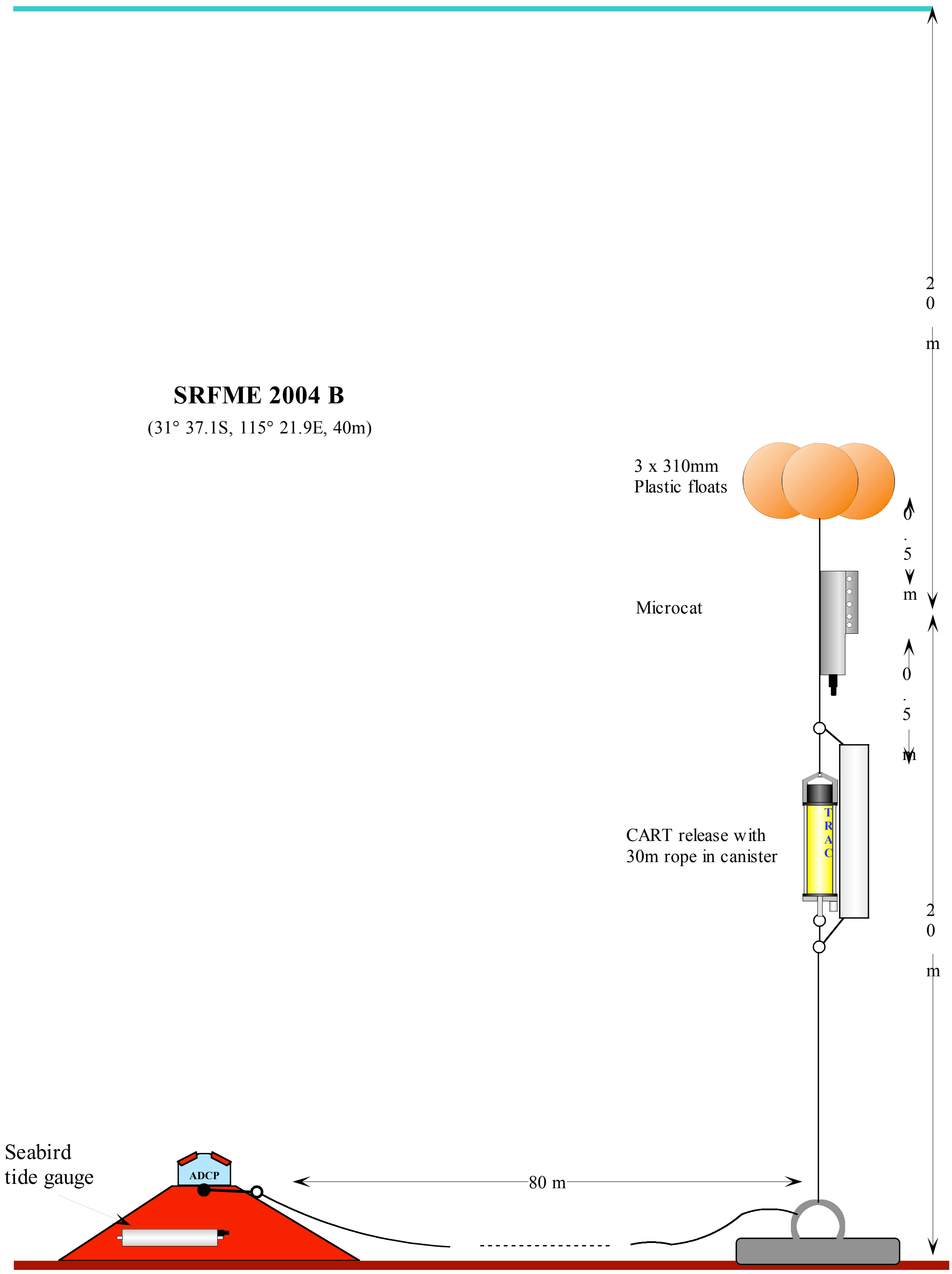

Figure 25: Mooring B, where the Microcat is SBE 2972 and ADCP is RDI 3712 (no data due to failure) and RDI 3713. No data was collected by the Seabird tide gauge.

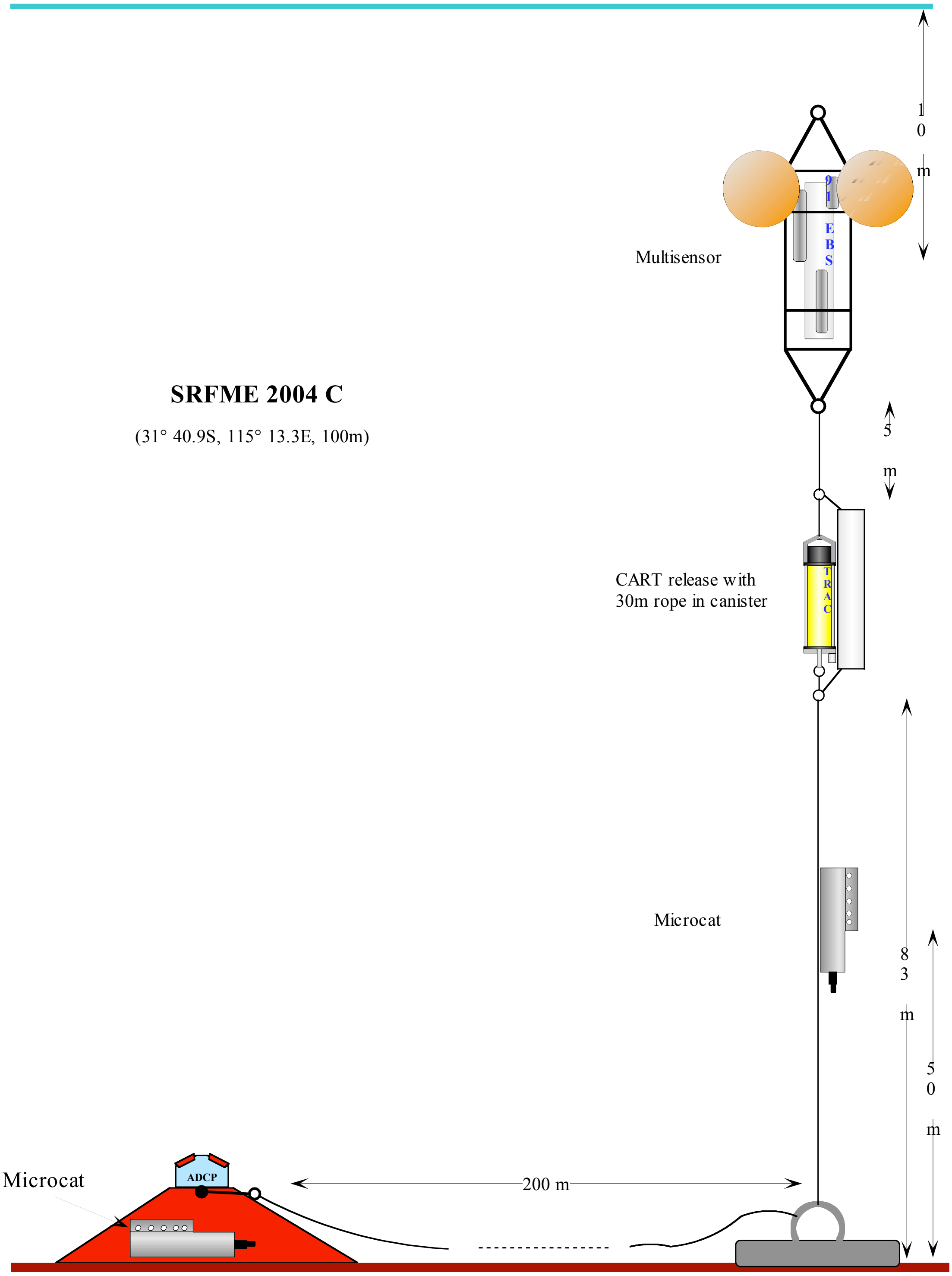

Figure 26: Mooring C, where the Multisensor is SBE 4536, the Microcats are SBE 3027 and 3050 and the ADCP is RDI 3712 or 3713.

Acknowledgements

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