CRUISE REPORT

DISCOVERY CRUISE 192 (BOFS LEG A3)

9 - 27 JUNE 1990

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1. SUMMARY

1.1 Cruise objectives

This cruise formed the fifth and final leg of the 1990 BOFS Lagrangian Experiment, and overlapped the second BOFS leg on the RRS Charles Darwin (Fig. 1.1). The objectives of this cruise, revised to take account of events on previous BOFS 1990 cruises, were as follows in order of priority:

1. Rendezvous with the RRS Charles Darwin in order to transfer urgently needed equipment (this was identified as a top priority by the BOFS Steering Committee).
2. Resurvey, using SeaSoar and underway surface chemical measurements, the area marked by the drifting buoys released on Discovery 190.
3. Carry out up to 16 CTD casts within the survey area.
4. Recover the remaining drifting buoys.
5. Recover a BOFS Bathysnap at 48°N (this was a May 1989 deployment).

Despite loss of time to bad weather, these objectives were largely achieved:

1. Completed successfully: the opportunity was taken to carry out nutrient and oxygen intercalibrations.
2. The drifting buoys spread to cover a very large area during the Lagrangian Experiment (Fig. 1.2), so that resurvey of the whole area was totally impracticable. A survey concentrating on the track of the overlapping Darwin B2 cruise was successfully completed.
3. Two CTD sections of 5 stations were completed: the number of stations was limited by time constraints.
4. Three IDB buoys remained to be recovered at the end of the Lagrangian Experiment. Attempts were made to locate two of these using positions relayed via the Argos satellite link, together with shipboard RDF equipment. Although the ship passed close to the buoys, visual location proved impossible and thus no buoys were recovered.
5. Recovered successfully: this was carried out at a time when the CTD system was inoperable due to storm damage.

1.2 Itinerary

The cruise track is shown in Fig. 1.3, and details of the stations worked and of the SeaSoar tows are given in Tables 1.1 and 1.2. The cruise timetable was as follows:

June 9	depart Barry
June 11-12	first SeaSoar transect
June 12	rendezvous with RRS Charles Darwin
June 12-19	survey around Darwin's cruise track
June 20-21	Bathysnap recovery
June 21-24	CTD sections
June 24-25	attempted Argos buoy recovery
June 27	arrive Barry

Table 1.1 Details of stations worked

Station	Cast no	Lat. N	Long.W	Start time	Finish time	Max. depth	Gear deployed and samples
12107#1	D192/C1	46 33.1	15 42.1	163/0923	163/0950	300	CTD/nutrients
12107#2	D192/C2	46 30.0	15 46.6	163/1220	163/1505	4052	CTD/O_2,sal.
12108		48 01.9	19 33.0	172/1255	172/1322	25	301 GoFlo/ productivity
12109#1	D192/C3	47 49.2	16 57.5	172/2328	172/2359	300	CTD/chemistry
12109#2	D192/C4	47 48.1	16 58.3	173/0100	173/0332	4490	CTD/salinity
12110#1	D192/C5	47 56.0	16 46.2	173/0503	173/0743	4752	CTD/salinity
12110#2	D192/C6	47 56.3	16 46.4	173/0819	173/0856	300	CTD
12110#3	D192/C7	47 56.3	16 46.2	173/0904	173/0924	300	CTD/chemistry
12111#1	D192/C8	48 02.7	16 32.1	173/1108	173/1323	4260	CTD
12111#2	D192/C9	48 03.0	16 30.6	173/1344	173/1402	300	CTD/chemistry
12112#1	D192/C10	48 10.0	16 20.8	173/1530	173/1748	4200	CTD
12112#2	D192/C11	48 11.3	16 19.7	173/1817	173/1840	300	CTD/chemistry
12113#1	D192/C12	48 17.1	16 07.8	173/1952	173/2226	4803	CTD/chemistry
12113#2	D192/C13	48 17.4	16 06.4	173/2319	173/2347	300	CTD/chemistry
12114#1		47 04.8	15 50.6	174/0633	174/0718	25	301 GoFlo/ productivity
12114#2	D192/C14	47 04.6	15 50.9	174/0734	174/0959	4000	CTD
12114#3	D192/C15	47 04.5	15 50.7	174/1015	174/1033	300	CTD/chemistry
12115	D192/C16	46 57.6	16 02.4	174/1233	174/1446	4000	CTD/chemistry
12116#1	D192/C17	46 50.8	16 13.8	174/1649	174/1716	300	CTD/chl-a
12116#2	D192/C18	46 50.8	16 12.3	174/1748	174/1955	4000	CTD/chemistry
12117#1	D192/C19	46 43.1	16 18.5	174/2215	174/2236	300	CTD/chemistry
12117#2	D192/C20	46 42.5	16 26.5	174/2320	175/0323	4000	CTD/chemistry
12118	D192/C21	46 35.9	16 38.5	175/0515	175/0718	4000	CTD/chemistry

Table 1.2 Details of SeaSoar tows

Tow name	Start Time	Finish Time	Start position Lat.N	Start position Long.W	Finish position Lat.N	Finish position Long.W
APPROACH 1	162/1419	162/2040	48 00.6	14 17.1	47 41.3	15 17.6
APPROACH 2	162/2040	163/0425	47 41.3	15 17.6	46 55.8	16 15.2
APPROACH 3	163/0425	163/0650	46 55.8	16 15.2	46 55.1	15 57.4
TRANSECT 1	163/1912	164/0638	46 13.9	15 41.5	47 00.1	14 05.3
TURN 1	164/0638	164/0833	47 00.1	14 05.3	47 12.8	14 19.0
TRANSECT 2	164/0833	164/1851	47 12.8	14 19.0	46 19.4	15 49.7
TURN 2	164/1851	164/2058	46 19.4	15 49.7	46 31.0	16 06.0
TRANSECT 3	164/2058	165/0747	46 31.0	16 06.0	47 24.5	14 34.6
TURN 3	165/0747	165/0957	47 24.5	14 34.6	47 36.8	14 50.3
TRANSECT 4	165/0957	165/2315	47 36.8	14 50.3	46 33.3	16 39.9
TURN 4	165/2315	166/0049	46 33.3	16 39.9	46 40.5	16 49.7
TRANSECT 5	166/0049	166/1402	46 40.5	16 49.7	47 48.7	14 55.0
TURN 5	166/1402	166/1522	47 48.7	14 55.0	47 56.3	15 05.0
TRANSECT 6	166/1522	167/0447	47 56.3	15 05.0	46 49.9	17 00.2
TURN 6	167/0447	167/0609	46 49.9	17 00.2	46 57.8	17 09.0
TRANSECT 7	167/0609	167/1828	46 57.8	17 09.0	48 05.3	15 16.8
TURN 7	167/1828	167/1942	48 05.3	15 16.8	48 12.3	15 26.4
TRANSECT 8	167/1942	168/0918	48 12.3	15 26.4	47 04.4	17 26.2
TURN 8	168/0918	168/1029	47 04.4	17 26.2	47 13.0	17 35.3
TRANSECT 9	168/1029	169/0210	47 13.0	17 35.3	48 33.5	15 14.5
TURN 9	169/0210	169/0339	48 33.5	15 14.5	48 41.7	15 24.0
TRANSECT 10	169/0339	169/1600	48 41.7	15 24.0	47 37.9	17 11.5
[TRANSECT 10A]	169/1600	169/1900	47 37.9	17 11.5	47 27.9	17 29.8
[TURN 10]	169/1900	169/2052	47 27.9	17 29.8	47 38.0	17 41.3
[TRANSECT 11A]	169/2052	169/2230	47 38.0	17 41.3	47 43.4	17 25.1
TRANSECT 11	169/2230	170/1100	47 43.4	17 25.1	48 50.4	15 37.3

Note: The 'tows' marked in brackets show periods when SeaSoar was inboard for attention, but underway chemistry was running

Figure 1.1 Schedule of BOFS 1990 Lagrangian Experiment cruises

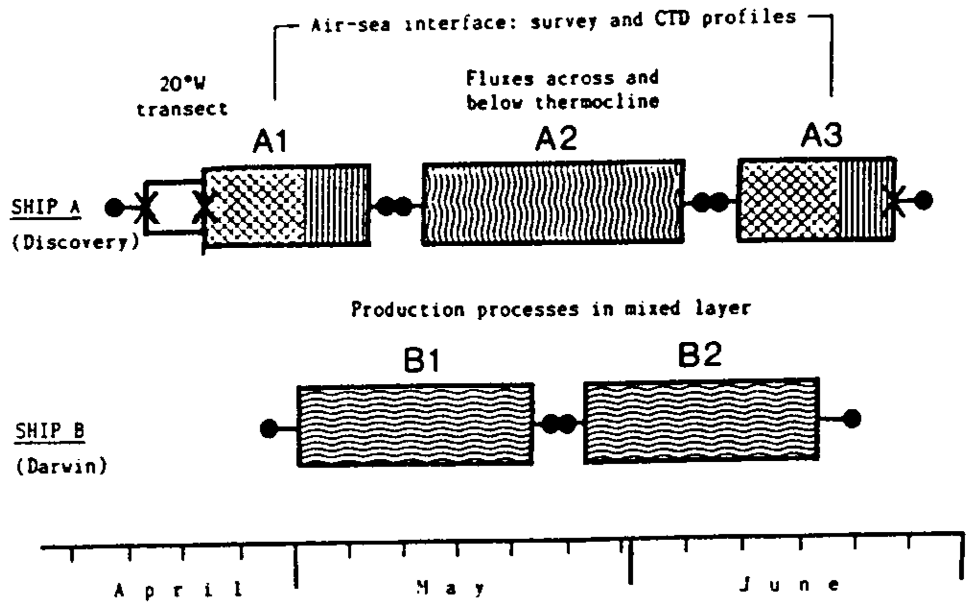


Figure 1.2 Tracks of drifting buoys during the Lagrangian Experiment. The "Central" buoy 3917 followed by RRS Charles Darwin is shown as a plain diamond.

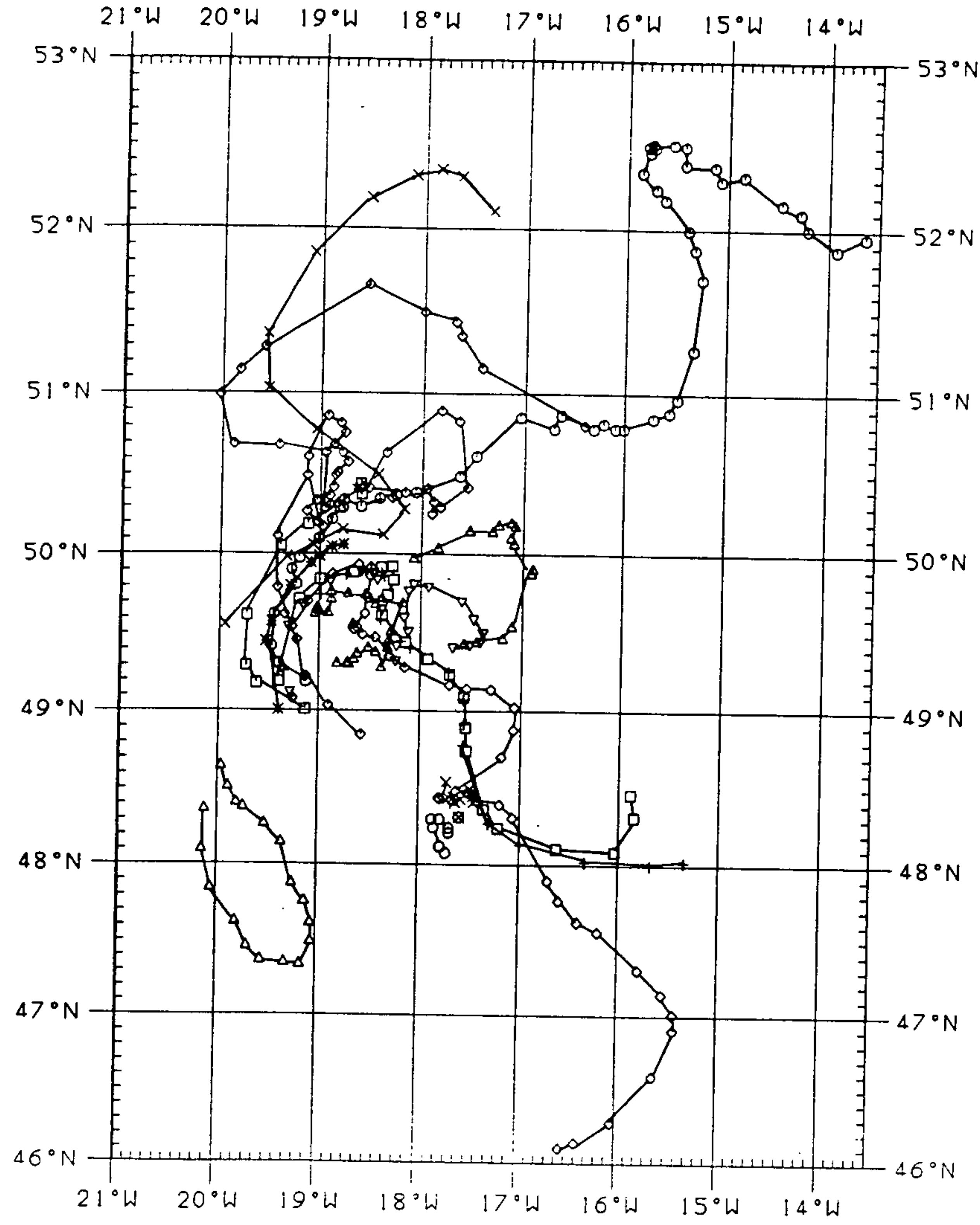
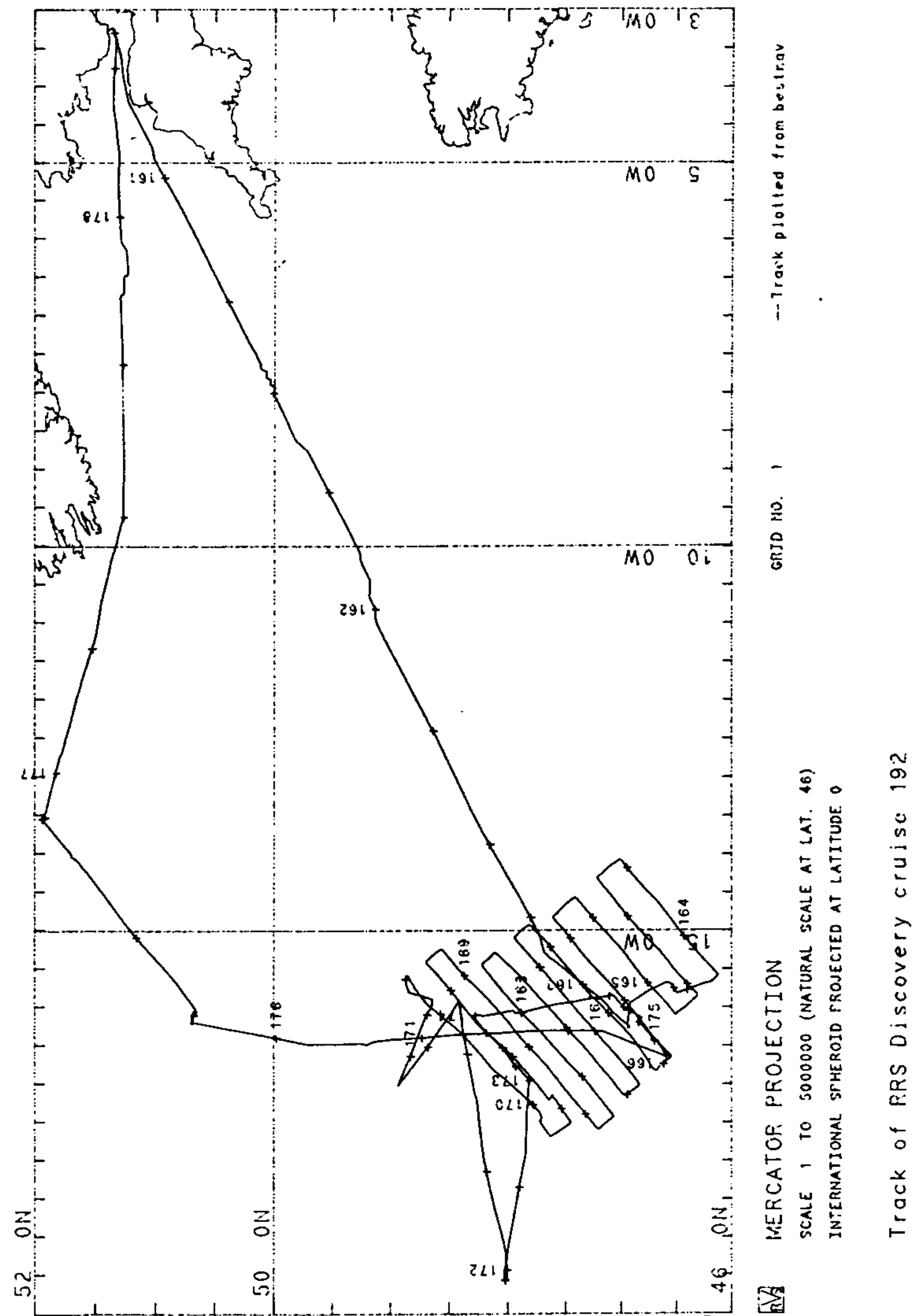


Figure 1.3 Cruise track



2. NARRATIVE ACCOUNT

In order to make up time lost on earlier 1990 BOFS cruises, the port call at the start of this cruise was scheduled for only 48hrs. Major activities required during this port call included reinstallation of the ADCP after repair, and installation of the new SeaSoar winch and cable. In the event, the new winch was not received from the manufacturers until 7th June, so that installation followed delivery almost immediately. Although much of the winch installation went smoothly, it became clear that it would not be possible to test the communications between the SeaSoar and its deck unit via the new cable before the scheduled sailing time (0800 on June 9th). It was therefore decided to delay sailing by one tide in order to allow full installation of this new system before sailing.

On June 8th, one day before departure, the Principal Scientist discovered that only one computer technician had been allocated to the cruise, despite the fact that RVS had successfully pressed for two computing berths during cruise planning. The decision to send only one computer technician had apparently been taken 6 weeks previously, but the cruise scientists had not been informed. After some discussion with RVS, a student was allocated to fill the vacant computing berth in order that the requirement for 24 hour computer watch coverage could be fulfilled.

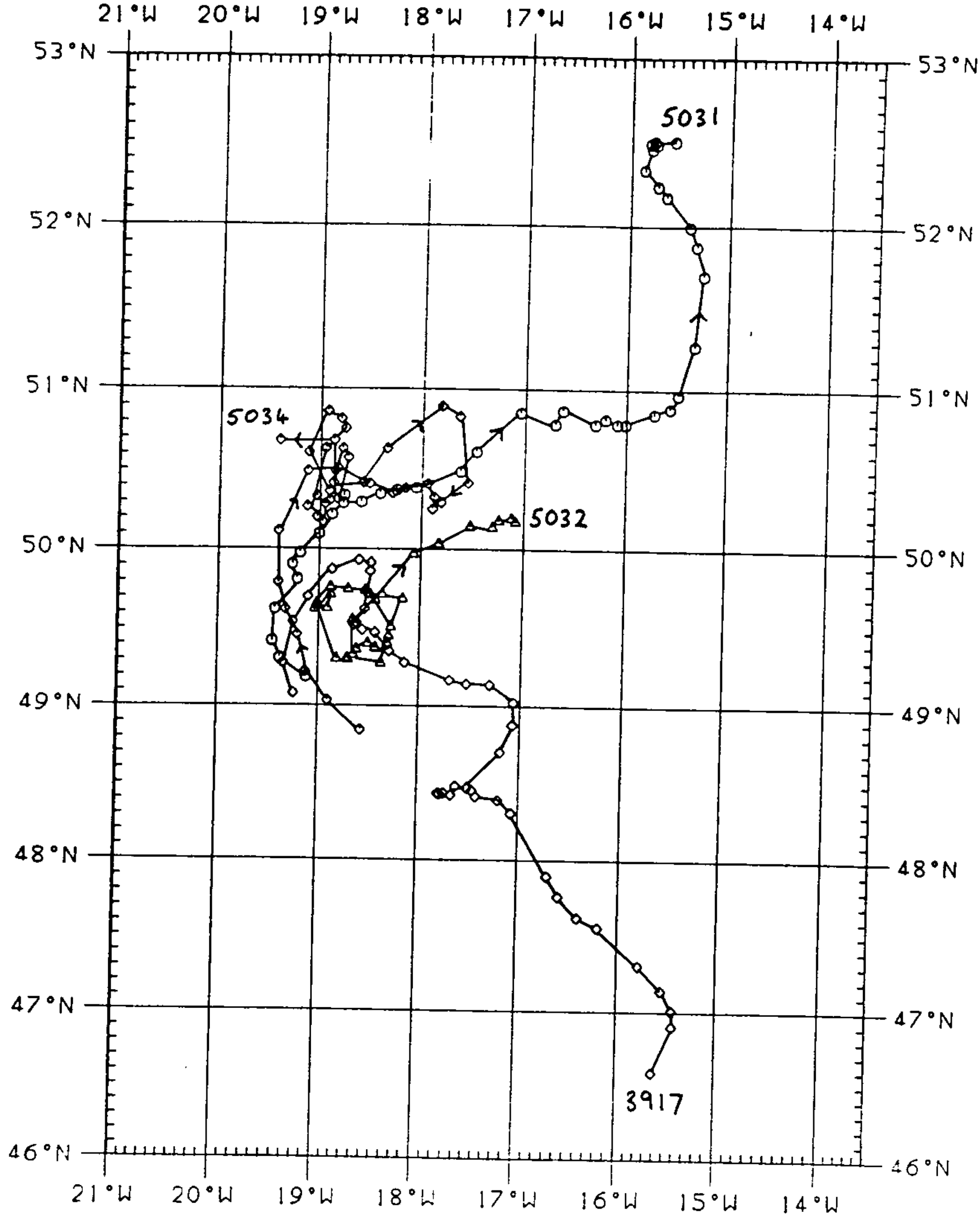
The ship departed from Barry at 1800A on June 9th. The ADCP was calibrated the following morning in approximately 100m of water, and appeared to be working satisfactorily. At 1400Z on 10th June the seawater distribution system was switched on and underway chemical measurements started, manned by a three watch system. At 1500Z the first Icefish deployment was carried out successfully.

On 11th June the pCO_2 level A interface, which had given some problems on Discovery 190, was found to be wrongly programmed. The programming error was corrected, and no further problems were encountered. At 1400Z the SeaSoar was successfully deployed: this was the first use of the new winch. Minor problems were encountered with the fairing guides which need to be raised for deployment and recovery. It appears that the guides are made to accommodate a greater difference in height between the winch and the stern A-frame. The SeaSoar tended to fly a long way to starboard (up to 45°), especially at depth. Maximum depth at that time was about 320m.

The SeaSoar was deployed in order to carry out a transect across the track of the drifting buoy (3917) which Darwin had been following. The buoy track had been close to a straight line for about a week (Fig. 2.1), and the transect was designed to find out whether the track was indicating a frontal feature. When plotted out, the Seasoar data did indeed show a front very close to the buoy track. It was decided that the main SeaSoar survey should be devoted to mapping this feature back up the drifting buoy track.

The ship arrived on station with Darwin at 0910Z June 12th. The weather was fine and calm. Prior to the rendezvous, plans were agreed by radio for nutrient and oxygen intercalibrations. The nutrient intercalibration was considered to be particularly important in the light of discrepancies between nutrient measurements on Darwin and Discovery reported from an earlier rendezvous. Both ships carried out shallow and deep CTD casts, with subsequent exchange of nutrient samples by small boat. The equipment required by the Darwin was also transferred successfully. The CTD problems reported by Discovery 190 (leakage at depth) appeared to have been solved by the removal of the oxygen probe,

Figure 2.1 Tracks of remaining drifting buoys up to 12 June



although this resulted in the loss of oxygen data since there was no spare probe. Having completed the rendezvous activities, the ship left station at 1700Z, and launched Seasoar at 1900Z to begin the box survey.

The original box survey plan was for 150km long legs at 30km spacing. However, during the third and fourth legs it became apparent that (i) the front was still to the SW of the centre line of the box, and (ii) there were other complex structures present. In order to map these features more effectively it was decided (i) to lengthen the 4th leg of the transect by 30km, and (ii) to set the next (5th) transect at 20km spacing. The 20km spacing was retained for the rest of the survey, but further small changes were made to the length of the legs in order to ensure that features of interest were adequately mapped. The box survey track is shown in Fig. 2.2, and the temperature structure found in Fig. 2.3.

On 14th June, problems were encountered with the SeaSoar control system. The SeaSoar was reluctant to dive, and left under automatic control it remained at the surface. Under manual control it could with care be persuaded to dive, although it still tended to stay at the surface even with the wings fully down. The data were still of good quality, so the SeaSoar was flown manually in preference to a recovery to sort out the control problems. These problems were later eased by reducing the length of towing cable from 560m to 520m. The conductivity sensor twice became blocked, but cleared each time after a short period of being towed at the surface, and recovery was again avoided.

On 18th June the SeaSoar had to be recovered to repair the cable termination after almost 6 days continuous work. The SeaSoar was recovered at 1600Z and redeployed at 2200Z: the survey continued with underway chemistry only while repairs were underway.

Having completed the box survey, the SeaSoar was recovered at 1330Z on 19th June in heavy seas and near gale force winds. Some damage was sustained to the Seasoar during recovery. The next planned activities were CTD sections along legs 4 and 10 of the SeaSoar box survey. However, at 1600Z it was found that the CTD and the starboard platform had been damaged, presumably by a wave. The Master decided to heave to, and scientific watches were stood down until the weather moderated. Assessment of the damage (20th June) revealed that 9 out of 12 Niskin bottles had been broken, the suspension strop of the CTD frame had been bent, and that all of the stanchions on the starboard platform had been fractured. This left a total of 6 Niskin bottles (including the 3 spares), which were sufficient to carry out CTD sections sampling at 6 depths providing that the sample volumes were adjusted to allow all samples to be taken from a single bottle. However, it was clear that the repairs needed to make the CTD operational would take the best part of a day, so options were considered for recovery of deployed equipment while repairs were being carried out. It was clear that recovery of the Bathysnap during CTD repairs, followed by CTD sections, with buoy recovery as last activity represented the most efficient use of time. Details of the Bathysnap recovery can be found in section 3.18.

The first CTD section, along leg 10 of the SeaSoar box survey, was begun at 2300Z on 21st June. In order to allow time for Argos buoy recovery, the CTD work was limited to two sections of 5 stations at spacings of 20km between stations. At each station the CTD was lowered to a depth of at least 4000m in order to obtain temperature and salinity data. Bottle samples were taken at 300m, 150m, 70m, 30m, 10m, and 2m for consistency with the CTD work carried out on Discovery 190. At one station in each section, bottle samples were taken on

Figure 2.2 SeaSoar survey track. Icefish deployment and recovery (section 3.3) are shown by triangles and circles respectively. CTD stations are marked by squares.

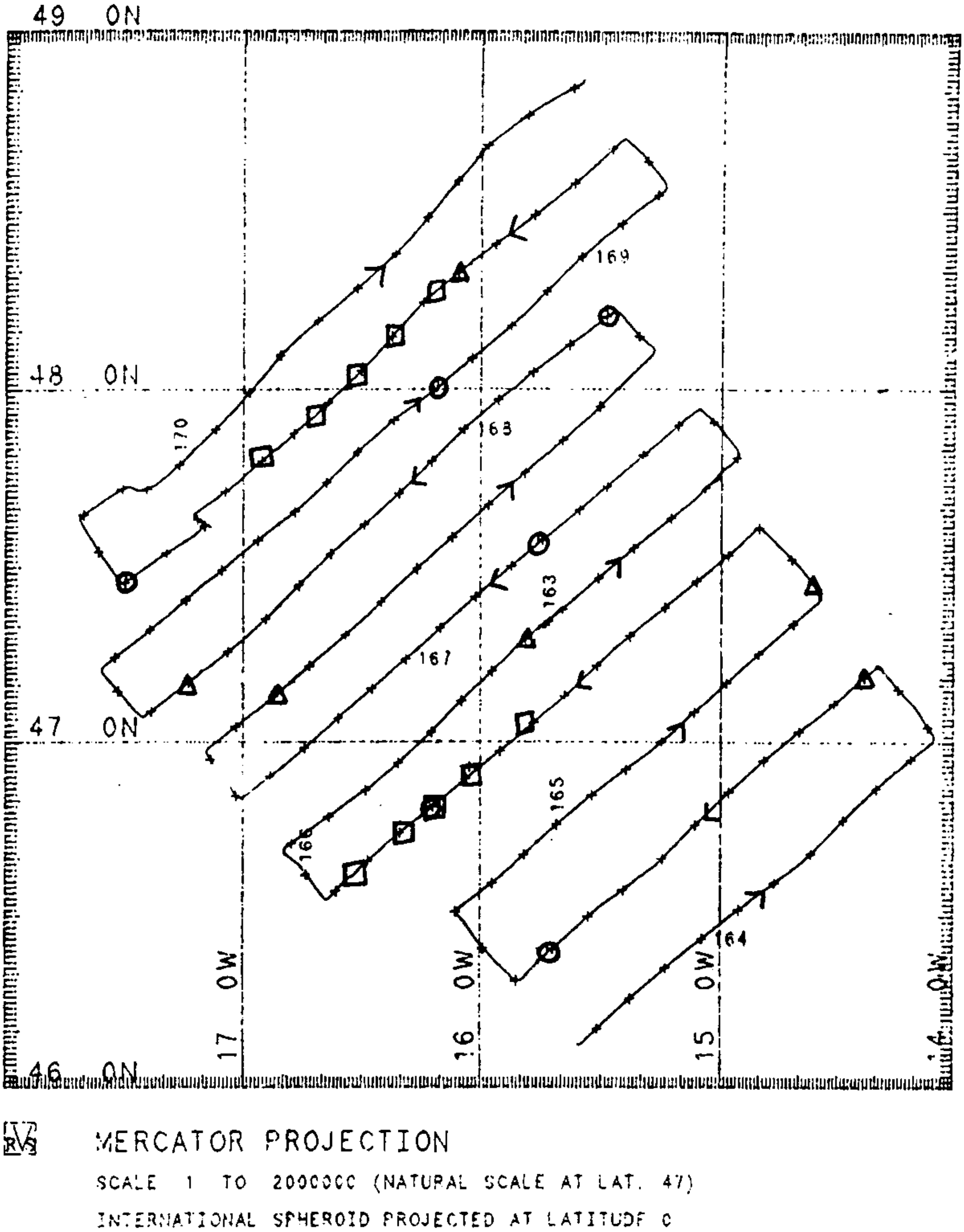
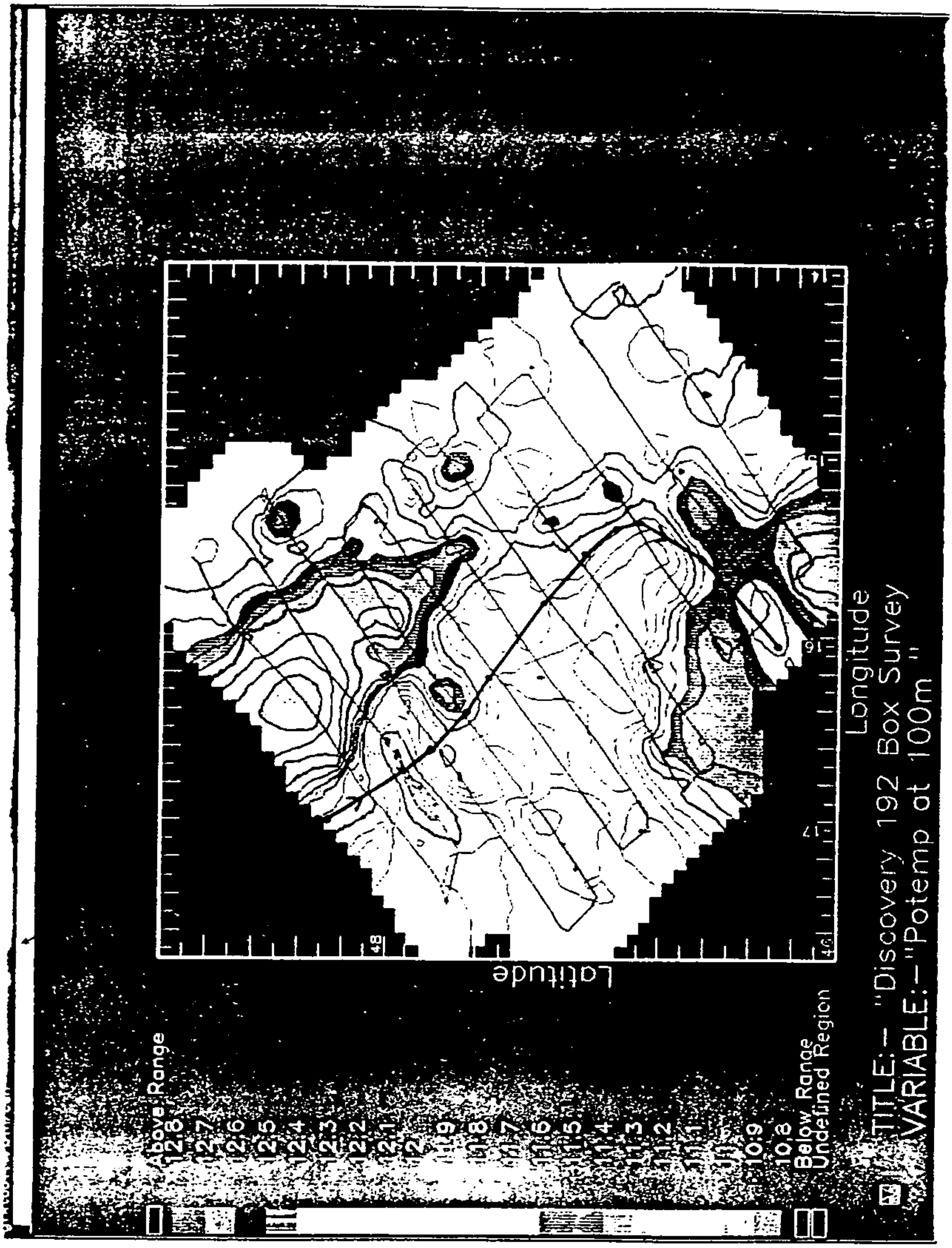


Figure 2.3 100m temperature contours from the SeaSoar survey. The full line shows the track of the central Argos buoy 3917.



a deep cast in order to obtain deep water samples for intercomparison between the various techniques being used for analysis of the CO_2 system. A further Niskin bottle was lost at the 3rd station of the first section, but was subsequently replaced by a storm-damaged bottle which had been repaired. Some time was lost on the second CTD section (along leg 4 of the SeaSoar survey) due to a total power failure (0635Z on 23rd June), and due to a hydraulic fault (0005Z on 24th June) which filled the starboard winch console with oil. The second CTD section was completed at 0720Z on 24th June.

The remainder of the cruise time was allocated to recovery of the three IDB Argos buoys (5031, 5032 and 5034) which remained deployed (Fig. 2.1). 5031 was by now in Irish waters, but permission to recover had been obtained. 5032 had been giving poor and intermittent signals, so it was decided to attempt recovery of 5034 and 5031. Details of these activities can be found in section 3.18. Both buoys were successfully located by RDF, but despite perfect conditions could not be located visually. It was concluded that the surface drogue flotation was totally immersed or missing, and that the buoys were awash.

3. SCIENTIFIC ACTIVITIES

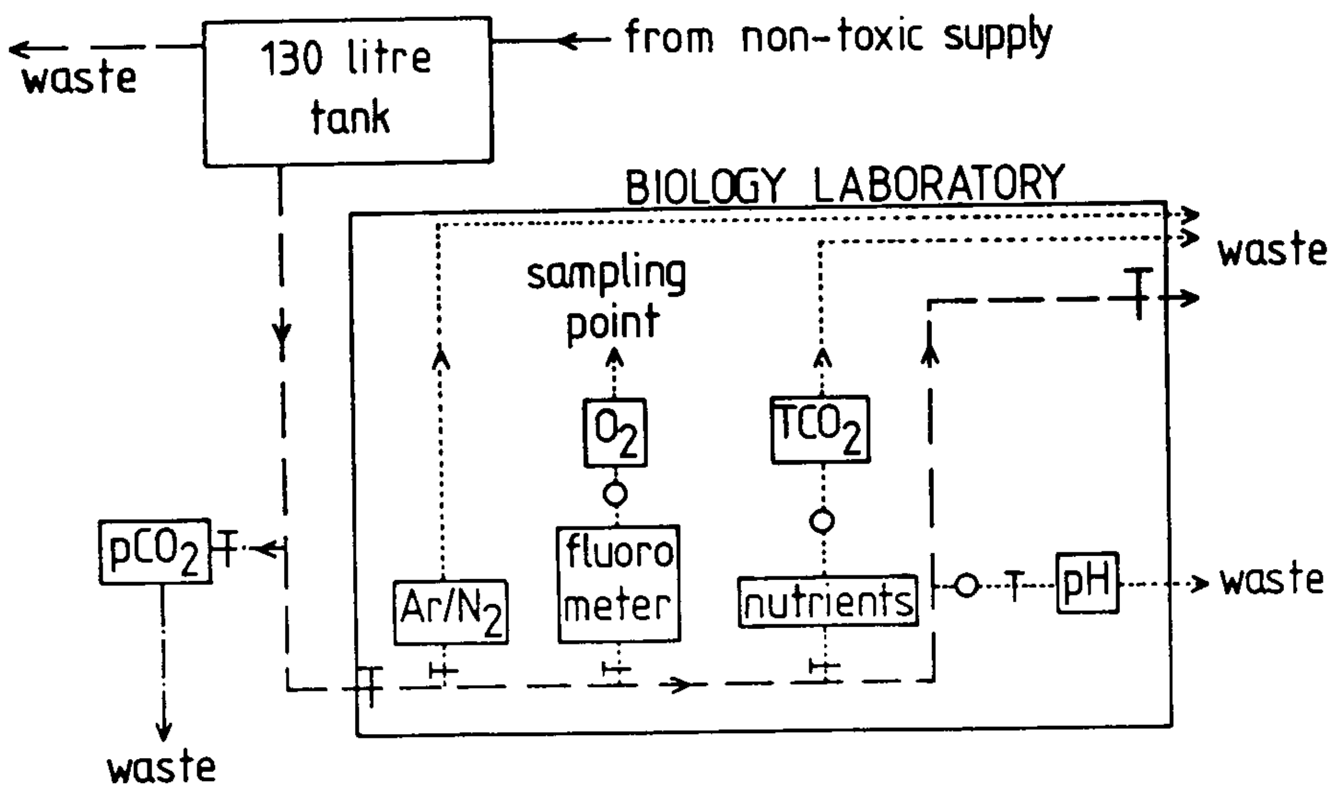
3.1 Seawater supply system (David Turner, Peter Williams)

This was similar to that used on Discovery 190, which was in turn developed from the system used on Discovery 182. Water from the non-toxic pump was fed into a black plastic header tank (volume approx. 130 litres) which was situated one deck above the laboratory and acted as a debubbler. The output from this tank was fed into the laboratory where the flow was divided to feed the different instruments as shown in Fig. 3.1. All waste tubes discharged below the level of the shelter deck. New features added for the 1990 cruises were control valves on each of the side arms, and impeller-type flow indicators on each of the side arms. These allowed the flows in the various side arms to be adjusted and monitored more effectively, and also eased the problem of filling each side arm and expelling air from the pipes, since all the other side arms could be shut off for this purpose. The major difficulty was the use of black plastic tubing throughout, which made it difficult to locate the offending air bubbles when flow was stopped. Clear tubing (except on the input to the fluorometer) would be an improvement.

Figure 3.1 Seawater supply system

Legend:

————	1½" hose
— —	1" hose
— · —	3/4" hose
- - - - -	½" hose
—T—	control valve
- -O- -	impeller-type flow indicator



3.2 SeaSoar Data Processing (Kelvin Richards, Jim Aiken, David Woolf)

The SeaSoar data stream was split, because of computational difficulties, into two parts, one containing pressure, temperature, conductivity, oxygen and fluorescence data the second containing the 16 channels of upward and downward welling irradiance data. As on Discovery 190 this produced a problem as the two data streams had different clocks. An attempt was made to synchronise the two datasets by noting the times of the beginning and end of each data file and adjusting the time variable accordingly in both datasets. When the light data was subsequently recombined with pressure it was found that the time of the minimum pressure and maximum light still did not agree, the time interval varying by a few seconds in each data record. It was unclear as to whether the problem was still due to a timing error or the attitude of the SeaSoar changing as it came up to the surface.

As on Discovery 190 the pressure, temperature, conductivity, oxygen and fluorescence data were processed using the Pstar system on the level C Sun 3/60 workstation. The procedure closely followed that outlined in a draft document by King, Alderson and Read. The raw SeaSoar data were split into 4 hour intervals. Each dataset was calibrated and had bad data points removed using a combination of automatic despiking routines and the recently developed semi-interactive editing program. The cleaned-up data reside in files labelled ss192nnn (see Table 3.1). The light files have the same numbering system. Every 12 hours the datasets were appended, merged with bestnav and the data gridded onto 8m intervals in the vertical and 4km along ship track (files sa192nnn, gr192nnn and dn192nnn, see Table 3.1). The data for the box survey were subsequently collected together into the grand file survey192. To aid plotting of the data the data were split into the individual legs of the survey (11 in all, Table 3.2, Fig. 2.2). The start of each file corresponds to the western side of the box and each leg is 228km long. The spacing between legs 1, 2 and 3 is 30km with subsequent spacing 20km. Missing data due to different lengths of the actual ship track on each leg have been filled in. Plots were produced of each leg using Pstar routines. Horizontal maps were produced using the RVS conplot routine. GF3 format files were produced of the survey192 file and the leg files.

Table 3.1 4hr and 12hr SeaSoar data files

SeaSoar tows (Table 1.2)	4 hr file			12hr file
	name	start	end	
Approach 1	ss192001	162/1500	162/1600)	
	ss192002	162/1600	162/2000)	
Approach 2	ss192003	162/2000	163/0000)	sa192001
	ss192004	163/0000	163/0400)	
Approach 3	ss192005	163/0400	163/0600	sa192002
Transect 1	ss192006	163/1930	164/0000)	
	ss192007	164/0000	164/0400)	sa192003
Turn 1	ss192008	164/0400	164/0820)	
Transect 2	ss192009	164/0820	164/1200)	

Table 3.1 4hr and 12hr SeaSoar data files (contd.)

SeaSoar tows (Table 1.2)	4 hr file			12hr file
	name	start	end	
	ss192010	164/1200	164/1600)	
Turn 2	ss192011	164/1600	164/2000)	sa192004
Transect 3	ss192012	164/2000	165/0000)	
	ss192013	165/0000	165/0400)	
Turn 3	ss192014	165/0400	165/0840)	sa192005
Transect 4	ss192015	165/0840	165/1200)	
	ss192016	165/1200	165/1600)	
	ss192017	165/1600	165/2000)	sa192006
Turn 4	ss192018	165/2000	166/0000)	
Transect 5	ss192019	166/0000	166/0400)	
	ss192020	166/0400	166/0800)	sa192007
	ss192021	166/0800	166/1200)	
Turn 5, Transect 6	ss192022	166/1200	166/1600)	
	ss192023	166/1600	166/2000)	
	ss192024	166/2000	167/0000)	sa192008
	ss192025	167/0000	167/0400)	
Turn 6, Transect 7	ss192026	167/0400	167/0800)	
	ss192027	167/0800	167/1200)	sa192009
	ss192028	167/1200	167/1600)	
Turn 7, Transect 8	ss192029	167/1600	167/2000)	
	ss192030	167/2000	168/0000)	
	ss192031	168/0000	168/0400)	sa192010
	ss192032	168/0400	168/0830)	
Turn 8, Transect 9	ss192033	168/0830	168/1200	
	ss192034	168/1200	168/1600	
	ss192035	168/1600	168/2000	sa192011
	ss192036	168/2000	169/0000	
Turn 9, Transect 10	ss192037	169/0000	169/0400	
	ss192038	169/0400	169/0800	
	ss192039	169/0800	169/1200	sa192012
	ss192040	169/1200	169/1600	
Transect 11	ss192041	169/2300	170/0400	
	ss192042	170/0400	170/0800	sa192013
	ss192043	170/0800	170/1150	

Table 3.2 SeaSoar leg files for box survey

SeaSoar tow (Table 2.2)	Leg file	Distance run Start	End
Transect 1	gr192.leg1	1240	1392
Transect 2	gr192.leg2	1424	1574
Transect 3	gr192.leg3	1606	1760
Transect 4	gr192.leg4	1792	1972
Transect 5	gr192.leg5	1996	2188
Transect 6	gr192.leg6	2210	2397
Transect 7	gr192.leg7	2416	2604
Transect 8	gr192.leg8	2628	2860
Transect 9	gr192.leg9	2844	3072
Transect 10	gr192.leg10	3104	3268
Transect 11	gr192.leg11	3340	3548

3.3 Icefish tows (Alison Weeks, Jim Aiken)

Multispectral near-surface irradiance measurements were made during the passage to and in the survey area with a towed package of instruments referred to here as the "Icefish". Fluorescence, temperature and pressure were also recorded in the solid state logger in the towed body. These measurements give simultaneous reflectance ratios and concentrations of chlorophyll-a (the latter after calibration of the fluorometer in the Icefish; section 3.5). 8 tows were completed, one of which was across the shelf break. The details are given in Table 3.3. The Icefish tows carried out during the SeaSoar box survey are shown in Fig. 2.2.

Table 3.3 Icefish tows

Tow number	Position Start	End	Time Start	End	Freq /s	Depth /m
D69001	49 55.5N/08 15.7W	49 38.1N/09 05.3W	161/1344	161/1910	5	5,12
D69002	48 12.7N/13 44.3W	47 46.5N/14 55.0W	162/1112	162/1910	5	10
D69003	47 11.4N/14 23.0W	46 23.8N/15 42.7W	164/0903	164/1807	5	7
D69004	47 27.3N/14 36.8W	46 48.7N/16 11.9W	165/0815	165/2005	5	7
D69005	47 17.9N/15 48.8W	47 34.1N/15 45.6W	166/0800	166/2013	5	7
D69006	47 08.6N/16 51.7W	48 12.4N/15 28.9W	167/0805	167/1959	10	7
D69007	47 10.4N/17 13.7W	48 00.3N/16 10.7W	168/0802	168/2005	10	7,5
D69008	48 19.7N/16 05.5W	47 28.1N/17 29.5W	169/0759	169/1859	10	5

TSG Calibration

Mean difference = −0.283
σ = 0.1 — 12→19 June

Against gridded Seasoars

Mean difference = −0.176
σ = 0.08 — 21–24 June

Against CTDs

Mean correction −0.21

3.4 Salinity and temperature calibrations (Robin Powell, Alison Weeks, Polly Machin)

The CTD salinity sensor was calibrated using 18 bottle samples taken during the two CTD sections, and the CTD temperature sensor from the thermometer on the first (deepest) Niskin bottle fired on each cast. The thermosalinograph and SeaSoar salinity sensors were calibrated using samples taken from the non-toxic seawater supply. Samples for SeaSoar calibration were timed to correspond with the SeaSoar being at the surface, taking due account of the distance between the SeaSoar and the ship, and of the transit time of the water through the supply system. These were compared with SeaSoar salinities averaged over 0-10m depth. The calibrations yielded corrections to the sensor outputs as follows:

$$X_{(true)} = X_{(sensor)} + E$$

with the values of E given in Table 3.4. The salinities and temperatures of the CTD bottle samples (Table 4.1) have been corrected in accordance with Table 3.4.

Table 3.4 Salinity and temperature calibrations

Parameter (X)	Sensor	Correction (E) ± 1 s.e.	N
Salinity	CTD	-0.0429 ± 0.0011	18
Temperature/°C	CTD	0.0056 ± 0.0008	14
Salinity	SeaSoar	0.0545 ± 0.0084	27
Salinity	Thermosalinograph	0.0273 ± 0.0004[a]	17
		-0.0230 ± 0.0004[b]	5

a until 21st June
b from 22nd June (sensor cleaned on 21st June)

3.5 Chlorophyll calibrations (Alison Weeks, Polly Machin, Miles Finch)

Underway measurements of fluorescence were obtained from a flow-through Turner Designs fluorometer attached to the seawater supply system (section 3.1). Chelsea Instruments fluorometers were incorporated in the SeaSoar and the CTD for vertical profiles of measurements of fluorescence. The Icefish also contained a fluorometer. Each of these fluorometers was calibrated by acetone extraction of the GF/F filtrate from discrete samples, followed by fluorescence measurement on a Turner Model 112 bench fluorometer. The flowthrough, SeaSoar, and Icefish fluorometers were calibrated from 2-hourly samples taken from the seawater supply system, timed to coincide with the surfacing of the SeaSoar as described for salinity samples above. A total of 95 underway chlorophyll samples were obtained, all in triplicate. Two replicates of each sample were analysed immediately, and the third frozen for post-cruise analysis. For all CTD stations apart from the Darwin intercalibration station (12107; Table 1.1) the SeaSoar fluorometer was transferred to the CTD frame: the normal CTD fluorometer was not used during the CTD sections. Calibration samples were taken from the Niskin bottles fired during shallow casts (Table 4.1): one third of these were triplicate samples with a frozen replicate for post-cruise analysis.

At the end of the cruise, a repeat calibration of the bench fluorometer revealed that its response had changed by 50% during the cruise. The frozen samples were therefore analysed at PML, and the calibrations given below are based on these post-cruise analyses. The calibration equations take the form:

$$\text{Chl-a} = A + B * \text{Fluor}$$

The values of A and B are summarised in Table 3.5. The SeaSoar fluorometer calibrations do not yet include corrections for light levels, and the data have merely been divided into day and night sets.

Table 3.5 Chlorophyll calibration data

Fluorometer	A ± 1 s.e	B ± 1 s.e.	N	R
Flowthrough	0.2329 ± 0.0587	0.0587 ± 0.0121	28	0.68
Icefish	data not yet available			
SeaSoar (day)	0.3099 ± 0.0379	0.2524 ± 0.0437	52	0.63
SeaSoar (night)	0.2125 ± 0.0708	0.3611 ± 0.0640	21	0.78
SeaSoar on CTD	-0.2322 ± 0.0981	0.3173 ± 0.0544	28	0.75

3.6 Phytoplankton sampling (Alison Weeks, Polly Machin, Miles Finch)

Samples were taken from the seawater supply system for analysis of phytoplankton species. Duplicate samples were taken; one was fixed with acidic lugols iodine, and the other with formaldehyde. In addition, six samples were taken for the measurement of a range of plant pigments by HPLC. Phytoplankton and HPLC samples were also taken from the Niskin bottles on two shallow CTD casts (stations 12110#3 and 12113#2).

3.7 Productivity (Miles Finch)

Productivity measurements were carried out using a deck mounted incubator with a fine mesh to imitate light levels in the water. Initial measurements of productivity using surface water samples showed little or no production at the surface. Studies of the fluorescence indicated that the chlorophyll maximum was at about 25m and so subsequent samples were taken from this level using 30l Go-Flo bottles. Levels of production over a 24 hr period ranged from 1.9 to 2.6 µMC as measured by pCO_2 and 1.29 to 2.28 µM/kg as measured by oxygen. These levels when compared to the productivity measurements taken on Discovery 190 are much lower indicating that the bloom of phytoplankton has declined from its peak.

3.8 Oxygen (Peter Williams, Miles Finch)

During the CTD transects 12 casts were analysed for oxygen concentration and saturation, with analytical precision in the region of 0.1 $\mu mol.kg^{-1}$. The results are given in Table 4.1.

A very successful oxygen intercomparison was carried out during the rendezvous with RRS Charles Darwin (Dr. Duncan Purdie). On station 12107#2 (Table 1.1), oxygen was sampled from Niskin bottles fired from the same depths on each ship. A high precision was obtained, and of the 9 pairs of data only two were noticeably discrepant (Table 3.6). Excluding these two points, an excellent linear regression is obtained with a very small intercept and slope close to unity (Table 3.6, Fig. 3.2). The discrepancies observed at 700 and 2000m almost certainly reflect sampling errors, which may result from significant O_2 gradients at those depths.

Table 3.6 Oxygen intercalibration with RRS Charles Darwin

Depth/m	Discovery			Darwin
	T/°C	Salinity	$[O_2]/\mu mol.kg^{-1}$ ± 1 s.e.	$[O_2]/\mu mol.kg^{-1}$ ± 1 s.e.
400	10.929	35.557	251.74 ± 0.25	251.91 ± 0.04
500	10.779	35.536	251.33 ± 0.12	250.88 ± 0.23
600	10.497	35.498	246.02 ± 0.25	246.99 ± 0.49
700	10.351	35.480	242.50 ± 0.10	245.67 ± 0.20
800	9.505	35.379	209.76 ± 0.19	209.14 ± 0.37
1000	8.245	35.378	196.16 ± 0.07	197.16 ± 0.07
1200	6.125	35.188	219.13 ± 0.04	218.77 ± 0.03
1500	4.569	35.049	249.28 ± 0.12	248.16 ± 0.17
2000	3.647	34.967	266.86 ± 0.16	257.82 ± 0.52
2500	3.326	34.996	259.02 ± 0.09	N.D.
3000	2.918	34.989	248.22 ± 0.19	N.D.
4051	2.530	34.951	235.89 ± 0.13	N.D.

Linear regression analysis of the equation

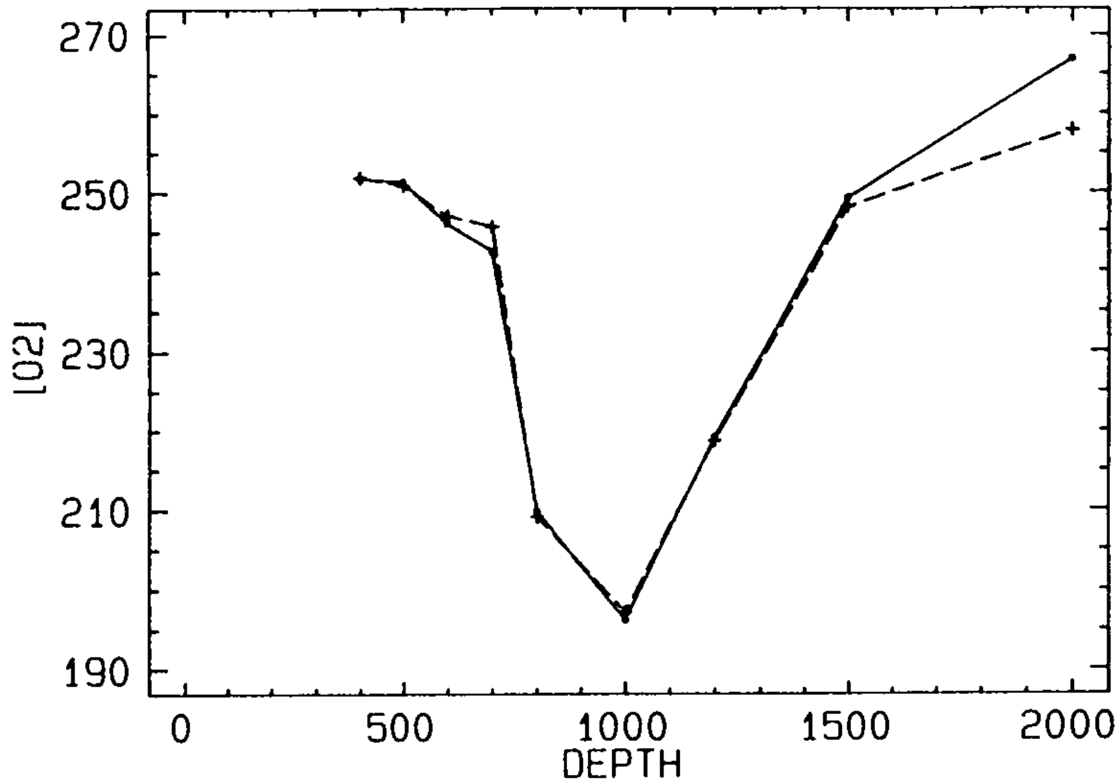
$$[O_2](\text{Discovery}) = A + B * [O_2](\text{Darwin})$$

Points	A	B	R	N
All	-10.86 ± 13.11	1.049 ± 0.055	0.9904	9
All except 700,2000	-1.75 ± 3.58	1.008 ± 0.015	0.9994	7

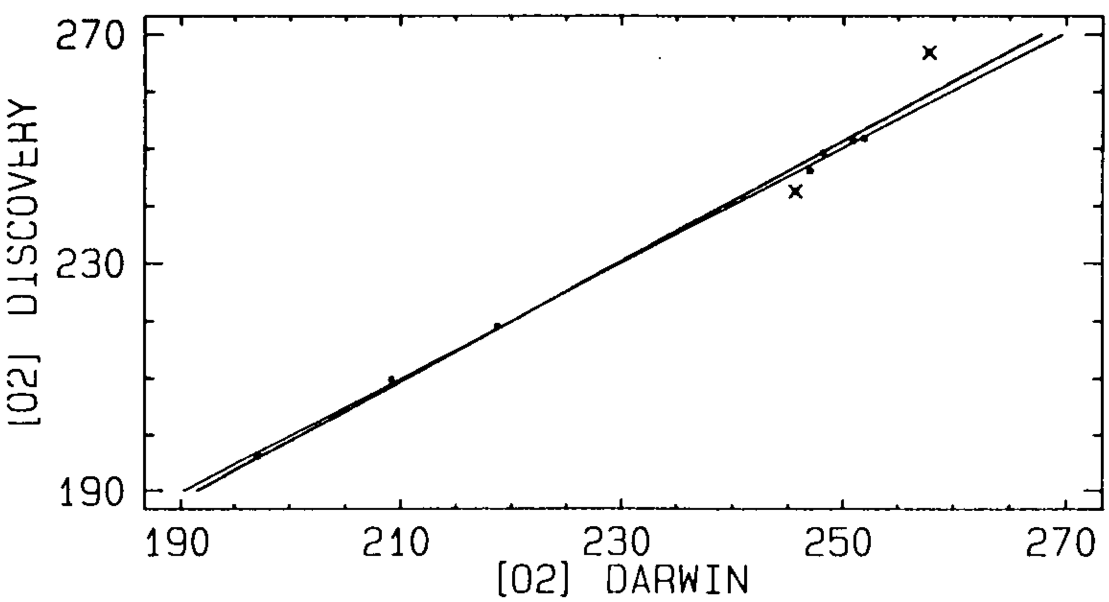
Underway oxygen measurements were carried out using two Endeco type 1125 pulsed dissolved oxygen electrodes. The electrodes were placed in a flow through cell connected to the non-toxic seawater supply (section 3.1). The electrodes were operated by a controller connected to a microcomputer. The computer stored the data on floppy disc, with periodic transfer to the ship's level C system. The electrodes, although calibrated prior to the cruise, required checking throughout the cruise to ensure that the calibration did not drift. This was achieved by taking water samples for Winkler analysis every six hours from the non-toxic supply. The time of each sample coincided with a reading from the electrodes. Regression of the electrode data against the Winkler data showed

Figure 3.2 Oxygen intercalibration (concentrations in µmol.kg^{-1}).

(a) [O_2] profiles ■——■ Discovery + - - - + Darwin



(b) regression analysis - - - regression fit to all points
—— fit to all except 700, 2000m (marked ×)



that the calibration did not change significantly during the cruise. Dissolved oxygen values in the surface waters were in the range 246μmol.kg^{-1} to 257μmol.kg^{-1}, significantly lower than those observed on Discovery 190 (280 to 290 μmol.kg^{-1}).

3.9 pCO_2 (Roger Ling)

pCO_2 was measured by gas chromatography as on Discovery 182 and 190. During the port call preceding the cruise a considerable amount of work had to be done on the system following a gas regulator failure. The valve system was rearranged to bypass a faulty motor controller, and the catalyst was replaced due to suspected damage caused by the gas failure. The controlling software was also rewritten to accommodate the change in the pCO_2 chromatograph. Underway pCO_2 measurements were started during the approach Seasoar tows before the rendezvous with Darwin. A full set of underway data was obtained from the box survey, and discrete samples were also analysed from the CTD casts (Table 4.1).

3.10 Total CO_2 by coulometry (Carol Robinson)

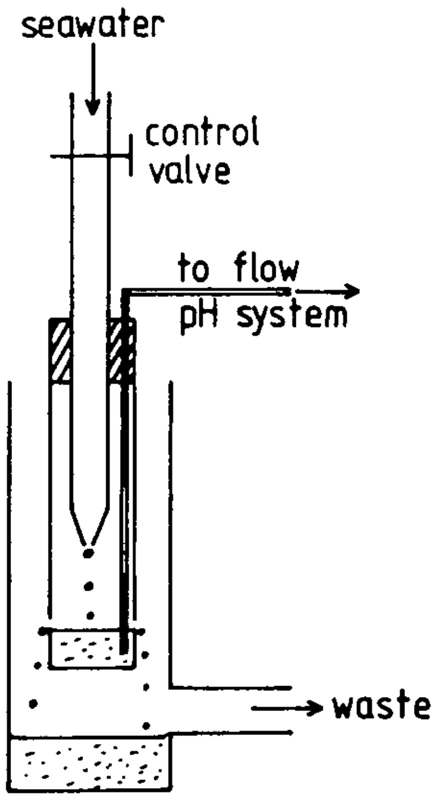
The measurement schedule of coulometric total inorganic carbon during RRS Discovery 192 essentially repeated that of Discovery 190 (see cruise report), involving continual underway analysis for 7 days, whilst the ship completed a box grid survey, and a further 4 days of discrete vertical profiles within the box area. The coulometric instrumentation has been fully described elsewhere, and generally performed well throughout the cruise. Recent development of automated standardisation and calibration of the analytical system was field tested, and can now be finely tuned in the more controlled laboratory environment at UCNW. Initial interpretation of the underway data (TCO_2, with concomitant pCO_2, fluorescence, and nutrients) shows a positive correlation between TCO_2, pCO_2, and nutrients, and a negative relationship between TCO_2 and chlorophyll fluorescence. In general, the TCO_2 concentrations were homogeneously low, as may be expected for surface waters in a post bloom situation. The inclusion within the grid area of a number of frontal features will allow further interpretation in the light of physical, as well as chemical oceanographic parameters, e.g. temperature, salinity, and alkalinity. The measurements carried out during the CTD sections are summarised in Table 4.1.

3.11 pH (David Turner)

pH was measured by glass electrode potentiometry in an automated flow system with a free diffusion liquid junction. The system is the same as that used on Discovery 190, and is a development of that used on Discovery 182. NBS buffers (pH 4 and 7) were used to confirm that the flat head glass electrodes used showed close to theoretical response (>99%). For seawater pH measurements the electrodes were calibrated in Tris-artificial seawater buffer. The buffer was prepared on board by mixing preweighed portions of Tris and Tris.HCl solids with preweighed quantities of artificial seawater. pH samples from Niskin bottles were drawn directly into glass syringes, and the syringes connected directly to the flow system for analysis.

Underway pH measurements continued to suffer from the problems of drift noted on Discovery 182 and 190. Hydrostatic pressure on the flow system inlet was eliminated as a cause by using a small constant head seawater reservoir. This was followed by a series of experiments in which the flow system was earthed at different points, and the electrode potential compared with that obtained from a discrete sample collected at the same time from the seawater supply system. Each earthing arrangement resulted in a different and varying potential offset, with large offsets observed (e.g. 10mV). It was concluded that the incoming seawater stream was carrying sufficient electric current to cause significant errors in the glass electrode potential measurements. The source was not identified, but it is likely to be either the ship itself or the oxygen electrode which is also connected to the seawater supply system. In order to overcome this problem it was necessary to electrically isolate the sample from the seawater supply during measurement. This was achieved using the arrangement shown in Fig. 3.3. Between measurements the chamber was flushed with seawater, but during measurements the seawater inlet was slowed to a drip feed to achieve electrical isolation. This arrangement appeared to remove the offsets noted above.

Figure 3.3 Underway pH sampling



3.12 Alkalinity and total CO_2 by potentiometry (Kay Pegler)

Total alkalinity (TA) and total dissolved inorganic carbon (TCO_2) were measured by a potentiometric titration method. The system comprised a Metrohm 655 autoburette, a Metrohm 605 pH-meter and a closed titration cell with a defined volume of 128.25 ml. The 5 ml burette and the cell are jacketed and combined with a Lauda water bath thermostatted to maintain a stable temperature of 25°C. The titration was driven by a Hewlett Packard 9825B desk top calculator, which also stored the titration curve values, which were recorded as volume of titrant (0.20004M HCl) versus the potential (mV) of an Ingold combination electrode. The calculation of TA and TCO_2 from the titration curves was carried out using a Hewlett Packard Language (HPL) equivalent of the Basic programme of Bradshaw et al. (1981).

160 replicates from the seawater supply system were analysed, mainly from the area of the SeaSoar box survey, together with single samples from CTD Niskin bottles (Table 4.1). The titration analyses were carried out immediately after sampling.

3.13 Alkalinity by spectrophotometry (Kerstin Müller)

Total alkalinity was determined using a spectrophotometric acid titration technique. Following the method of King and Kester (1989), individual pH readings were derived from absorbance ratios of the indicator bromophenol blue. Absorbances were measured using an HP8452 diode array spectrophotometer, and standardised hydrochloric acid titrant (approx. 0.4N) was added from a Metrohm 665 Dosimat. The titration was carried out in the pH range 3.1 to 2.5. Following corrections for the association of hydrogen ion with sulphate, fluoride, and the indicator, the linear Gran method was used to calculate the total alkalinity.

Initial problems with the precision of the analytical technique necessitated a revision of the analytical procedure. Although this precluded underway measurements, analysis of duplicate samples showed that the problems were solved in time for the CTD sections during the second half of the cruise. The results from the CTD sections are given in Table 4.1.

3.14 Nutrients (Helen Edmunds)

The five nutrients nitrate, nitrite, silicate, phosphate and ammonia were measured during the SeaSoar surveys. Continuous analyses from the seawater supply system provided an overall picture of surface nutrients: only small concentrations remained due to the spring bloom having used up all available nutrients.

On 12 June an intercalibration with the RRS Charles Darwin took place as the results of previous intercalibration exercises had proved worrying. Discussions by radio with Bob Head, the nutrient analyst on Darwin, identified possible sources of error. The largest discrepancy in previous intercalibrations had occurred with silicate, with standards the most obvious source of error. It transpired that the two ships had been using different media to make up their standards. The Darwin working standards were made up in surface seawater taken at the time of analysis, while all Discovery standards were made up in Milli-Q water. There are arguments for and against each method, but it is clear that procedures should be standardised for future exercises of this nature so that comparable nutrient data can be obtained by analysts on different ships.

The intercalibration consisted of shallow CTD casts by both ships, followed by exchange of primary standards and CTD bottle samples. On Discovery, sets of standards (using both Darwin's and Discovery's primary standards) were made up in surface seawater supplied by Darwin. These were run first, together with Milli-Q water as a blank: it transpired that Darwin's surface seawater was not in fact nutrient-free. Finally, the CTD samples were run, first those of Darwin, then those of Discovery. The samples had been stored in cool boxes, and were run simultaneously on the two ships. The different sets of analyses have all been compared by linear regression analysis, with the results shown in

Table 3.7. These data were all obtained using Darwin's standards made in "nutrient-free" seawater supplied by Darwin. A number of points are clear. Firstly, the results obtained on the Darwin samples are poor compared with those obtained from the Discovery samples: this no doubt reflects the problems involved in storing and transporting the samples before analysis. Inspection of the nutrient profiles (Figs. 3.4 to 3.7) reveals that the problem lies with the Darwin samples which had been transported to Discovery. Concentrating on the Discovery samples, it is clear that some smaller systematic differences remain. However, the overall result is encouraging in that the major discrepancies revealed in earlier BOFS intercalibrations were not found.

As a result of this intercalibration, the reasons for discrepancies in nutrient data have become clearer. Firstly, the two ships were using independently prepared primary standards, which were found to differ by small percentages. Secondly, different protocols were used to prepare working standards, leading to errors when the seawater used for dilution was not in fact nutrient-free. Thirdly, even when samples were analysed using the same standards some differences remained. For any future exercise of this type the lessons are clear. First, use a single batch of carefully prepared and checked primary standards. Second, use a single, reliable protocol for standard dilution and blank preparation. Third, run the instruments side by side on shore before the start of the cruise programme to iron out any remaining differences.

Nutrients were determined in all Niskin bottles from the CTD sections: the results are listed in Table 4.1.

Table 3.7 Nutrient intercalibration analysis by linear regression

Nutrient	A ± 1 s.e.	B ± 1 s.e.	R
Darwin samples			
Nitrate	0.28 ± 0.54	0.924 ± 0.061	0.9850
Nitrite	0.061 ± 0.050	0.768 ± 0.216	0.8018
	0.054 ± 0.004	0.962 ± 0.019	0.9899[a]
Silicate	0.19 ± 0.15	1.031 ± 0.047	0.9928
Phosphate	0.40 ± 0.10	0.528 ± 0.247	0.6281
Discovery samples			
Nitrate	-0.19 ± 0.08	0.934 ± 0.001	0.9996
Nitrite	0.055 ± 0.001	0.842 ± 0.043	0.9906
Silicate	-0.04 ± 0.03	1.069 ± 0.011	0.9997
Phosphate	0.13 ± 0.001	0.873 ± 0.017	0.9987

a after removing discrepant data at 300m

Figure 3.4 Nitrate intercalibrations
———— Darwin analyses
- - - - - Discovery analyses

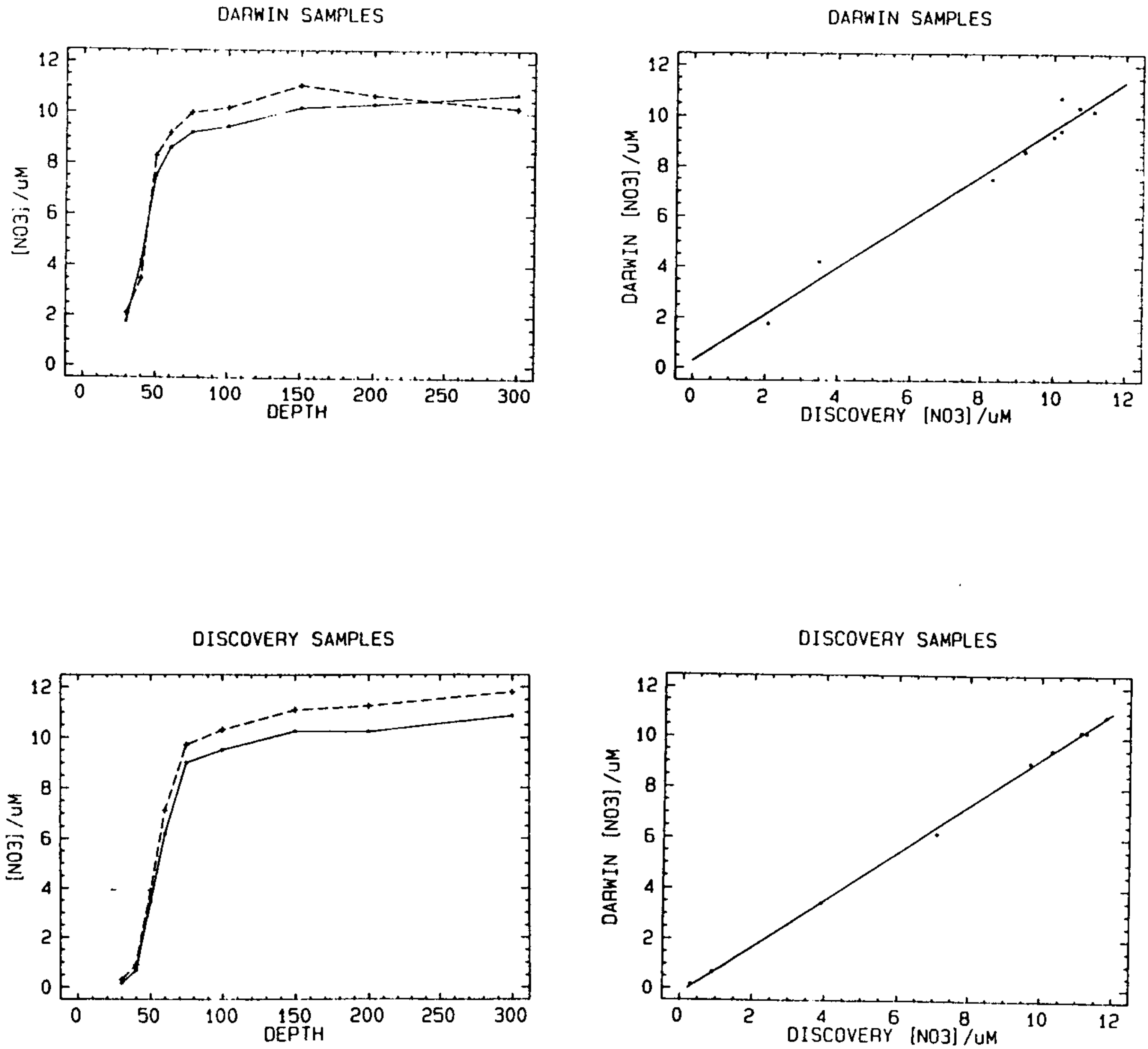


Figure 3.5 Nitrite intercalibrations
——— *Darwin analyses*
– – – – – *Discovery analyses*

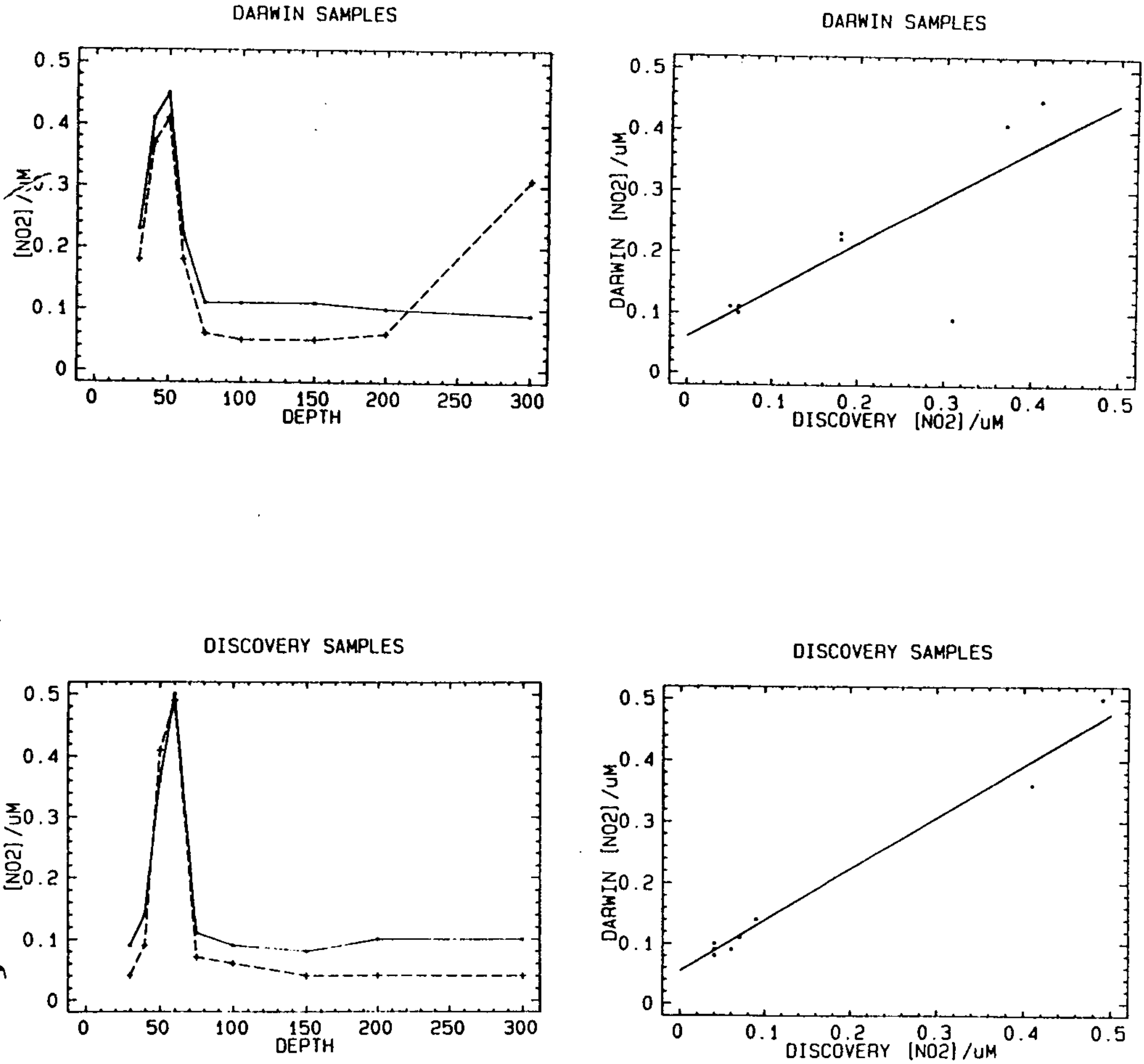


Figure 3.6 Silicate intercalibrations
—————— Darwin analyses
- - - - - Discovery analyses

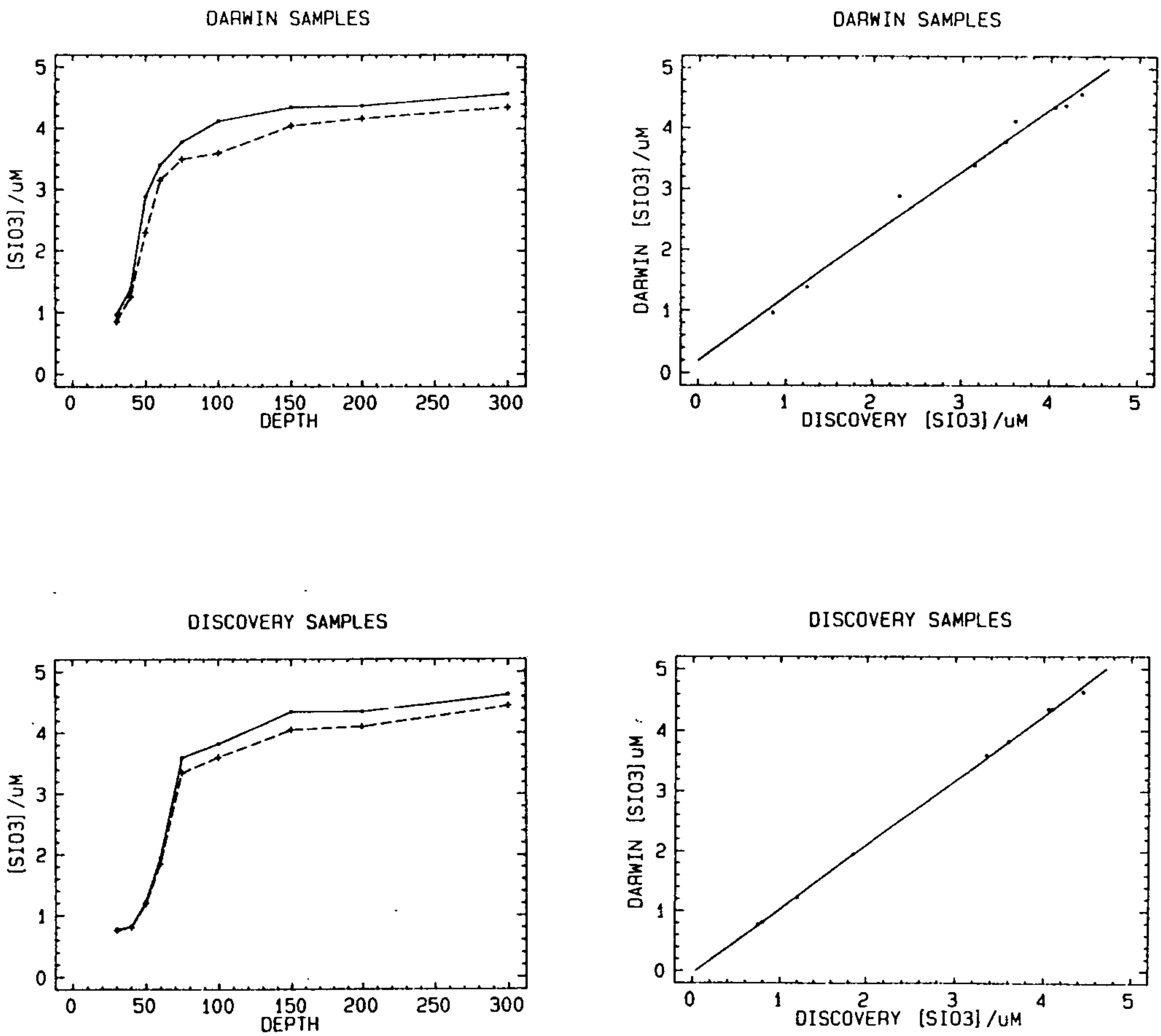
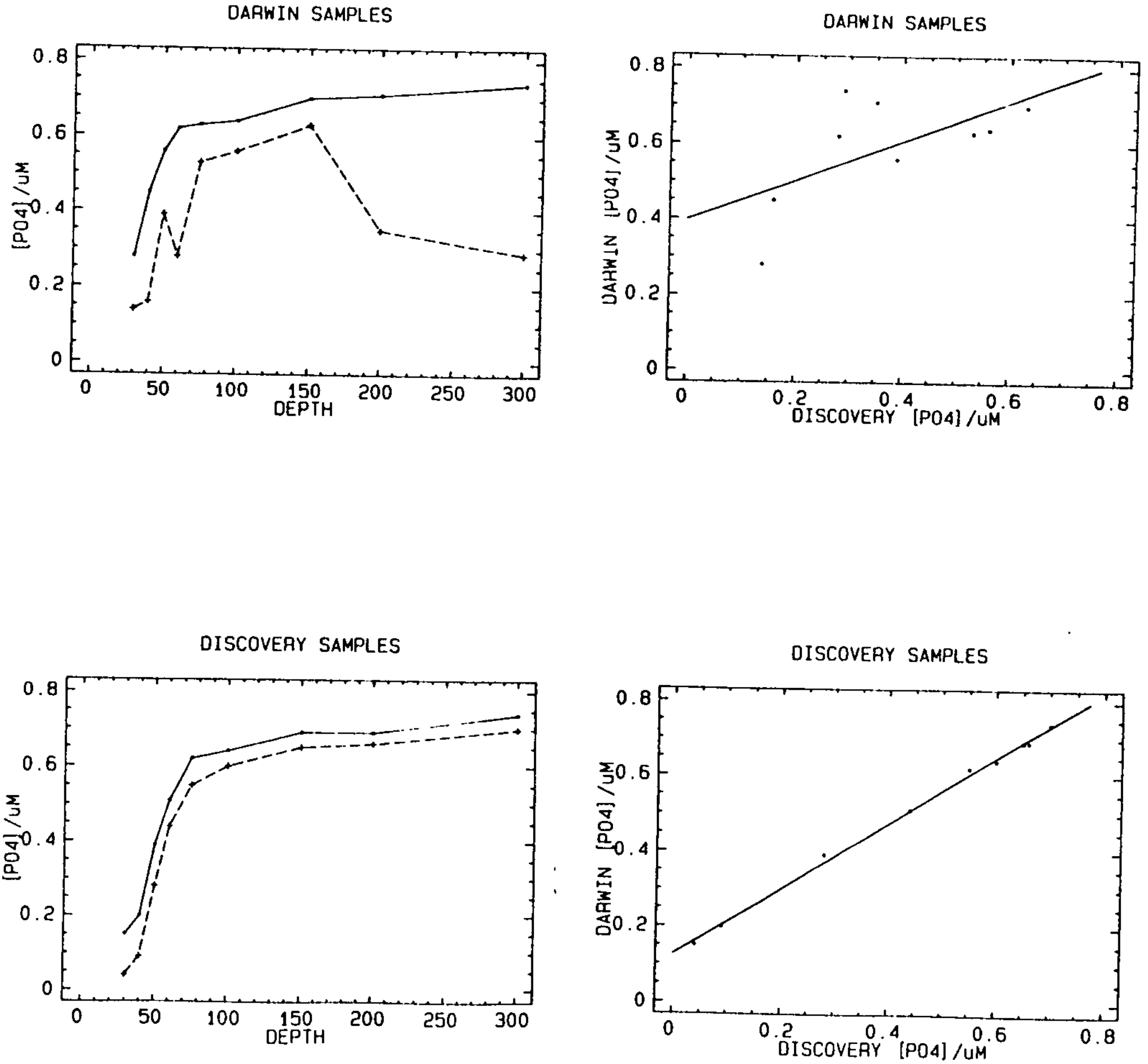


Figure 3.7 Phosphate intercalibrations
———— Darwin analyses
- - - - - Discovery analyses



3.15 Argon and nitrogen (Roger Ling)

These gases were measured by gas chromatography as on Discovery 190. The measurement is carried out on the second channel of the pCO_2 chromatograph, and considerable work was required on the argon/nitrogen channel during the pre-cruise port call. A new thermal conductivity detector cell was fitted, and a service engineer was called to deal with further faults which had been discovered. During the first few days of the cruise, priority was given to the pCO_2 system, with the result that the argon/nitrogen system was not ready for use during the approach SeaSoar transects. However, underway data were collected throughout the main SeaSoar box survey, and discrete samples from surface casts at the CTD stations were also analysed. The chromatograms await manual reprocessing in order to determine the argon and nitrogen concentrations.

3.16 Meteorology (David Woolf)

A set of observation sheets for meteorology and sea state were supplied to each of the five summer BOFS cruises. A sheet was completed regularly three times a day throughout each cruise, by David Woolf on Discovery 192 and by the bridge watchkeeper on the other legs. The observations covered sea state, the presence of breaking waves and windrows, winds, visibility, clouds and rainfall. Most of these observations are cover for the shipboard instrumented measurements (Discovery's meteorological package; Metpak and a wave recorder on Darwin) and will allow basic screening of this data.

The observations of breaking waves, windrows and rain were originally intended to help in the interpretation of ARIES data (acoustic measurements of bubbles). Given only a stunted ARIES data series, the measurements of wind speed and the observations of breaking waves will have a primary role in the estimation of air-sea gas transfer by direct and bubble-mediated mechanisms for the study period.

3.17 ADCP (David Woolf, Kelvin Richards)

Following repair, the ADCP was reinstalled on Discovery immediately before the cruise. The ADCP was calibrated on the passage out by the standard method of zig-zag manoeuvres at 8 knots, the standard SeaSoar survey speed. Calibration by two methods are possible; one using the GPS navigation and the other based on the signal returned from the seafloor (bottom-tracking). The data from the calibration manoeuvres was used to calculate an 'amplitude factor' and a 'heading correction'. Both methods gave practically the same answer for the amplitude factor but very different heading corrections (Table 3.8). The bottom-tracking calibration values were used.

Table 3.8 ADCP calibration

Calibration method	Amplitude factor	Heading correction/°
Bottom-tracking	0.977	0.276
GPS	0.974	2.081

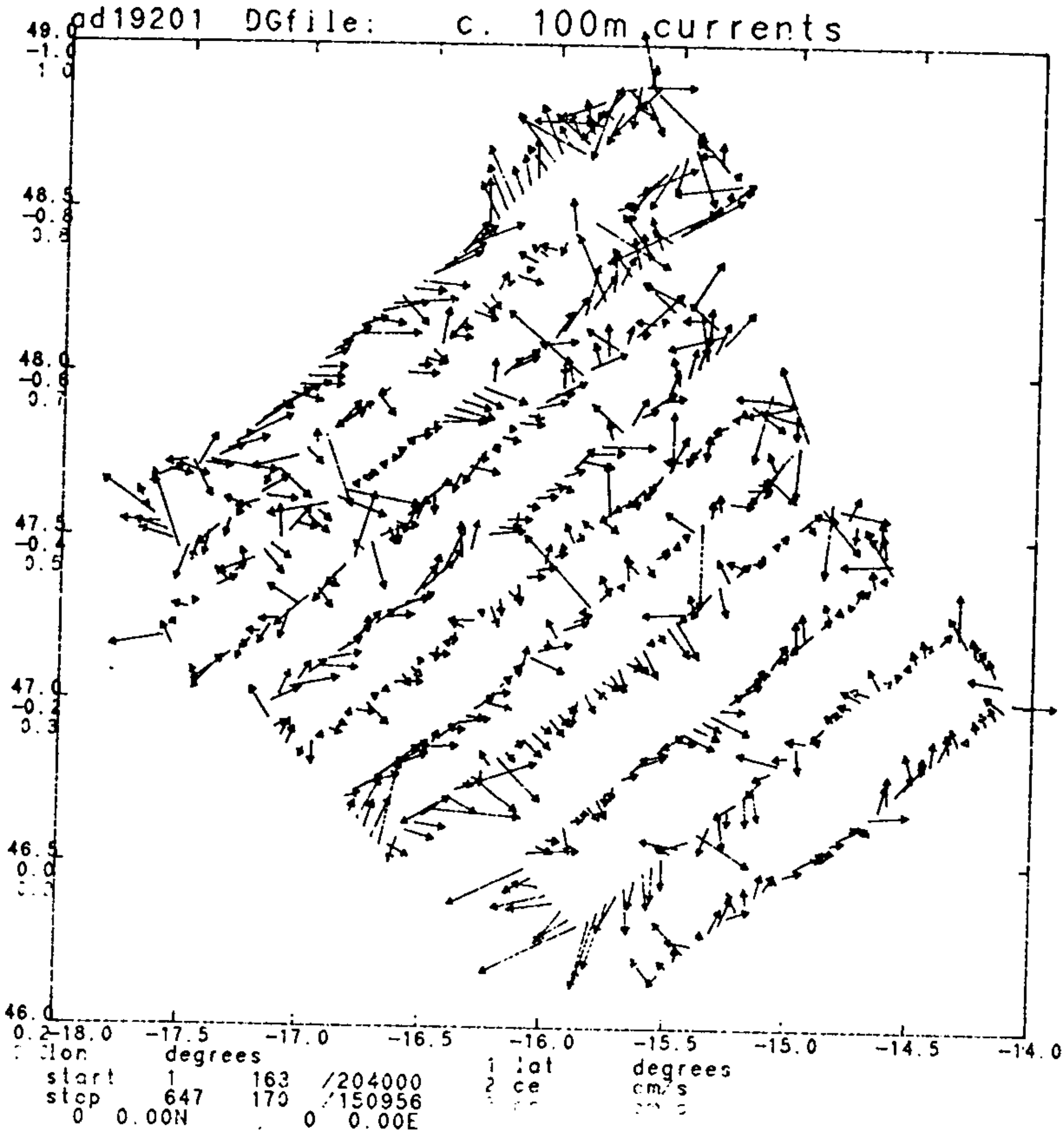
ADCP data was logged throughout most of the cruise, but the most useful data are those from the SeaSoar box survey. We have processed the data from the Seasoar survey (163/2010 to 170/1210) in 14 twelve-hour sections (numbered 02-15) using the p-star execs adpexec0, adpexec1, adpexec2, adpexec3. The start and finish times of all the processed sections of data are given in Table 3.9. Two raw files, bot192(nn) and adp192(nn), and the smaller gridded and averaged file adp192(nn).av generated by adpexec2 have been archived. 'adpexec3' calculates and plots the shear velocity in the top 300m relative to a reference depth (here the average of acoustic bins 31-40, 244-316 metres). Shears of the order of 10cm/s from 4 metres to fifty metres depth were common, with less shear in the deeper water.

The adp192(nn).av files were appended together and merged with the GPS navigation file for the same period. Vector addition of adcp velocities and the ship velocities gives a set of calculated current velocities. When this procedure was first performed, we discovered a major systematic error, with calculated velocities biased to be 90 degrees clockwise of ship heading. The most likely problem was the heading correction, and so we recalibrated the adcp velocities using the GPS heading correction and and recalculated the current velocities. These latter results are more encouraging, they show no obvious bias. A number of rogue values, most probably associated with the ship turning, were found. Most of these values were excluded by the simple expedient of removing all values of current component of greater than 100cm/s. The file adrecal2 containing the data for the entire survey has been archived. Currents averaged over the top twenty metres (bins 1-3), circa 100 metres (bins 11-15) and circa 200 metres (bins 25-30) were calculated and plotted using 'vecplo'.

Table 3.9 ADCP data files

File index (nn)	Start	End
01	162/1500	163/0600
02	163/2010	164/0810
03	164/0800	164/1200
04	164/1200	165/0000
05	165/0000	165/1200
06	165/1210	165/2355
07	165/2355	166/1155
08	166/1210	166/2355
09	166/2355	167/1155
10	167/1210	167/2355
11	167/2355	168/1155
12	168/1210	168/2355
13	168/2355	169/1155
14	169/1210	170/0010
15	170/0010	170/1210
16	170/1210	171/0010
17	171/0010	171/1210

Figure 3.8 Currents at 100m from ADCP



Current values of the order of 50cm/s are typical. These velocities generally overwhelm shears in the top 200 metres so that the pattern at all three depths investigated are similar: the 100m currents are shown in Fig. 3.8. The data is fairly noisy, but a great deal of genuine structure is evident in the plots, including a south-easterly flow along the principal front identified by the SeaSoar survey, and a number of smaller eddy features. Hopefully, the structure will be revealed more clearly and in more detail after further processing with contour plots of the stream function or the potential vorticity field.

3.18 Equipment recovery (Ian Waddington)

3.18.1 Bathysnap. This Bathysnap was deployed on 19/5/89 (Discovery 182) at 48 00.817N, 19 33.953W (GPS). Accoustic contact was achieved at 171/0054, and accoustic renavigation confirmed that the unit was at the GPS deployment position. In the prevailing wind and swell conditions, it was considered unwise to release the Bathysnap until daylight. The unit was released at 171/0927, position 48 00.6N, 19 32.5W (GPS). The ship hove to, and the rise of the unit followed. Shortly before surfacing, the accoustic signal was lost in noise. On surfacing the RDF beacon was detected on the HFR3 receiver and on the bridge VHF (171/1040). Location of the unit proved difficult as the RDF was swamped by the strong signal, but visual location was difficult in the strong swell. The unit was sighted at 171/1139 (48 01.3N, 19 33.7W), and was grappled at 171/1152 (48 01.5N, 19 33.6W). Recovery was hampered by the failure of the forward hydraulics. Recovery was achieved using the ship's forward crane, alternately lifting and stopping off the lines. The bathysnap frame was fully inboard by 171/1222.

On inspection, the recovery light and RDF were found to be operating correctly, and the flag in good condition. However, the holding bolts for the ballast weight had almost corroded away. The buoyancy package was in good order. The temperature channel on the current meter was found to have failed on 17 December 1989, and records were noisy on all channels to 18 April 1990. This was due to main battery failure, and on decoding the lithium back up battery was found to on the point of failure. The flash connector was found to be damaged, though this probably occurred during recovery. The flash end cap and detector were found to be damaged due to corrosion at the tightening hole. The flash was reconnected, but no operation was detected. The camera was in good condition. Subsequent examination at IOSDL revealed that the flash had failed to operate throughout the deployment.

3.18.2 IDB Argos buoy 5034. The buoy was detected at 177/0340 on the RDF HFR3. and the code could be identified on the handar 602A. By steaming courses to establish beam on positions for the buoy, a box was established within which the buoy was located. At dawn a visual search was commenced with the ship maintaining RDF contact with the buoy. Weather conditions were perfect with a calm sea and excellent visibility. However, no visual contact was made, and at 177/0810 the search was abandoned.

3.18.3 IDB Argos buoy 5031. The buoy was detected at 177/1737 on the RDF HFR3 and courses steamed to establish location. A live track plot was initiated on the computer navigation, and with RDF bearings plotted against this the buoy was again boxed. Once again, no visual contact could be established, and at 177/2100 with failing light the search was abandoned.

3.19 Computing (Andrew Cormack, Richard Shaw)

This was a very intensive cruise with watchkeeping required of the computer staff around the clock. It was extremely fortunate that two computer staff were on board, even though the late arrival of the second caused some concern before sailing.

A large range of instruments were logged and the rate at which data was generated was high, particularly when the SeaSoar was in use. On the whole the system coped well with this although there were indications that it was at times approaching its maximum capacity. The 'SeaSoar' and 'lights' level As were particularly hard pressed, and with proper clock synchronisation becoming an urgent requirement these may need to be replaced shortly. The use of two level As to process the SeaSoar data was not really satisfactory due to the problems of separately drifting clocks although a temporary solution to this problem was found.

Two level As had to be rewritten when they were found to be misreading their input messages. These were requested for cruise 190 and used on that cruise so it was surprising that they were still not in working order. Other level As, although they can be made to work, are not satisfactory for shipboard work. Several hours of thermosalinograph data were lost at various stages in the cruise due to that level A's problems in starting correctly.

Disk space for the Pstar system was felt to be insufficient as removal of data onto magnetic tape became a full-time occupation. An archive directory was created within the RVS processed data area which allowed a complete tape to be written at once. This avoided the problems experienced on previous cruises when appending to part-complete archive tapes.

It was not possible to make GF3 archive tapes on board as the half-inch tape driver produced unreadable tapes as well as reading past the end of tape mark. A decision needs to be made on the future use of half-inch tapes and a working tape driver is badly required. This problem will continue when Sun 4 computers are installed as the tape driver for that machine is in an even worse state.

4. CTD BOTTLE DATA

These data are listed in Table 4.1. For the phytoplankton samples, the sample bottle numbers are listed. Argon and nitrogen data are not yet available (section 3.15).

Table 4.1 CTD bottle data

Depth m	Salinity psu	Temp. °C	O_2 %sat	O_2 µmol/kg	TCO_2 µmol/kg	NO_3 µmol/lit	NO_2 µmol/lit	PO_4 µmol/lit	SiO_3 µmol/lit	NH_4 µmol/lit	Alkalinity µmol/kg (pot.)	Alkalinity µmol/kg (photo.)	pH value	pH temp °C	pCO_2 µatm	pCO_2 temp °C	chl-a µg/lit	phyto bottles	HPLC sample no
DISCOVERY STATION 12107#1																			
5	35.51	15.39									2343								
10	35.70	15.37									2330								
20	35.71	15.36									2333								
30	35.71	15.34				0.30	0.04	0.04	0.70		2329								
40	35.70	15.03				0.90	0.08	0.09	0.75		2332								
50	35.75	14.03				3.65	0.39	0.28	1.10		2332								
60	35.73	12.91				6.70	0.47	0.44	1.75		2335								
75	35.71	12.17				9.10	0.07	0.55	3.70		2328								
100	35.68	11.82				9.70	0.05	0.60	3.45		2327								
150	35.67	11.45				10.40	0.04	0.65	3.85		2317								
200	35.61	11.31				10.50	0.04	0.66	3.90		2314								
300	35.58	11.10				11.05	0.04	0.70	4.20		2317								
DISCOVERY STATION 12107#2																			
400	35.56	10.93		251.74							2314								
500	35.54	10.78		251.33							2314								
600	35.50	10.50		246.02							2312								
700	35.48	10.35		242.50							2311								
800	35.38	9.51		209.76							2310								
1000	35.38	8.25		196.16	2179.19						2315								
1200	35.19	6.13		219.13	2178.14						2298								
1500	35.05	4.57		249.28	2168.65						2297								
2000	34.97	3.65		266.86	2160.93						2288								
2500	35.00	3.33		259.02	2169.67						2295								
3000	34.99	2.92		248.22	2183.77						2317								
4052	34.95	2.53		235.89							2339								
DISCOVERY STATION 12109#1																			
7	35.72	14.54	102.5	247.41	2070.44	1.77	0.14	0.13	0.78	0.14	2342	2331	8.090	20.51	293.4	15.00	0.46		
10	35.72	14.54	102.1	247.71	2070.36	1.73	0.14	0.13	0.76	0.14	2344	2374	8.089	20.50	293.3	15.00	0.49		
30	35.77	14.54	102.2	247.45	2069.25	1.77	0.14	0.13	0.77	0.14	2337	2327	8.088	20.47	294.1	15.00	0.50		
70	35.69	12.27	94.4	239.65	2172.09	9.17	0.05	0.60	3.07	0.00	2341	2322	7.981	20.51	393.3	15.00	0.02		
150	35.67	11.81	96.2	246.56	2177.50	8.95	0.04	0.60	3.12	0.00	2328	2316	7.910	20.31	400.7	15.00	0.01		
300	35.56	11.18	89.7	237.54	2134.06	10.90	0.04	0.74	3.90	0.00	2328	2313	7.931	20.31	434.6	15.00			
DISCOVERY STATION 12110#3																			
7	35.73	14.74	101.7	245.74	2063.90	1.32	0.11	0.10	0.68	0.30	2349	2331	8.119	20.76	289.0	15.00	0.42	4903,4904	1
10	35.73	14.74	101.8	245.85	2064.54	1.37	0.11	0.10	0.68	0.30	2342	2328	8.112	20.77	291.2	15.00	0.50	4905,4906	2
30	35.74	14.73	101.5	245.38		1.37	0.11	0.10	0.68	0.30	2342	2323	8.105	20.77	290.7	15.00	0.51	4907,4908	3
70	35.69	11.90	95.5	243.98	2120.27	11.90	0.05	0.59	3.32	0.00	2338	2318	7.941	20.82	397.5	15.00	0.03	4909,4910	4
150	35.62	11.50	95.6	246.60	2125.47	17.60	0.04	0.63	3.76	0.00	2331	2314	7.966	20.86	410.1	15.00	0.01	4913,4914	5
300	35.54	10.89	96.3	246.12	2130.18	14.10	0.05	0.77	4.39	0.00	2374	2303	7.961	20.87	431.8	15.00		4915,4916	6

Table 4.1 CTD bottle data (contd.)

Depth m	Salinity psu	Temp. °C	O_2 %sat	O_2 µmol/kg	TCO_2 µmol/kg	NO_3 µmol/lit	NO_2 µmol/lit	PO_4 µmol/lit	SiO_3 µmol/lit	NH_4 µmol/lit	Alkalinity µmol/kg (pot.)	Alkalinity µmol/kg (photo.)	pH value	pH temp °C	pCO_2	pCO_2 temp °C	chl-a µg/lit	phyto bottles	HPLC sample no
DISCOVERY STATION 12111#2																			
2	35.72	14.70	102.3	247.71	2065.88	1.22	0.11	0.14	0.82	0.13	2344	2327	8.091	20.95			1.00		
10	35.72	14.64	102.3	247.66	2065.56	1.22	0.11	0.10	0.82	0.13	2338	2331	8.095	20.97			0.50		
70	35.71	12.48	95.5	241.26	2115.74	10.48	0.28	0.54	2.22	0.00	2325	2350	7.991	20.92			0.10		
150	35.65	11.64	94.9	244.17	2126.04	12.37	0.05	0.63	4.70	0.00	2322	2312	7.940	20.97			0.01		
300	35.59	11.19	95.7	248.38	2126.88	12.61	0.04	0.65	4.30	0.00	2321	2310	7.941	21.08			0.01		
DISCOVERY STATION 12112#2																			
2	35.75	15.11	103.6	248.11	2064.40	1.23	0.10	0.09	0.76	0.15	2336	2327	8.107	21.30	287.5	15.00			
30	35.75	14.79	101.9	248.58	2064.90	1.23	0.10	0.10	0.76	0.15	2336	2321			290.5	15.00	0.57		
70	35.71	12.18	94.4	239.76	2120.45	11.40	0.07	0.59	2.98	0.00	2327	2317	8.095	21.33	396.4	15.00	0.07		
150	35.66	11.68	95.6	245.39	2123.54	12.10	0.05	0.64	3.94	0.00	2323	2312	7.958	21.34	415.9	15.00	0.01		
300	35.58	11.19	95.8	245.42	2125.67	13.10	0.05	0.69	4.45	0.00	2326	2317	7.975	21.36	424.2	15.00	0.01		
DISCOVERY STATION 12113#1																			
500	35.41	10.10	84.5	224.80	2144.30	15.30	0.04	0.88	6.36		2318	2307	7.900	21.45	362.9	8.00			
1000	35.35	7.24	72.5	206.30	2179.13	19.50	0.03	1.16	10.39		2314	2311	7.830	21.44	441.8	8.00			
1500	35.00	4.14	84.2	258.00	2167.98	18.80	0.03	1.15	10.40		2291	2285	7.819	21.44	445.8	8.00			
2500	35.00	3.21	81.6	255.94	2172.74	19.50	0.03	1.22	17.50		2306	2301	7.824	21.43	439.9	8.00			
4800	34.95	2.56	74.3	236.82	2207.04	23.20	0.03	1.49	24.00		2338		7.813	21.38	456.0	8.00			
DISCOVERY STATION 12113#2																			
2	35.73	14.77	102.8	248.04		1.31	0.12	0.10	0.83	0.14							0.55	4911,4912	1
30	35.74	14.76	102.5	247.34		1.20	0.12	0.10	0.78	0.14								4926,4927	2
70	35.70	12.14	94.5	240.89		10.80	0.05	0.58	3.17	0.00								4924,4925	3
150	35.65	11.67	95.7	245.82		11.00	0.04	0.60	3.86	0.00								4922,4923	4
300	35.57	11.11	95.4	248.46		11.90	0.05	0.65	4.22	0.00								4920,4921	5
DISCOVERY STATION 12114#3																			
2	35.80	15.37	102.8	245.12	2063.31	0.54	0.08	0.07	1.06	0.00	2333	2342	8.136	20.72	285.9	15.00	0.58		
10	35.80	15.35	103.1	245.37	2063.70	0.59	0.08	0.07	1.06	0.00	2335	2333	8.082	20.71	283.6	15.00	0.69		
30	35.80	15.34	102.8	244.92	2063.30	0.59	0.08	0.07	1.06	0.00	2344	2338	8.101	20.71	283.8	15.00	0.64		
70	35.72	12.63	96.2	242.45	2113.96	9.34	0.40	0.54	2.53	0.13	2330	2313	7.889	20.76	380.1	15.00	0.21		
150	35.66	11.66	95.8	244.73	2124.60	12.50	0.05	0.85	4.20	0.00	2323	2324	7.820	20.91	410.2	15.00	0.02		
300	35.60	11.23	95.7	248.54	2126.91	13.00	0.04	0.89	4.50	0.00	2327	2317	7.809	20.95	418.9	15.00			
DISCOVERY STATION 12115																			
2	35.78	15.41	102.9	244.90	2062.73	0.49	0.08	0.07	1.06		2339	2329	8.091	21.34	281.4	15.00	0.64		
10	35.79	15.45	102.9	244.70	2065.14	0.49	0.08	0.07	1.06		2335	2330	8.044	21.46	284.7	15.00	0.71		
30	35.79	15.36	102.9	245.02	2064.43	0.49	0.03	0.07	1.06		2337	2334	7.827	21.52	282.2	15.00	0.67		
70	35.70	12.10	96.8	246.44	2123.90	10.80	0.03	0.57	3.40		2327	2322	7.994	21.74	395.3	15.00	0.14		
150	35.65	11.60	95.5	245.87	2127.34	12.10	0.03	0.64	3.90		2327	2319	7.983	21.94	409.2	15.00	0.01		
300	35.58	11.18	91.2	237.05	2133.51	13.70	0.03	0.72	4.47		2314	2294	7.964	21.98	432.8	15.00	0.01		

Table 4.1 CTD bottle data (contd.)

Depth m	Salinity psu	Temp. °C	O_2 %sat	O_2 µmol/kg	TCO_2 µmol/kg	NO_3 µmol/lit	NO_2 µmol/lit	PO_4 µmol/lit	SiO_3 µmol/lit	NH_4 µmol/lit	Alkalinity µmol/kg (pot.)	Alkalinity µmol/kg (photo.)	pH value	pH temp °C	pCO_2	pCO_2 temp °C	chl-a µg/lit	phyto bottles	HPLC sample no
DISCOVERY STATION 12116#1																			
2	35.81	15.67															0.55		
10	35.81	15.67															0.62		
15	35.81	15.60															0.67		
20	35.82	15.64															0.55		
35	35.81	15.47																	
100	35.74	12.29															0.04		
DISCOVERY STATION 12116#2																			
2	35.81	15.66	103.4	244.99	2064.61	0.24	0.06	0.01	1.23		2337	2334	8.125	22.08			0.52		
10	35.81	15.66	103.7	245.13	2063.54	0.24	0.06	0.01	1.23		2341	2328	8.136	22.09			0.54		
30	35.81	15.63	103.4	244.76	2064.28	0.24	0.06	0.01	1.23		2337	2334	8.116	22.17			0.50		
70	35.76	12.50	95.4	240.65	2115.98	7.63	0.06	0.32	1.80		2328	2330	8.007	22.31			0.09		
150	35.73	12.12	96.3	245.00	2118.62	9.70	0.05	0.41	2.90			2318	7.999	22.39					
300	35.64	11.54	94.9	244.49	2123.86	12.10	0.04	0.52	4.00		2320	2321	7.985	22.42			0.01		
DISCOVERY STATION 12117#1																			
2	35.80	15.71	101.9	245.25		0.24	0.06	0.01	1.10								0.59		
10	35.80	15.70	102.0	245.12		0.24	0.06	0.01	1.10								0.51		
30	35.78	15.02	100.5	242.30		1.40	0.16	0.01	1.30								0.48		
70	35.73	12.16	95.4	245.84		10.30	0.05	0.43	3.20								0.08		
150	35.68	11.77	94.7	245.58		11.10	0.05	0.47	3.60										
300	35.61	11.27	96.5	250.71		12.00	0.04	0.52	4.00										
DISCOVERY STATION 12117#2																			
500	35.56	10.91	73.7	192.53		19.10	0.02	1.06	8.90		2326	2329	7.869	22.59	563.4	15.00			
1000	35.44	8.76	73.7	197.53		19.10	0.07	1.06	9.00		2324	2338	7.875	22.57	565.8	15.00			
1500	35.13	5.07	68.3	192.02	2172.81	19.20	0.02	1.10	10.10		2303	2295	7.858	22.62	593.3	15.00			
2000	34.99	3.84	80.2	239.93	2161.87	18.70	0.07	1.10	10.10		2295	2311	7.856	22.61	580.8	15.00			
2500	35.00	3.42	85.5	263.62	2168.79	19.10	0.02	1.10	24.00		2303		7.860	22.62	581.4	15.00			
4000	34.96	2.57	83.0	258.58	2205.38	22.90	0.02	1.40	24.00		2336		7.855	22.61	605.2	15.00			
DISCOVERY STATION 12118																			
2	35.70	14.89	104.2	250.75	2068.49	1.80	0.12	0.07	1.85		2338		8.113	22.51	297.7	15.00	0.95		
10	35.70	14.89	103.5	249.05	2068.60	1.80	0.12	0.07	1.85		2335		8.117	22.52	295.0	15.00	0.97		
30	35.70	14.81	103.2	248.64	2072.15	2.30	0.13	0.07	1.85		2339		8.115	22.52	294.6	15.00	0.78		
70	35.65	11.59	94.7	243.75	2128.56	15.40	0.06	0.67	4.37		2327		7.994	22.52	409.7	15.00	0.02		
150	35.62	11.28	97.7	253.31	2127.89	15.40	0.04	0.71	4.25		2328		7.997	22.51	411.3	15.00	0.01		
300	35.60	11.17	97.2	232.54	2129.39	15.40	0.05	0.73	4.28		2325		8.000	22.45	415.0	15.00			

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