CRUISE REPORT IR6 FA9503 and FA9508

WOCE IR6, RV *Franklin* Cruise 9503 and 9508 in the East Indian Ocean

Expedition Designation (EXPOCODE): 09FA9503 and 09FA9508

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Ship: RV Franklin

A Cruise Narrative for FA9503

Ports of Call: Fremantle, Western Australia; Dampier Western Australia

Cruise Dates: April 1 to 22, 1995

A.1 Cruise Summary

Cruise Track

The cruise track and station locations are shown in Figure 1: only small volume samples were taken. The cruise track was chosen to follow the TOGA/WOCE XBT line IX1 between Northwest Cape and Singapore and which has been monitored by volunteer observers since 1984. To help average over tidal and other ageostrophic motions, two occupations were made of the shelf/slope section off Shark Bay, which captured the Leeuwin Current and its subsurface countercurrent. The section terminates in deep water at the edge of the Java Trench just south of the Indonesian EEZ boundary (as it was then defined). Having extra time we steamed back down along the line, running the ADCP, before reoccupying the Shark Bay section. We then headed north to occupy a section across the WOCE ICM6 current meter array at 20S, before steaming to Dampier on the northwest coast of Australia.

Number of Stations

A total of 71 CTD/rosette stations were occupied using an in-house 24 bottle rosette equipped with 3L GO and in-house-made Niskin water sample bottles, and a EG&G Mk III CTD and an altimeter.

Sampling

The following water sample measurements were made: salinity, oxygen, total nitrate, phosphate and silicate. CTD salinity and oxygen were also measured (though oxygen is not yet calibrated and not reported as of Oct. 1997).

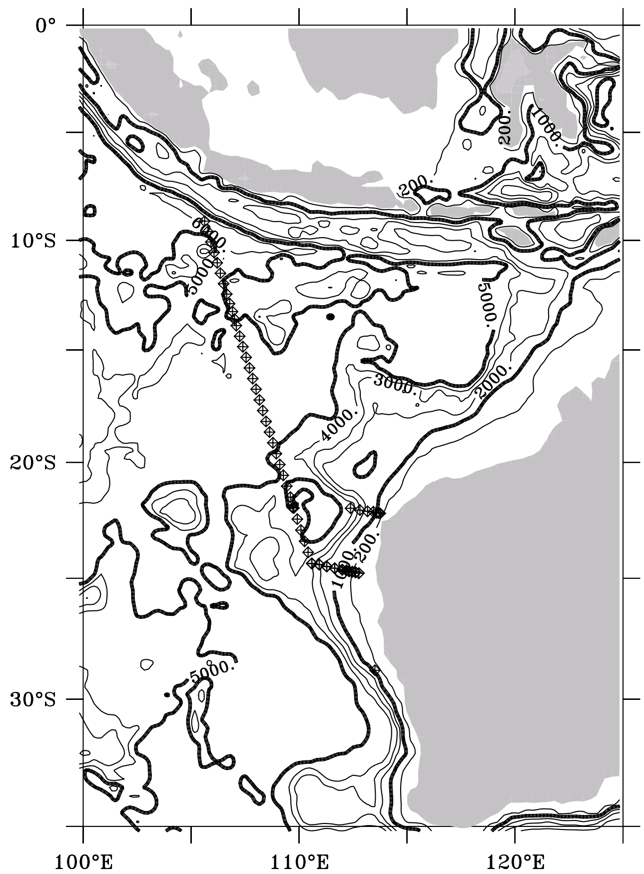

FIGURE 1 Positions of CTD rosette stations taken along FA9503.

Floats, Drifters, and Moorings

No floats, drifters, or moorings were deployed on this cruise.

A.2 List of Principal Investigators

S. Wijffels, G. Meyers

CTD and hydrochemistry data

CSIRO Division of Marine Research

M. Tomczak

Flinders Institute of Atmospheric and Marine Science

Flinders University of South Australia

A.3 Scientific Program

The principal objectives of the cruise were:

- To observe the seasonal variation of the Indonesian through flow and the associated changes in hydrographic structure and regional currents

- To assess the representativeness of the once-off, basin-wide WOCE hydrographic survey in relation to annual and inter-annual variations.
- To assess the consistency of estimates of the volume transport of the currents and the distribution of chemical tracers using inverse methods.

Methods

The CTD/rosette package used for all casts consisted of: a 24 position GO rosette and pylon with 3L Niskin bottles that were built in-house and with 5L GO bottle as spares; an EG&G Mk IIIC CTD that had been upgraded for WOCE work; and an Benthos 2216 Altimeter (with 200 m range for bottom finding). Two of the rosette bottles (second deepest and surface) were fitted with reversing thermometers to check for gross temperature and pressure calibration shifts. The conducting cable on the ship's CTD winch had recently been lengthened by splicing 1000m on to the end to accommodate the deep waters (>5000m) expected during this cruise. The splice was carefully checked for degradation during every cast.

Upon recovery of the rosette at the end of a cast, the CTD sensors were rinsed with freshwater and covered. The rosette was then moved into a covered wetlab for sampling. The Niskin bottles were checked for obvious misfires, entanglements and leaks, which were then noted. Oxygen samples were drawn first, rinsing as per WOCE protocol. Nutrients and salinity samples were then taken, with the former in made in duplicate in small plastic tubes. Due to a lack of man-power, the nutrient samples were not processed immediately. Instead samples were frozen for several days before the autoanalyser was setup and began processing stations. (see sections below). A log of Niskin performance based on the observations of the CTD watch and the salinity analyses was used to weed out a rather large number of poorly performing Niskins, which resulted in the bottle data from the first half of the cruise being badly degraded.

Acoustic Doppler Current Profiler (ADCP) measurements were made continuously employing a hull mounted 150 kHz unit manufactured by RDI. Underway measurements of surface temperature and salinity were made by an Ocean Data TSG-103 thermosalinograph and a Simrad EA500 Echosounder provided continuous water depth measurements. An Ashteck OEM GPS receiver provided continuous position data. All data was logged by networked SUN workstations.

Repeat sections were made across the Australian shelf and slope, both at the start of the cruise, and towards the end after a stream back south along the cruise track. A supplementary set of stations were also made across the WOCE current meter line ICM6 near 20S.

Narrative

All times are Australian Western Standard Time.

Franklin departed Fremantle on time at 0800 1/4/95. After a compass swing that took about one hour we proceeded northwest towards a nominal test site in 1000m of water off Fremantle. Some minor problems occurred in getting the underway systems up and running. Once the ADCP was running we began dropping XBTs hourly as part of an opportunistic survey of the nascent Leeuwin Current.

On the way to the test site it was determined that the rubbers in the small CSIRO Niskins we too perished to use and would all have to be replaced. We decided to abandon the test cast that day in favor of a site off the Abrolhos in daylight the next day.

A test station was completed using CTD #8 in approximately 800m of water off the Abrolhos Islands at midday on 2/4/95. Due to strong currents and winds, the rosette had to be brought up about 100m during the firing of the bottles as the ship was advected up the slope. The 1000m of wire spliced onto the conductivity cable, worked fine at the test and at all subsequent stations.

After the test station we proceeded to the first station off Shark Bay in following seas and winds. We continued to drop XBTs every hour on route. Comparison of the CTD and bottle salinities from the test cast showed a large offset (>0.5psu); otherwise the bottles appeared to be working well. Only one leaker was found on the test cast.

The first shelf occupation off Shark Bay was started at 15:47 on 3/4/95. To make up for the disruption of the bottle firing in the test cast all the bottles were fired again in the salinity minimum. Through the subsequent shallow stations on the slope the Niskins performed well. However, problems with the Niskins arose at station 19. Several bad leakers occurred on nearly every subsequent station. It was soon discovered that the o-rings in the bottom of the Niskins were displaced on retrieval.

We started carefully checking all the o-rings on the rosette before each cast. This appeared to stem the worst leaks (i.e. no water making it to deck) however, numerous smaller leaks persisted, and sometimes the o-rings would still be displaced after the cast. Some experiments with the knot position in the rubbers was tried to little effect. We had swapped out the worst of the CSIRO bottles but there were only two spare 3L bottles available.

A table was started to keep note of the leakers. After station 34, with bottle problems not being solved by changing rubber positions, we found that we could fit the General Oceanics (GO) bottles on certain positions on the rosette. We started to replace the worst CSIRO leakers with the GO bottles. In hindsight, I realize that we should have swapped over to using the larger rosette frame with all GO bottles, despite the time needed to make the change over, the difficulty in handling the larger rosette, and the Master’s fears of exceeding safe wire tensions.

By station 24, inter-comparison with the 3 previous deep casts (21-23) revealed large drifts in the CTD conductivity. A hysteresis in the upcast was also noted on the display by the watch standers. At station 25 after a cast with CTD #8, we swapped to CTD #2 and made a second cast at the same location. While CTD#2 was in the water, exploratory surgery on CTD #8 showed a cracked conductivity cell. However, the repeat cast with CTD#2 produced no data from the oxygen channels. We subsequently found that the oxygen board was not working and that we had no spare. Rather than going on with CTD #2 without oxygen traces, we opted to replace the conductivity probe in CTD #8.

All subsequent stations were carried out with CTD #8 with the new conductivity probe. The conductivity trace showed little drift between casts and no hysteresis. As leakers were identified via the bottle table, they were replaced by GO bottles where possible. By station 40, eight GO bottles were on the rosette. Close examination of the leaking CSIRO Niskins showed that the bottom lips were deformed and flared outwards, possibly explaining the leaks. This problem must have occurred previously, as four of the CSIRO niskins had replaced lip rings of grey plastic. These niskins only rarely leaked.

At station 40, deep oxygen CTD traces showed a shift and a strange feature turned up at depth (~4000db). This feature persisted from cast to cast. Examination of the upcast data showed the feature was not at the same pressure. At station 48 we replaced the oxygen sensor in CTD #8. The feature persisted. Subsequent analysis of the raw data showed that the oxygen current channel was not registering over a specific range. This was deduced to be due to problems with the A-D converter in the CTD. We later found a similar problem in the primary pressure and oxygen temperature channels. The CTD was powered down between stations 49 and 50 which seemed to solve the problem. However, it turned up again in later casts.

Our final station on the outgoing leg north of Christmas Island occurred on 14/4/95 at 0400 in calm seas. Being in 5990m of water, we took the CTD down to its pressure rating of 6000db. It was not only the CTD that had not been down that deep before! As the last few wraps of wire went out, a spacer-plate on the winch drum cheek came loose. As the wire started to come in again, it caught and buckled the plate. Luckily Erik Madsen was up by the drum to wash the wire, and saw the buckled plate under the first incoming wrap, preventing a possible disaster (damaged cable at the least, perhaps even a loss of the CTD and cable). The upcast was made slowly by bashing the plate away from the wire as it came in, taking about 4 hours. The level-wind was a mess. With further CTD work uncertain we headed south again as planned, steaming over our track with the ADCP logging.

On 14/4/95 in 5830m of water we stopped to attempt to fix the wire drum. The wire was spooled out to the last wrap with a dead weight at the end. A strong wire angle was maintained by steaming ahead at 1-2kt. The ships' engineers did a remarkable job at straightening the plate and welding it in place again. As the wire was spooled on, the level wind worked well. The entire operation took eight and one half hours.

After a rough ride into the wind and swell, which contrasted dramatically with our northward leg, we started a reoccupation of the Shark Bay shelf section at 1000 19/4/95. This section was completed in rough seas at 0930 20/4/95. The newly repaired winch drum performed well. We then proceeded onto the shelf to carry out a 6 hour ADCP calibration run. Once done, we steamed back out to sea along the Shark Bay line. An XBT/ADCP survey consisting of two shelf crossings was made between the Shark Bay line and the ICM6 current meter line (see cruise track).

The CTD section along the ICM6 mooring line (#64 - #71) started at 0720 on 21/4/95 and ended at 0120 on the 22/4/29 in lumpy seas and moderate winds. With a 24 hours steam ahead we then proceeded to Dampier.

Preliminary Results

Distribution of the bottle data taken during the cruise, excepting repeat boundary current occupations, is shown in Figure 2. The bottle data sampled during the cruise has been compared to that taken from the *RV Knorr* from the WOCE leg I10 which is nearly coincident with IR6. This revealed both the degradation of the bottle data due to leaking Niskins (see below) as well as large offsets and scatter within the Franklin data set, often between adjacent stations. The latter problem was assessed as due to strong drifts in the sensitivity of the Technicon AA II Autoanalyser, and attempts were made to calculate this based on standards run at sea. This procedure only partially collapsed the data to the I10 deep values, meaning that the autoanalyser sensitivity could not be adequately tracked with the standards used at sea. To salvage the data to some extents (for use at least in the upper waters), at each station, the *Franklin* bottle data was compared with the 3 closest collocated I10 stations extrapolated to the same potential temperature, and for each nutrient channel a concentration ratio (*Franklin*:*Knorr*) found for bottles fired below 5˚C. For shallow stations the ratio was found by linearly extrapolating against station number (as a measure of time). This concentration factor was then applied to the Franklin data. Additionally, for silica, a 2µmol/kg offset was noted at the start and subtracted from the *Franklin* data before fitting concentration ratios. The results for nitrate are shown in Figure 3. The expected reliability of the data after this treatment is difficult to assess as the possible drift of the autoanalyser within a station is large. However, based on the concentration factor range of 0.93 to 1.15, the expected error is around 10%.

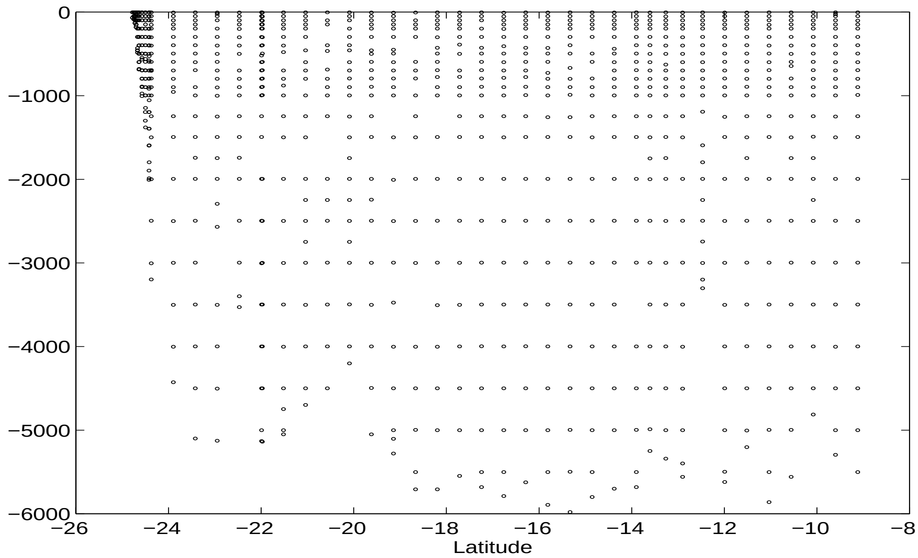

FIGURE 2 Bottle sample locations.

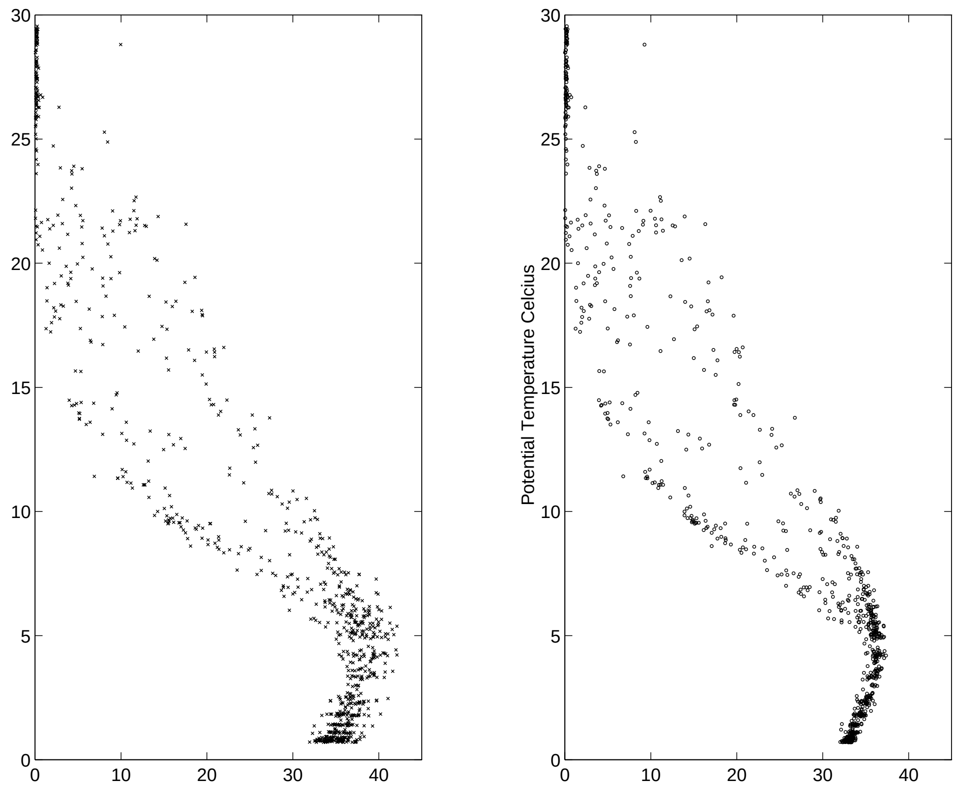

FIGURE 3 Nitrate concentrations from *Franklin* before (left) and after (right) a concentration factor was applied based on a station by station comparison with the *Knorr* data from the WOCE section I10.

Hence the *Franklin* data is of little use for discerning nutrient variations below about 1000m (5˚C).

A.4 Major Problems Encountered on the Cruise

There were several.

- Despite assurances to the contrary in the three years leading up to the cruise, *Franklin* was denied permission, at the last minute, to enter the Indonesian EEZ in order to complete a coast-to-coast section. Hence, we were not able to achieve our primary objective, which was to measure synoptically, the top-to-bottom Pacific Indian Throughflow.
- Previous to the WOCE cruise the primary CTD (#8) was shipped back to the Hobart Laboratories for calibration. However, the agent mistakenly sent the instrument by road freight. Due to a large cyclone, the main highway across the desert was washed out, leaving CTD #8 to cook in the desert sun for 1 week in the back of a truck. Upon arrival in Hobart CTD #8 was immediately air-freighted back to Western Australia to meet the start of the cruise without being calibrated. The latter treatment resulted in a cracked conductivity cell which was not detected until station number 24 after we had completed several consecutive deep casts.
- As mentioned above, a large number of bottle samples are missing or suspect due to leaking Niskin bottles during the first half of the cruise.

A.5 Other Observations of Note

An extremely fresh 80m thick surface layer was found north of about 13˚S. Surprisingly this layer appeared to be moving southwards at over 1kn, a feature of the velocity field that persisted for the several days we sampled in the region near Christmas Island. Subsequent analysis reveals this to be a large southward excursion or eddy of the energetic South Java current, as indicated by high salinities in the thermocline waters below.

A.6 List of Cruise Participants

Susan Wijffels (Chief Scientist)	CSIRO
Jeff Butt	CSIRO
Bernadette Heaney	CSIRO
Erik Madsen	CSIRO
Dave Terhell	CSIRO
Val Latham	CSIRO
Bob Griffiths	CSIRO
Werner Morawitz	Scripps Oceanographic Institution (USA)
Brett Goldsworthy	CSIRO
Andrew Walch	Australian Ocean Data Center
Chris Surman	Murdoch University

B Cruise Narrative for FA9508

Ports of Call: Fremantle, Western Australia; Christmas Island; Darwin, Northern Territory, Australia

Cruise Dates: September 13 to October 14, 1995

B.1 Cruise Summary

Cruise Track

This was a repeat of the IR6 section made during FA9503: the cruise track and station locations are shown in Figure 1. Stations made during FA9503 up to the boundary of the

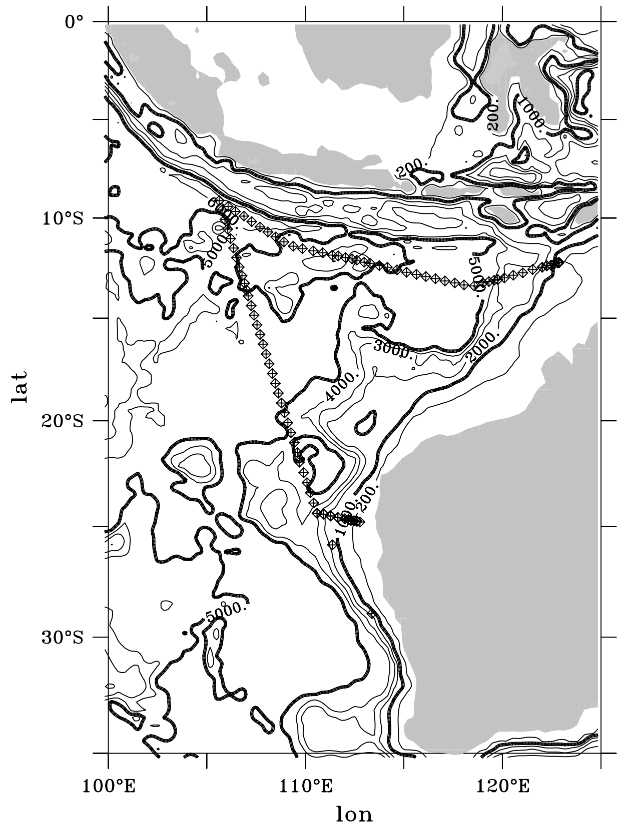

FIGURE 4 Positions of CTD rosette stations taken along FA9508.

Indonesian EEZ were reoccupied, and then the section was continued west, skirting the Indonesian EEZ to Ashmore Reef, south of Timor. Only small volume samples were taken. The WOCE CTD work was interrupted twice during the cruise: between stations 42 and 58 for a 3 day high-resolution survey of the hydrographic front at 15˚S performed using SEASOR and shallow hydrographic casts (PI, Matt Tomczak; these data are not reported here); a port call at Christmas Island between stations 67 and 68 to exchange crew members. Repeat crossing were made at both shelf breaks (Shark Bay and Ashmore Reef), sampling only for salinity and oxygen.

Number of Stations

A total of 120 CTD/rosette stations were occupied using an in-house constructed 24 bottle rosette equipped with 3L/5L GO and in-house constructed Niskin water sample bottles, and a EG&G Mk III CTD. Of the total number of stations, 16 were not part of the WOCE transect (43-58) and 3 were test stations (1-3).

Sampling

The following water sample measurements were made: salinity, oxygen, total nitrate, phosphate and silicate. CTD salinity and oxygen were also measured (though oxygen is not yet calibrated and not reported as of Oct. 1997).

Floats, Drifters, and Moorings

No floats, drifters, or moorings were deployed on this cruise.

B.2 List of Principal Investigators

S. Wijffels, G. Meyers

CSIRO Division of Marine Research

Dr. Bambung Herunadi and Muhummad Ilyas

BPPT, Jakarta

M. Tomczak

Flinders Institute of Atmospheric and Marine Science

Flinders University of South Australia

B.3 Scientific Program

Methods

Same as those used in FA9503

Narrative

All times are Australian Western Standard Time.

13.9.95 *Franklin* departed Fremantle at 1000. At this time we have no word from the Indonesian Government whether *Franklin* will be allowed to work in Indonesia’s Exclusive Economic Zone (EEZ). However, provision has been made to pick up an Indonesian security officer from Christmas Island around September 28 should permission be granted.

Problems arose getting the ADCP up and running, and so we turned north on the shelf to stay inshore of the Leeuwin Current. Once the ADCP was logging satisfactorily we headed northwest to cross the shelf and slope, commencing an ADCP and XBT survey of the Leeuwin Current, similar to the survey done in April on FR3/95. XBTs were dropped on the hour every hour as we made our way north to the site of the first test cast off the Abrolhos Islands.

14.9.95 A test cast was done off the Abrolhos in about 1500m of water with the newly-collared small diameter 3L CSIRO Niskins. Gary Meyers (Chief Scientist) had received news that his mother was gravely ill and decided he must leave the ship in Geraldton. We arrived off the Geraldton breakwater at 1600. Gary departed Franklin on the pilot boat. We head offshore again, commencing XBTs in 50m of water near the shelf break.

15.9.95 Results of our first test cast look are ambiguous, as the salinity minimum appeared to have a lot of fine structure. A second test cast was made. Both crew and ORV staff were not happy to see the large rosette (fits 5L Niskins bottles) put into action, considering it to be cumbersome and possibly dangerous in rough weather. During the night the ORV staff worked on repairing the 3L bottles. The Niskins were pressurized with compressed air and then submerged in water in the wet lab's sink (Helmond's idea). Many and various problems were found: loose rubbers, leaks at the glue joints in the end caps, leaking spigots and leaking glue joints at the new collars. XBT survey continues.

16.9.95 We started again with a revamped set of bottles approaching the first cast in the Shark Bay section (station #3). All the bottles were fired at the same depth to check performance. Spikes in CTD data noted and solved when Dave Edwards checked the winch slip rings. Bottle results of station 3 are good (standard deviation of bottle-CTD salts = +/-0.002psu excluding four obvious leakers). I decide to stay with small rosette, using 5L bottles to replace leakers where necessary and with Helmond fixing bottle problems as we go e.g. gluing joints, replacing end caps etc. Niskin Bottle Log started. The log is based on reports by the CTD watches of visibly leaking bottles, as well as on daily inspection of the salinity residuals (CTD - bottle salts) produced by the hydrology personnel.

17.9.95 Working inshore on Shark Bay section, weeding leakers (via Niskin Log) off the rosette and replacing them with 5L bottles used on FR3/95. Conductivity cell calibration seems stable.

18.9.95 Bottle results are still not good. Ian Helmond continues to fix 3L bottles as we go.

19.9.95 CSIRO 3L bottles continue to give bad results - more and more 5L bottles are put onto small rosette.

23.9.95 Finished station 42, the last of WOCE station before starting 3 days of SEASOR work in the water mass front near 15˚S. SEASOR work begins with Karstenson and Carvalos at the reigns.

Several problems had arisen with the CTD:

1. Dissolved oxygen noted to be bad on station 41, and found to be bad DO temperature which had given out on the upcast of 40. Decided to do station 42 with the bad probe and then carry out surgery on the CTD while SEASOR work was underway. Anticipate that DO temperature from previous casts might be substituted for corrupted casts or proxy DO temperature derived from the *in situ* temperature.

2. 3L bottle performance continues to degrade with use and we have reached point where there will be no more space for 5L replacements. Decide to switch to large rosette and 5L Niskin set.

24.9.95 Second day of SEASOR survey steaming south along the WOCE line. All seems to be running well, after some initial adjustments.

During SEASOR work, ships crew use the crane to lower the large rosette down to the main deck. CTD 8 was opened up and DO temperature probe replaced. CTD 8 was set up in the large rosette. Of the 3L bottles, 5 seemed to perform well and these were moved to the large rosette. The rosette was then filled with 5L bottles from the hold (a mix of GO and CSIRO made Niskins).

25.9.95 Begin series of shallow casts every 8nm returning northwards along the WOCE line, resampling the region surveyed by SEASOR. On the first of these the dissolved oxygen was still bad. This turned out to be an error in the calibration file and easily solved, though not easily spotted. Cast restarted.

Halfway back where the WOCE line was interrupted, a second 13 hour SEASOR survey was done perpendicular to the WOCE track. Resumed shallow CTDs at 8nm spacing heading north along the WOCE line.

26.9.95 Resumed WOCE section with station 59. Worked our way northwards to Christmas Island without event. We encountered very strong westward currents north of 13˚S. Large rosette has not been a problem from the safety or handling aspect, though the weather has been calm.

28.9.95 Off Christmas Island. Used up about 4 hours prior to meeting pilot with some SEASOR development tests. Spent day at Christmas Island - welcome respite. Let off FIAMS personnel (Carvalos and Karstenson) and Mark Raymer, while welcomed aboard Lidia Pigot and Bob Griffiths. At 1700 we drop the mooring and head north to the next WOCE station.

Still no news yet on clearance from Indonesia. The possibility still exists of getting clearance while we are within range of Christmas Island.

30.9.95 At northern most limit of Australian EEZ around Christmas Island. No news from Indonesia. Started work on a line that with take us east to Ashmore Reef south of Timor. Data from 5L Niskins is showing excellent results. A few random leakers, but overall much better. We have done several 6000db (CTD limit) casts at edge of the Java Trench during which the wire tension went to over 50% of cable breaking strength. No problems were encountered. Weather has been calm.

1.10.95 Station work continues eastward with little event.

4.10.95 Today is the deadline for the option of steaming back to Christmas Island to collect an Indonesian Security officer. Dave Vaudrey rang to say that there was still no answer from Indonesia. He suggested one last attempt to get permission through Minister Habibi, and reported that Division of Oceanography was prepared to grant the needed extra day of ship time should permission come tomorrow. We continue to work eastwards.

5.10.95 No word from Hobart or Jakarta.

6.10.95 Dave Vaudrey rang to say that they have had no success in extracting an answer from Jakarta. We decide that it is too late to press further.

9.10.95 Station 104: climbing broad shelf-slope towards Ashmore Reef. Schools of tuna around us.

10.10.95 Finished first occupation of Ashmore Shelf section. Steam out to 2000m along line to start section occupation, aiming for 18 hour time difference between occupations to realize opposite phases of the semi-diurnal tide. Full moon a few days ago.

11.10.95 Second occupation of Ashmore section completed. Finished last CTD station (#120) in ~150m of water 3nm off the reef. Deployed SEASOAR in late afternoon for testing new large wing panels. SEASOAR towed along WOCE line as CTD data suggest several strong salt fingering layers in the thermocline near Ashmore.

12.10.95 SEASOAR work continues through early morning. We then began our transit to Darwin. SEASOAR was again deployed for a few hours in shallow water for testing the bottom avoidance system.

14.10.95 Arrive in Darwin at 0800.

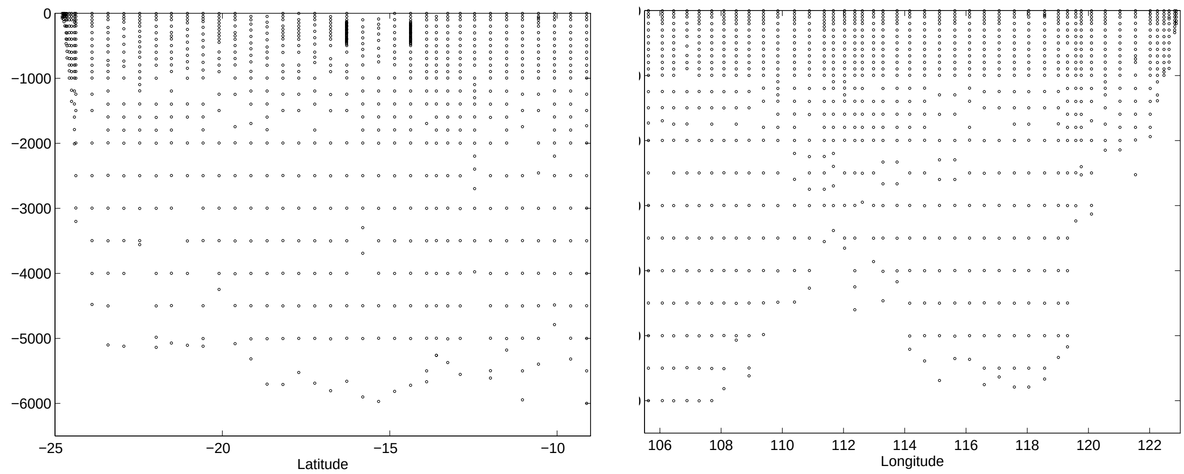

FIGURE 5 Bottle sample locations: stations 12-70 are plotted against latitude on the repeat of IR6; stations 70-114 plotted against longitude during the east-west section to Ashmore Reef.

Preliminary Results

Distribution of the bottle data taken during the cruise, excepting repeat boundary current occupations, is shown in Figure 5. The bottle data sampled during the cruise has been compared to that taken from the *RV Knorr* from the WOCE leg I10 which is nearly coincident with IR6. This revealed both the degradation of the bottle data due to leaking Niskins (see below) as well as a large offsets and scatter within the *Franklin* data set, often between adjacent stations. The latter problem was found during FA9503 and we used the same method to collapse the *Franklin* data at depth to the *Knorr* I10 data (see section above n FA9503). The quality of the bottle data is much better for this occupation of IR6, than as for FA9503, due to better Niskin performance, as well as more frequent runs of standards through the autoanalyser to keep track of instrument sensitivity. The results for nitrate before and after the I10 comparison are shown in Figure 6. The expected reliability of the data after this treatment is difficult to assess as the possible drift of the autoanalyser within a station is large. However, the drift was better tracked and the concentration factors applied to bring the data into agreement with the RV Knorr data ranged from 0.98-1.05 and so the expected error is around 5%. The bottle samples after station 58 are generally less affected by leaks, as these were taken using larger 5L Niskin bottles which performed better.

B.4 Major Problems Encountered on the Cruise

- Once again Franklin was denied permission to enter the Indonesian EEZ in order to complete a coast-to-coast section.
- Stations 1-42 were made with revamped but still leaking 3L Niskins.

B.5 Other Observations of Note

In contrast to the conditions observed in April, we encountered much stronger currents at the northern end of the section in the South Equatorial Current(SEC). Preliminary transport

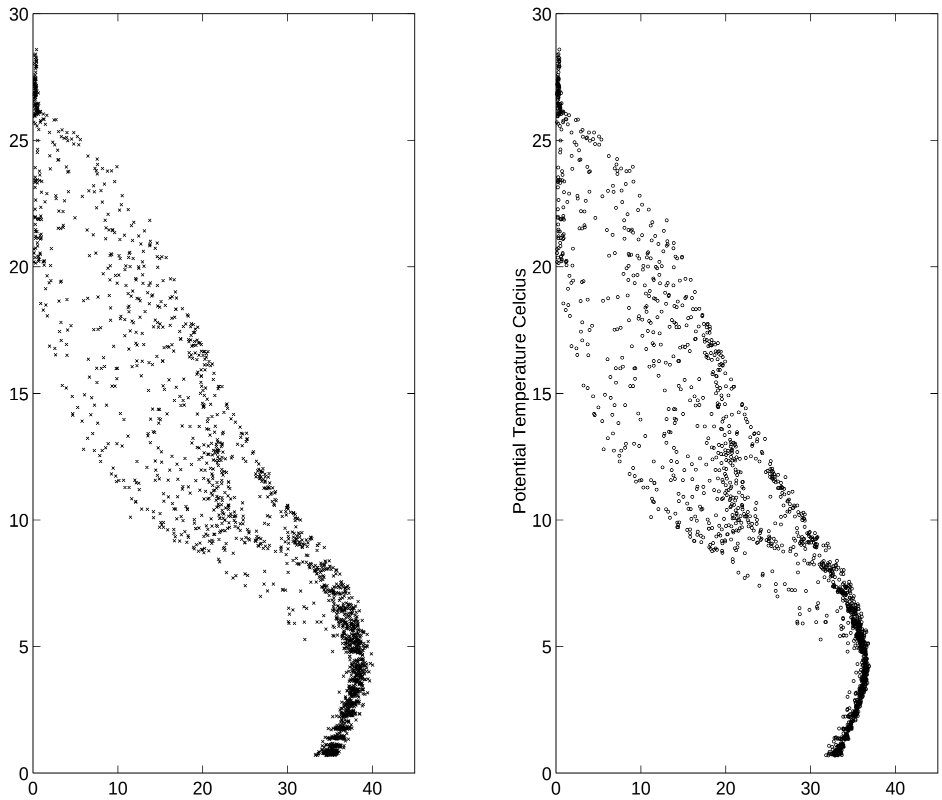

FIGURE 6 Nitrate concentrations from Franklin before (left) and after (right) a concentration factor was applied based on a station by station comparison with the Knorr data from the WOCE section I10.

calculations show that relative to 2000db, the SEC was transporting roughly 65Sv between 14 and 9˚S. Some of this water is presumably supplied by both the Throughflow and the South Java Current. Relative to 2000db, the net transport into the region enclosed by the section is around only 2Sv. The repeat shelf occupation 18hours apart off Ashmore Reef shows considerable internal tides: over 50m in main thermocline.

B.6 List of Cruise Participants

Susan Wijffels	CSIRO
Bob Beattie	CSIRO
Dave Edwards	CSIRO
Lindsay Pender	CSIRO
Ian Helmond	CSIRO
Bob Griffiths	CSIRO
Val Latham	CSIRO
Alison Featherstone	CSIRO
Lydia Pigot	CSIRO
Muhummad Ilyas	BPPT, Jakarta, Indonesia
Johannes Karstenson	Flinders University of South Australia
Oldemar Carvalos, Jr.	Flinders University of South Australia

C Underway Measurements

C.1 Navigation and Bathymetry

During both cruises (FA9503 and FA9508) GPS Selective Availability was in force and so the expected accuracy of position fixes is around 100m. However, temporal coverage was good (almost 100%). The bathymetry data collected by the Simrad EA500 Echosounder appears of good quality throughout the cruises. Ship speed was measured by a doppler speed log and heading by the ships gyroscope, logged by in-house software on the central unix acquisition system.

A comparison of the ship drift versus ADCP 15m currents suggests that the doppler speed log records with a low bias, such that true ship speed = recorded speed *0.96.

C.2 Acoustic Doppler Current Profiler (ADCP)

by Jeff Dunn and Susan Wijffels

An RDI 150 kHz narrow-band unit is mounted in a well at amidships, and was manually lowered into position on fixed tracks (giving a rotational stiffness of within 0.1 degree) at the start of the cruise. When locked down, the transducer head is at 3.8m depth below the surface. In-house software is used to record the data in 3 minute averages in 50x8 m bins from 8 m to 408 m. Bin depths have been calculated based upon a fixed sound speed of 1475m/s.

Data quality was very good during the cruises and coverage is nearly 100%. A moderate amount of on-station data was mildly corrupted in the top 50m by one acoustic beam intersecting the water dragged by the CTD wire. All but the most subtly affected bins have been removed (as there is no way of correcting for this effect).

To maximize the amount of usable data, the final integration of GPS-corrected profiles was done with Reference Layer Averaging (RLA) on bins 3-7, the gaps (mainly arising from CTD-wire rejections) filled with RLA on bins 6-10, then gaps in shallow areas filled with non-RLA integrated profiles. The data were then averaged into 20 minute profiles. Using the data collected, the water profile vectors are calibrated by being rotated through an angle A and multiplied by a scaling factor 1+B. The rotational calibration (A) corrects for misalignment of the transducer with respect to the ship's gyro compass and for errors in the gyrocompass. Evidence was found for changes in this angle with time during the processing of the data, but this hasn't been corrected for as the gyro behavior is not well known. Using bottom tracking and an acceleration method, the average calibration factors for the cruises are: A = 0.9 degrees and B = 1.013 for FA9503 and A = 1.16 degrees and B = 1.001 for FA9508.

Due to GPS Selective Availability and the gyro compass, errors as large as 10cm/s may occur in the 20 minute averaged velocity profiles referenced by GPS, and 2-3cm/s for those referenced using bottom tracking.

C.3 Thermosalinograph measurements

by Susan Wijffels and Dave Edwards

An Ocean Data TSG-103 thermosalinograph is installed in the wet laboratory on the Franklin pumping from a seawater intake at amidships 2m below the surface. When Franklin is underway, draw-down of water to the aft of the ship results in an effective sampling depth of 1m. Water temperature is recorded at the intake. At the thermosalinograph, temperature is recorded along with conductivity to determine salinity after the water has passed through a debubbler. Routine comparison of the thermosalinograph with the surface bottle of CTD casts gives a scatter of 0.04psu and 0.04C.

Based on pump flow rates takes 23.2 seconds for the water to pass from the sea intake to the wet lab, and another 2.6 seconds for it to travel from the valve through the debubbler to the Thermosalinograph, making a total of 25.6 seconds. The delay between the temperature measurement (at the sea intake) and the salinity measurement (in the wet lab) is about 25 seconds. At 11 knots or 5.5 meters/second, the *Franklin* would travel 142 meters, or two and a half ship lengths, so a change in salinity would be recorded 142 meters after the event.

The surface salinity and temperature from the cruises are shown in Figure 7, along with the surface bottle results.

C.4 Meteorological Measurements

The meteorological sensors on *Franklin* are installed on a mast above the ship's superstructure, rising off the bridge. Parameters measured are wind speed and direction (ship relative), air temperature, relative humidity, light intensity and air pressure. All channels are logged using CSIRO developed hardware and then sent on to the central UNIX acquisition network.

Wind speed and direction were measured by a RIMCO 130mm cup anemometer and RIMCO vane. Wind direction and speed were checked for biases through tracking how the anemometer responded to the ship's acceleration on and off station. No significant biases were found.

Air temperature was measured by an Analog Devices AD590 solid state temperature sensor, which is calibrated every 2 years using a 2 point icebath/room temperature calibration. Humidity was measured by a Vaisala HMP35A humidity probe, also calibrated every 2 years using a 2 point calibration using saturated and desiccated air environments. Both these sensors are mounted in a Stevenson Shield.

Light is measured by a LICOR LI-192SB sensor, logged via CSIRO developed hardware, and has an expected error of 5% though no in-house calibrations have been performed.

D Hydrographic Measurement Techniques and Calibrations

D.1 Niskin Bottle Performance

As described in the cruise narratives problems were encountered on both cruises with Niskin bottles. On the first cruise (FA9503) the test station delivered CTD- bottle differences

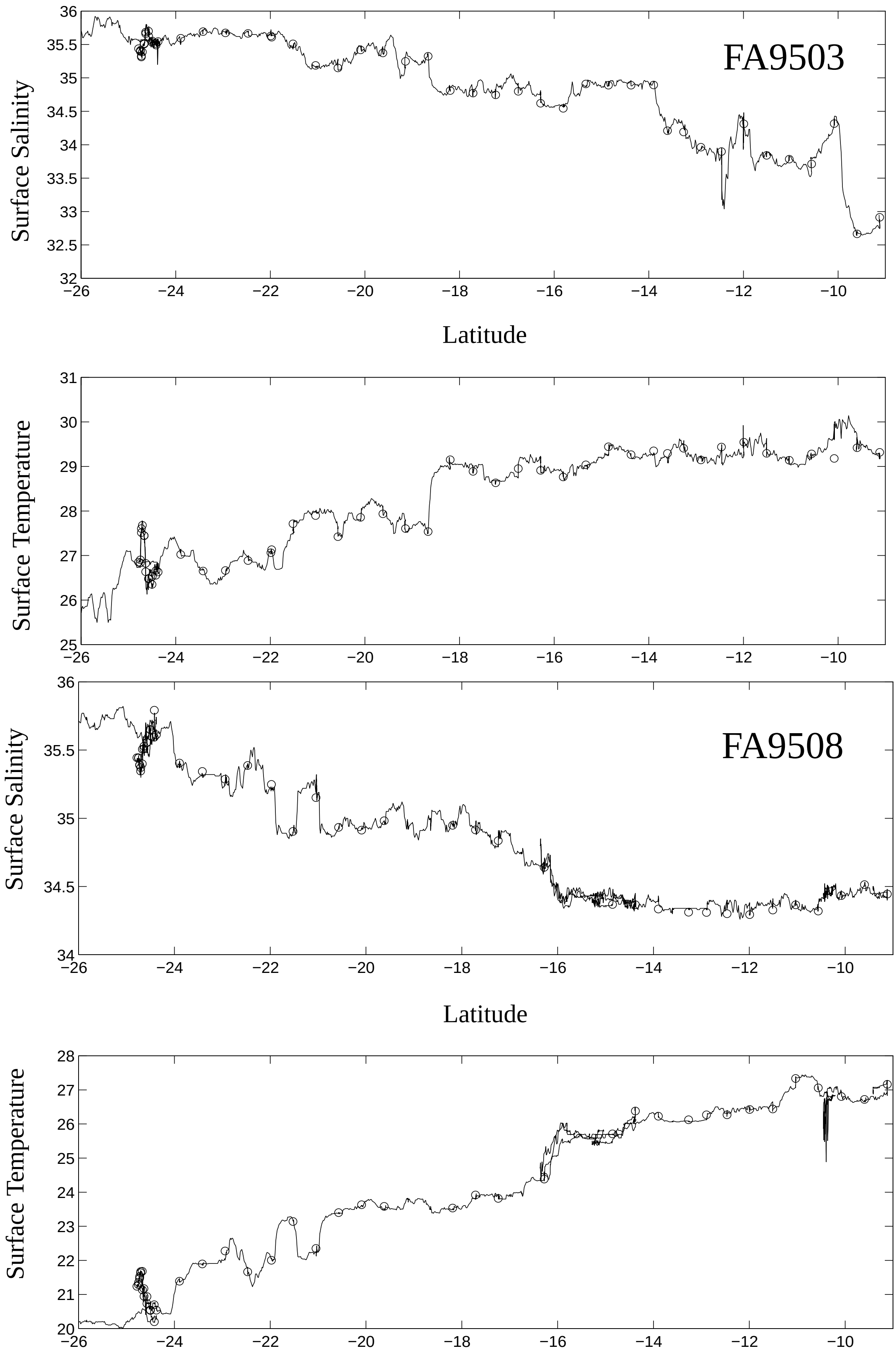

FIGURE 7 Thermosalinograph data as a function for latitude for the CTD sections along with the surface bottle values (circles).

with a maximum of 0.002 and standard deviation (over 24 bottles) of 0.0007, suggesting good bottle performance. In support of this, the CTD-bottle differences are shown for potential temperatures colder than 2˚C in Figure 8, where the bulk of differences are below 0.002 after

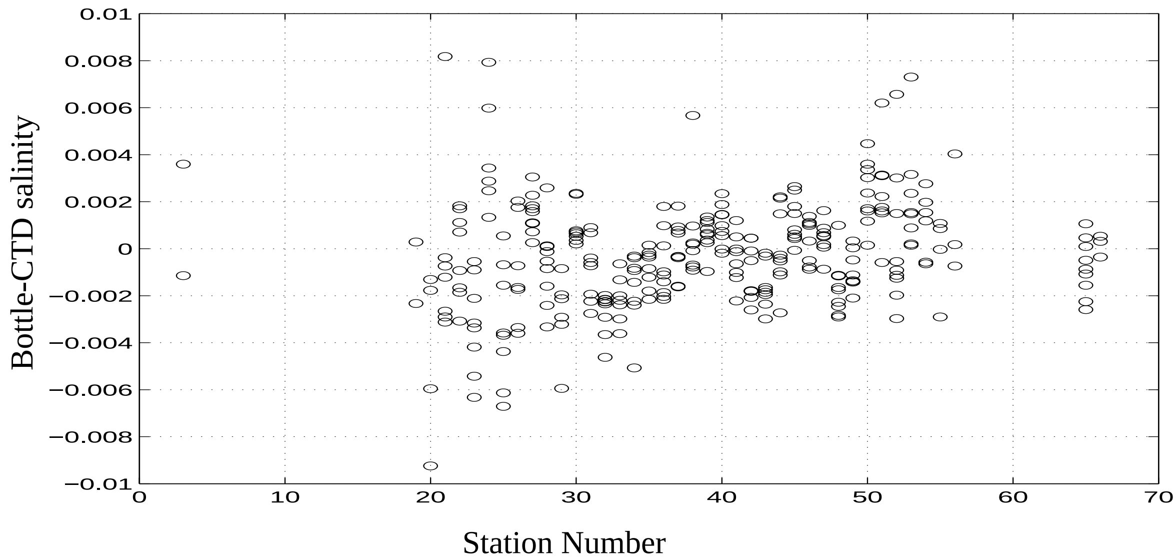

FIGURE 8 Salt residuals vs station number for bottles colder than 2C for FA9503, the first occupation

station 30, as leaking bottles were replaced on the rosette by spares or repaired bottles. Bottle performance degraded again after station 40, likely due to the observed deformation of the lips of the bottles from the impact of closing.

On the second cruise, FA9508, three test casts were done to assess the performance of the Niskin bottles, which had been repaired in Hobart between the cruises. On each test cast all bottles were triggered at the same depth in a region of low gradients. The first test cast revealed a large scatter in salinities (std = 0.013), suggesting numerous leaks. The bottles were worked on, and a second test cast performed, which showed better results (+/- 0.010). Further repairs gave acceptable results of (+/- 0.003) on the final test cast. Over the coarse of the station work, however, the repaired bottles degraded once more, and so, during the break in the WOCE work for the SEASOR survey, we changed over to a second larger rosette which accommodated 5L Niskin bottles. The salinity residuals shown in Figure 9, shows some improvement in residual scatter at depth after station 58.

D.1 Sample Salinity Measurements.

By Dave Terhell and Susan Wijffels

Salinity samples taken at every station are allowed to come to room temperature in the laboratory before being analyzed on a Yeokal Inductively Coupled Salinometer Serial No. WF74. International seawater standards from Ocean Scientific International are used to calibrate the salinometer at the beginning of each batch of samples. The international seawater sample batches used were P123 and P125. Temperature in the laboratory was not well controlled, sometimes fluctuating by 2˚C. This most likely accounts for the slow variation seen in deep salinities during the *Franklin* cruises in comparison to the bottle salinities taken in the same region from the *RV Knorr* along I10 (Figure 10). We thus believe the variations in deep *Franklin* salinities are not real. As a result the deep CTD data, which is calibrated to the bottle salts, also expresses this drift.

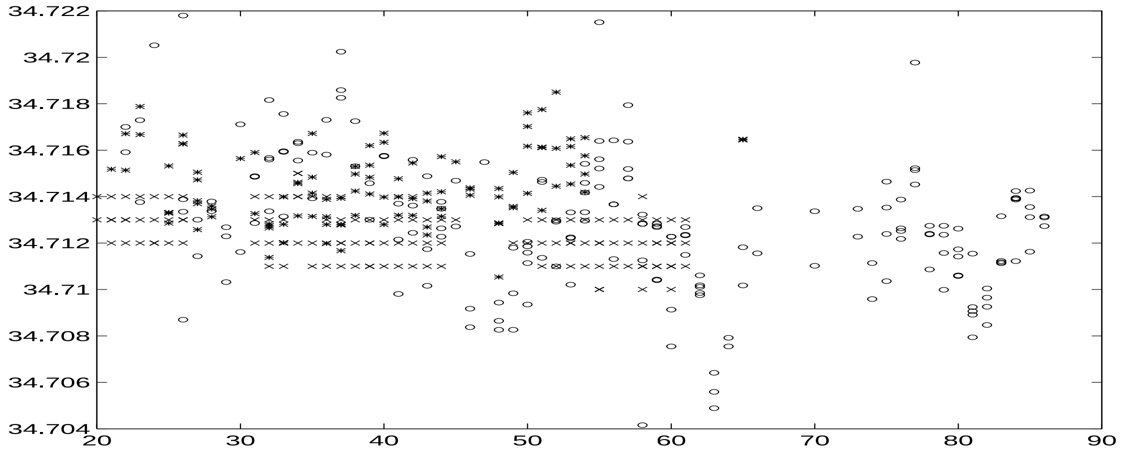

FIGURE 10 Bottle salinities for potential temperatures colder than 0.9C versus station number for the two Franklin occupations of IR6(FA9503 *; FA9508 o) and those for I10(x). While the I10 data show a broad weak pattern of variation, the Franklin salts show stronger variation which is likely due to salinometer drift associated with poor temperature control in the ship's laboratory.

D.2 Sample Oxygen Measurements

by Dave Terhell

Bottle oxygen samples were extracted before any other sampling from the Niskins. They were taken in order from deepest to shallowest to minimize oxygen take up. Analysis followed the Winkler method with titration being made against an aliquot of the sample. The endpoint was determined amperometrically using a Metrohm Titrator and a Dosimat 665 (10ml) automatic burette. The method is described in "A Practical Manual For the Determination of Salinity, Dissolved Oxygen and Nutrients in Seawater" (Eriksen, 1997, Antarctic CRC Report No. 11). The reported accuracy of the method is about +/- 0.9 μmol/l with a standard deviation of replicate samples of +/- 0.025 μmol/l (Knapp et al, 1990).

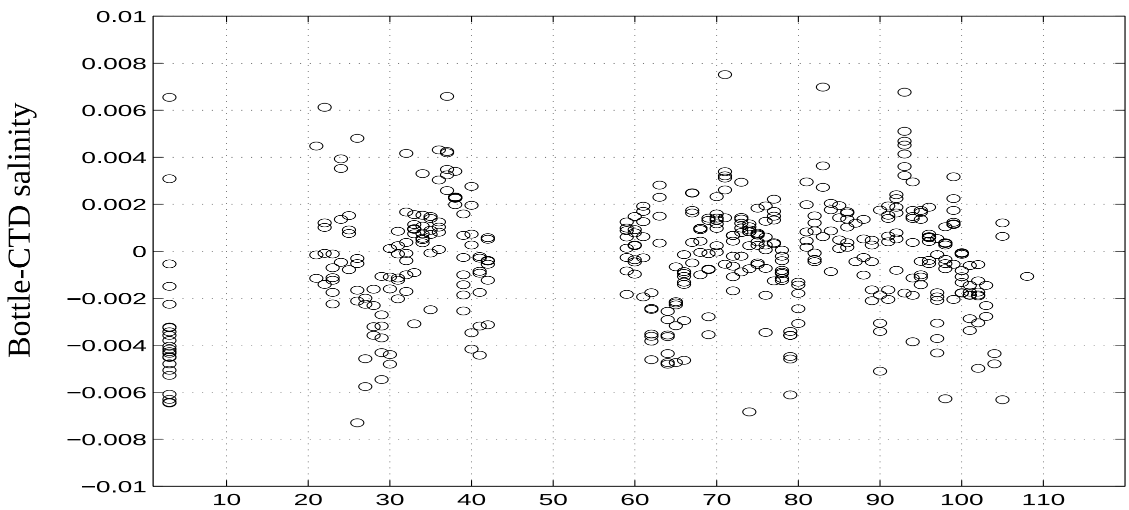

FIGURE 9 Salt residuals vs station number for bottles colder than 2C for FA9508.

D.3 Nutrients

By Dave Terhell

The nutrient analyses were performed using a Technicon AA II Autoanalyser. The methods used for the analysis of Silicate, Phosphate and Nitrate are detailed in “Hydrochemistry Manual” (Plaschke, in prep; Airey et al., 1987). Sensitivity of the analysis was measured at regular intervals and the concentrations were corrected to reflect any changes in this sensitivity during each run. Results, however, suggest that large drifts occurred within each run that could not be adequately tracked with the procedures in place.

Plaschke, R. Hydrochemistry Manual, (in prep)

Airey, D., Sandars, G (1987) Automated Analysis of Nutrients in Seawater, CSIRO Marine

D.4 CTD Processing: FA9503

by Neil White

CTD unit number 8 (an EG&G Mk IIIC unit) was used for all but one station. Calibration of the Mk III CTD #8 was done in May 1994 for temperature and August 1994, and August 1995 for pressure. The other station (number 26) was done with unit number 2 (an NBIS Mk IIIB unit).

Pressure calibration

Data from the stainless steel pressure transducer was used for all stations. Constants from a third order fit to the last laboratory calibrations were used but a new offset term was calculated for each station using the pressure of the first 'in water' data records. For unit 8 these offsets had a range of 2 db.

Calibrations are done in-house using a Budenberg Deadweight Tester at about 50 points between 0 and 6200db. In August 1994, the pressure data from CTD #8 fit the calibration data to within 2db for increasing pressure. However, under decreasing pressure, hysteresis of up to 5db at 1000db were present.

Temperature calibration

Temperature calibration constants are derived from data taken from two triple-point temperature baths (0.01˚C and 26.863˚C). The fit temperatures have a 99% confidence interval of 0.003˚C. The calibration for CTD #8 was unchanged between March and May, 1994. Post-cruise calibration data is not yet available to determine whether any shift in calibration had occurred during 1995.

Conductivity calibration and processing

Conductivity is calibrated for groups of stations using the bottle salinity data. The conductivity calibration closely follows the technique used by Bob Millard's group at WHOI. The calibration is done for a group of stations at a time, and for each group an offset (**a**), a scaling factor (**b**) and a station-dependent factor (**c**) are derived through a fitting procedure. If the raw conductivity is C_{unc}, the calibrated conductivity is C_{cal} and the station number is *s*,

then

$$C_{cal} = \mathbf{a} + C_{unc} * (\mathbf{b} + s*\mathbf{c})$$

Stations 1-24 were conducted with a cracked conductivity cell which required special treatment, as detailed below.

The normal symptom of a cracked conductivity cell is that at the start of the downcast the salinity starts very low and ramps up to the 'true' value over a few hundred meters. The salinity then stays fairly true for the rest of the downcast and for the upcast. This problem affected stations 2 - 24.

As the offset and the speed at which it reduces changes from station to station there is no practical way (that I can see) of reconstructing the true signal from downcast data. Therefore the upcast data was used for stations 2 - 24. This is far from an ideal solution because the sensors are in the wake of the sensor package and, apart from the noise this will introduce, this also means that the sensors will, for part of the time at least, be in water which has been dragged up from deeper, by anything up to a few meters.

Upcast data was filtered in exactly the same way as downcast data and then the order of the filtered data reversed (by time) before production of 2 decibar averages.

Reasonable calibrations could be produced by this method for stations 2 - 20. However, for stations 21 - 25 the calibration was noisy with a pattern of high conductivity residuals in one sense at the surface and in deep water and high residuals in the opposite sense at around 500 - 1500 decibars. These residuals were typically around 0.005 - 0.008 psu and the pattern was quite consistent for these five stations. One of the results of this problem was that the deep theta-S curves could not be made to match the curvature of the curves from the bottle data. A cubic polynomial in pressure was fit to these residuals and this correction term was applied to all conductivities for these stations for the purpose of producing calibration constants and calibrated data. The profile data produced using this method gave a better calibration (standard deviation of salinity residuals of .003 psu) and also a much better match in the deep theta-S curves.

It seems that the cell had become more badly cracked by station 21 and had become less linear than before. This correction term models this new non-linearity. Again, this is not an ideal approach but I feel that it is justified in this case because:

- the behavior is quite consistent from one station to the next,
- the residuals are fairly small, and
- as we are using the upcast data to produce the profiles, the same data is being used for the calibration as is being used for the profiles
- there are no issues of hysteresis or of different behavior on the up- and down-casts.

The final grouping settled on was: stations 1, 2-5, 16-20, 21-25, 26, 27-54, 55- 71. After calibration the standard deviation of the salinity residuals for the whole cruise is.0025 psu. Group-by-group discussion follows:

Station 1

This station was a bottle test station and was done before the conductivity sensor became cracked, so can not be grouped with any other stations on this cruise. As all the samples were at the same depth it was not possible to calculate a conductivity slope term, so the conductivity slope from the last time the CTD was used was used and the bias adjusted to give the best calibration. As this last station was the last station of Fr 2/95 (several weeks and two long road trips before) this is not an ideal calibration, but seems to be the best available. As this station is not part of the science program this is of no great consequence. Salinity data from this station should be used with caution.

Stations 2 - 25

The treatment of these stations is described above. The calibrations for the shallow stations 10 - 15 look noisy, but I couldn't see any justifiable way of improving them.

Station 19

Cut from 871 - 873 decibars - bad conductivity data - fouling?1

Station 26

This station was done with unit 2. The intention was to use it for the rest of the cruise after the cracked conductivity cell on unit 8 was discovered. However, as the oxygen board was not working and there was no spare on board it was decided to put a new conductivity cell in unit 8 and use that for the rest of the cruise. As the samples were well spread through the water column the calibration for this station is reliable.

Stations 27 - 71

These two groups (27 - 54 and 55 - 71) were quite straightforward. There was a four day break between stations 54 and 55, so the break in calibration groupings is very believable.

Problems with oxygen data

A problem with the digitizing board for the multiplexed channels caused some jumps in the oxygen data, especially in deep water. The problem may also occur in shallower water, but may not be apparent because of the greater noisiness and rates of change of the data in shallower water. This problem has been encountered by a number of institutions using the IIIC units and a fix has been issued by GO. Examination of the raw data did not suggest an easy way of fixing the data, as it does not seem to be a simple 'sticky bit' problem. Presently we are not reporting the CTD oxygen to the WOCE DAC.

D.5 CTD Processing: FA9508

by Neil White, Bob Beattie and Bernadette Heaney

CTD Unit

CTD unit 8 was used. Station 62 had some dips that were tests of CTD 10 - these were not processed.

Conductivity calibration

Conductivity (salinity) calibration was done over the cruise as 4 groups, stations 1-71, 72-73, 74-75, 76-120 (station 70 was the most northerly station). 1745 out of 2124 bottle values were used for calibration. The standard deviation of the salinity residuals after calibration was .0027 psu.

The calibrated CTD upcast salinities for the deeper portions of stations 37, 83 and 93 are up to 0.005 psu less than the bottle salinities. However, the CTD data is in good agreement with that for the adjoining stations, and it is assumed that the effect was produced by a short-term instability in the salinometer output (see above).

Extraordinary edits

Station 98: a sudden drop in conductivity occurred; to compensate we added 0.004 to salinities > 2450 db; 2444-2448 db salinity was edited to match values prior and following.

TABLE B.6: Data points ignored

Station no	points	pressure db	comments
76	93594-94261	3252-3274	
96	10653-10866	346 - 350	density inversion
108	49922-49922	1820	bad conductivity spike
109	1,340		
114	7247-8819	> 170	density inversion

Note on Groupings

The plot of CTD and bottle salinity offsets for the cruise produced by the first calibration run indicated that the cruise could be one group. But Susan Wijffels' plot of offsets indicated bad fit about stations 70-75 and about the high 90's. The bad fit about the high 90's was an instrument fault on station 98 giving a false conductivity value.

It was thought maybe 72, 73 and maybe 74 were a group. Groupings of 1-71, 72-74, and 75-120 were tried. But the jump between 74 and 75 was unacceptable. Further groupings were tried until 1-71, 72-73, 74-75, 76-120 gave smoother results. Overlay plots of deep temperature versus bottle and CTD salinity validated this grouping.