FRANKLIN

National Facility
Oceanographic Research Vessel

RESEARCH SUMMARY

Cruise FR 6/95

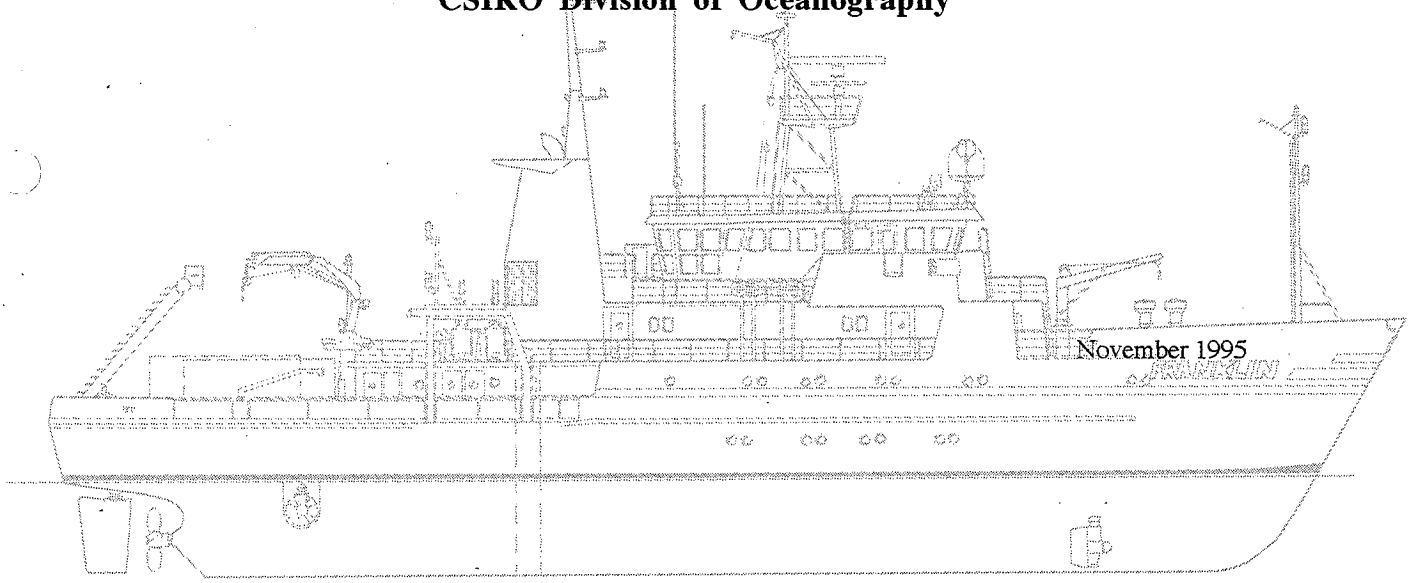
INTERNAL TIDAL EVOLUTION ON THE NORTHWEST SHELF

Itinerary
Sailed Fremantle 0800 17 June 1995
Arrived Fremantle 0800 9 July 1995

Moored Measurements and CTD sections of the flow of Deep and Bottom Water into the Western Australian Basin of the Indian Ocean

Principal Investigator

Dr T.J. McDougall
CSIRO Division of Oceanography



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AUSTRALIA

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R.V. Franklin
National Facility
Oceanographic Research Vessel

Research Summary
Cruise FR06/95

Itinerary

Sailed	Fremantle	0800	Sat	17 June 1995
Arrived	Fremantle	1700	Wed	28 June 1995
Sailed	Fremantle	2200	Wed	28 June 1995
Arrived	Fremantle	0840	Sun	9 July 1995

Principal Investigator

Dr T. J. McDougall, CSIRO Division of Oceanography

Cruise Objectives

(i) To deploy moored current meters in the passage between Cape Mentelle and Broken Plateau to measure the flow of Deep and Bottom water into the West Australian Basin.

(ii) To use the moored current-meter data together with several realisations of the hydrography across the section between Cape Mentelle and Broken Ridge to deduce the flow of Bottom, Deep and Intermediate Waters in this region.

(iii) To estimate the vertical diffusivity across the potential temperature surfaces less than 1.1°C in the West Australian Basin using the deduced volume flow rates of Deep and Bottom water across the section from Naturaliste Plateau to Broken ridge.

(iv) By obtaining more reliable estimates of the equatorward flux of deep and bottom water into the West Australian Basin, contribute to the estimate of the poleward heat flux borne by the Indian Ocean.

Personnel

Ship's Crew

Master	Neil Cheshire	
Mate	Dick Dougal	
2nd Mate	Ian Menzies	
Chief Engineer	Terry Carruthers	
1st Engineer	Peter Harding	(1st part of cruise)
	Ray Elliot	(2nd part of cruise)
Elec. Engineer	Don Roberts	
Bosun	Yannick Hansen	
AB	Bruce Mackerras	
AB	Rosco Bryson	
AB	Norm Marsh	
Greaser	Sao Wong	
Chief Steward	John Formosa	(1st part of cruise)
	John Tilley	(2nd part of cruise)
Chief Cook	Gary Hall	
2nd Cook	Tom Oates	

Scientific Party

Trevor McDougall	CSIRO	Oceanography	Chief Scientist
David Jackett	CSIRO	Oceanography	
Fred Boland	CSIRO	Oceanography	
Danny McLaughlan	CSIRO	Oceanography	
Kevin Miller	CSIRO	Oceanography	
Jeff Dunn	CSIRO	ORV Computing	
Phil Adams	CSIRO	ORV Electronics	
Mark Rayner	CSIRO	ORV Hydrology	
David Terhell	CSIRO	ORV Hydrology	
Karen Edwards	Canberra Institute of Technology		
Swee Hin Cheng	Royal Malaysian Navy		(1st part of cruise)

Cruise Narrative

We departed Fremantle on time at 0800 on Saturday 17th June and headed south to begin a line of stations westward along 34° 10' S (about the latitude of Cape Mentelle). The first station was done in 165m of water at 2130hrs. After the second station (CTD cast #02) we did another one (CTD cast #03) at the same location where we fired all twelve bottles at the salinity minimum at 1000m. When CTD #04 was begun (at about 0800 on the 18th June Local Time), the bow thruster malfunctioned and the CTD was retrieved from 100m so that the engineers could work on the problem. For several days thereafter the bow thruster could only deliver 50% of its full thrust and this restricted the weather conditions in which we could work.

With short interruptions due to the weather of only a few hours, we managed to do CTD casts #05 to #12 over the course of the next few days while deploying two moorings, M10 and M9 on Wednesday 21 June.

After deploying the third mooring, M8, on the morning of Thursday 22 June the wind picked up, gusting to 35 knots and we were unable to do any work for more than 24 hours. On Friday evening we did do two more CTDs and then we deployed the fourth mooring, M7 on Saturday morning 24 June. The wind then picked up again, gusting to its usual 35 knots as another front threatened all day and eventually passed us at dinner time. We could do no work for another 24 hours, until 1030AM on Sunday 25 June when we did CTD #015. There followed two more CTDs and mooring M6 at 10:23 LT on Monday morning 26 June.

Following CTD #18 at 17:30LT on Monday 26 June we had to turn around and head for Fremantle because the first engineer had taken ill. We docked at Fremantle two days later at 1700LT Wednesday 28 June. The chief steward also saw the doctor in Fremantle and was diagnosed with a hernia and so was ordered off the ship. Fortunately, a replacement chief steward was found at short notice and our sailing was not delayed because of this. While in port we took on 60 tons of fuel, and we departed at 2200LT.

The sailing back to our working location was calm and uneventful. A fire drill was performed on Friday morning. The weather remained very favourable while we completed the remaining five mooring deployments and associated CTD casts. The CTD system gave a small problem on three successive casts. After having been in the water for four hours, it overflowed a buffer in the top few hundred metres of water, just before bringing it back on deck.

After completing 28 CTD casts on the line between Naturaliste Plateau and Broken Ridge, we steamed to the northwest in the direction of Tryal Ridge from where we began 11 CTD casts at a spacing of 12 miles in a direction towards Fremantle. The aim of these stations was to measure the slopes of density surfaces deeper than 4000 m as an indication of the amount of deep transport that goes north on the eastern side of Tryal Ridge. The density section revealed rather weak slopes of neutral surfaces.

Summary of work completed

The primary aim of this cruise was to deploy the ten current meters and this was done successfully. Figure 1 shows the cruise track and the positions of the ten moorings, M1 - M10 (laid in the reverse order). In addition, 39 CTD casts were made, mostly in deep water. The first 28 of these were on the same line as that of a cruise of RRS *Charles Darwin* in 1987 and many of these 28 casts were designed to be at the same position as casts from that cruise. These 28 casts were basically on two straight courses, with casts #01 - #13 being at constant

latitude, and #14 - #28 towards the WNW. The long detour to Fremantle between moorings M6 and M5 is obvious on the cruise track.

The deepest part of the gap between Broken Plateau and Naturaliste Plateau lies between M1 and M10, with an average depth in this region greater than 5000 m. Figure 2(a) shows the section of neutral density in this deep gap on this cruise and this is to be contrasted with the corresponding section (Figure 2(b)) from the *Charles Darwin* section from 1987. The deep density field has evidently changed dramatically, although it is not known on what timescale these changes may occur.

Higher in the water column there has been a very distinct and statistically significant change of the water masses over the 7.5 years since the *Charles Darwin* cruise. This is illustrated in Figure 3 where the potential temperature anomaly of the Charles Darwin casts in this region are plotted against neutral density. The first step in forming this figure was to form the average potential temperature as a function of neutral density for the present cruise, labelled $\overline{\theta}(1995)$, in Figure 3. The scatter of the individual casts of the present cruise about the mean value is no more than ±0.05°C. By contrast, it is seen in Figure 3 that in the density range 26.9 kg m^{-3} to 27.25 kg m^{-3} the 1987 cruise data was warmer along density surfaces by about 0.1°C. This density range corresponds to the water between the Sub-Antarctic Mode Water and the salinity-minimum (Intermediate) Water, and covers the depth range from about 550 m to 900 m.

This cooling along density surfaces over the past 7.5 years of 0.1°C is consistent with the observed cooling on density surfaces in this region over longer periods (work in progress, Bindoff and McDougall). Moreover, such cooling on density surfaces is consistent with a warming (and some freshening) at the sea surface at the latitudes where these water masses are formed.

Figure 4(a) shows the S-θ curve of all the first 28 CTD casts of this cruise. There is a significant variation of the water masses at and below the salinity minimum showing that water of this density comes from both north and south of the section. By contrast, at a potential temperature of 2.15 °C the S-θ curve is very tight for all these casts. In fact, the variation of salinity at constant θ was only ±0.0017 psu even before any post-cruise calibrations.

The S-θ curves for the second CTD section are shown in Figure 4(b). The outlying cast #33 is very obvious, but Figure 4(c) shows that its properties lie in the envelope of the water mass variations found on the southern section. The anomalous water on cast #33 was found between 1100 m and 1600 m. This feature had no signature on the neighbouring casts and the density field indicated that it was an SCV (Submesoscale Coherent Vortex).

Acknowledgments

The entire *Franklin* crew is thanked for their excellent support and cooperation throughout the cruise. I am very grateful to Dr Yvonne Bone for forgoing two days of her cruise, FR07/95, so allowing us to complete the planned work of this cruise.

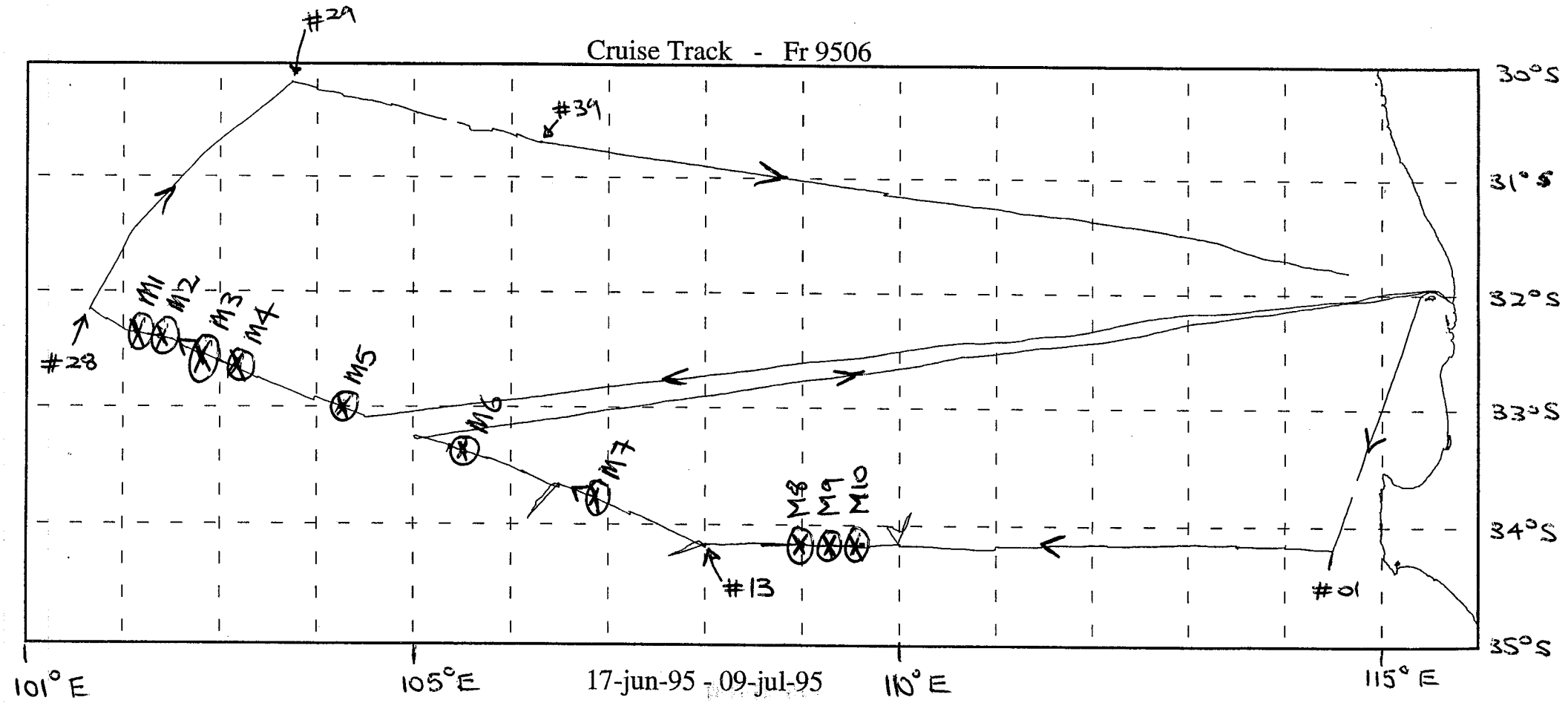
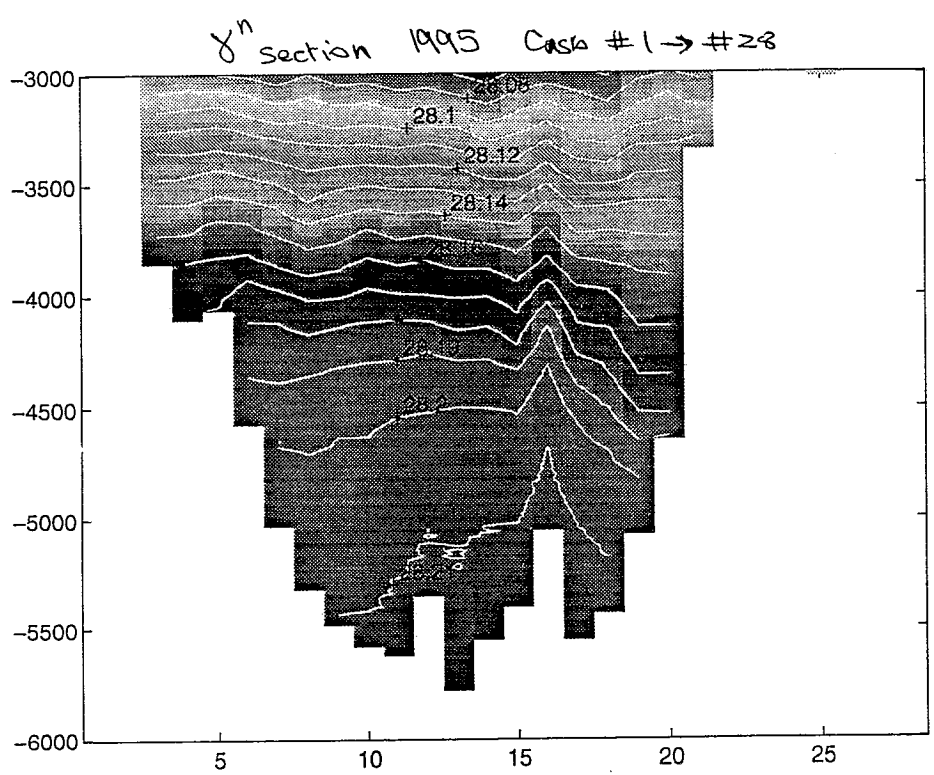
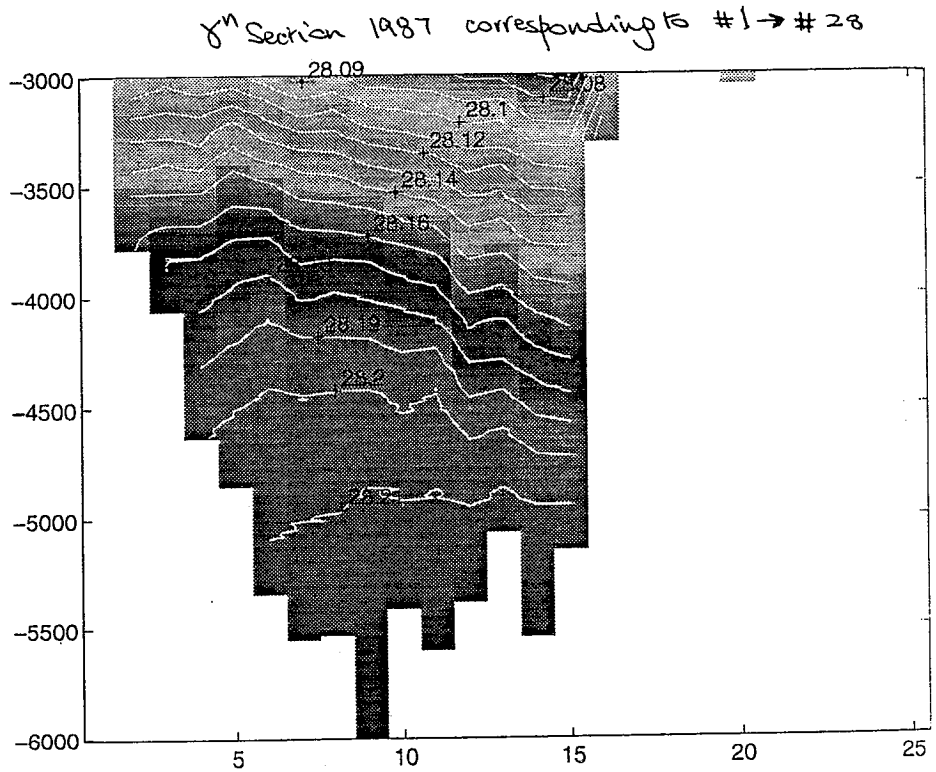

Cruise Track - Fr 9506
#29
#39
#28
#13
#01
M1
M2
M3
M4
M5
M6
M7
M8
M9
M10
30°S
31°S
32°S
33°S
34°S
35°S
101° E
105° E
110° E
115° E
17-jun-95 - 09-jul-95

Figure 1


γ^n section 1995 Cases #1 → #28
-3000
-3500
-4000
-4500
-5000
-5500
-6000
5
10
15
20
25
28.1
28.12
28.14
28.2

(a)


γ^n Section 1987 corresponding to #1 → #28
28.09
28.1
28.12
28.14
28.16
28.19
28.2
-3000
-3500
-4000
-4500
-5000
-5500
-6000
5
10
15
20
25

(b)

Figure 1.

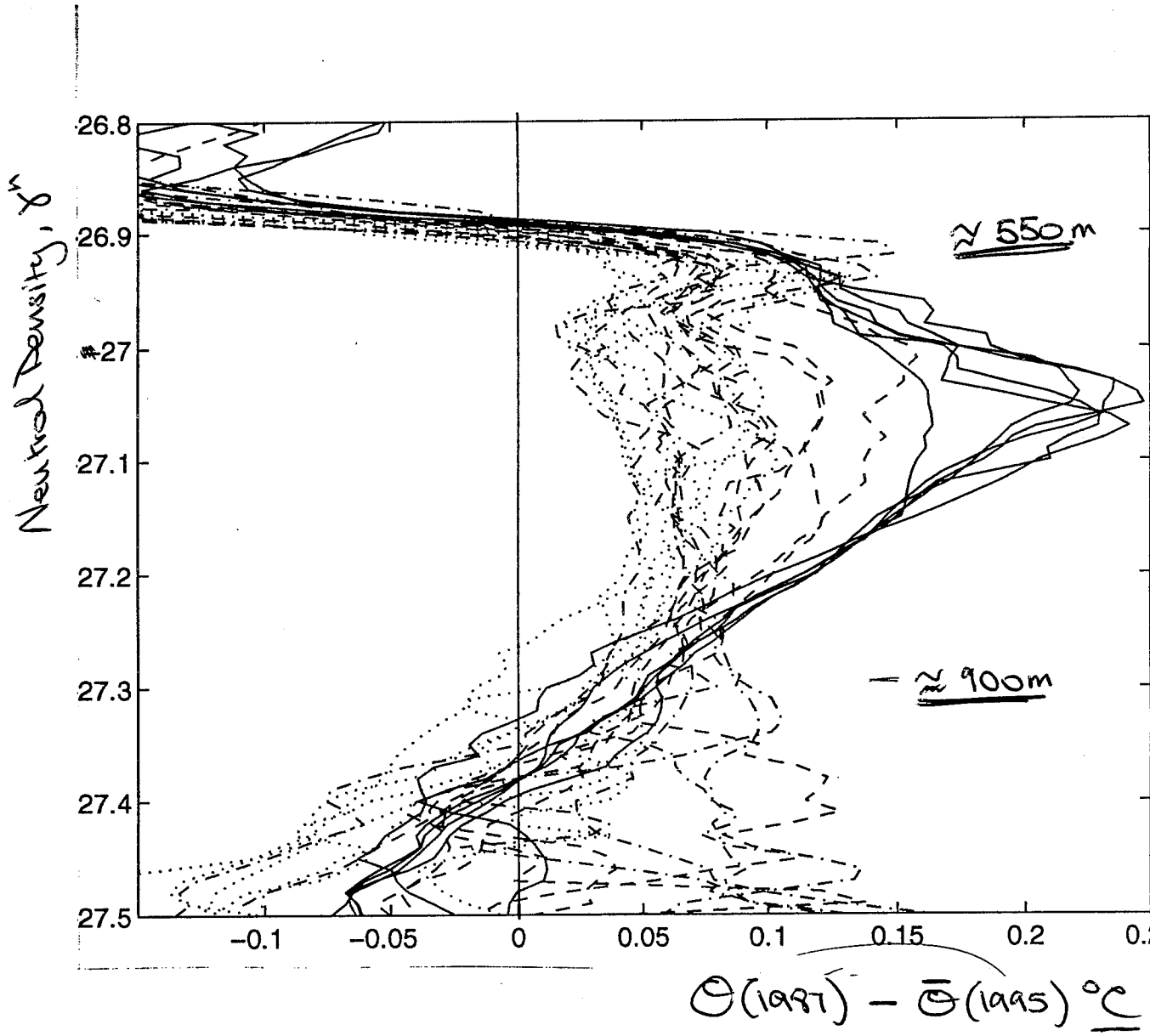
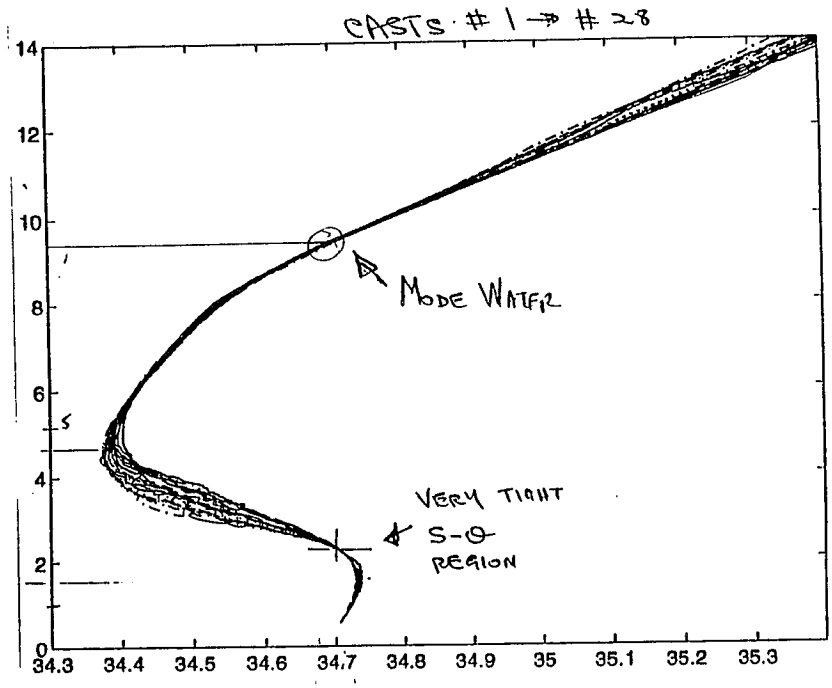
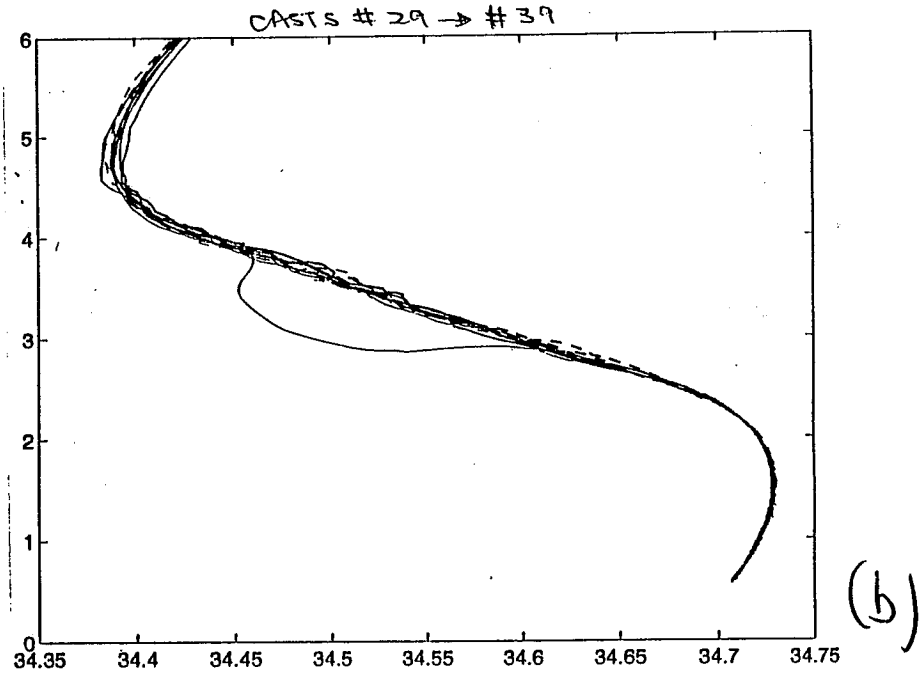

Neutral Density, γ^n
26.8
26.9
27
27.1
27.2
27.3
27.4
27.5
−0.1
−0.05
0
0.05
0.1
0.15
0.2
≈ 550m
≈ 900m
$\Theta(1997) - \bar{\Theta}(1995)$ °C

Figure 3


CASTS # 1 → # 28
MODE WATER
VERY TIGHT
S-Θ
REGION
(a)


CASTS # 29 → # 39
(b)

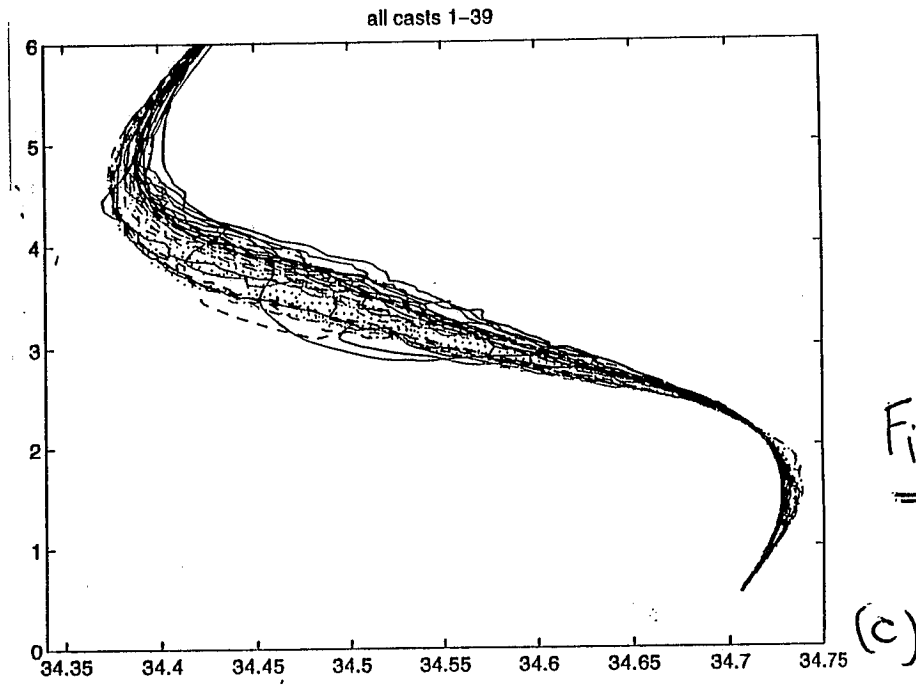

all casts 1-39
(c)

Figure 4