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James Rennell Centre
for Ocean Circulation

INTERNAL DOCUMENT No. 1

World-Wide Eddy Database
Vers 1.1

H Desai, J T Allen & D Smeed

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Institute of
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A World-Wide Eddy Database

by

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(This work was carried out at the James Rennell Centre for Ocean Circulation, with the support of DRA Maritime Division, Procurement Executive, Ministry of Defence)

DOCUMENT DATA SHEET

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ABSTRACT

This report briefly introduces a database of published eddy observations that has been set up at the James Rennell Centre for Ocean Circulation.

The World-Wide Eddy Database (WED) enables a simple comparision of eddy temperature, density or velocity structures to be made and has been built around a commercially available spreadsheet package. At the time of writing 40 eddies have been assimliated into the database.

KEYWORDS

DATA COLLECTION
OCEANIC EDDIES

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Introduction

Our ability to model the ocean is restricted by the practical limitations on the temporal and spatial frequency of in-situ hydrographic observations and the computational expense of running high resolution numerical models. It is therefore necessary to obtain the maximum amount of information possible from the data available. One method of doing this is Feature Modelling. This method has been used with some success in the intensively studied region of the Gulf Stream (Robinson, Spall and Pinardi 1988). The indication is that promising results should be achievable elsewhere but require a broader analysis of eddy structures than those purely associated with a strong western boundary current. Feature modelling techniques are based on the idea that eddies may be classified into particular categories (Allen, Pollard and New 1991) which may then be identified from a limited number of observations. For example, an AVHRR image provides information only about the sea-surface temperature, but from knowledge of historical in-situ measurements and the equations of motion which govern the evolution of the temperature field, it will be possible to infer the sub-surface structure of eddies and fronts identified by the image with a minimum requirement for additional data. Analytical models of observed features may then be embedded into the output from numerical models to produce an improved analysis. Feature modelling, therefore, requires the identification of the necessary parameters to categorize eddies and an understanding of the way in which each category of eddy interacts with the surrounding water mass. With this aim in mind the 'World-Wide Eddy Database' (WED) has been set up and is a continuing project at the James Rennell Centre for Ocean Circulation to contrast and compare thoroughly researched and well documented observations in the form of a historical climatology of eddies and other structures.

Naturally remarks drawn from this project are biased towards areas of present oceanographic research. The frequency of entries in a given area does not reflect the frequency of occurrence of eddies in that area, but rather the number of observations that have been made there. However, it seems reasonable to suggest that these results will be valuable in identifying key characteristics of eddy structures.

Presently the WED is structured around a simple low cost spreadsheet package, Microsoft Excel, on an Apple Macintosh microcomputer. However the intention is that the WED will not become too software dependent as its increasing size may in the future make other packages more appropriate.

There are at this time forty entries in the database. Only references that contain sufficient information to derive the majority of the basic database parameters are included. For this reason the large majority of references examined had to be excluded.

The Database

For each entry in the database the following information is stored: letters in parenthesis indicate the relevant column(s) in the spreadsheet.

Source of data

Reference to publication describing the observations. {B-G}
The type of hydrographic data presented in the publication. {P}
Duration of measurements. {L}

Location

Latitude and longitude of observation. {H,I}
Starting date of observation. {J,K}

Local environment

Depth of water column. {M}
Sea floor characteristics (i.e. abyssal plane, continental shelf, shelf break,..etc) {N}
Depth and amplitude of permanent and seasonal thermoclines. {X,Y,Z,AA}

Eddy parameters

Sense of rotation. {O}
Eddy centre depth; defined as the depth at which the greatest stratification anomaly, i.e. the largest relative change in vertical separation between adjacent isopycnals, occurs. (figures 1 and 2) {Q}
Eddy radius; a characteristic length scale defined as the horizontal distance between the eddy centre axis and

the point of maximum horizontal gradient in vertical distance between the two isopycnals that bound the eddy centre. (figures 3 and 4) {R}

Maximum tangential velocity and comment regarding its derivation, i.e. measured or calculated from density gradients. {S,T}

Propagation speed and direction of the eddy. {U,V}

Surface signature. (e.g. warm & light or cold & dense..etc) {AB}

The depth of 5 isopycnals at three locations, X=-R,0,R where X is the distance along a section across the eddy, X=0 is the centre and R is the eddy radius. {A}

These depths are stored in separate tables indicated in this column from which simple diagrams of the eddy structures can be constructed. These diagrams are appended to the end of this report.

Miscellaneous

Any other general comments. {W}

Discussion

The WED was conceived as a suitable project for an undergraduate student on an industrial training year. However after only a few months considerable interest had been shown in the project both from within the institute and from visitors to the James Rennell Centre.

One of the most significant results that has appeared, and of particular interest to feature modelling, regards the presence of some kind of surface signature with every eddy observation. However, both cyclonic and anticyclonic eddies may be accompanied by cold or warm surface thermal signatures. The implication here is that eddy structures may only be inferred from satellite information if both thermal and altimetric data are combined with the background knowledge obtained from a study such as this one.

It is not the intention of this report, at such an early stage in the development of the WED, to draw any firm conclusions about any observed relationships between eddy parameters. However, neglecting those observations greater than one standard deviation from the mean, the average depth of eddy centre (greatest stratification anomaly) for cyclonic eddies in the database is 134 metres: for the anticyclonic eddies this figure is 258 metres. The concept that the mean depth of anticyclonic eddies could be twice that of cyclonic eddies is intriguing as it is generally supposed that cyclonic eddies, having deeply upwelled cores (Gründlingh 1987, Richardson et al. 1979), extend further in the vertical than anticyclonic eddies. Several explanations have been suggested for this statistical observation, both in terms of the fluid dynamics governing an eddy structure and the method by which the depth of an eddy is established in the database, all of which are under further investigation.

The structure of an eddy is governed by a requirement to conserve potential vorticity and therefore a balance between horizontal length scale (L), tangential velocity (U) and vertical depth scale (D). Due to a lack of full ocean depth water column data very few observations contain sufficient information relating to the vertical extent of the eddy. Therefore in WED version 2 we shall concentrate on obtaining characteristic depth scales, by means of an improved method of assimilating observations into the database, to examine the correlation of these three parameters. From these improved correlations it will be possible to classify eddies in terms of their U:L:D relationship.

Additional studies are also to be carried out for WED version 2 using cruise data such as that from Charles Darwin 51 (Griffiths 1990) and Vivaldi (Pollard, Leach and Griffiths 1991) to investigate the range of different eddy structures that may be found in any particular location or generated by any particular mechanism. This will enable answers to be given to important questions such as 'do eddies generated at western boundary currents have different characteristic structures to those formed by the subduction of water along isopycnal surfaces ?'

References

References to eddy observations included in the database are given in the spreadsheet, later in this document.

Allen J. T., R. T. Pollard and A. L. New (1991) How do eddies modify the stratification of the thermocline ?. *Ocean Variability & Acoustic Propagation. J. Potter and A. Warn-Varnas (eds.).* Kluwer Academic Publishers, The Netherlands, pp 417-431.

Griffiths G. (1990) RRS Charles Darwin cruise 51 24th July-21st August 1990 Temperature salinity and velocity structure of the Iceland Færœs Front and North Atlantic Water inflow to the GIN Sea. *IOSDL cruise report* no.216.

Gründlingh M. L. (1987) Anatomy of a cyclonic eddy of the Mozambique Ridge Current. *Deep Sea Research,* **34**, pp 237-251

Pollard R. T., H. Leach and G. Griffiths (1991) Vivaldi cruise report. *to be published.*

Richardson P. L., C. Maillard and T. B. Stanford (1979) The physical structure and life history of cyclonic Gulf Stream ring 'Allen'. *Journal of Geophysical Research*, **84**, pp 7727-7741

Robinson A. R., M. A. Spall and N. Pinardi (1988) Gulf Stream simulations and the dynamics of ring and meander processes. *Journal of Physical Oceanography,* **18**(12), pp 1811-1853.

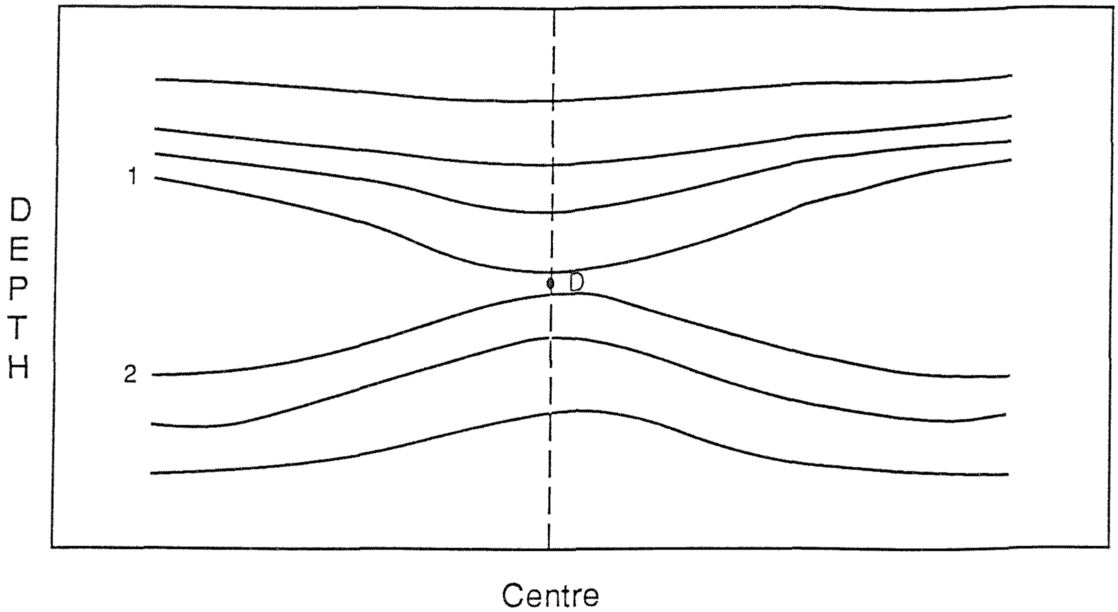


Figure 1:- The greatest stratification anomaly across this isopycnal section occurs between isopycnals 1 and 2. Thus D is the centre of the eddy.

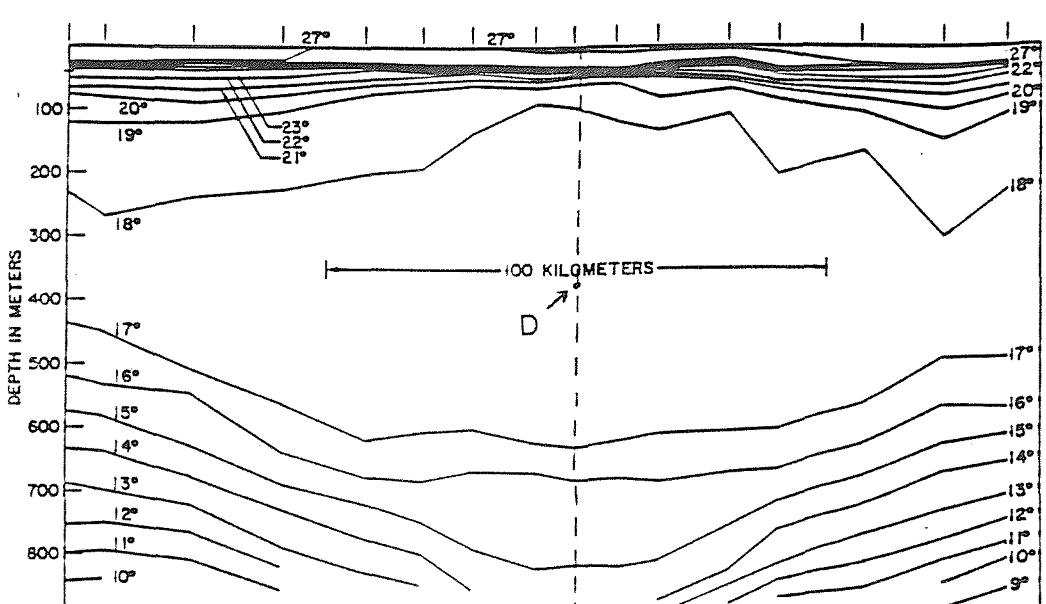


Figure 2:- D shows the eddy centre depth at 360 m
(Figure 2, Brundage et al, 1986)

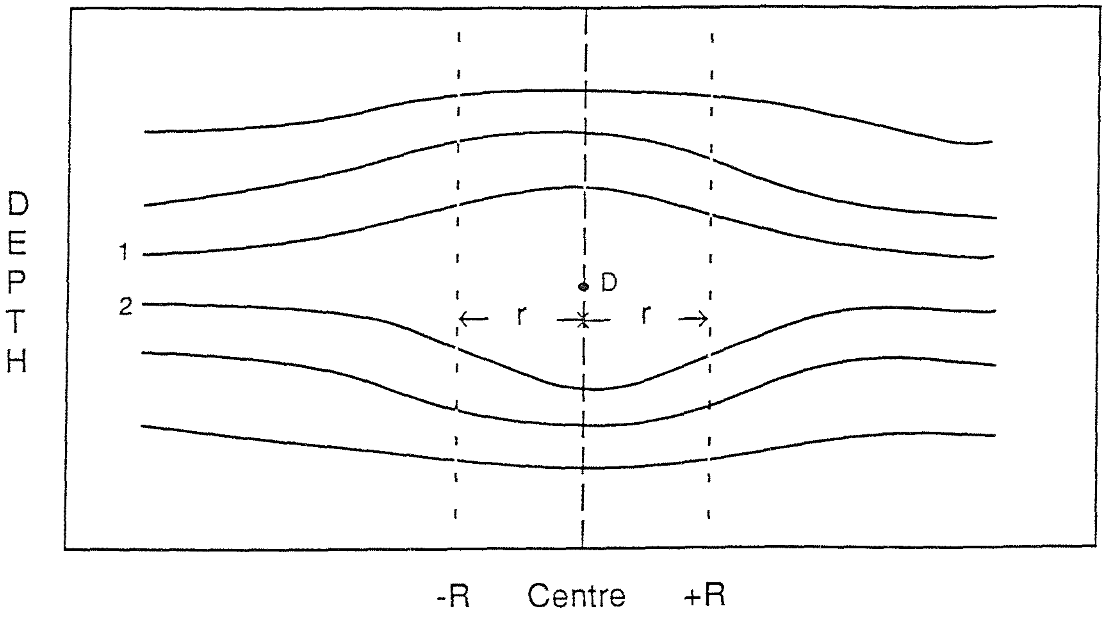


Figure 3:- This shows the depth of the eddy centre, D, and the radius, r, where ±R are the points of maximum gradient on the two isopycnals bounding the eddy centre (labelled 1 and 2).

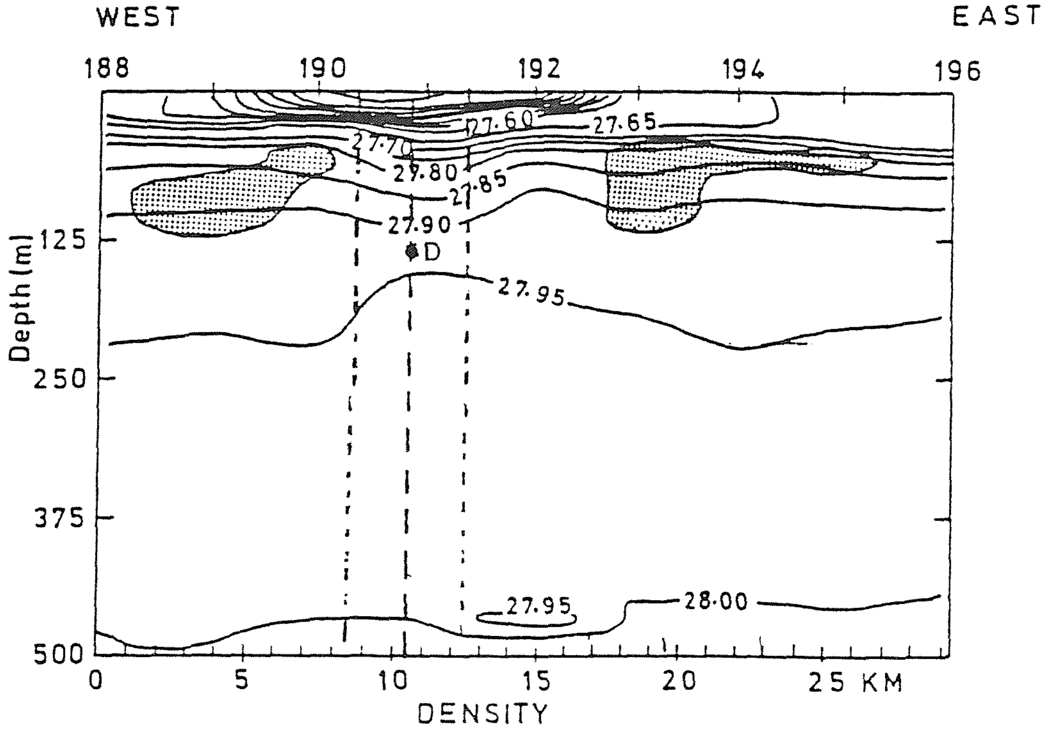


Figure 4:- Shows eddy centre depth, D, ±R and radius r *(figure 10, eddy E13, Johannesson et al, 1987)*.

	A	B	C	D	E	F	G	H
1	DEPTH OF 5 ISOPYCNALS	REFERENCE	AUTHOR	JOURNAL	DATE	VOL	PAGES	LATITUDE
2	Ref:- Paper 1	Mesoscale Eddies in the Fram Strait Marginal Ice Zone during the 1983 and 1984 Marginal Ice Zone Experiments (E1)	J A Johannesson	Journal of Geophysical Research	1987	92	6754-6772	~79°N
3	Ref:- Paper 2	A Deep Cyclonic Meddy in the West European Basin	U Schaur	Journal of Physical Oceanography	1987	27	31796	47°N
4	Ref:- Paper 3	Observations of a Small-Scale Baroclinic Eddy in the Ligurian Sea	S Marullo	Deep Sea Research	1985	32	215-222	44°N
5	Ref:- Paper 4	Evolution of a Cyclonic Gulf Stream Eddy	V A Bubnov et al	Oceanology	1986	26	553-556	38°N
6	Ref:- Paper 5	The Physical Structure and Life History of Cyclonic Gulf Stream Ring Allen	P L Richardson et al	Journal of Physical Oceanography	1979	84	7727-7741	37.5°N
7	Ref:- Paper 6	Mesoscale Eddies in the Fram Strait Marginal Ice Zone during the1983 and 1984 Marginal Ice Zone Experiments (E13)	J A Johannesson	Journal of Geophysical Research	1987	92	6754-6772	~80°N
8	Ref:- Paper 7	Structure and Origin of a Small Cyclonic Eddy observed during POLYMODE Local Dynamics Experiment	E J Lindstrom et al	Journal of Physical Oceanography	1983	16	562-570	31°N
9	Ref:- Paper 8	Anatomy of a Cyclonic Eddy of the Mozambique Ridge	M L Grundlingh	Deep Sea Research	1987	34 no 2	237-251	30°S
10	Ref:- Paper 9	The Physical Oceanography of Two Rings Observed by the Cyclonic Ring Experiment	D B Olson	Journal of Physical Oceanography	1979	10	514-528	36°N
11	Ref:- Paper 10	The Delagoa Bight Eddy	J R E Lutjeharms et al	Deep Sea Research	1988	35 no 4	619-634	26°S
12	Ref:- Paper 11	Hydrography and Microstructure of an Arctic Cyclonic Eddy	J Morrison et al	Journal of Physical Oceanography	1990	95	9411-9420	~74°N
13	Ref:- Paper 12	Physical, Chemical and Biological Structure of a Coastal Eddy near Cape Mendocino	Hayward et al	Journal of Marine Research	1990	48	825-848	40.5°N
14	Ref:- Paper 13	Generation of Eddy Structures in the Faeroe-Shetland Strait by Tidal Currents	A Yu Proshutinskity	Oceanology	1988	28 no 5	567-571	61°N
15	Ref:- Paper 14	A Mesoscale Eddy Dipole in the Offshore California Current	J J Simpson et al	Journal of Geophysical Research	1990	95	13009-13022	32°N
16	Ref:- Paper 15	A Cyclonic Frontal Eddy in the Antarctic Circumpolar Current	Y A Ivanov et al	Oceanology	1983	25	22-25	57°S
17	Ref:- Paper 16	A Cyclonic Eddy in the Antarctic Circumpolar Current and Heat Transport Across the Antarctic Front	M N Koshlyakov et al	Oceanology	1985	25	685-692	47-48°S
18	Ref:- Paper 17	Further Studies of a Cold Eddy on the Eastern Side of the Gulf Stream Using Satellite Data and Ship Data	F M Vukovich et al	Journal of Physical Oceanography	1978	8	838-845	31.5°N
19	Ref:- Paper 18	Generation and Evolution of a Cyclonic Ring at Drake Passage in Early 1979	R G Peters et al	Journal of Physical Oceanography	1982	12	712-719	57°S
20	Ref:- Paper 19	A Cyclonic Eddy in the Antarctic Circumpolar Current South of Australia	V G Savchenko et al	Journal of Physical Oceanography	1978	8	825-839	~51°S
21	Ref:- Paper 20	Observations of an Anticyclonic Eddy of 18°C Water in the Sargasso Sea	W L Brundage	Journal of Physical Oceanography	1986	16	717-727	30°N
22	Ref:- Paper 21	An Anticyclonic Eddy in the Northwestern Pacific	K T Bogdanov et al	TUAS	1985	281	1210-1213	40°N
23	Ref:- Paper 22	Eddies off Southeastern Australia	G R Cresswell et al	Deep Sea Research	1986	33	1527-1562	35-38°S
24	Ref:- Paper 23	Abyssal Eddy in the Southwest Atlantic	A L Gorden et al	Deep Sea Research	1986	33	839-847	46°S
25	Ref:- Paper 24	Baroclinic Eddies in the Arctic Ocean	J L Newton et al	Deep Sea Research	1974	21	707-719	76°N
26	Ref:- Paper 25	The Tourbillon Experiment: A Study of a Mesoscale Eddy in the Eastern North Atlantic	Le Groupe Tourbillon	Deep Sea Research	1983	30	475-511	47°N
27	Ref:- Paper 26	An Offshore Eddy in the California Current System	J J Simpson et al	Progress in Oceanography	1984	13	1-49	32.4°N
28	Ref:- Paper 27	An Anticyclonic, Baroclinic Eddy off Sitka, Alaska, in the Northeast Pacific Ocean	S Tabata	Journal of Physical Oceanography	1982	12	1260-1281	57°N
29	Ref:- Paper 28	Movement and Geographical Distribution of Anticyclonic Eddies in the Eastern Levantine Basin	Y Feliks et al	Deep Sea Research	1987	34	1499-1508	~34°N
30	Ref:- Paper 29	Life Cycle of a Gulf Stream Anticyclonic Eddy Observed from Several Oceanographic Platforms	G A Gotthardt	Journal of Physical Oceanography	1974	4	131-134	~38°N
31	Ref:- Paper 30	The Effect of Warm Core Eddies on the Oceanic Productivity off Northeastern New Zealand	J M Bradford	Deep Sea Research	1982	29	1501-1516	37°S
32	Ref:- Paper 31	The North Atlantic Current and its Associated Eddy Field Southeast of the Flemish Cap	W Krauss et al	Deep Sea Research	1987	34	1163-1185	47°N
33	Ref:- Paper 32	The Structure of an East Australian Current Anticyclonic Eddy	J C Andrews et al	Journal of Physical Oceanography	1976	6	756-765	35°S
34	Ref:- Paper 33	A Mesoscale Eddy Dipole in the Offshore California Current	J J Simpson et al	Journal of Physical Oceanography	1990	95	13009-13022	33°N
35	Ref:- Paper 34	The Subthermocline Lens D1, Part 1, Description of Water Properties and Velocity Profiles	B A Elliot et al	Journal of Physical Oceanography	1985	16	532-548	31°N
36	Ref:- Paper 35	Observation of an Anticyclonic Eddy near the Continental Shelf Break South of New England	R W Houghton et al	Journal of Physical Oceanography	1985	16	60-71	39°N
37	Ref:- Paper 36	Velocity and Hydrogrpahic Structure of a Gulf Stream Warm-Core Ring	T M Joyce	Journal of Physical Oceanography	1984	14	936-946	40°N
38	Ref:- Paper 37	Structure and Evolution of Warm Core Eddies in the Eastern Mediterranean Levantine Basin	S Brenner	Journal of Geophysical Research	1989	94 no C9	12, 593-12607	33°N
39	Ref:- Paper 38	Wintertime Convection in Warm-Core Rings: Thermocline Ventilation and the Formation of Mesoscale Lenses	R W Schmitt et al	Journal of Geophysical Research	1985	90 no C5	8823-8837	40°N
40	Ref:- Paper 39	Anticyclonic Eddy Observations in the Slope Water Abroad CGC Evergreen	J A Fornshell et al	Journal of Physical Oceanography	1979	9	992-999	~40°N
41	Ref:- Paper 40	Some Features of Frontal Eddies of the East Australia Current	K N Fedorov et al	Oceanology	1982	24	158-163	35°S

	I	J	K	L	M	N	O	P
1	LONGITUDE	YEAR OF OBS	MONTH OF OBS	DURATION OF OBS	DEPTH TO BOTTOM	SEA FLOOR REGION	EDDY SENSE	DATA AVAILABLE
2	~2°W	1984	May	2.5 months	5000 m	Abyssal Plane	Cyclonic	Temp, salinity, density, geo vel
3	20°W	1983	September/October	~2 months	~2000 m	Abyssal Plane	Cyclonic	Potemp, salinity, density, geo vel
4	9°E	1979	November	2 weeks	2000 m	Abyssal Plane	Cyclonic	Temp, density contours
5	65-66°W	1984	January	3 months	1000 m	Abyssal Plane	Cyclonic	Temp
6	63°W	1976	September	5 months	5000 m	Abyssal Plane	Cyclonic	Temp, salinity, velocity
7	~6.5°E	1984	June	10 days	5000 m	Abyssal Plane	Cyclonic	Temp, salinity, density, geo speed
8	69.5°W	1978	June	2 months	3000 m	Abyssal Plane	Cyclonic	Temp, salinity, oxygen
9	39°E	1982	June	10 days	5000 m	Abyssal Plane	Cyclonic	Temp, salinity, density, geo vel
10	68°W	1977	May	80 days	2500 m	Abyssal Plane	Cyclonic	Density, pot vort
11	~35°E	1980	March	~2 months	1200 m	Continental Slope	Cyclonic	Temp, salinity, nitrate level
12	~146°W	1985	March	~3 months	~1000 m	N/A	Cyclonic	Temp, salinity, density, nitrate, chlorophyll, oxygen, percent oxygen saturation, velocity
13	124°W	1987	May	~3 weeks	>500 m	Just off Coast	Cyclonic	Temp, salinity, density, oxygen, geo vel, nutrients
14	4.5°W	1983	October	2 days	>200 m	Continental Slope	Cyclonic	Temp, salinity, oxygen, silicon
15	123°W	1985	July	16 days	>1200 m	Continental Slope	Cyclonic	Temp, salinity, density, oxygen, pot vort, PE, KE
16	168°E	1982	December	15 days	>1500 m	Abyssal Plane	Cyclonic	Temp, salinity, density
17	26°E	1982	December	2 months	4500 m	Abyssal Plane	Cyclonic	Temp, density, velocity, KE
18	74 0°W	1975	March	1 month	3000 m	Abyssal Plane	Cyclonic	Temp, salinity, geo vel
19	65°W	1979	January	1 month	2500 m	Just off Continental Rise	Cyclonic	Temp, geopotential anomaly, density, salt anomaly
20	132°E	1977	January	2 months	4000 m	Abyssal Plane	Cyclonic	Temp, density, zonal geostrophic velociiy
21	69°W	1981	July/August	50 days	4000 m	Abyssal Plane	Double Anticyclonic	Temp, salinity, density
22	144°E	1983	April	~6 months	1200 m	Abyssal Plane	Double Anticyclonic	Temp, salinity, sound velocity
23	152°E	1980	November	13 months	1000 m	Abyssal Plane	Double Anticyclonic	Temp, salinity, geo currents
24	53.5°W	1985	N/A	N/A	6000 m	Abyssal Plane, just off Continental Rise	Double Anticyclonic	Potemp, salinity, density, oxygen
25	149°W	1972	March/April	4 weeks	1000 m	Abyssal Plane	Anticyclonic	Temp, salinity, density
26	14.87°W	1979	September/October	50 days	4500 m	Abyssal Plane	Anticyclonic	Temp, salinity, density, geo vel
27	124°W	1981	January	8 days	4000 m	Abyssal Plane, off shelf	Anticyclonic	Temp, density, salinity, oxygen, geo vel, angular vel, KE, APE, rel vort, pot vort
28	138°W	1977	April	~2 months	3000 m	Abyssal Plane	Anticyclonic	Geo vel, salinity, density, oxygen
29	~34°E	1983	October	~14 months	920 m	Abyssal Plane	Anticyclonic	Temp, salinity, geo current
30	69°W	1973	April	5 months	>800 m	Along Continental Slope	Anticyclonic	Temp
31	180°	1978	January	3 weeks	2400 m	Just off Shelf	Anticyclonic	Temp, salinity, density, chlorophyll, nitrate
32	41°W	1984	August	3 weeks	2000 m	Continental Slope	Anticyclonic	Temp, salinity, geo vel
33	152°E	1974	September	73 days	N/A SEE EDDY MARIO	Abyssal Plane	Anticyclonic	Temp
34	123°W	1985	July	16 days	>1200 m	Continental Slope	Anticyclonic	Temp, salinity, density, oxygen, pot vort, PE, KE
35	69.5°W	1978	May/June	~4 weeks	3000 m	Abyssal Plane	Anticyclonic	Potemp, salinity, potential density
36	71°W	1983	July	10 days	2400 m	Shelf Edge	Anticyclonic	Temp, salinity, density
37	64°W	1981	July	N/A	4500 m	Abyssal Plane	Anticyclonic	Potential temp, salinity, density, oxygen, nutrients (silicon nitrate)
38	27.5°E	1985	October	3 weeks	2000 m	Abyssal Plane	Anticyclonic	Temp, salinity
39	70°W	1982	February	6 months	3000 m	Abyssal Plane	Anticyclonic	Potemp, salinity, density, oxygen
40	~65°W	1978	September	2 months	3000 m	Abyssal Plane	Anticyclonic	Temp, salinity, currents
41	~158°E	1975	March	4 days	1000 m	Ayssal Plane	Anticyclonic	Temp

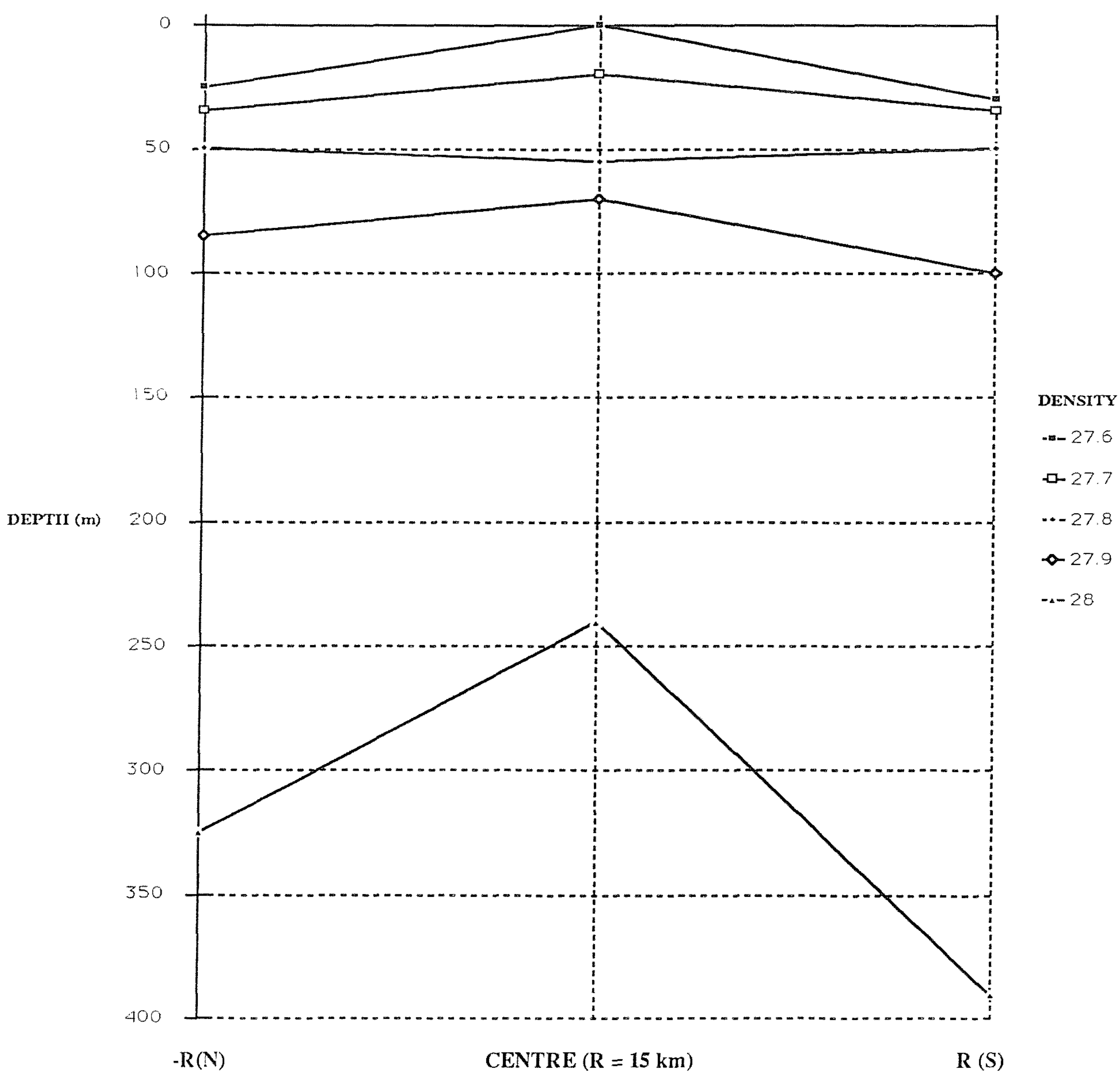
	Q	R	S	T	U	V
1	EDDY CENTRE DEPTH	EDDY RADIUS	MAX U (THETA)	COMMENT(U (THETA))	PROPAGATION SPEED	PROPAGATION DIRN
2	~75 m	~15 km	40 cm/s	Found at 50 m for E1	1-15 km/d	Southwards
3	~1800 m	~30 km	10 cm/s	At 1700 dbar	1.2-5.8cm/s	Westwards
4	~10 m	~1.8 km	50 cm/s	Mean from ship drift (max 1 m/s). This will include propagation speed.	N/A	N/A
5	250 m	17 km	50 cm/s	At the surface ref to 2000 db	5 km/d	Northeast between surveys 1 and 2. Equatorwards between 2 and 3
6	170 m	120 km	70 cm/s	Near 200 m, at 60 km radius	3 cm/s	Northwest
7	~130 m	~4 km	15-20 cm/s	Found at 125 m for eddy E13	1 km/d- 5 km/d	Eastwards
8	95 m	23 km	10-15 cm/s	Measured at 269 m from a current meter mooring	18 cm/s	Southwest
9	300 m	75 km	30-50 cm/s	Calculated using geostrophic approximation relative to 1000 db	N/A	N/A
10	100 m	~33 km	100-120 cm/s	1.2 m/s but not less than this	N/A	N/A
11	90 m	~90 km	N/A	N/A	N/A	N/A
12	140 m	~10 km	0.38 m/s	At a depth of 115 m	N/A	N/A
13	50 m	17 km	N/A	N/A	N/A	Equatorwards
14	100 m	56 km	50 cms	N/A	10 cm/s	N/A
15	250 m	35 km	20 cm/s	Rel to 1000 db	N/A	N/A
16	100 m	90 km	25 cm/s	Along a meridional section	11 cm/s	Northeastwards
17	150 m	54 km	40 cm/s	Rel to 1700 m	3.6 cm/s	Eastwards
18	300 m	80 km	N/A	N/A	10.7 km/day	Southwestwards
19	75 m	30 km	90 cm/s	Ring's north sector and subantarctic front were in proximity, rel to 3500 m	30 cm/s	Northwards
20	80 m	60 km	N/A	N/A	3 cm/s	North-northeastwards
21	360-700 m	~40 km	4 cm/s	N/A	4.3 km/d	West Southwest
22	200-250 m	45 km	74 cm/s	At surface (both geostrophic and current meters)	N/A	N/A
23	300-350 m	80 km	50-100 cm/s	N/A	0.3 m/s	Northwards
24	3700 m	55 km	8 cm/s	Relative to sigma 4 = 45.9 (see isopycnals)	N/A	Northwards
25	~200 m	~5 km	23 cm/s	Geostrophic currents are relative to 20 m (under ice)	2 cm/s	Northwards
26	550 m	~12.6 km	15-30 cm/s	Calculated using geostrophic currents referred to 3500 db	1.8 cm/s	Westwards
27	~350 m	25 km	25-30 cm/s	At a depth of 250 m geostrophic relative to 1450 db	N/A	N/A
28	70 m	80 km	N/A	N/A	15-40 cm/s	Westwards
29	200 m	25 km	20 cm/s	Down to 350 m	30-150 cm/s	Southwards then eastwards
30	140 m	~70 km	2-3 cm/s	Slow rate due to proximity of Gulf Stream	4-5 cm/s	Westwards
31	100 m	56 km	N/A	N/A	N/A	Northeastwards
32	160 m	50 km	N/A	N/A	N/A	Northeastwards
33	0 (SURFACE FEATURE)	125 km	60-178 cm/s	N/A	7 km/d (5-10 km/d)	Southwards
34	450 m	30 km	17 cm/s	Rel to 1000 db	40 cm/s	Westwards then northwards
35	1650 m	~20 km	28 cm/s	At 1500 db	11-16 cm/s	Southwest
36	35 m	8.1 km	50 cm/s	N/A	N/A	Southwestwards
37	400 m	55 km	4-5 cm/s	Ring rapidly changes size and shape due to strong interaction with Gulf Stream	3-5 cm/s	Westward
38	200 m	55 km	30 cm/s	At the surface rel to 1000 dbar	1 cm/s	Northeastwards
39	150 m	~30 km	N/A	N/A	N.A	Northeastwards
40	200 m	~18 km	N/A	N/A	9 km/d	Westwards
41	300 m	~55 km	2 cm/s	N/A	N/A	N/A

	W	X	Y	Z
1	COMMENT	DEPTH OF PERMANENT THEMOCLINE	DENSITY DIFFERENCE (PT)	DEPTH OF SEASONAL THERMOCLINE
2	N/A	N/A	N/A	0-40 m from diagram
3	Has moved north from source	N/A	N/A	N/A
4	N/A	N/A	N/A	20-60 m from diagram
5	N/A	700-1000 m	11°C (TEMP DIFFERENCE)	N/A
6	4-17 December	600-1100 m	~10°C (TEMP DIFFERENCE)	~65 m
7	N/A	N/A	N/A	HALOCLINE (BIG ONE) NO THERMOCLINE 0-50 m
8	N/A	600-1200 m	1 kg/m^3	30-50 m
9	N/A	Centre of thermocline between 50-150 m and only one thermodine exists	1.1 kg/m^3	N/A
10	N/A	600-1000 m	2.2 kg/m^3	50-100 m
11	N/A	N/A	N/A	80-100 m
12	N/A	200 m onwards (no limit due to lack of information)	N/A	N/A
13	Dynamic height field shows high velocity flow	N/A	N/A	N/A
14	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	50-300 m
16	New ring found to be formed as a result of a branching meander	N/A	N/A	20-100 m
17	Over 70 pairs of small cyclonic and anticyclonic eddies were found in 2 months	N/A	N/A	1-100 m
18	Cold perturbation, with high salinity core, was found south of cold eddy centre	N/A	N/A	N/A
19	Ring observed to be pushing through sub antarctic front	N/A	N/A	N/A
20	Possible anticyclonic circulation below 2000 m	800-1000 m	4°C (TEMP DIFFERENCE)	N/A
21	N/A	600-1000 m	~5°C below eddy (TEMP DIFFERENCE)	20-50 m
22	N/A	N/A	N/A	~50 m
23	Drifters - with superimposed looping motion (100 km diameter)	N/A	N/A	80-100 m
24	N/A	N/A	N/A	N/A
25	N/A	200-500 m	1.1kg/m^3	N/A
26	N/A	~650-1050 m	1.25 kg/m^3	100 m of upper layer
27	N/A	N/A	N/A	50-250 m
28	Rel to 1000 db surface (50 km from surface)	PRESENCE OF HALOCLINE (0-180 m)	1.8‰ (SALINITY DIFFERENCE)	N/A
29	N/A	20-70 m from diagram	1°C (TEMP DIFFERENCE)	N/A
30	Drifted for 4 months then coelesing with large meander	N/A	N/A	0-30 m
31	2 anticyclonic features close together	N/A	N/A	N/A
32	Rel to 1900 db	100-700 m	9°C (TEMP DIFFERENCE)	N/A
33	N/A	N/A	N/A	~75 (very difficult to tell)
34	Low oxygen water travels polewards	N/A	N/A	100-400 m
35	N/A	500-1000 m	1.2 kg/m^3	N/A
36	N/A	N/A	N/A	20-40 m
37	Cyclonic eddy 120 km from centre	100-500 m	1.0 kg/m^3	0-50 m
38	Disappearence of cold eddy - warm eddy pair, which weakened the warm eddy	N/A	N/A	1-100 m
39	N/A	200-400 m	0.5 kg/m^3	0-70 m
40	Eddy diminished from 3000 m to 1600 m in 2 months	N/A	N/A	N/A
41	N/A	300-500 m	5°C (TEMP DIFFERENCE)	0-70 m

	AA	AB
1	DENSITY DIFFERENCE (ST)	SURFACE FEATURES
2	~0.8 kg/m^3	Low temp, low salinity, low sigma polar water
3	N/A	Warm, high salinity, low density
4	1.7°C (TEMP DIFFERENCE)	Doming of isotherms breaks surface
5	N/A	Warm, domed
6	5°C (TEMP DIFFERENCE)	Warm, high salinity
7	0.6 (SALINITY DIFFERENCE)	Cold, low salinity, low density, big halocline
8	~1 kg /m^3	Low salinity, warm, less dense at the surface
9	N/A	Warm, light, and higher salinity at the surface
10	1.2 kg/m^3	Low density, dipped, high velocity, high temp
11	~4°C (TEMP DIFFERENCE)	High salinity, thermocline structure below 100 m, also warm
12	N/A	Cool, low salinity, low density
13	N/A	Cool, low salinity, domed
14	N/A	Domed, warm, saline
15	1.5 kg/m^3	Cold, fresh
16	0.3 kg/m^3	Cold, fresh, low density
17	0.6 kg/m^3	Low temp, high velocity, low density
18	N/A	Cold, fresh
19	N/A	Cold, low density
20	N/A	Cold, low salinity
21	< 4°C at the surface (TEMP DIFFERENCE)	(SEE EDDY MARIO) lens like feature at 15-16°C, low temp, low salinity, domed
22	~4°C (TEMP DIFFERENCE)	Warm, saline
23	2-3°C (TEMP DIFFERENCE)	Eddy maria pushes the thermocline down to < 500m, surface is warm, high salinity
24	N/A	Ice
25	N/A	Ice
26	1.25 kg/m^3	Low salinity, low temp, high density,domed
27	~1.8 kg/m^3	High salinity, high nutrients, low oxygen
28	N/A	Low salinity, low density, warm
29	N/A	High salinity, warm
30	N/A	Warm
31	N/A	High nutrients, low density, high salinity, warm
32	N/A	Warm, saline
33	3-4°C (TEMP DIFFERENCE)	Warm, depressed at the surface as this is a surface eddy
34	1.7 kg/m^3	Warm, saline, low oxygen
35	N/A	Low density, low salinity, cool
36	2.2 kg/m^3	Low salinity, cold
37	1.5 kg/m^3	Warm, saline, low density
38	5°C (TEMP DIFFERENCE)	warm, high salinity
39	1 kg/m^3	Warm, high salinity, high oxygen
40	N/A	Warm, saline
41	3°C (TEMP DIFFERENCE)	Warm

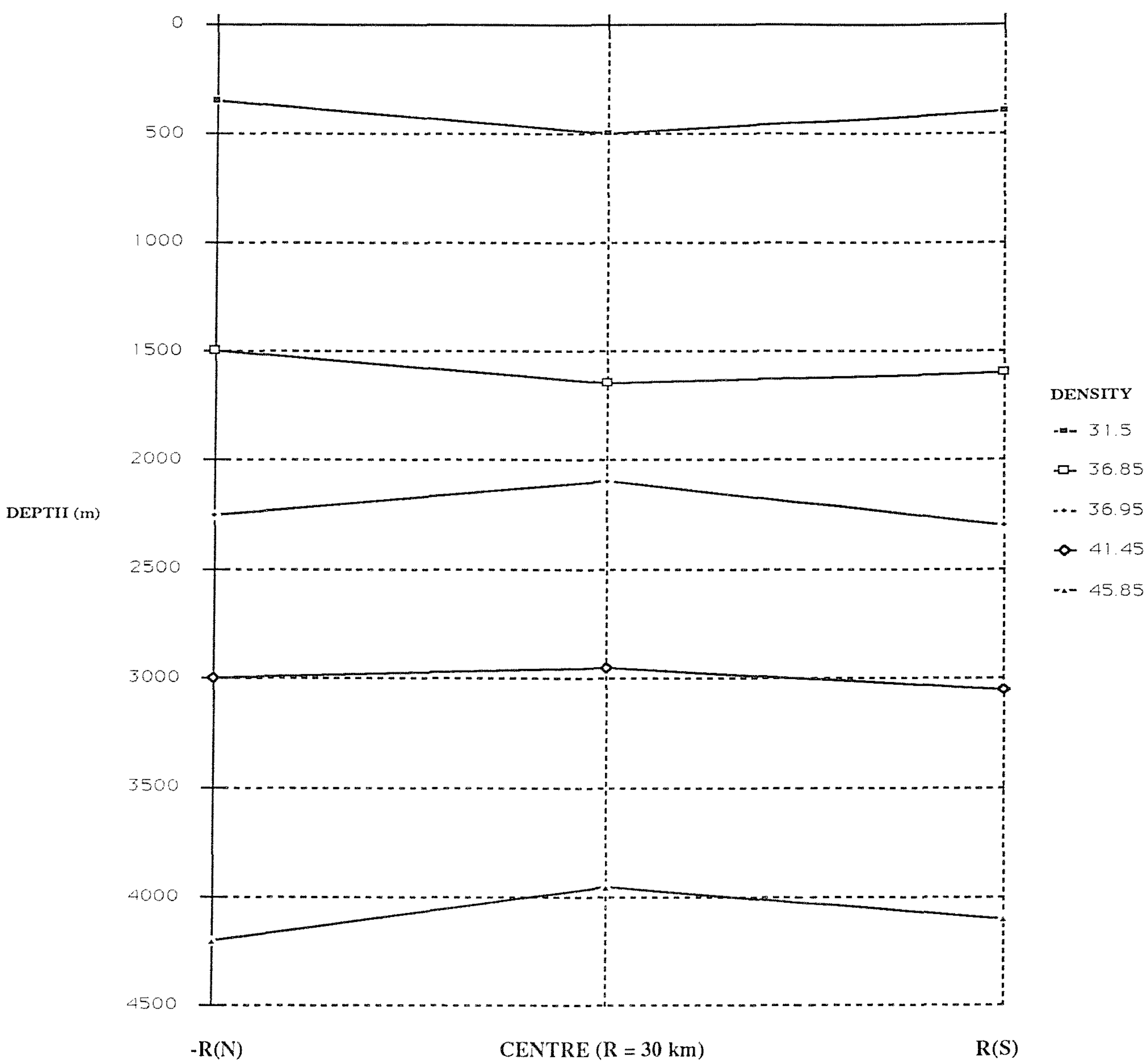
MESOSCALE EDDIES IN THE FRAM STRAIT MARGINAL ICE ZONE DURING THE 1983 AND 1984 MARGINAL ICE ZONE EXPERIMENTS (E1)

DENSITY (σ_t)		27.6	27.7	27.8	27.9	28.0
DEPTH	-R	25	35	50	85	325
(m)	C	0	20	55	70	240
	R	30	35	50	100	390



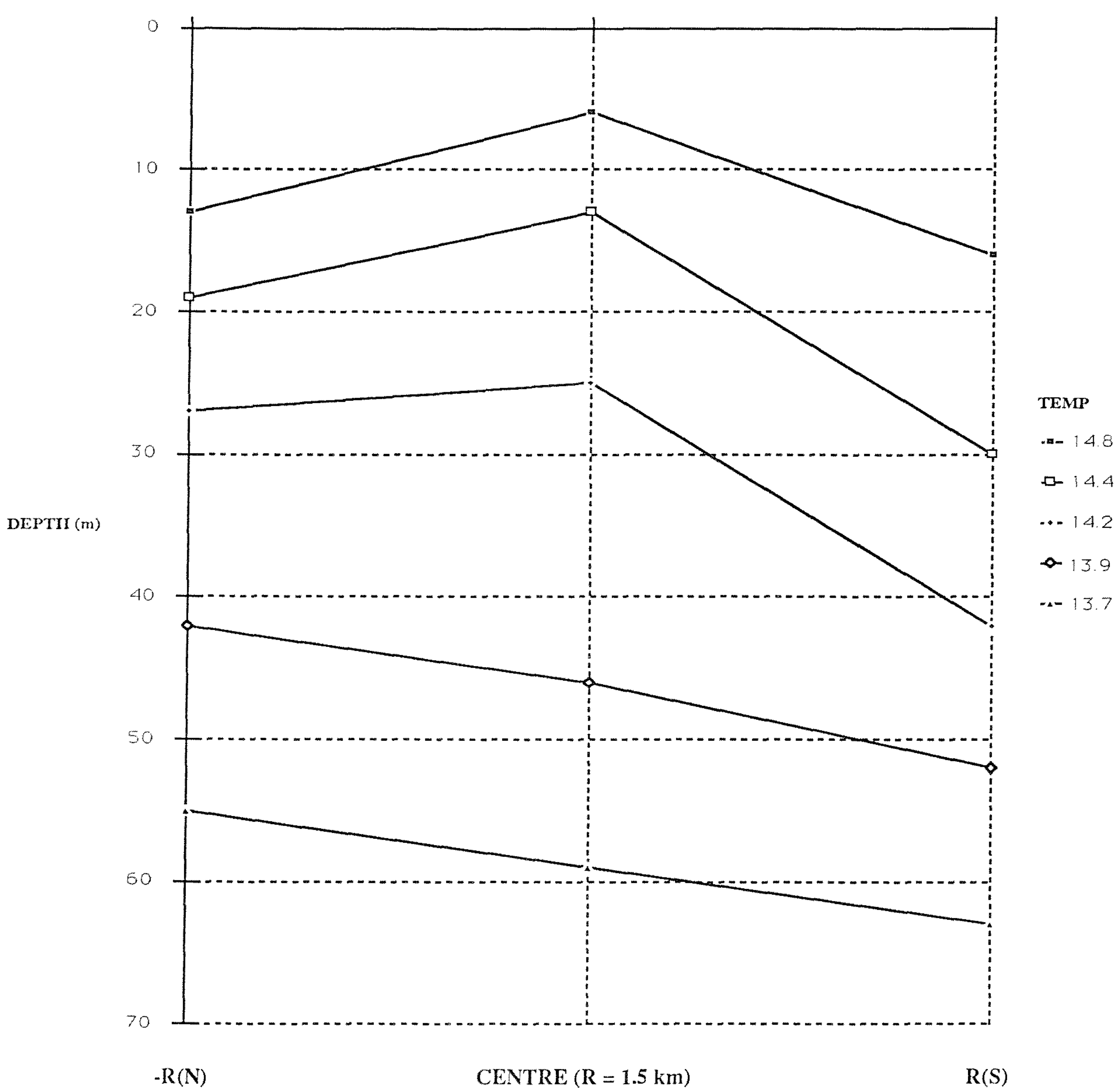
A DEEP CYCLONIC MEDDY IN THE WESTERN EUROPEAN BASIN

DENSITY		31.50 (σ_1)	36.85 (σ_2)	36.95 (σ_2)	41.45 (σ_3)	45.85 (σ_4)
DEPTH	-R	350	1500	2250	3000	4200
(m)	C	500	1650	2100	2950	3950
	R	400	1600	2300	2050	4100



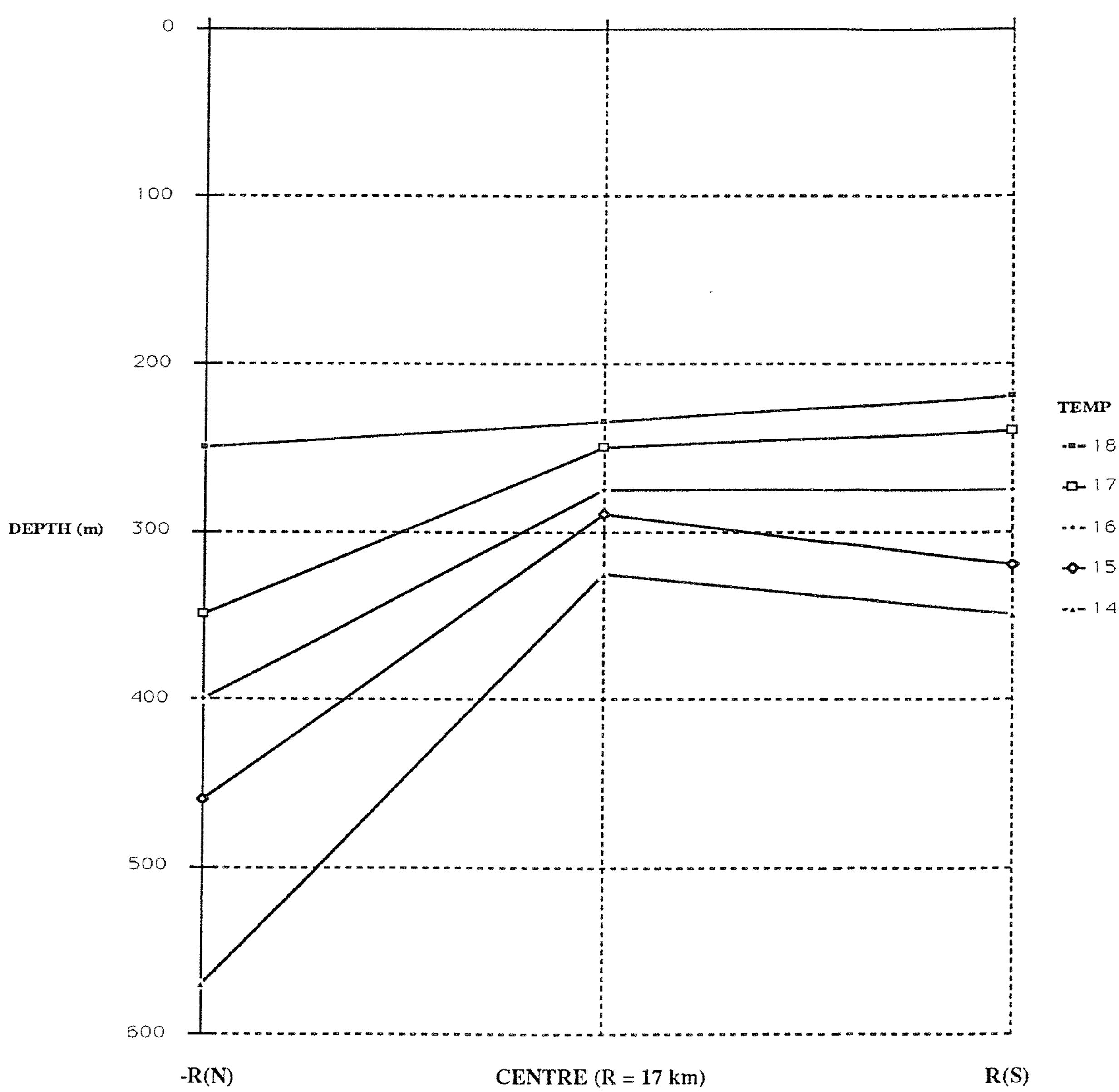
OBSERVATIONS OF A SMALL-SCALE BAROCLINIC EDDY IN THE LIGURIAN SEA

TEMPERATURE (°C)		14.8	14.4	14.2	13.9	13.7
DEPTH	-R	13	19	27	42	55
(m)	C	6	13	25	46	59
	R	16	30	42	52	63



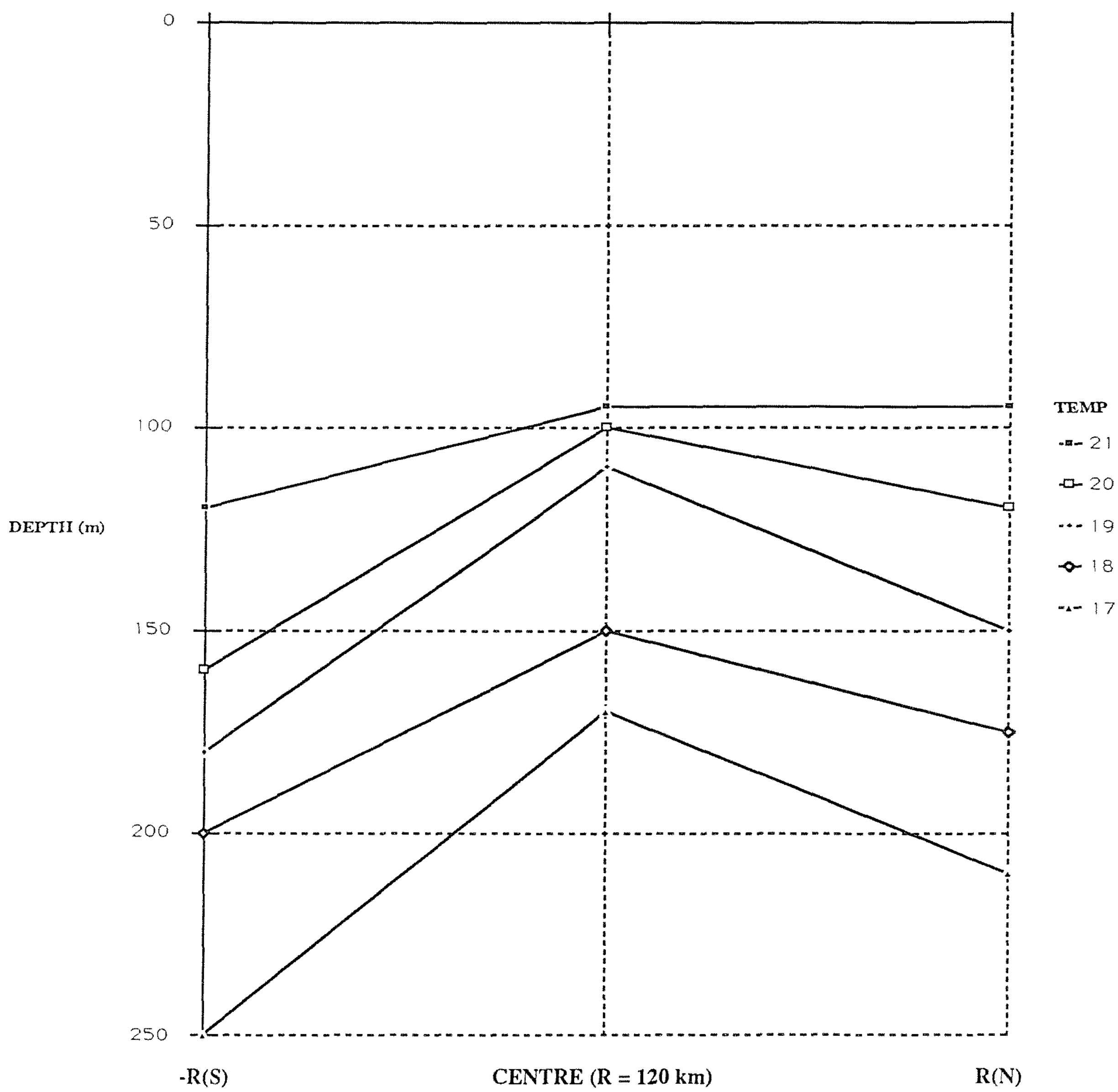
EVOLUTION OF THE CYLCONIC GULF STREAM EDDY

TEMPERATURE (°C)		18	17	16	15	14
DEPTH	-R	250	350	400	460	570
(m)	C	235	250	275	290	325
	R	220	240	275	320	350



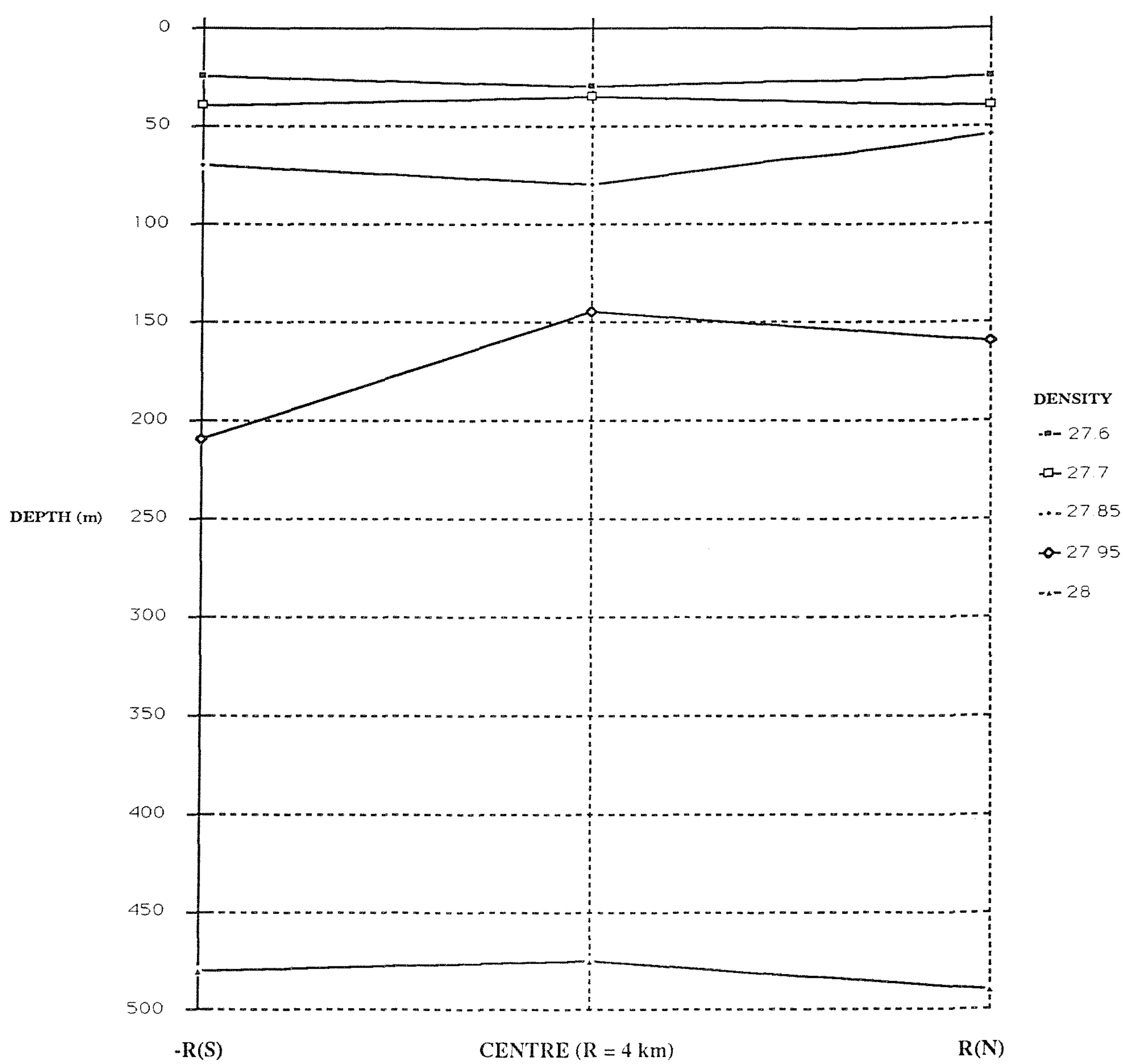
THE PHYSICAL STRUCTURE AND LIFE HISTORY OF CYCLONIC GULF STREAM RING ALLEN

TEMPERATURE (°C)		21	20	19	18	17
DEPTH	-R	120	160	180	200	250
(m)	C	95	100	110	150	170
	R	95	120	150	175	210



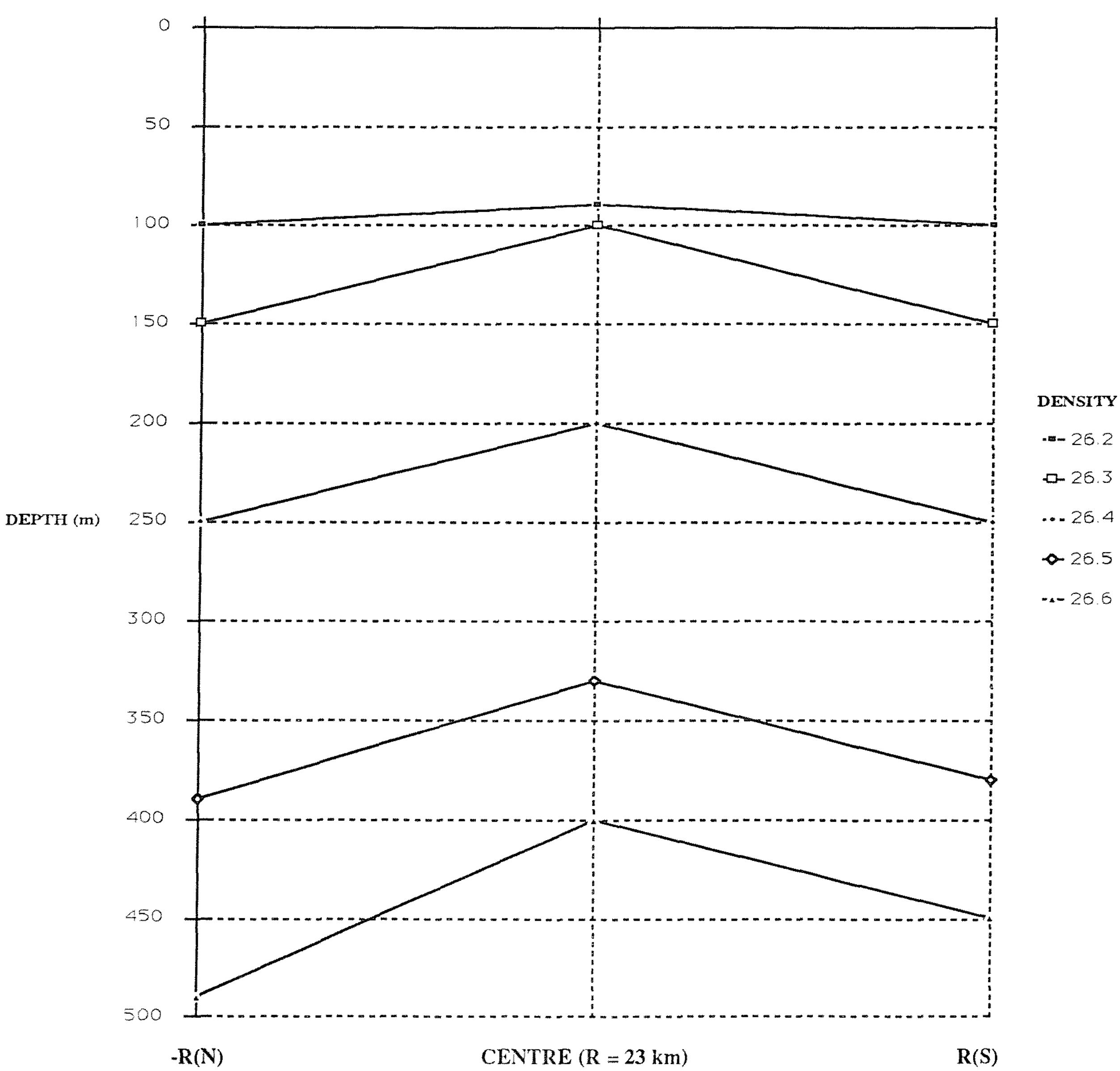
MESOSCALE EDDIES IN THE FRAM STRAIT MARGINAL ICE ZONE DURING THE 1983 AND 1984 MARGINAL ICE ZONE EXPERIMENTS (E13)

DENSITY (σ_t)		27.60	27.70	27.85	27.95	28.00
DEPTH	-R	25	40	70	210	480
(m)	C	30	35	80	145	475
	R	25	40	55	160	490



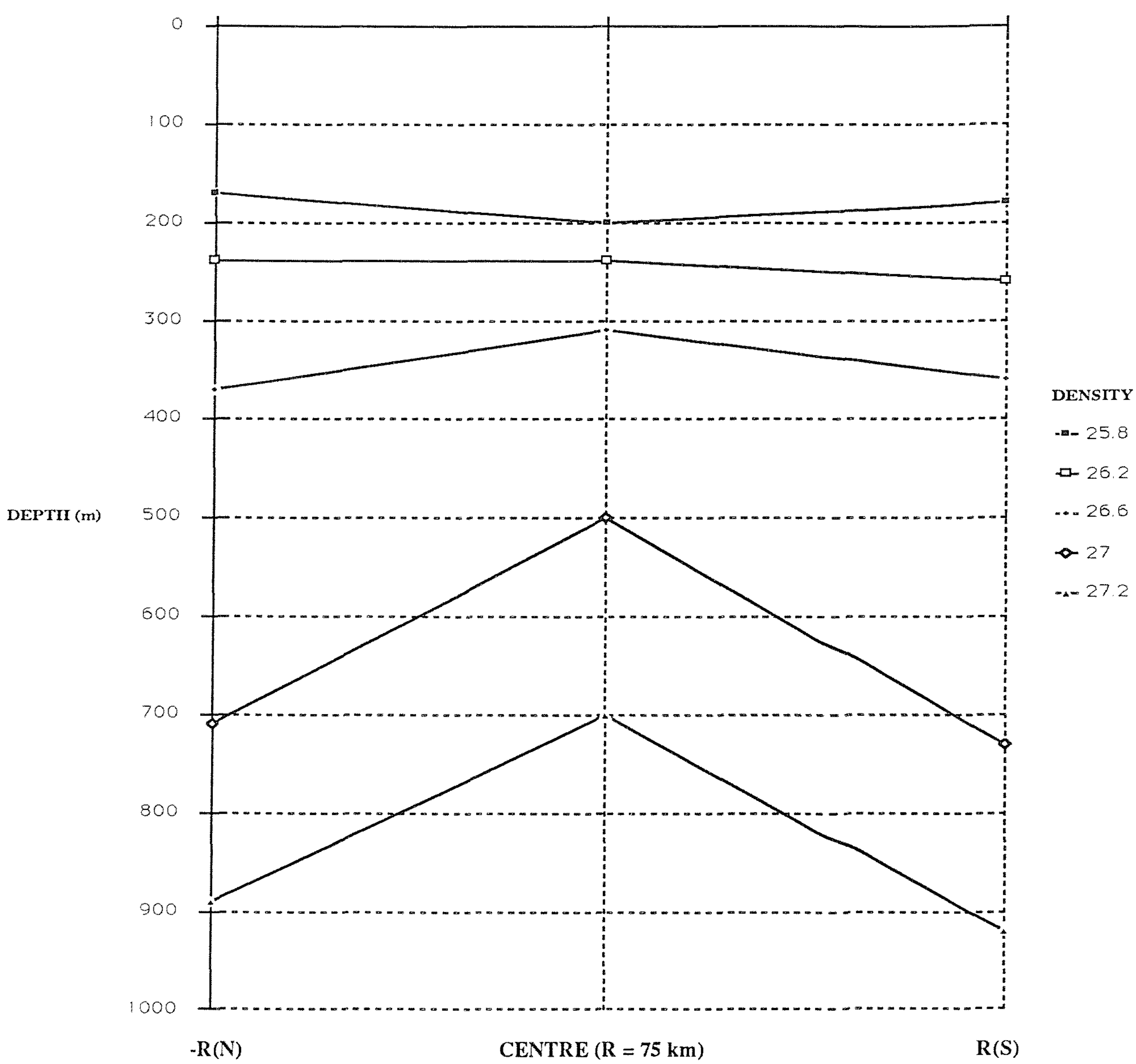
STRUCTURE AND ORIGIN OF A SMALL CYCLONIC EDDY OBSERVED DURING THE POLYMODE LOCAL DYNAMICS EXPERIMENT

DENSITY (σ_θ)		26.2	26.3	26.4	26.5	26.6
DEPTH	-R	100	150	250	390	490
(m)	C	90	100	200	330	400
	R	100	150	250	380	450



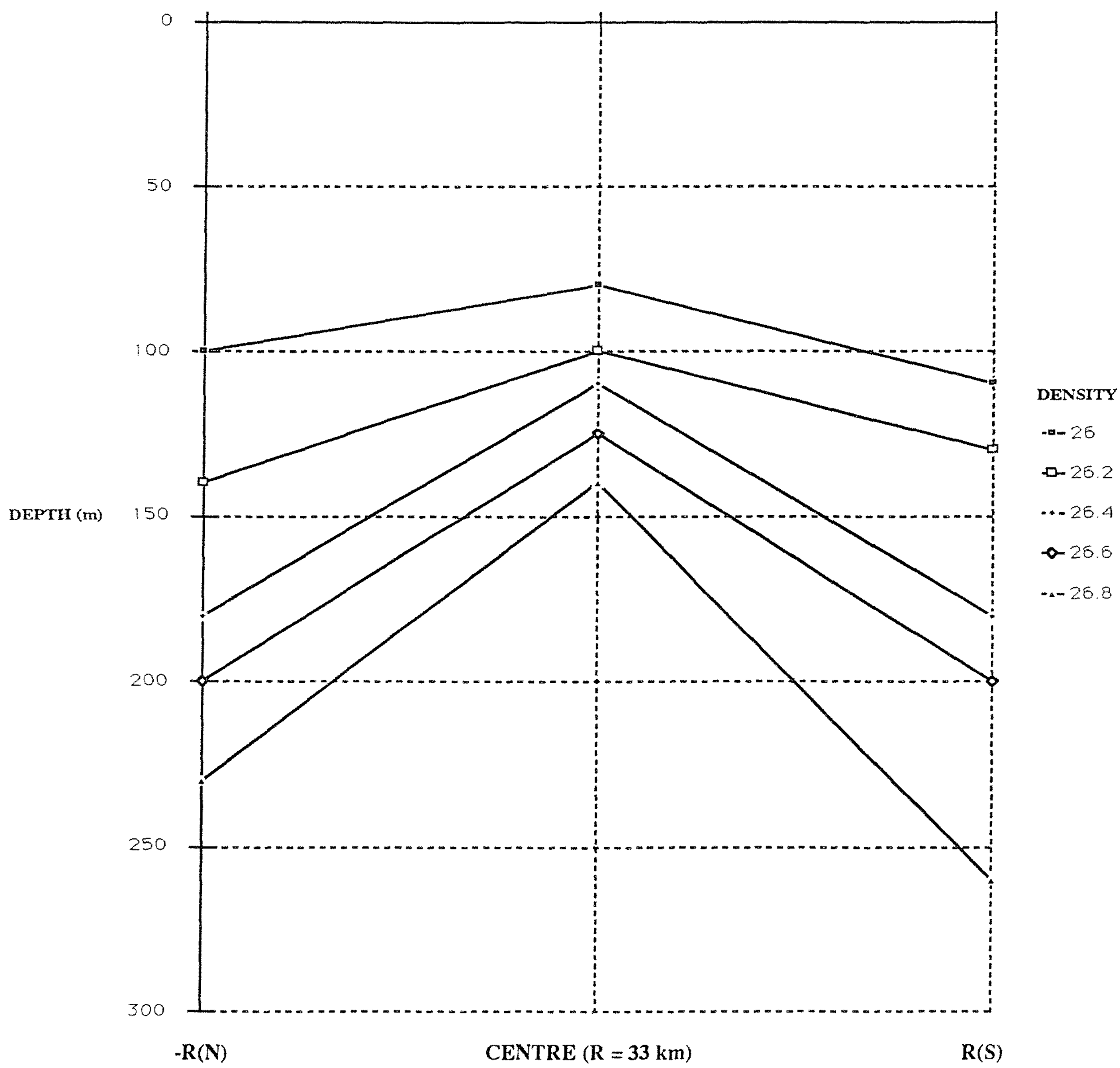
ANATOMY OF A CYLCONIC EDDY OF THE MOZAMBIQUE RIDGE CURRENT

DENSITY	(σ_θ)	25.8	26.2	26.6	27.0	27.2
DEPTH	-R	170	240	370	710	890
(m)	C	200	240	310	500	700
	R	180	260	360	730	920



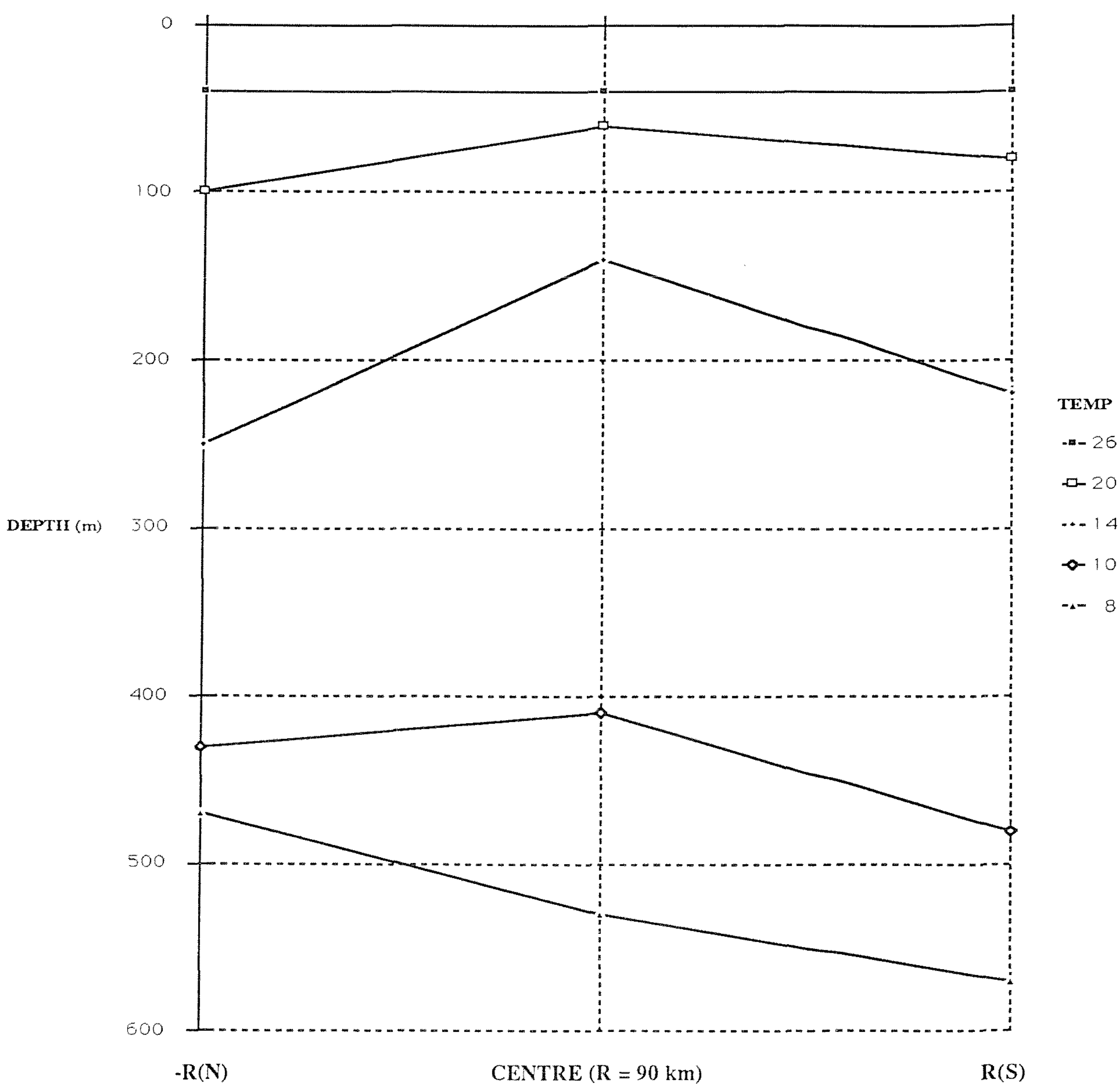
THE PHYSICAL OCEANOGRAPHY OF TWO RINGS OBSERVED BY THE CYCLONIC RING EXPERIMENT PART 2 DYNAMICS

DENSITY	(σ_θ)	26.0	26.2	26.4	26.6	26.8
DEPTH	-R	100	140	180	200	230
(m)	C	80	100	110	125	140
	R	110	130	180	200	260



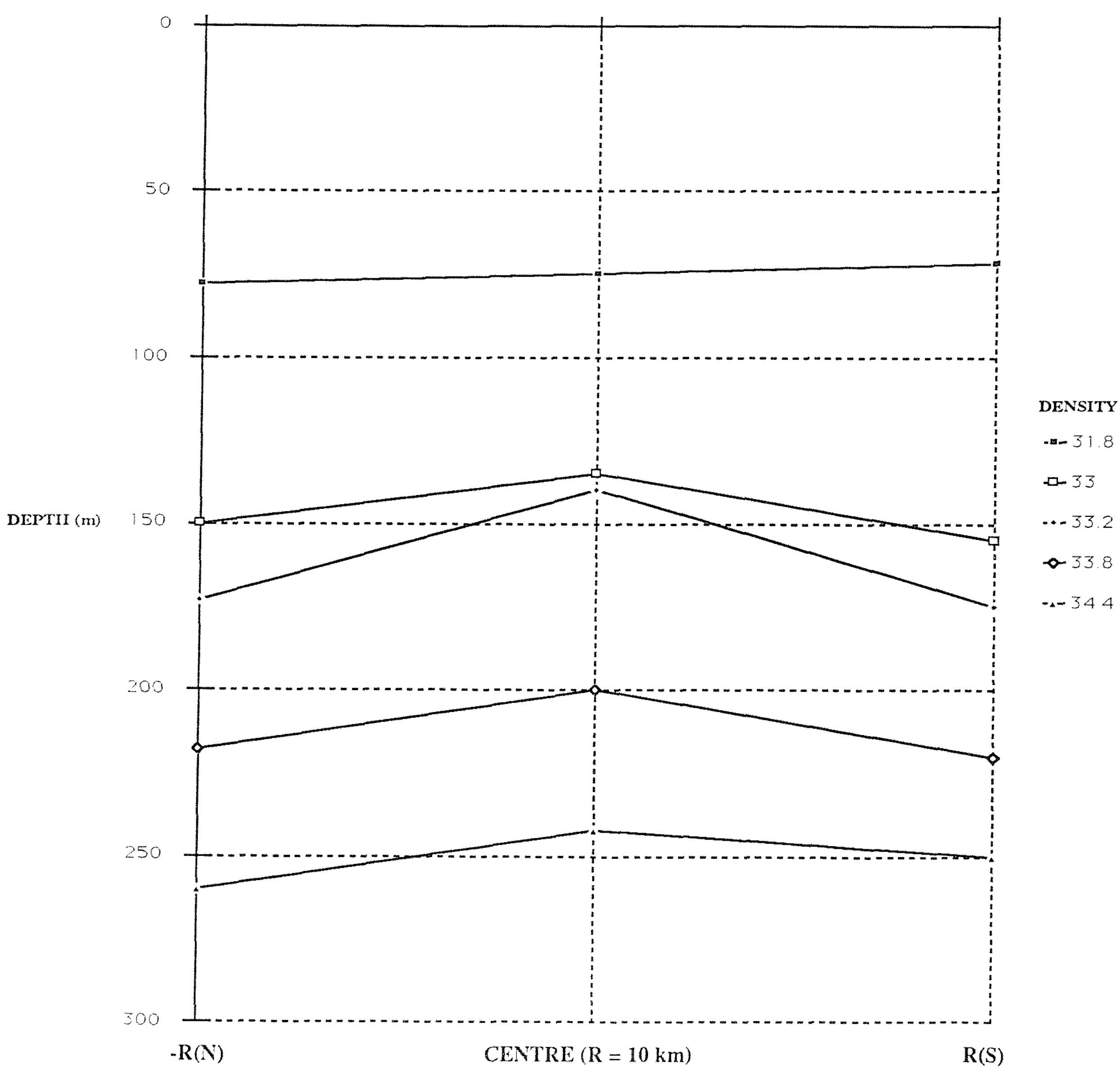
THE DELAGOA BIGHT EDDY

TEMPERATURE (°C)		26	20	14	10	8
DEPTH	-R	40	100	250	430	470
(m)	C	40	60	140	410	530
	R	40	80	220	480	570



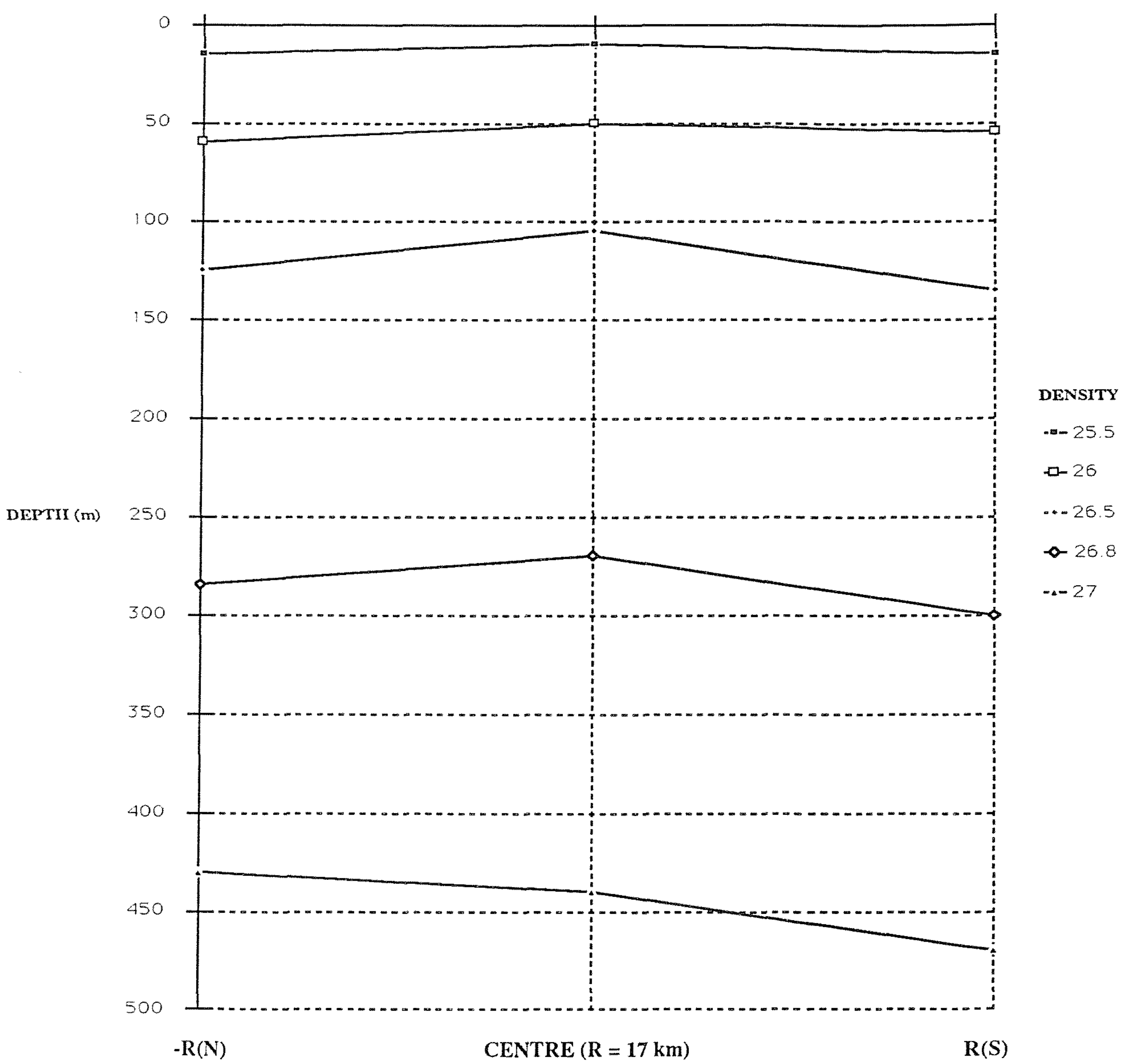
HYDROGRAPHY AND MICROSTRUCTURE OF AN ARCTIC CYCLONIC EDDY

DENSITY (σ_t)		31.8	33.0	33.2	33.8	34.4
DEPTH	-R	78	150	173	218	260
(m)	C	75	135	140	200	242
	R	72	155	175	220	250



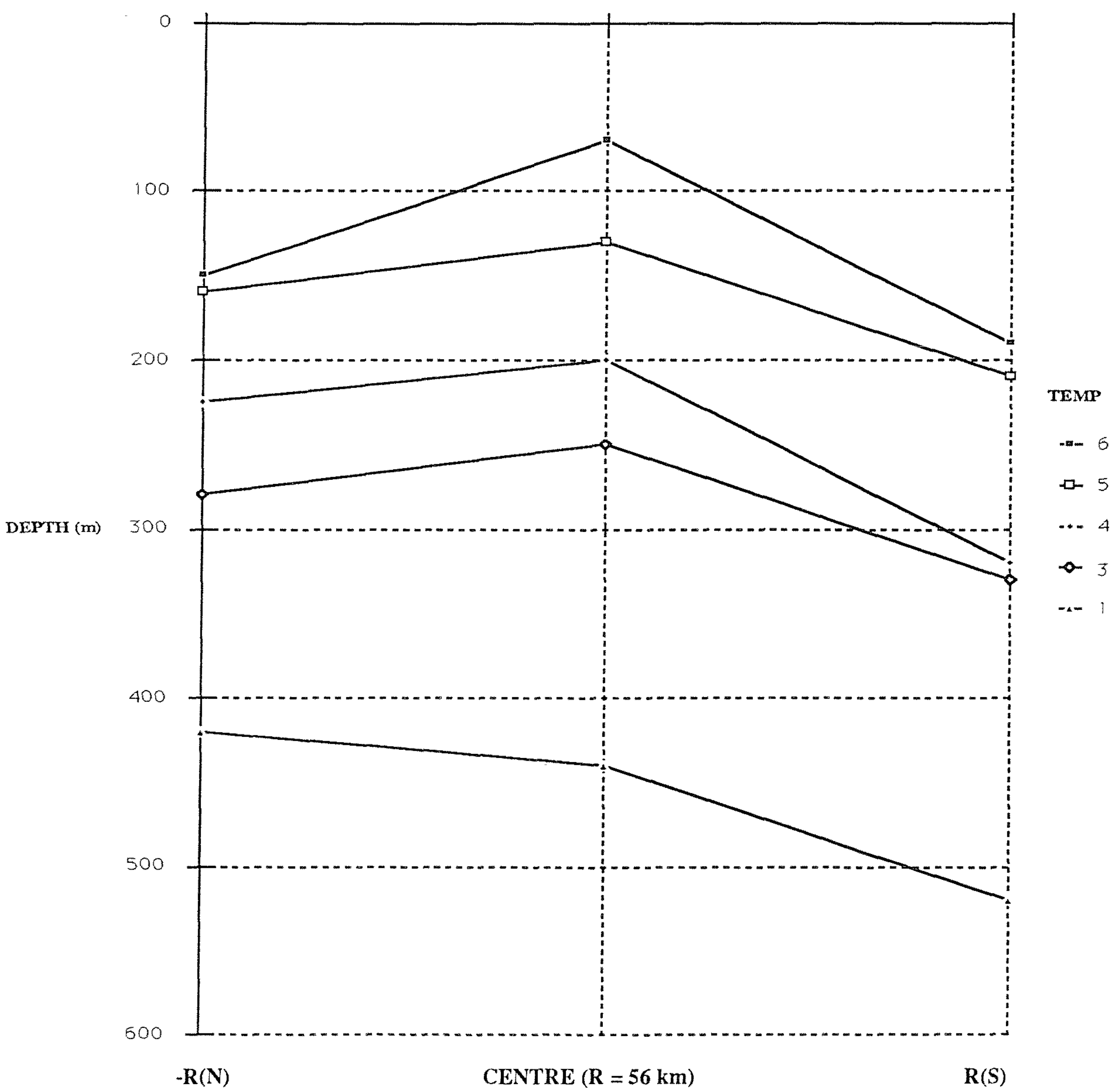
PHYSICAL, CHEMICAL AND BIOLOGICAL STRUCTURE OF A COASTAL EDDY NEAR CAPE MENDOCINO

DENSITY (σ_θ)		25.5	26.0	26.5	26.8	27.0
DEPTH	-R	15	60	125	285	430
(m)	C	10	50	105	270	440
	R	15	55	135	300	470



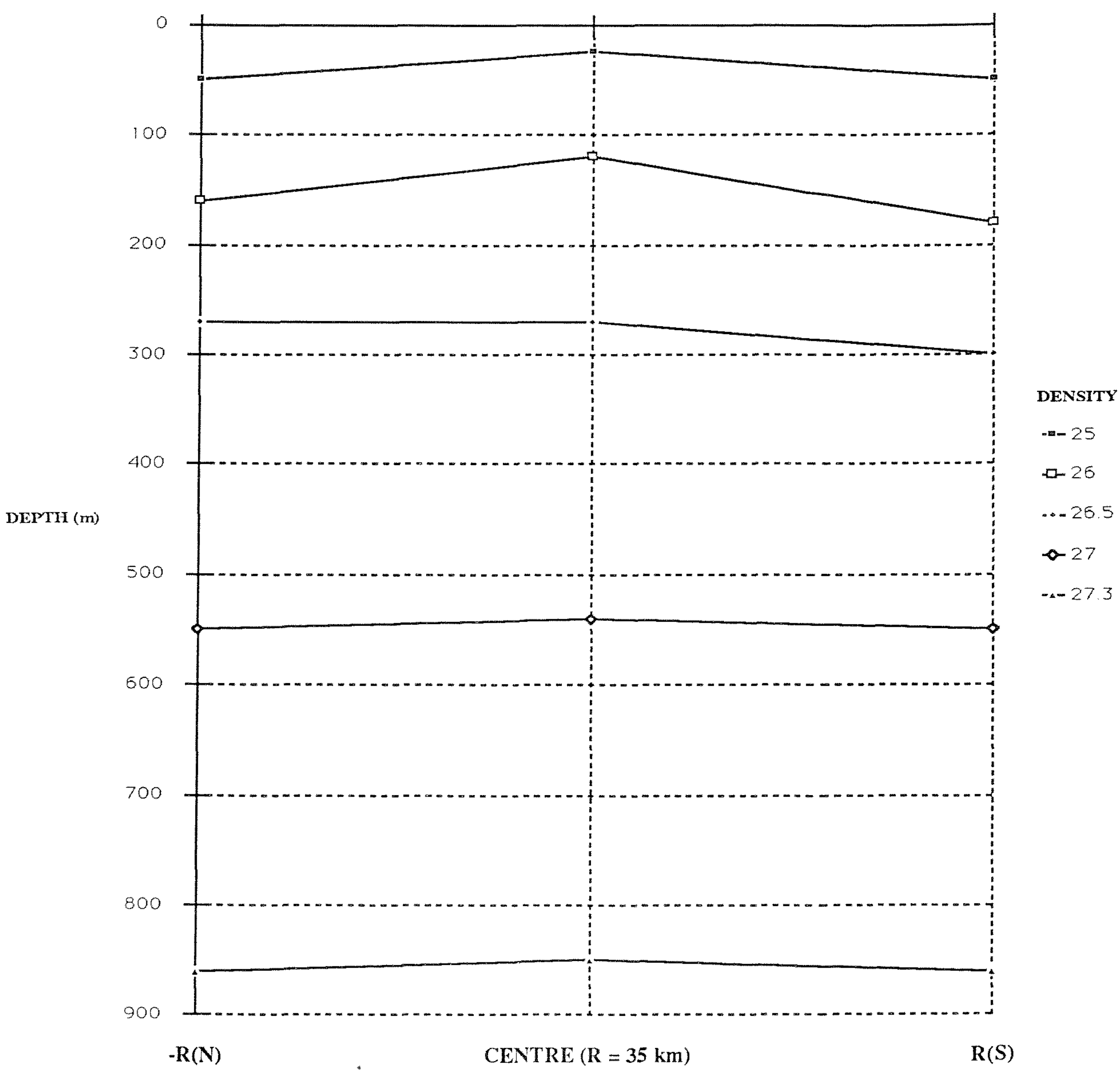
GENERATION OF EDDY STRUCTURES IN THE FÆRŒ-SHETLAND STRAIT BY TIDAL CURRENTS

TEMPERATURE (°C)		6	5	4	3	1
DEPTH	-R	150	160	225	280	420
(m)	C	70	130	200	250	440
	R	190	210	320	330	520



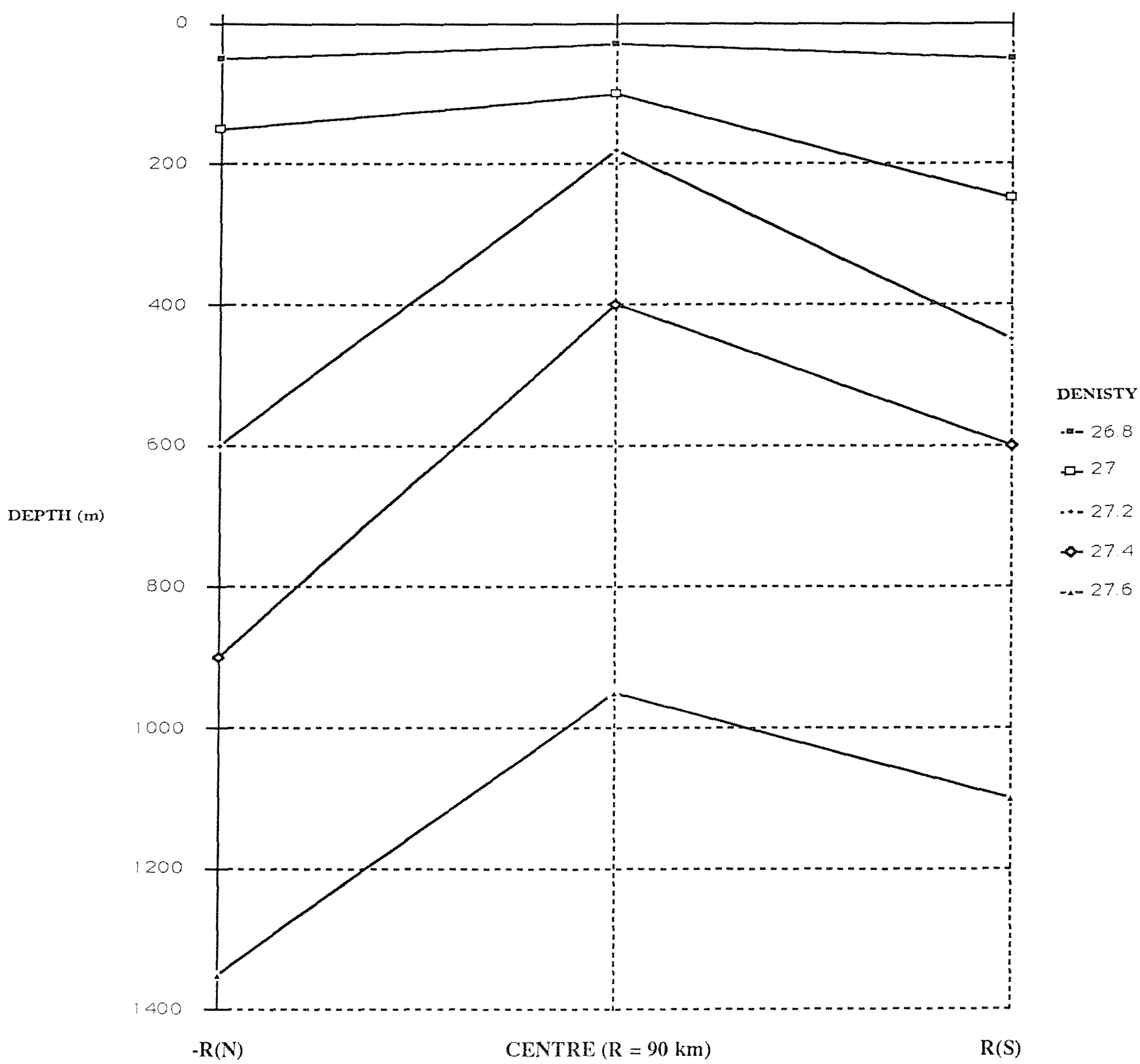
A MESOSCALE EDDY DIPOLE IN THE OFFSHORE CALIFORNIA CURRENT

DENSITY (σ_θ)		25.0	26.0	26.5	27.0	27.3
DEPTH	-R	50	160	270	550	860
(m)	C	25	120	270	540	850
	R	50	180	300	550	860



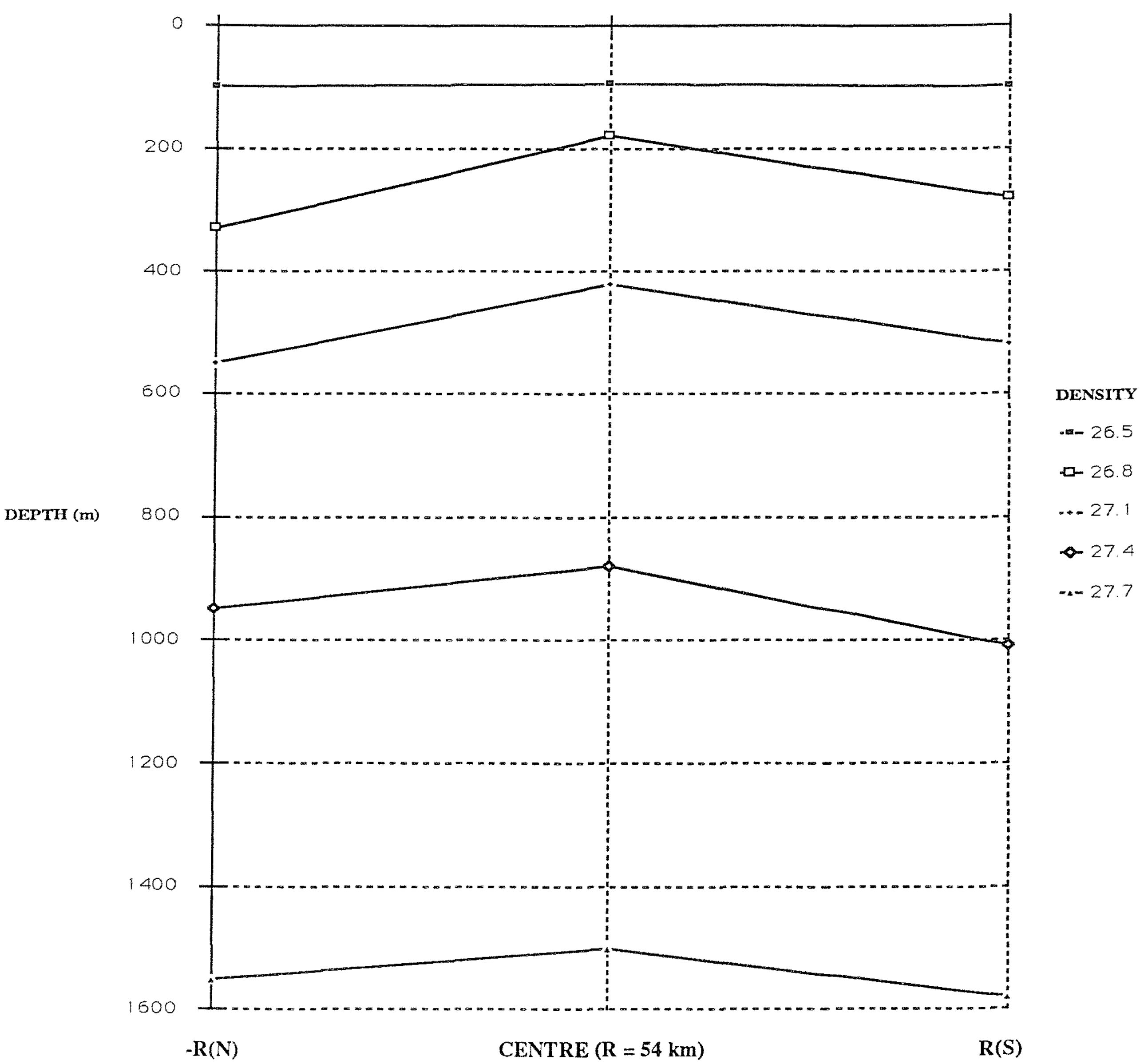
A CYCLONIC FRONTAL EDDY IN THE ANTARCTIC CIRCUMPOLAR CURRENT

DENSITY (σ_t)		26.8	27.0	27.2	27.4	27.6
DEPTH	-R	50	150	600	900	1350
(m)	C	30	100	180	400	950
	R	50	250	450	600	1100



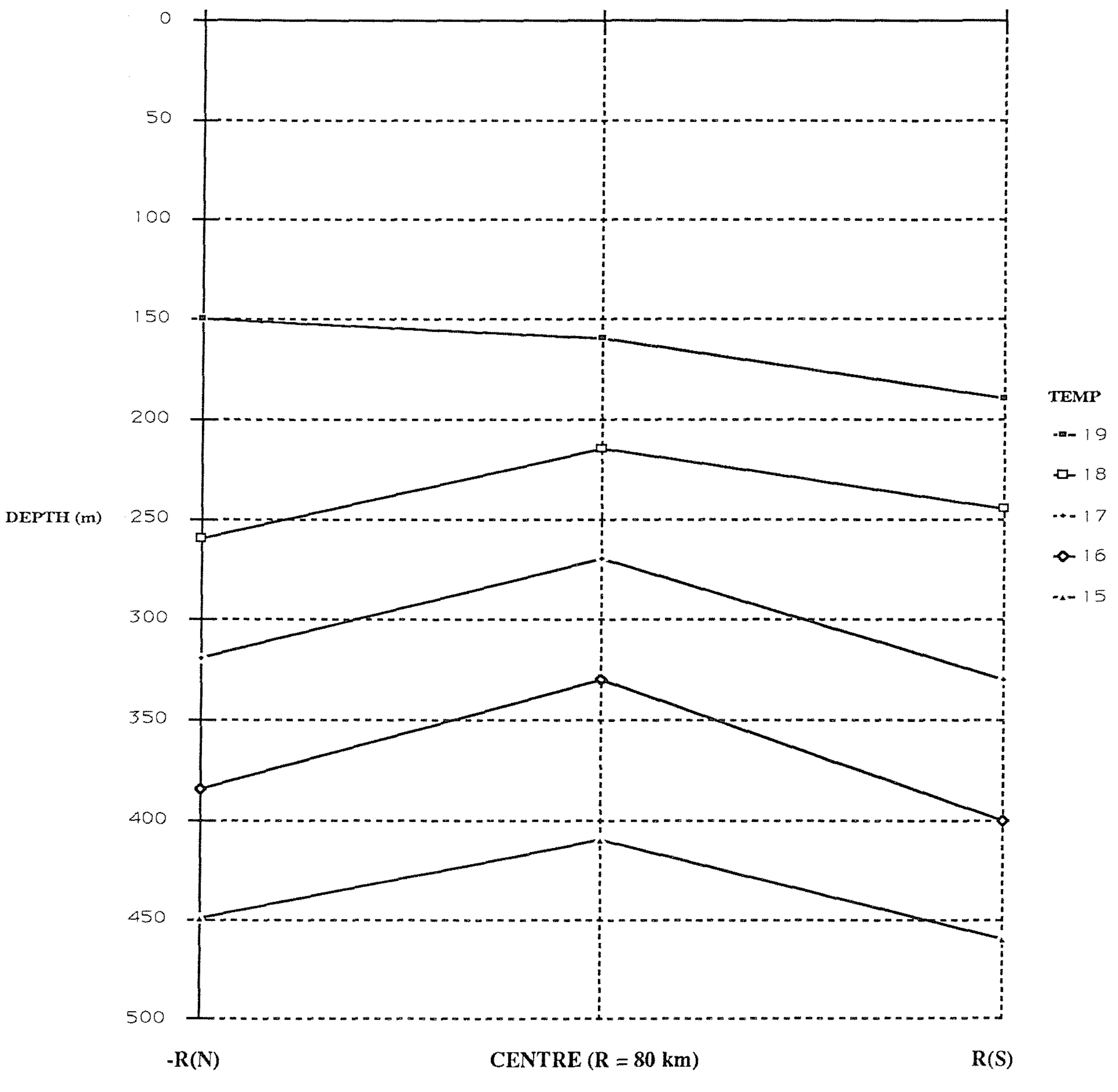
A CYCLONIC EDDY IN THE ANTARCTIC CIRCUMPOLAR CURRENT AND HEAT TRANSPORT ACROSS THE ANTARCTIC FRONT

DENSITY	(σ_t)	26.5	26.8	27.1	27.4	27.7
DEPTH	-R	100	330	550	950	1550
(m)	C	95	180	420	880	1500
	R	100	280	520	1010	1580



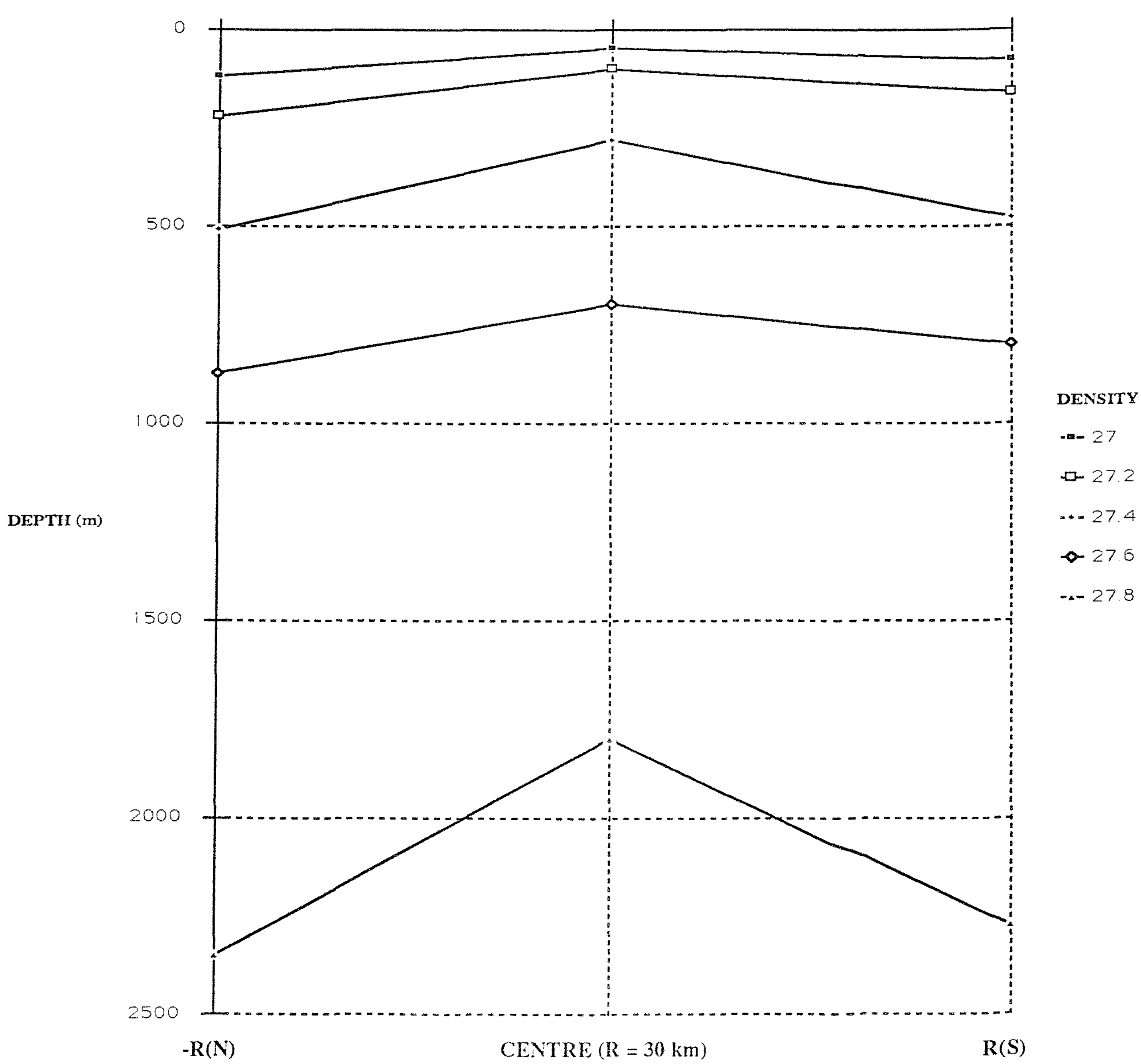
FURTHER STUDIES OF A COLD EDDY ON THE EASTERN SIDE OF THE GULF STREAM USING SATELLITE DATA AND SHIP DATA

TEMPERATURE (°C)		19	18	17	16	15
DEPTH	-R	150	260	320	385	450
(m)	C	160	215	270	330	410
	R	190	245	330	400	460



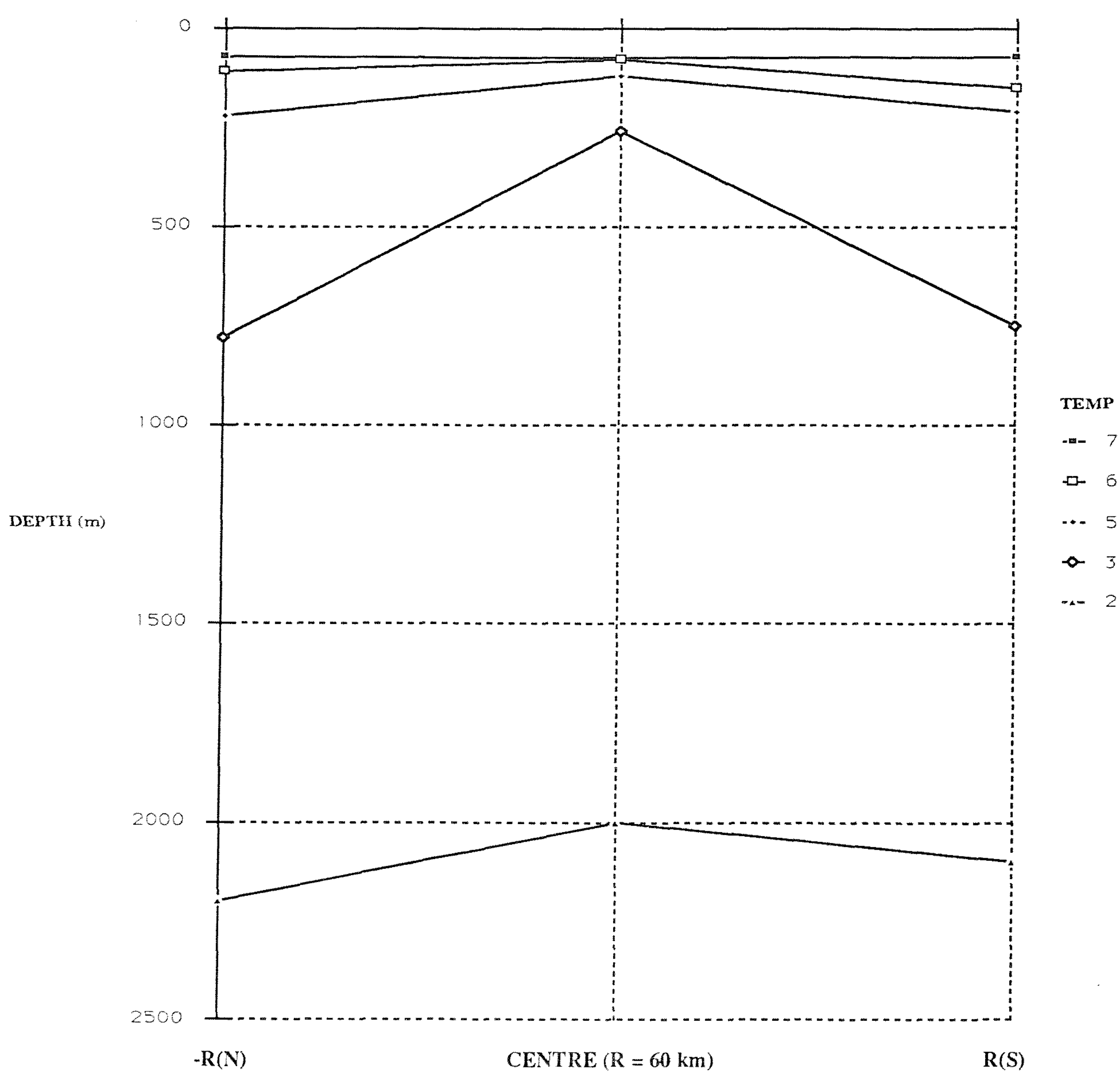
GENERATION AND EVOLUTION OF A CYCLONIC RING AT DRAKE PASSAGE IN EARLY 1979

DENSITY (σ_t)		27	27.2	27.4	27.6	27.8
DEPTH	-R	120	220	510	875	2350
(m)	C	50	100	280	700	1800
	R	80	160	480	800	2270



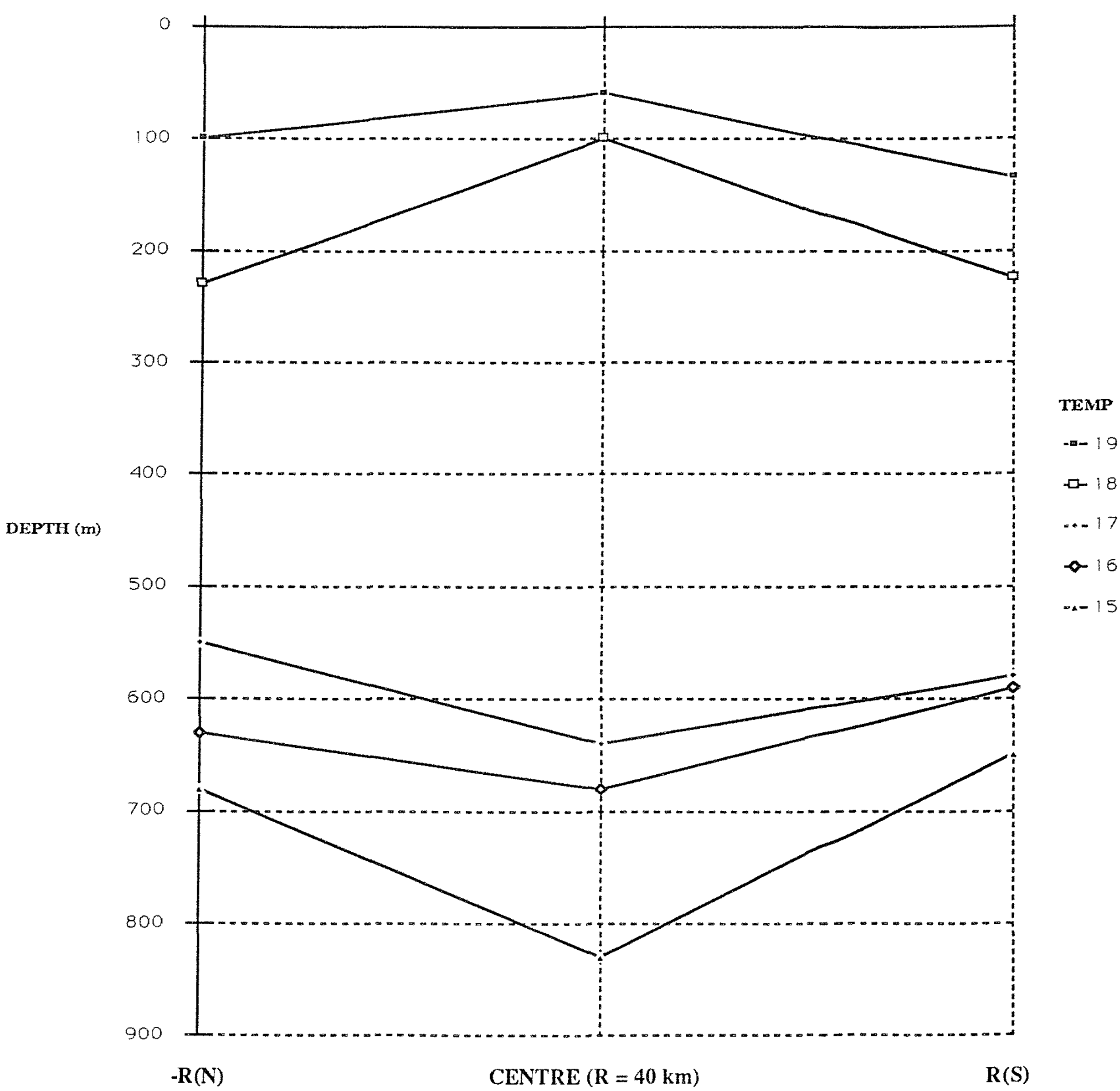
A CYCLONIC EDDY IN THE ANTARCTIC CIRCUMPOLAR CURRENT SOUTH OF AUTSTRALIA

TEMPERATURE (°C)		7	6	5	3	2
DEPTH	-R	70	110	220	780	2200
(m)	C	75	80	120	260	2000
	R	70	150	210	750	2100



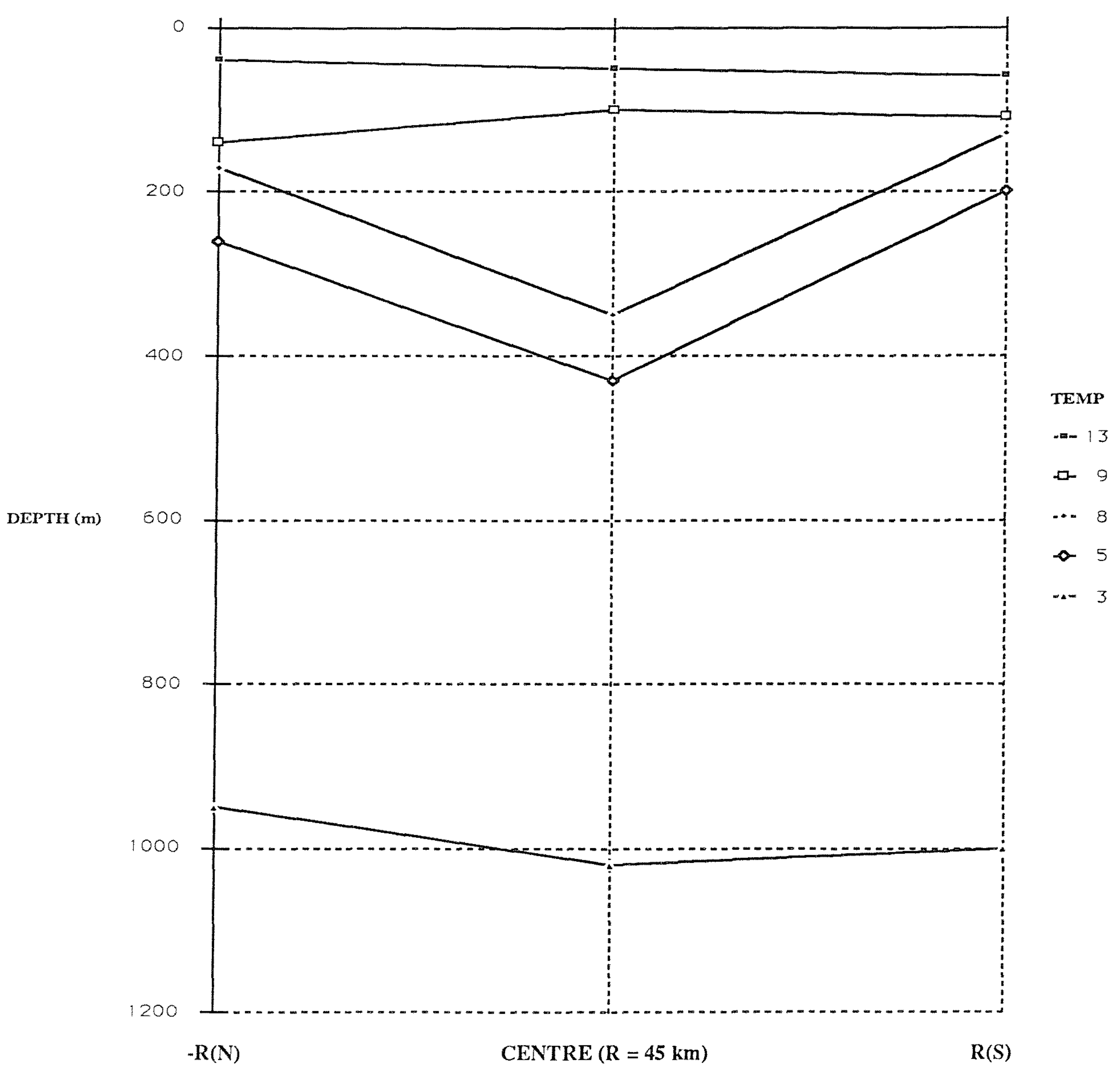
OBSERVATIONS OF AN ANTICYCLONIC EDDY OF 18°C WATER IN THE SARGASSO SEA

TEMPERATURE (°C)		19	18	17	16	15
DEPTH	-R	100	230	550	630	680
(m)	C	60	100	640	680	830
	R	135	225	580	590	650



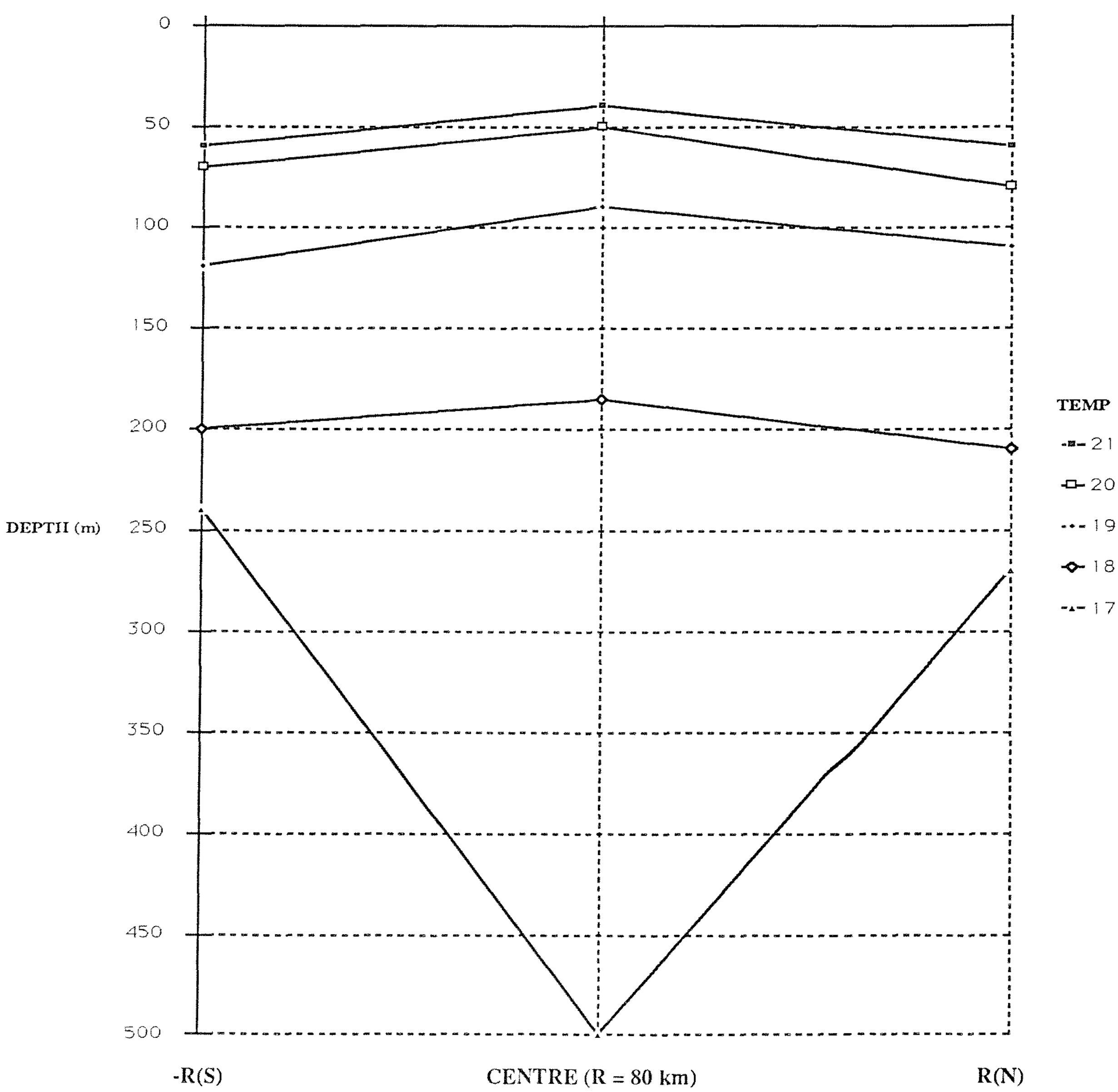
AN ANTICYCLONIC EDDY IN THE NORTHWESTERN PACIFIC

TEMPERATURE (°C)		13	9	8	5	3
DEPTH	-R	40	140	170	260	950
(m)	C	50	100	350	430	1020
	R	60	110	130	200	1000



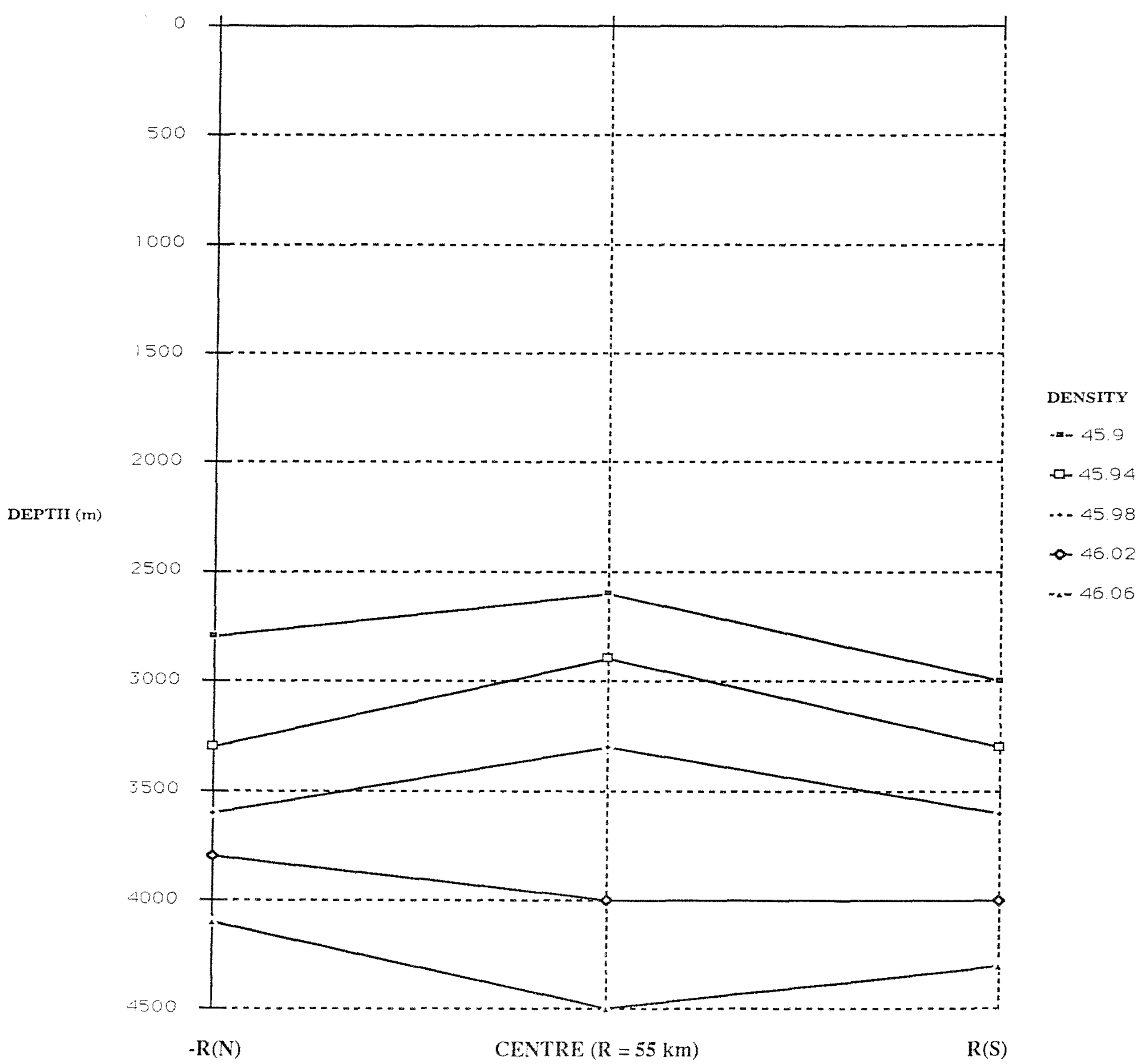
EDDIES OFF SOUTHEASTERN AUSTRALIA

TEMPERATURE (°C)		21	20	19	18	17
DEPTH	-R	60	70	120	200	240
(m)	C	40	50	90	185	500
	R	60	80	110	210	270



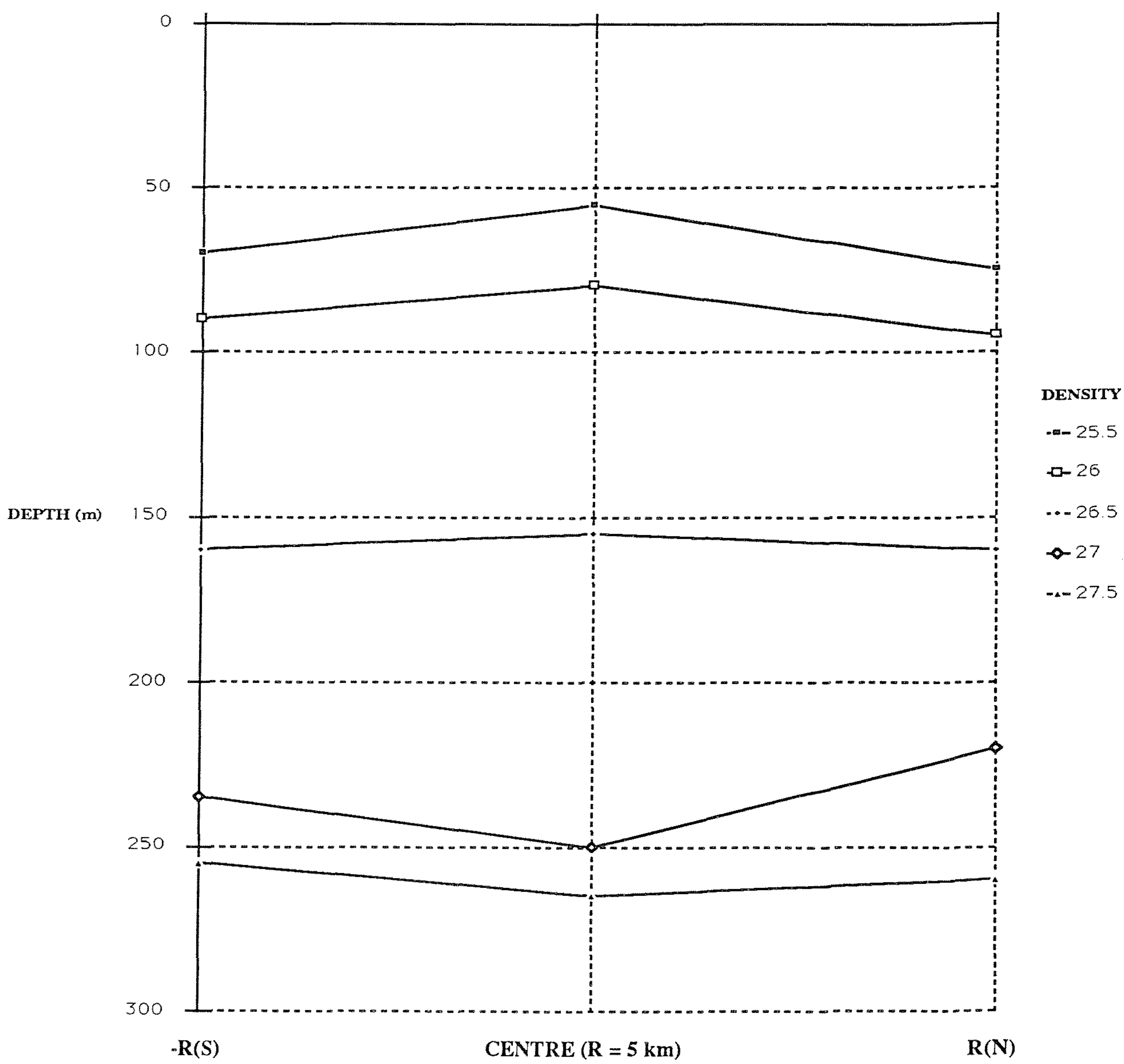
ABYSSAL EDDY IN THE SOUTHWEST ATLANTIC

DENSITY	(σ_4)	45.90	45.94	45.98	46.02	46.06
DEPTH	-R	2800	3300	3600	3800	4100
(m)	C	2600	2900	3300	4000	4500
	R	3000	3300	3600	4000	4300



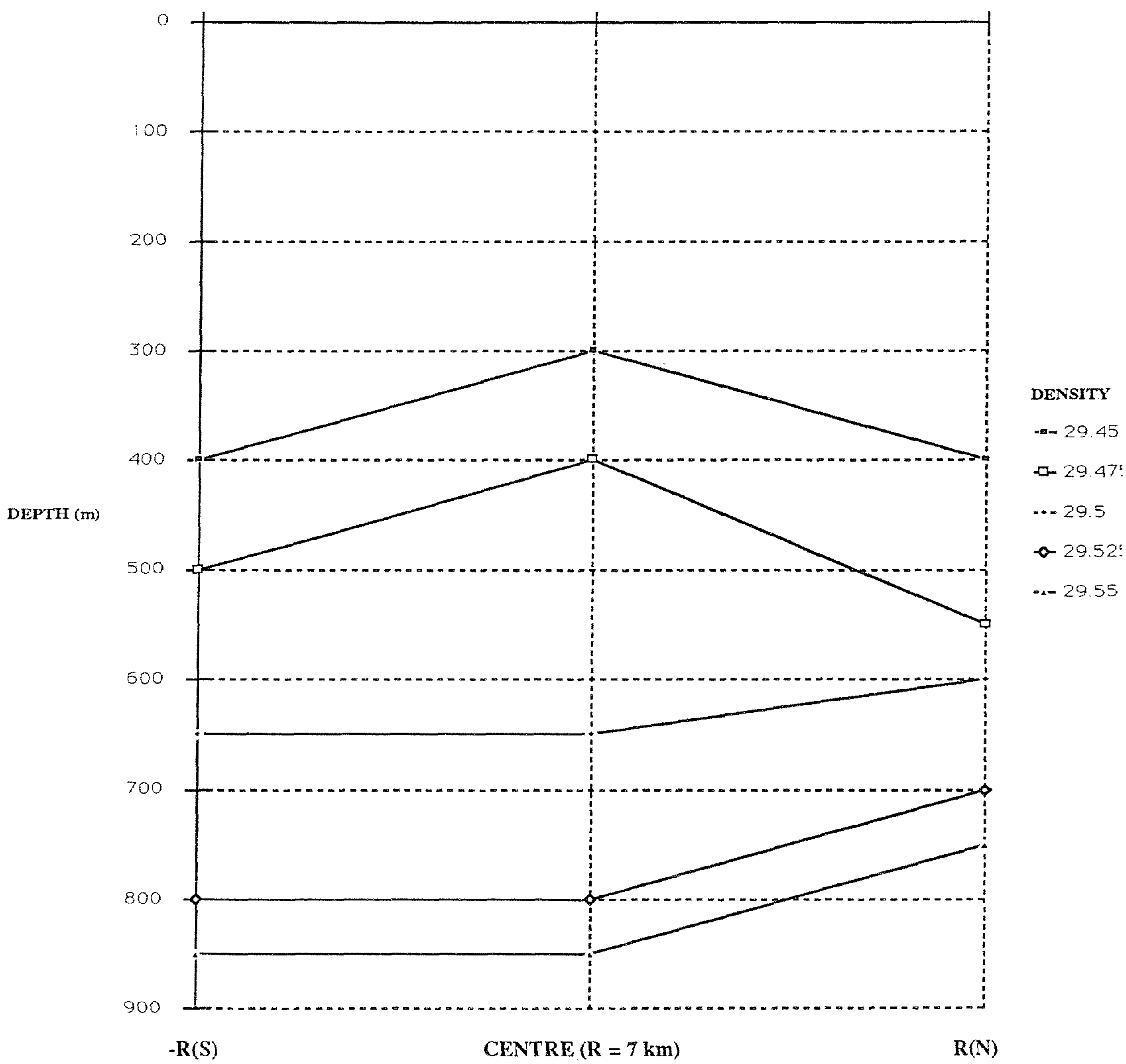
BAROCLINIC EDDIES IN THE ARCTIC OCEAN

DENSITY (σ_t)		25.5	26.0	26.5	27.0	27.5
DEPTH	-R	70	90	160	235	255
(m)	C	55	80	155	250	265
	R	75	95	160	220	260



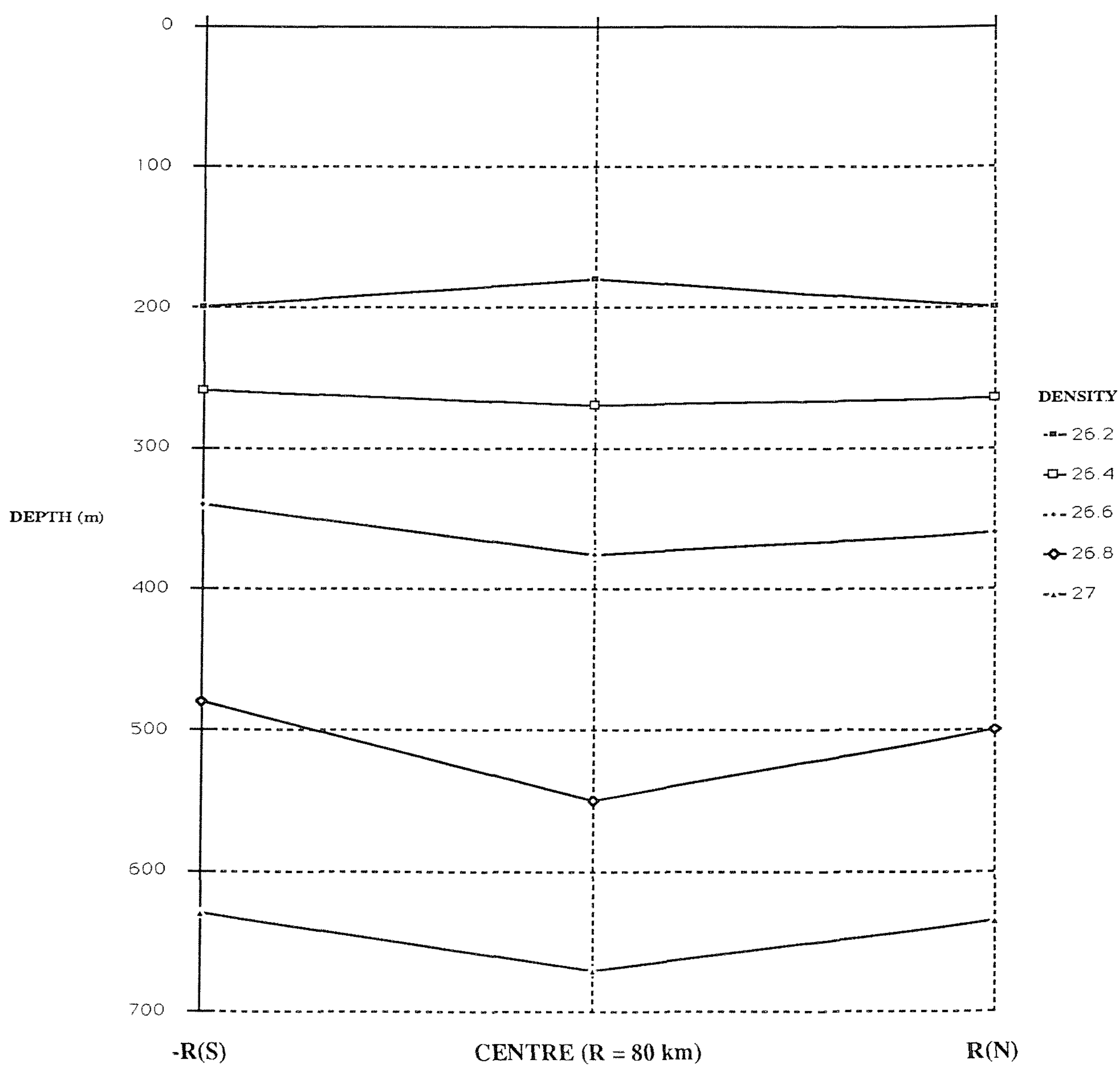
THE TOURBILLON EXPERIMENT:- A STUDY OF A MESOSCALE EDDY IN THE EASTERN NORTH ATLANTIC

DENSITY ($\sigma_{0.5}$)		29.45	29.475	29.50	29.525	29.55
DEPTH	-R	400	500	650	800	850
(m)	C	300	400	650	800	850
	R	400	550	600	700	750



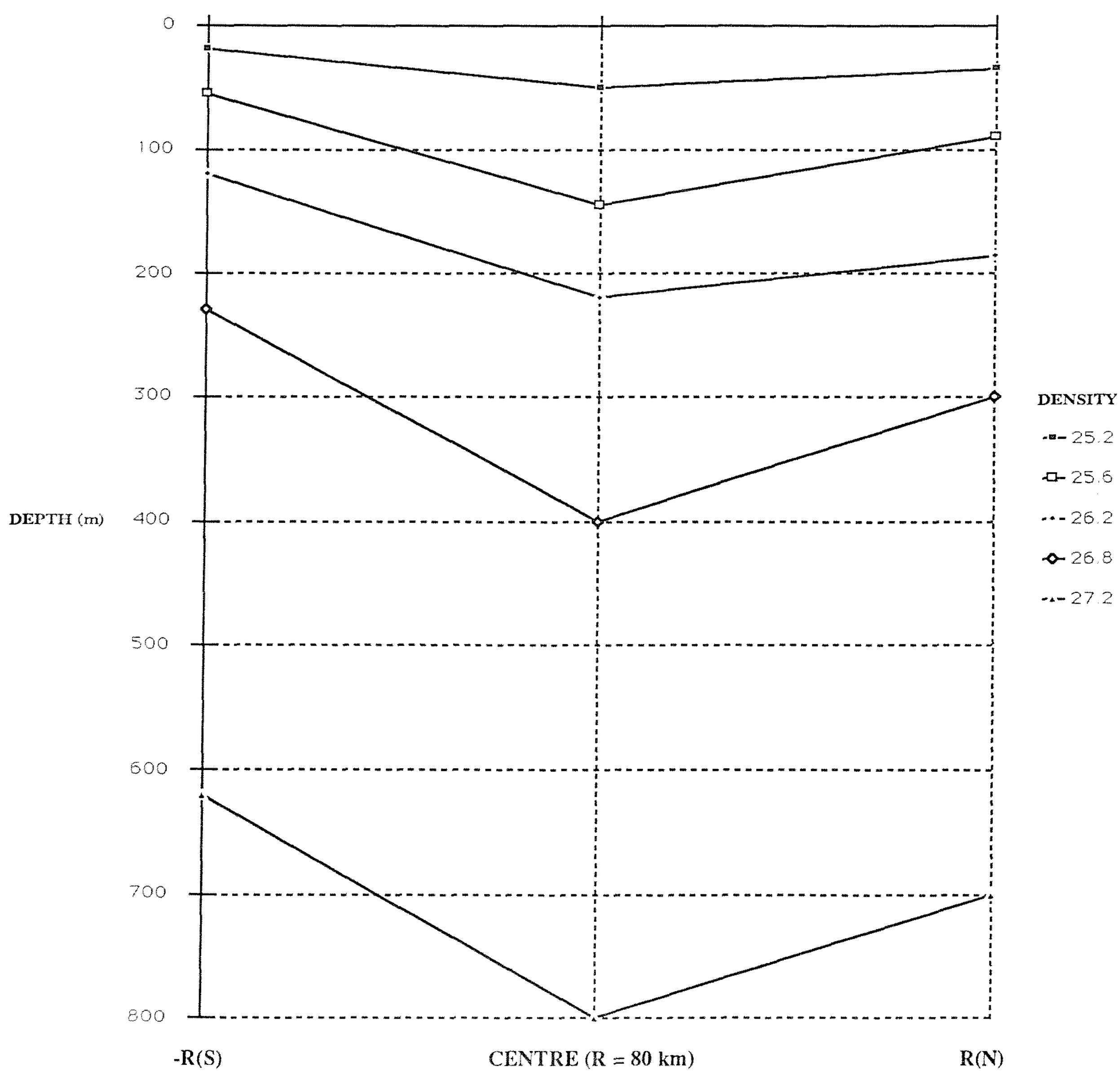
AN OFFSHORE EDDY IN THE CALIFORNIA CURRENT SYSTEM

DENSITY (σ_θ)	26.2	26.4	26.6	26.8	27.0
DEPTH -R	200	260	340	480	630
(m) C	180	270	375	550	670
R	200	265	360	500	635



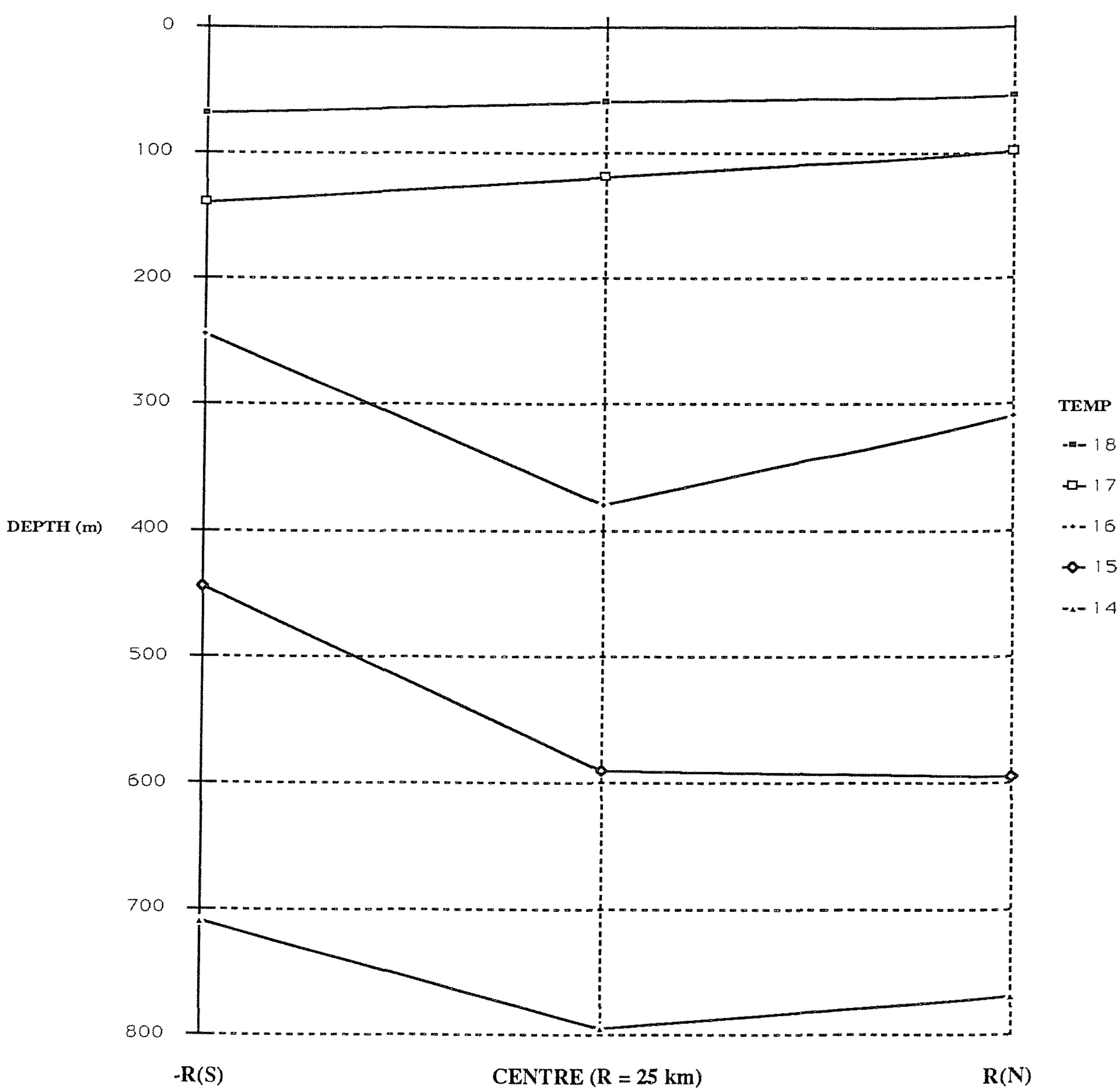
THE ANTICYLONIC BAROCLINIC EDDY OFF SITKA, ALASKA, IN THE NORTHEAST PACIFIC OCEAN

DENSITY (σ_t)		25.2	25.6	26.2	26.8	27.2
DEPTH	-R	20	55	120	230	620
(m)	C	50	145	220	400	800
	R	25	90	185	300	700



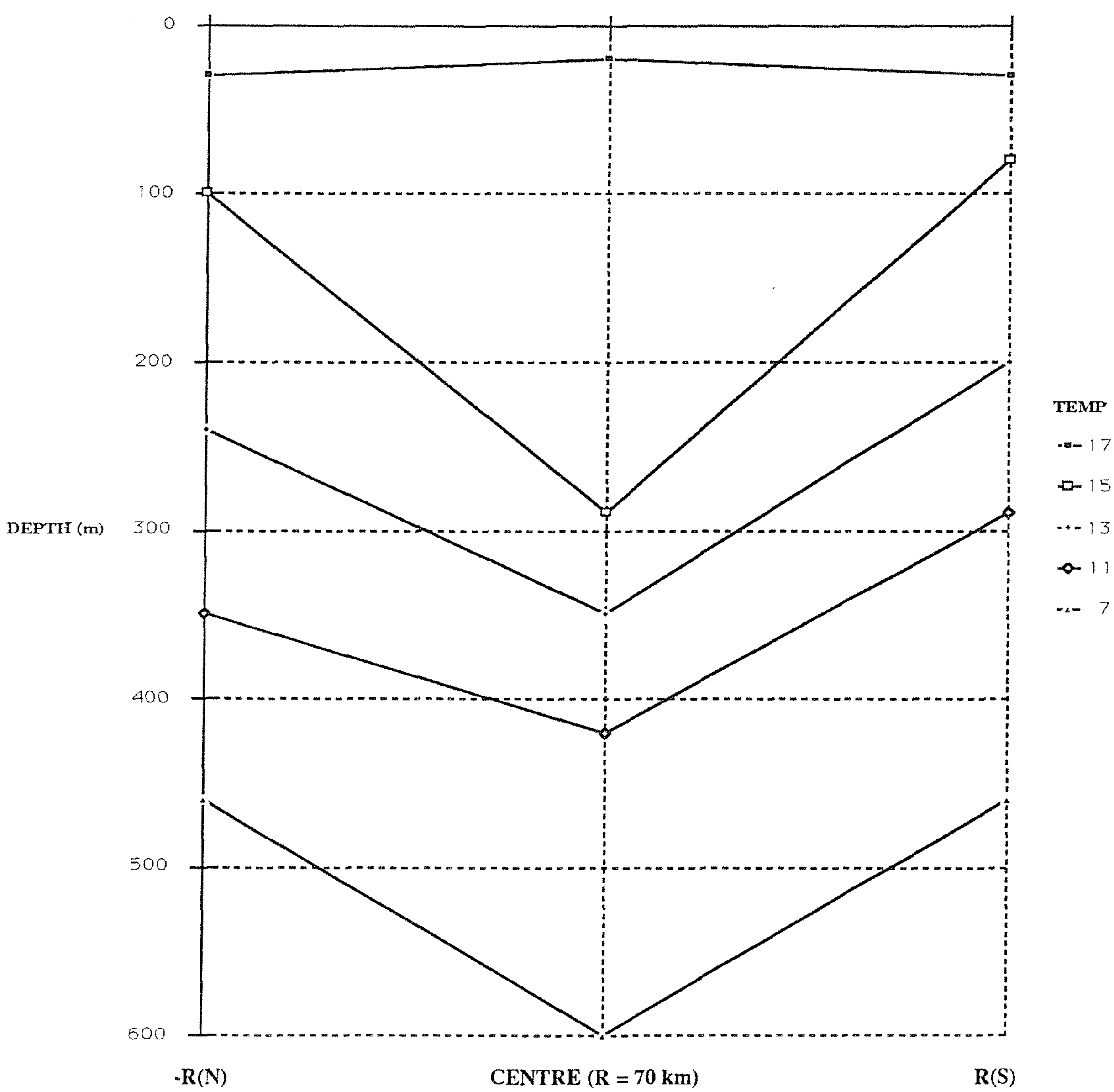
MOVEMENT AND GEOGRAPHICAL DISTRIBUTION OF ANTICYCLONIC EDDIES IN THE EASTERN LAVANTINE BASIN

TEMPERATURE (°C)		18	17	16	15	14
DEPTH	-R	70	140	245	445	710
(m)	C	60	120	380	590	795
	R	55	100	310	595	770



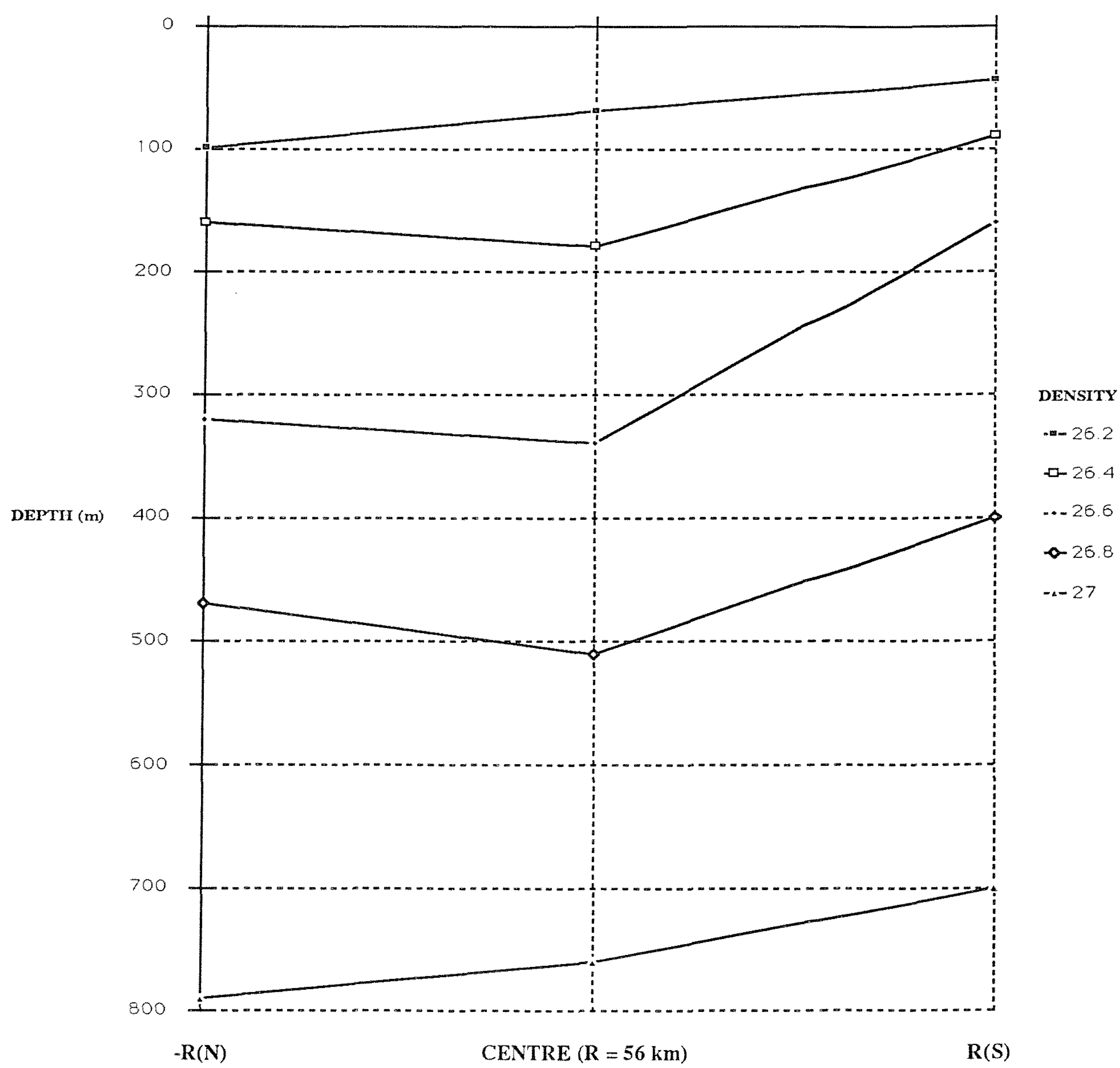
LIFE CYCLE OF A GULF STREAM ANTICYCLONIC EDDY OBSERVED FROM SEVERAL OCEANOGRAPHIC PLATFORMS

TEMPERATURE (°C)		17	15	13	11	7
DEPTH	-R	30	100	240	350	460
(m)	C	20	290	350	420	600
	R	30	80	200	290	460



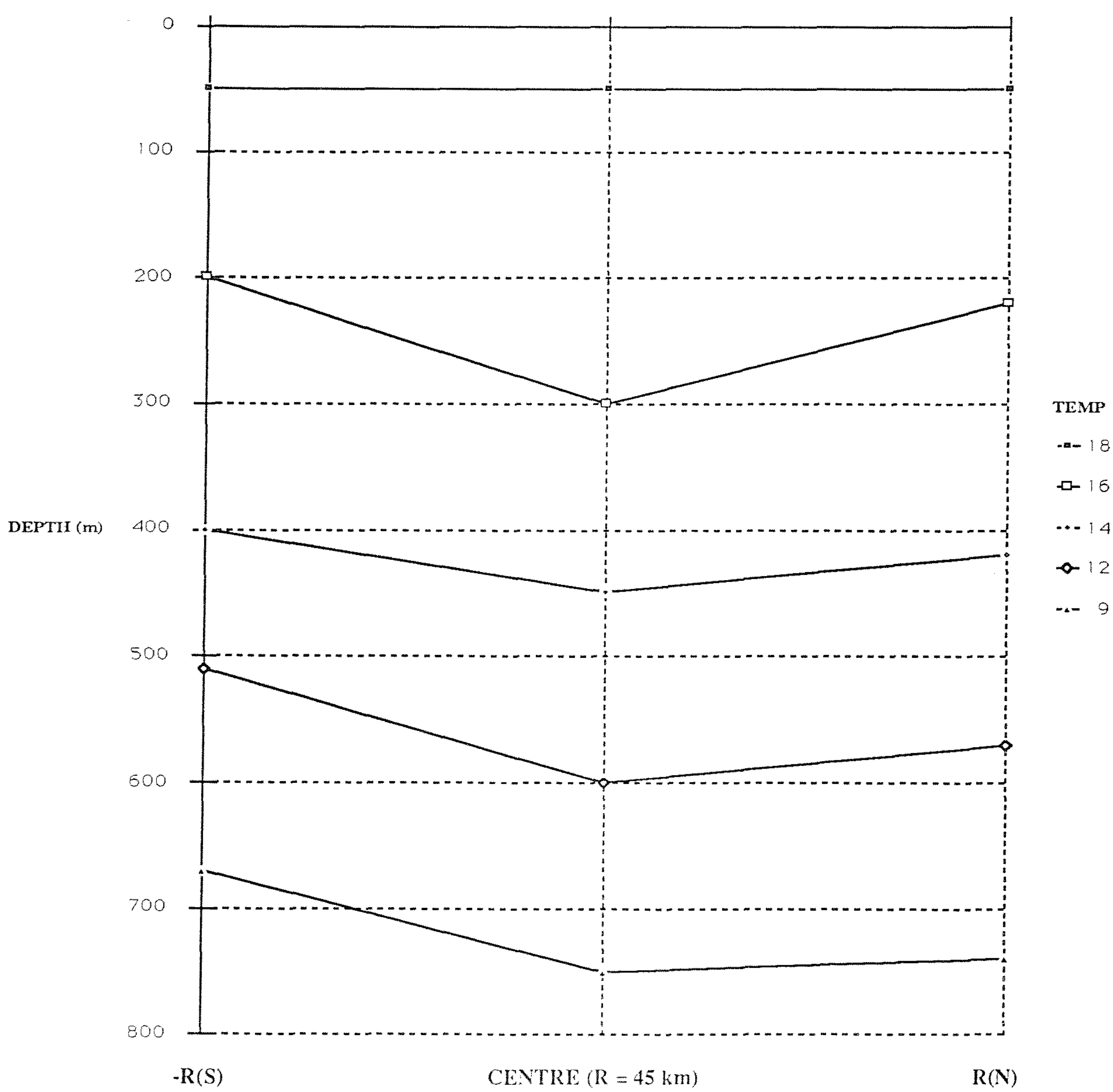
THE EFFECT OF WARM CORE EDDIES ON THE OCEANIC PRODUCTIVITY OFF NORTHEASTERN NEW ZEALAND

DENSITY	(σ_t)	26.2	26.4	26.6	26.8	27.0
DEPTH	-R	100	160	320	470	790
(m)	C	70	180	340	510	760
	R	45	90	160	400	700



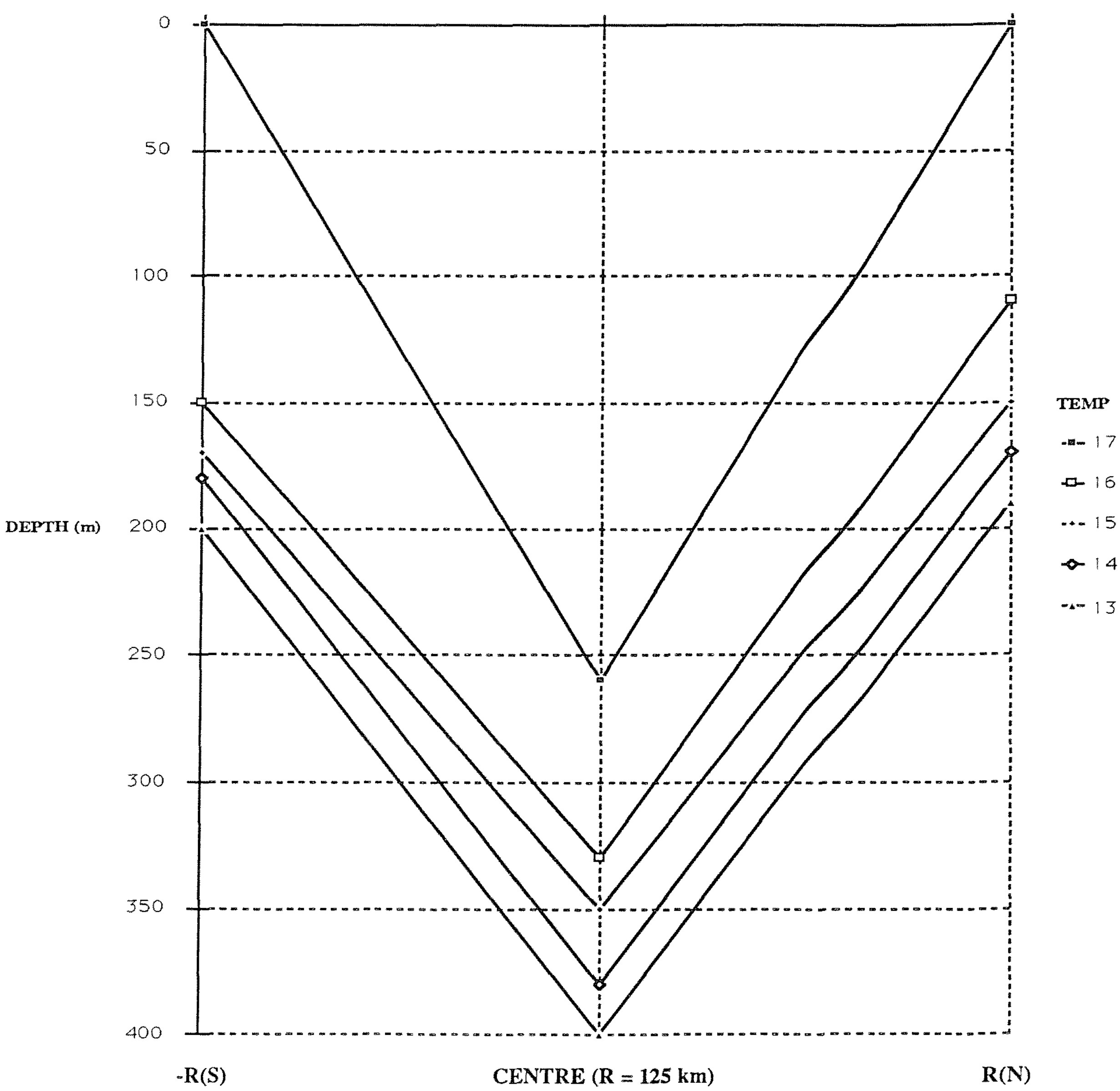
THE NORTH ATLANTIC CURRENT AND ITS ASSOCIATED EDDY FIELD SOUTHEAST OF THE FLEMISH CAP

TEMPERATURE (°C)		18	16	14	12	9
DEPTH	-R	50	200	400	510	670
(m)	C	50	300	450	600	750
	R	50	220	420	570	740



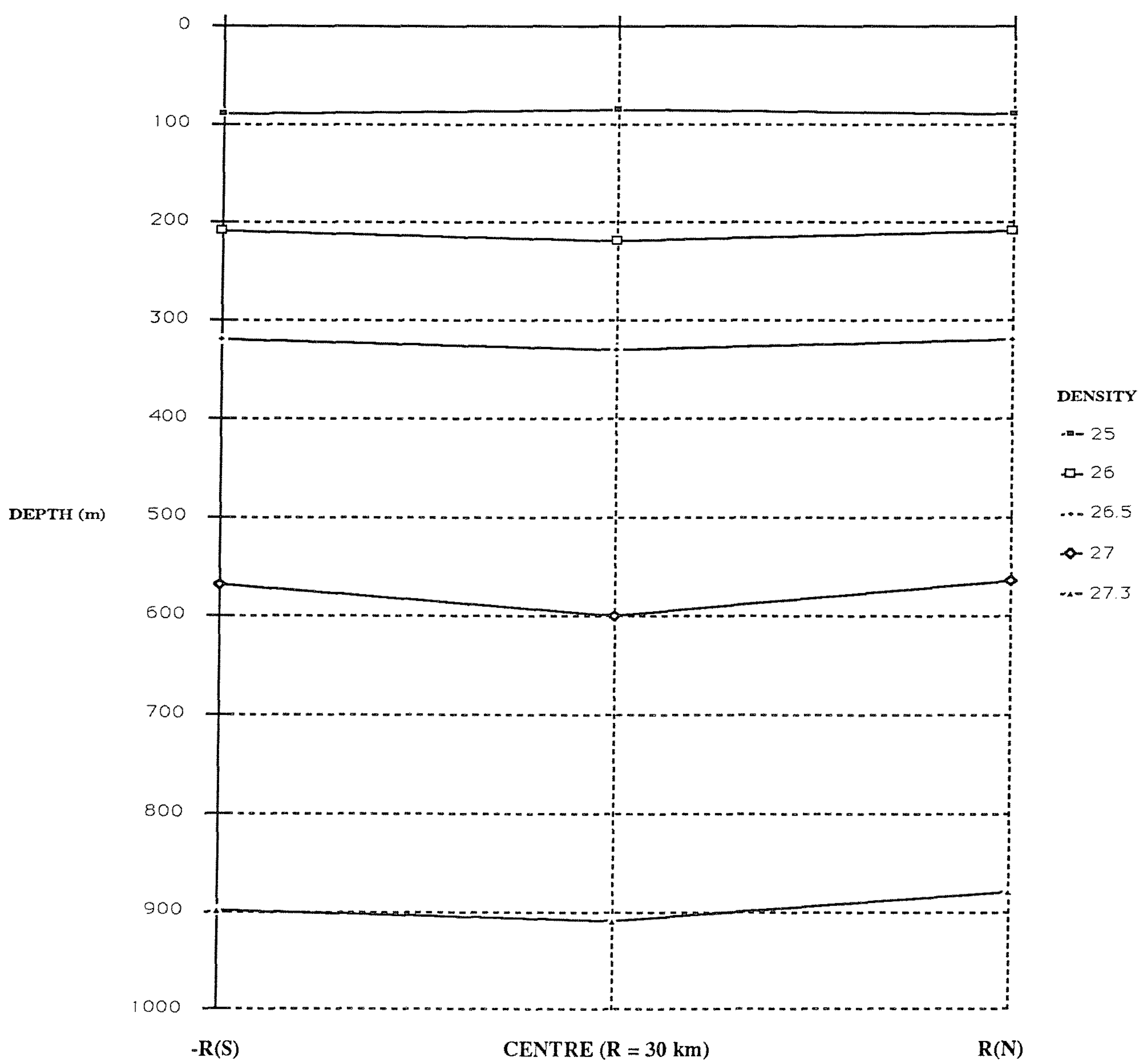
THE STRUCTURE OF AN EAST AUSTRALIAN CURRENT ANTICYLCONIC EDDY

TEMPERATURE (°C)		17	16	15	14	13
DEPTH	-R	0	150	170	180	200
(m)	C	260	330	350	380	400
	R	0	110	150	170	190



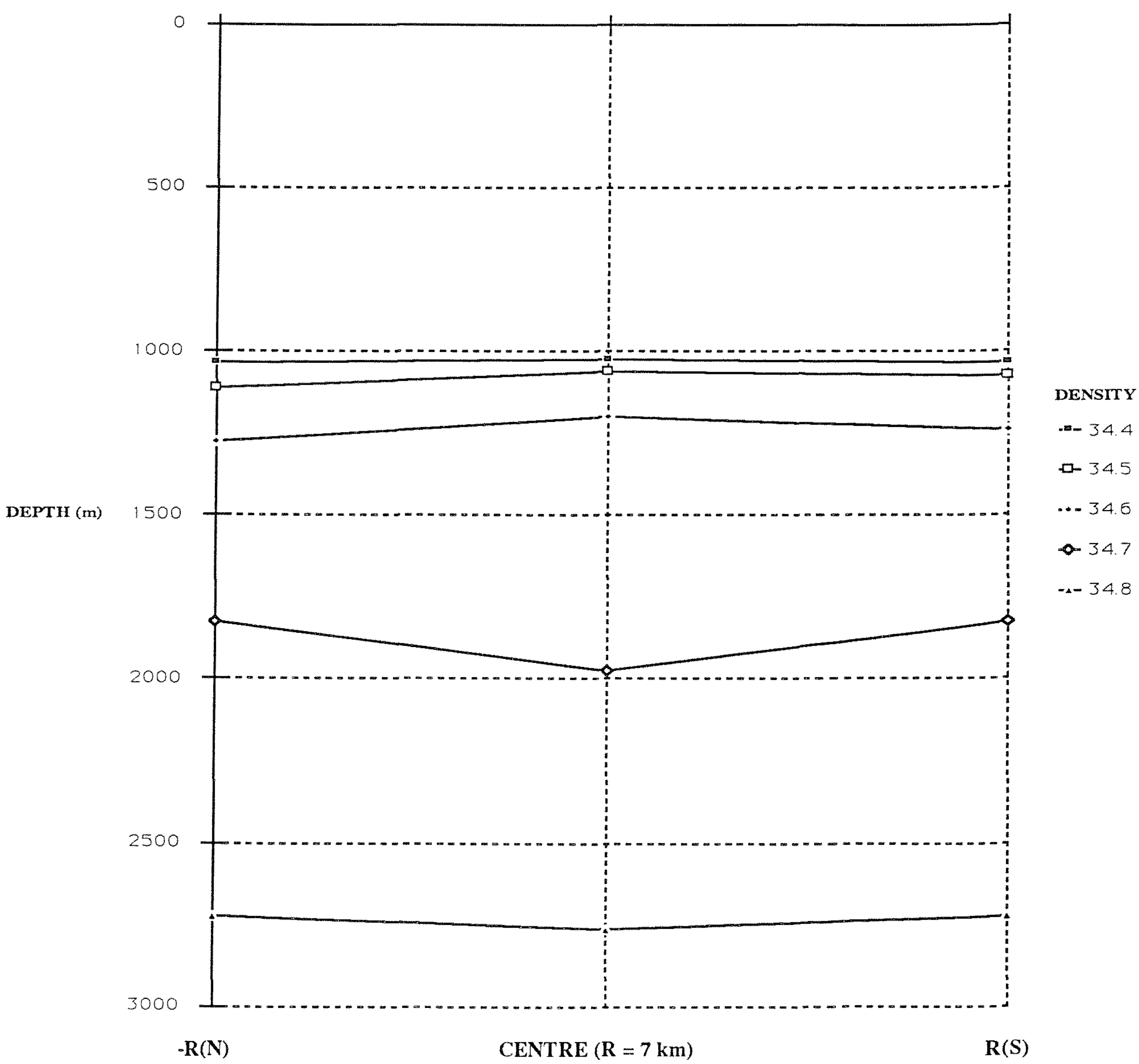
A MESOSCALE EDDY DIPOLE IN THE OFFSHORE CALIFORNIA CURRENT

DENSITY (σ_θ)		25.0	26.0	26.5	27.0	27.3
DEPTH	-R	90	210	320	570	900
(m)	C	85	220	330	600	910
	R	90	210	320	565	880



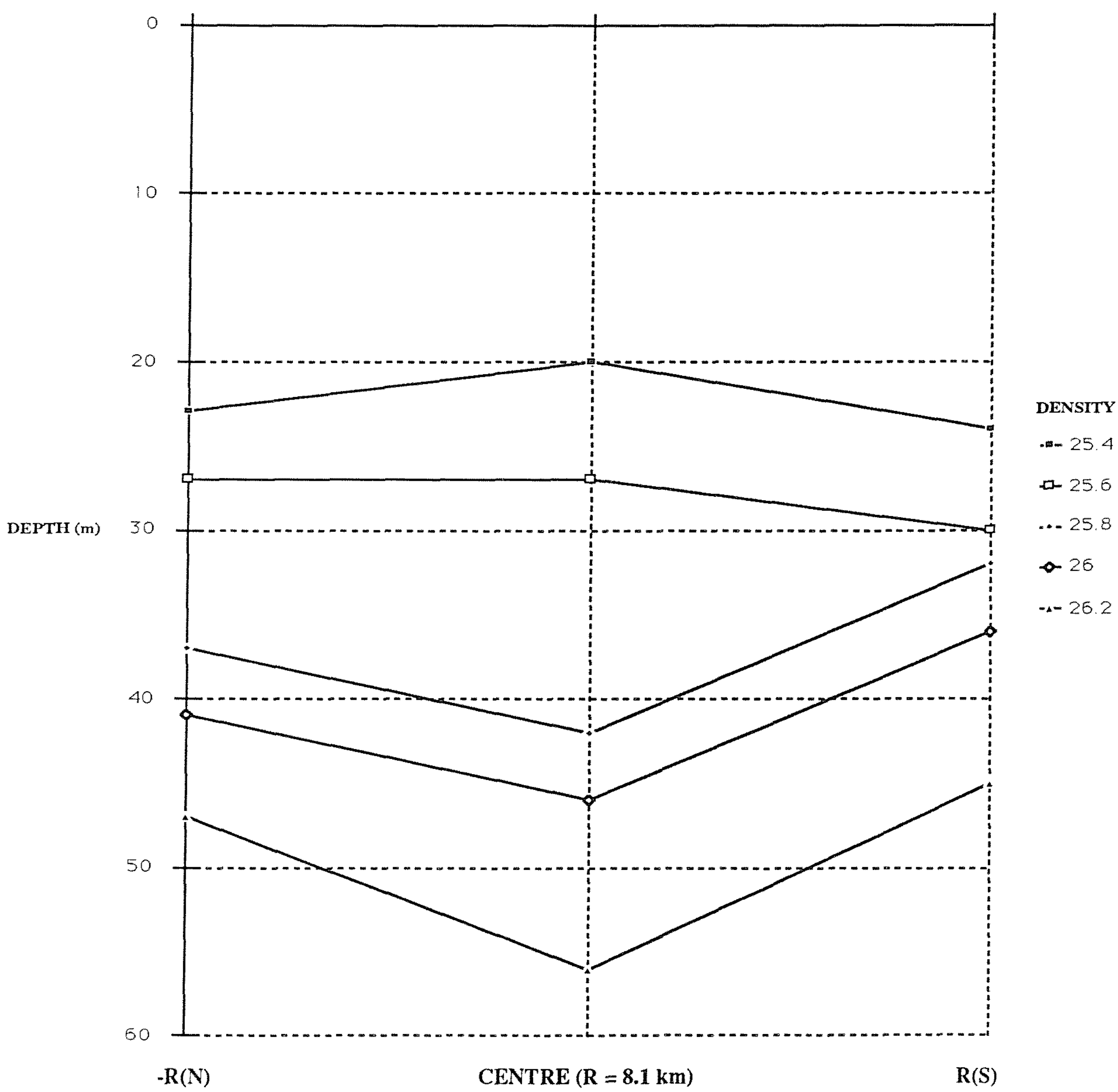
THE SUBTHERMOCLINE LENS D1, PART 1, DESCRIPTION OF WATER PROPERTIES AND VELOCITY PROFILES

DENSITY	($\sigma_{1.5}$)	34.4	34.5	34.6	34.7	34.8
DEPTH	-R	1038	1112	1275	1825	2725
(m)	C	1025	1062	1200	1975	2765
	R	1038	1075	1240	1825	2725



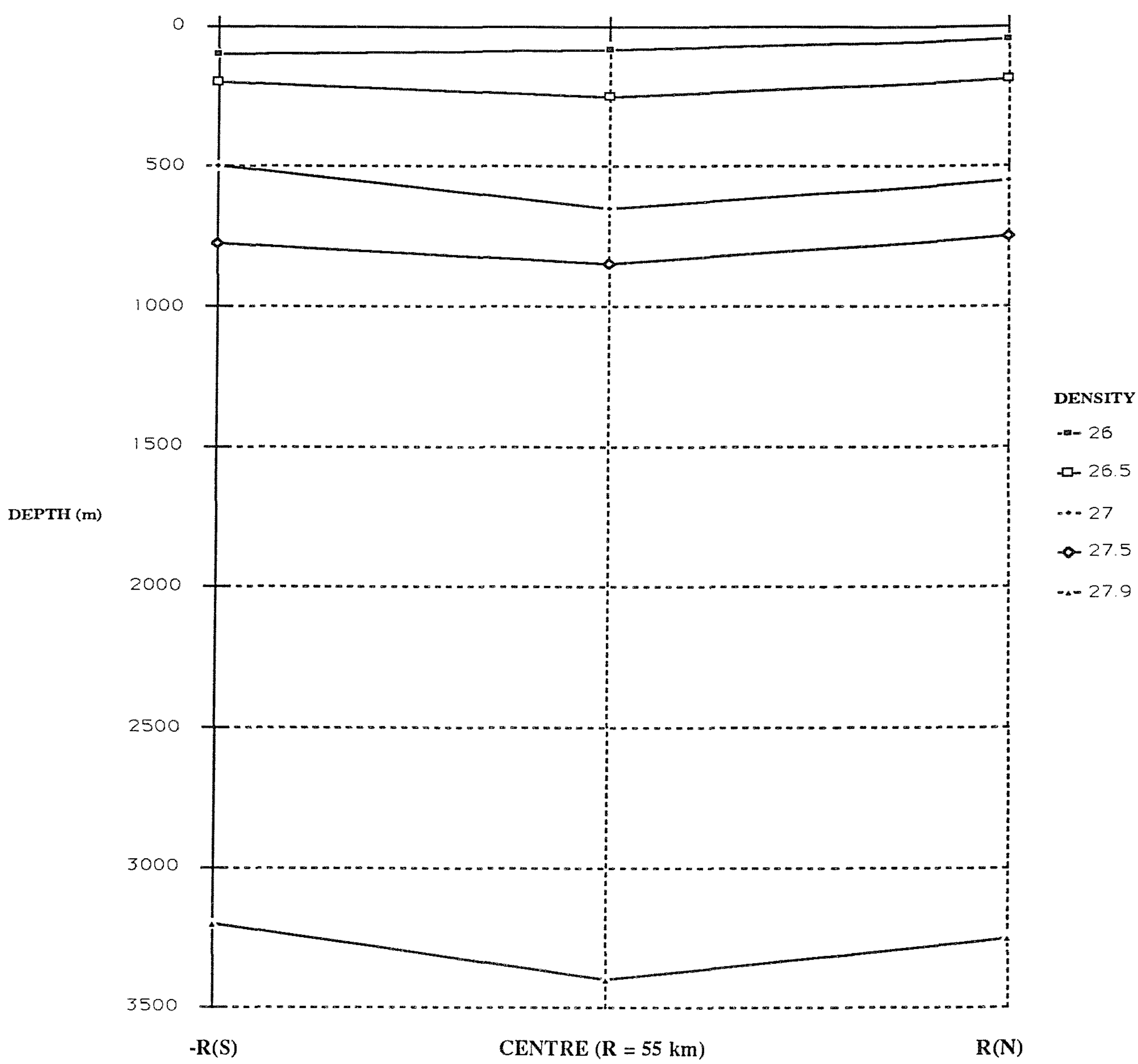
OBSERVATION OF AN ANTICYCLONIC EDDY NEAR THE CONTINENTAL SHELF BREAK SOUTH OF NEW ENGLAND

DENSITY (σ_t)		25.4	25.6	25.8	26.0	26.2
DEPTH	-R	23	27	37	41	47
(m)	C	20	27	42	46	56
	R	24	30	32	36	45



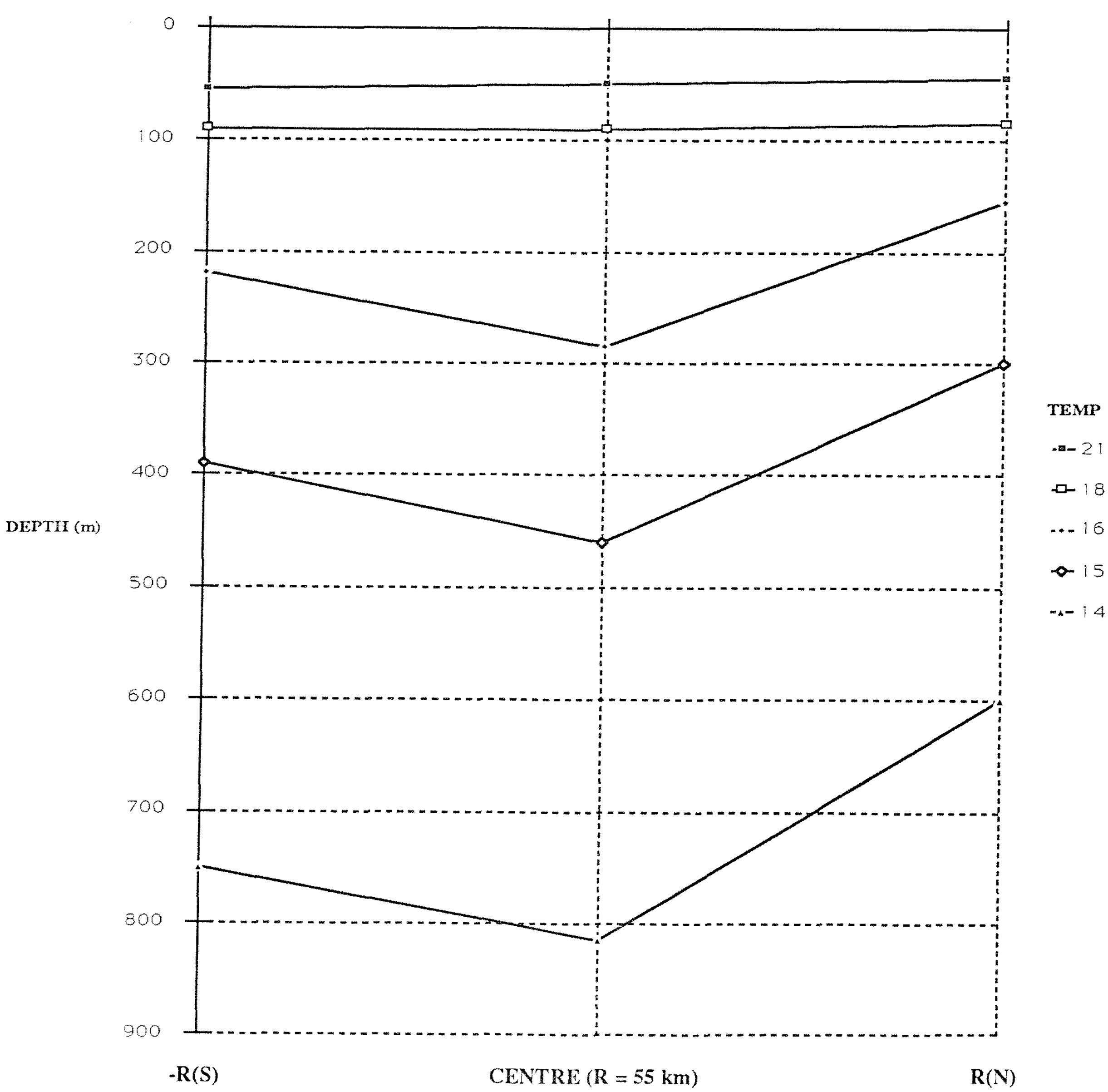
VELOCITY AND HYDROGRAPHIC STRUCTURE OF A GULF STREAM WARM-CORE RING

DENSITY (σ_θ)		26	26.5	27	27.5	27.9
DEPTH	-R	100	200	500	775	3200
(m)	C	85	250	650	850	3400
	R	50	190	550	750	3250



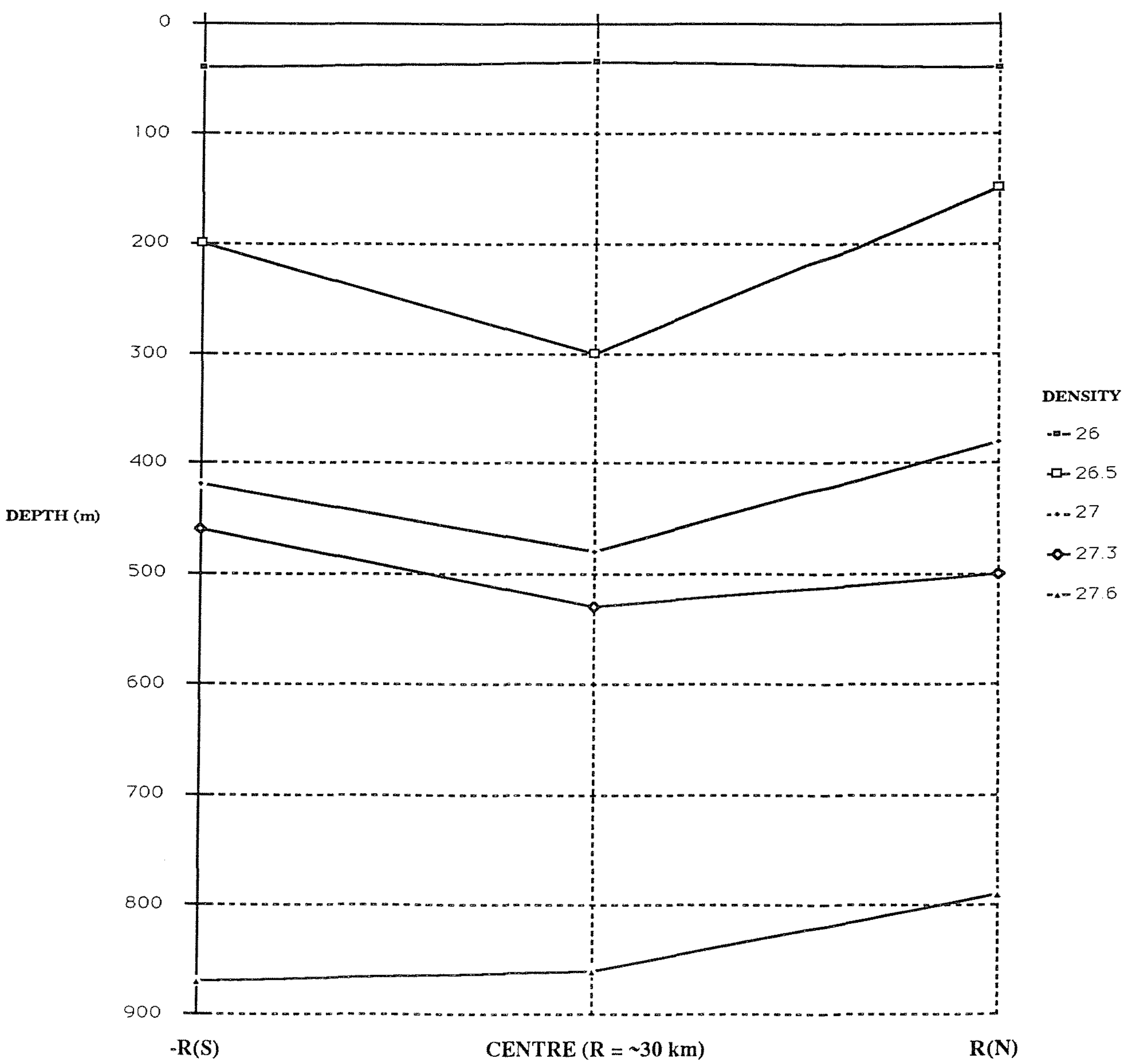
STRUCTURE AND EVOLUTION OF WARM CORE EDDIES IN THE EASTERN MEDITERRANEAN LEVANTINE BASIN

TEMPERATURE (°C)		21	18	16	15	14
DEPTH	-R	55	90	220	390	750
(m)	C	50	90	285	460	815
	R	45	85	155	300	600



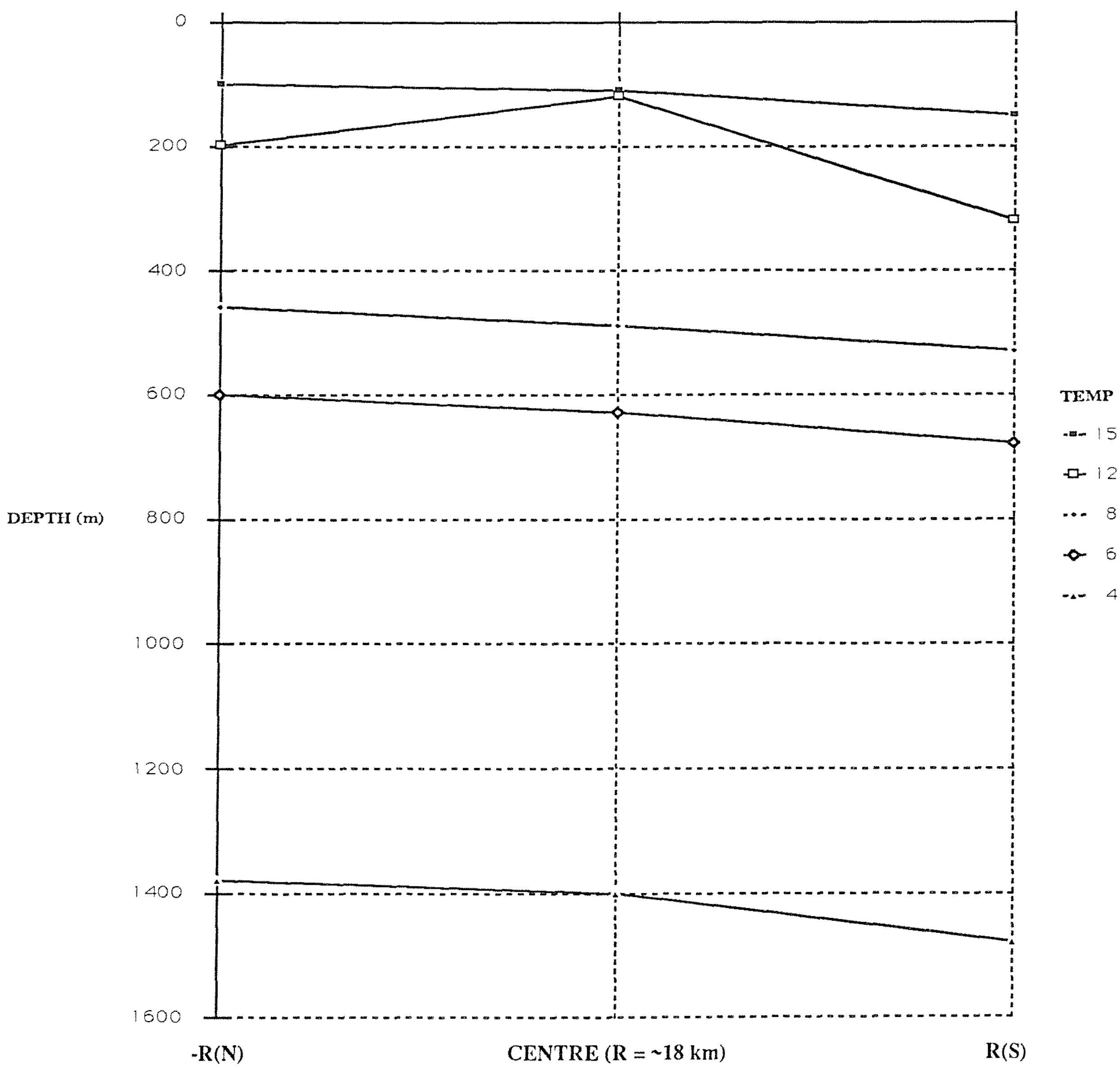
WINTERTIME CONVECTION IN WARM-CORE RINGS: THERMOCLINE VENTILATION AND THE FORMATION OF MESOSCALE LENSES

DENSITY (σ_θ)		26.0	26.8	27.0	27.3	27.6
DEPTH	-R	40	200	420	460	870
(m)	C	35	300	480	530	860
	R	40	150	380	500	790



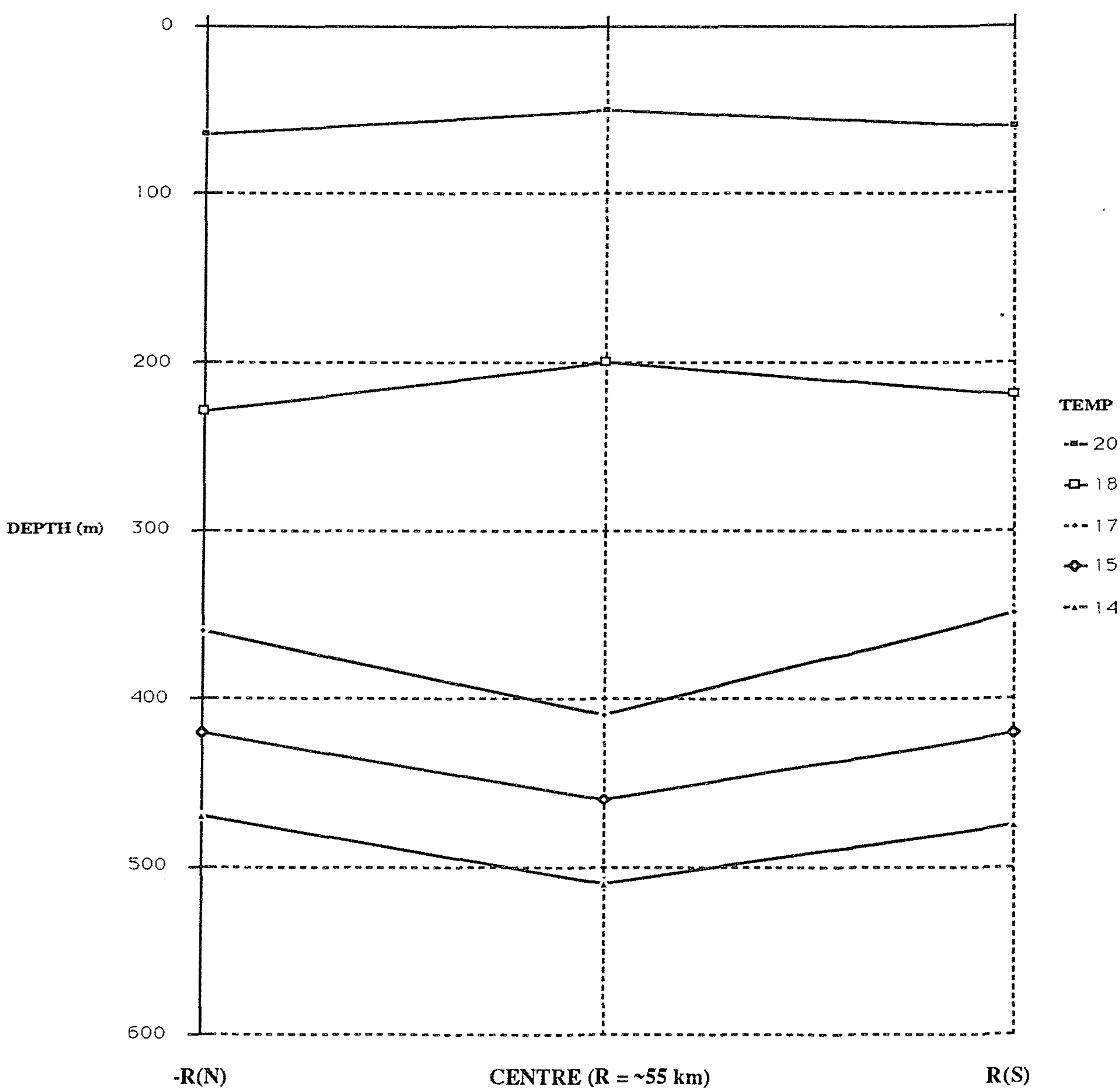
ANTICYCLONIC EDDY OBSERVATIONS IN THE SLOPE WATER ABROAD CGC EVERGREEN

TEMPERATURE (°C)		15	12	8	6	4
DEPTH	-R	100	200	460	600	1380
(m)	C	110	120	490	630	1400
	R	150	320	530	680	1480



SOME FEATURES OF FRONTAL EDDIES OF THE EAST AUSTRALIA CURRENT

TEMPERATURE (°C)		20	18	17	15	14
DEPTH	-R	65	230	360	420	470
(m)	C	50	200	410	460	510
	R	60	220	350	420	475



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