MASTER

DOE/EV/00889-7
VOL. 3

PROGRESS REPORT
CONTRACT DE-AS09-76EV00889

Larry P. Atkinson
-SKIO-

VOLUME 3

TECHNICAL REPORTS

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Technical Report Series
Number 80-1

HYDROGRAPHIC OBSERVATIONS OFF
SAVANNAH AND BRUNSWICK, GEORGIA
(MARCH, MAY, AND SEPTEMBER, 1977
AND JANUARY, 1978)

J. J. Singer
L. P. Atkinson
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and
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Georgia Marine Science Center
University System of Georgia
Skidaway Island, Georgia

INDEX VOLUME 3

Note: The technical reports are in order according to their tech report series numbers. In a case where data has been excluded, a yellow blank sheet has been inserted. The reports included are as follows:

<u>Series #</u>	<u>Title</u>
80-1	Hydrographic Observations off Savannah and Brunswick, Georgia (March, May and September, 1977 and January, 1978).
79-5	Hydrographic Observations in the Georgia Bight (April 1978).
79-3	Hydrographic Observations in the Georgia Bight (July 1977).
79-1	Hydrographic Observations in the Georgia Bight (December 1976).
78-7	ACTD System: Description, Operation, Data Acquisition and Processing.
78-5	Hydrographic Observations in the Georgia Bight (April 1977).
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HYDROGRAPHIC OBSERVATIONS OFF SAVANNAH AND BRUNSWICK, GEORGIA

(MARCH, MAY AND SEPTEMBER, 1977 AND JANUARY, 1978)

TECHNICAL REPORT 80-1

J. J. Singer

L.P. Atkinson

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S.S. Bishop

The Technical Report Series of the Georgia Marine Science Center is issued by the Georgia Sea Grant Program and the Marine Extension Service of the University of Georgia on Skidaway Island (P.O. Box 13687, Savannah, Georgia 31406). It was established to provide dissemination of technical information and progress reports resulting from marine studies and investigations mainly by staff and faculty of the University System of Georgia. In addition, it is intended for the presentation of techniques and methods, reduced data and general information of interest to industry, local, regional, and state governments and the public. Information contained in these reports is in the public domain. If this prepublication copy is cited, it should be cited as an unpublished manuscript.

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ACKNOWLEDGEMENTS

The authors thank all those who participated in these cruises. These include the following scientists, technicians and students: Jack Blanton, Beth Bonnett, Tom Creighton, Don Deibel, Marilyn DeVand, Jeff Goodwin, Paul Magid, Jean Nichols, Pat O'Malley, Gus Paffenhofer, Don Rice, Lynn Rubicam and Frank Taylor.

Special thanks go to the captains, mates and crews of the R/V Blue Fin and the R/V Columbus Iselin. Pat O'Malley directed nutrient analyses with the able assistance of Terry DeLoach, Paul Magid and Lynn Rubicam. Bob Redmond, Lori Knight and Dan McIntosh provided drafting and graphics assistance and Linda Land typed the text.

Funding for this research and report preparation was provided by the Department of Energy under contract EY-76-S-09-0889 to Dr. Atkinson.

This report is published as part of the Georgia Marine Science Center's Technical Report series issued by the Georgia Sea Grant Program under NOAA Office of Sea Grant 04-7-158-44126.

ABSTRACT

Seasonal onshore-offshore sections were run in March, May and September, 1977 and January, 1978 off Savannah and Brunswick, Georgia. In each instance upwelling was observed at the shelf break with significant nutrient fluxes into the surface and/or shelf waters. There are indications that eddies may have been responsible for some of these observations.

INTRODUCTION

This report contains data obtained during the following seasonal Georgia Bight cruises:

Table 1. Georgia Bight Cruises.

<u>Cruise Number</u>	<u>Date</u>	<u>Sections</u>	<u>Parameters Sampled</u>
BF-14-77	3/8-9/77	2 XBT	$^{\circ}\text{C}$
BF-38-77	5/26-27/77	1 CTD/XBT	$^{\circ}\text{C}$, O/O_2 , NO_3 , PO_4 , Si
BF-57-77	9/13-14/77	1 CTD/1 XBT	$^{\circ}\text{C}$, O/O_2 , NO_3 , PO_4 , Si
CI-01-78	1/23-26/78	2 XBT	$^{\circ}\text{C}$, O/O_2 , NO_3 , PO_4 , Si, Chl-a

These investigations were part of a larger multi-institutional Department of Energy program to understand event scale, physical, chemical and biological processes of the South Atlantic Bight, the continental shelf region from Cape Canaveral, Florida to Cape Hatteras, North Carolina. The studies reported here were concentrated in the Georgia Bight near Brunswick and Savannah, Georgia. The hydrographic data will be used to compare with data from moored instruments deployed by the University of Miami (Dr. Tom Lee). All data are presented in the Appendix and are on file with the National Oceanographic Data Center (NODC).

METHODS

SAMPLING

One or two onshore/offshore hydrographic sections were run during each cruise. These consisted of conductivity/temperature/depth (CTD) or expendable bathythermograph (XBT) casts along sections extending ESE of Savannah and Brunswick, Georgia. The stations were 10 to 20 kilometers apart and extended out to the shelf break (Figures 1-4).

At CTD stations, a General Oceanics Model 1015 Mark 5 Rosette multi-bottle array was used for water sampling. A Plessey Model 9400 CTD sensor system was attached below the array. Water sampling depths were determined from the temperature structure. Samples were taken near the surface, just above or below the thermocline, at the bottom and occasionally at other selected depths. Data are reported for temperature, salinity, nitrate, phosphate and silicate concentrations. Niskin bottle casts were also made at some but not all of the XBT stations.

CHEMICAL AND PHYSICAL PROCEDURES

Salinity samples were analyzed conductometrically using a Plessey Model 6230 N laboratory salinometer. Values obtained were used to calibrate the Plessey CTD system. A separate section of this report details the CTD calibration procedure. Temperature was determined with deep sea reversing thermometers, XBT's and the CTD system.

Nutrient samples were immediately frozen in 125 ml. polyethylene bottles and stored in the dark until thawed and analyzed ashore. Colorimetric determinations of the nutrient concentrations were made using a Bausch and Lomb Spectronic 88 Spectrophotometer. Silicate was determined by the method of Mullin and Riley (1955) as modified by Strickland and Parsons (1972), phosphate by the method of Murphy and Riley (1962) and nitrate by the cadmium column reduction technique of Gardner et al. (1976).

Chlorophyll-a was determined fluorometrically using the method of Yentsch and Menzel (1963) as described by Strickland and Parsons (1972).

XBT Data Acquisition and Processing

A Sippican Model LM3A handheld launcher and an MK2A-1 recorder were used for XBT casts. The temperature/depth plots were manually digitized and these data were placed in NODC format and merged with processed CTD data. Depths at which temperature is a whole or half degree are reported as are depths at which a significant mixed layer begins or ends.

CTD Data Acquisition and Processing

The CTD unit consisted of a Plessey Model 9400 CTD sensor system with a Model 8400 digital data logger and Kennedy Model 1600 incremental magnetic tape recorder for data acquisition and storage. A redundant XYY' plot was made of all casts using a Hewlett-Packard Model 7046 X-Y-Y recorder calibrated with a precision 10VDC source.

A second data acquisition system under development was also used during these cruises. It involved the addition of an HP 9825A Calculator to control the casts and to record the data on cartridge tape, and an HP 9862A Plotter to plot temperature during the cast and salinity immediately afterwards. This permitted immediate confirmation of data acquisition and its relative quality.

Details of the operation of these systems and the processing of data are presented in Chandler et al. (1978). A general outline of the magnetic tape data processing is presented in Table 2.

CTD and XBT Calibration

For primary calibration of temperature and salinity, a Niskin bottle equipped with paired protected deep sea reversing thermometers was tripped after a four-minute equilibration period at the maximum sample depth in mixed layers.

Additional salinity calibration data were collected from mixed layers during the upcast. At the bottom and at selected sampling depths, the CTD sampling rate was slowed and salinity calibration data were acquired before the bottles were tripped.

From analysis of these data (Tables 3 and 4), the following salinity offsets were applied to the CTD data from cruises BF-38-77 and BF-57-77. (Table 5).

Table 2. CTD Data Flow. Shipboard Acquisition to NODC Submitted.

Data Source/Disposition	Program	Data File
Tape from data logger	CTDRUN (Copies tape data to computer file)	CRUISE
	MAGREAD (Converts binary coded data to decimal)	BIRANG
Enter depth offset	CTDUNIT (Converts decimal units to engineering units)	LAG
	LAGFILT (Coarse filters and temperature lag)	LATCH
	DLATCH (Removes decreasing and repeated depths)	CTDATA
	CTDAVE5 (One meter average data)	AVE
	BROENK (Calculates salinity and sigma-t)	SGSA
Primary calibration from bottle casts Enter salinity offset	NODCFO (Converts to NODC format)	NODC
Type in headers on file HEAD	XBTMERG (Merges headers and XBT data)	NODC + HEAD
	NUTMERG (Merges NODC data with headers and chemical data)	FINAL
Submitted to NODC	CEMLIST (Calculates sigma-t specific volume anomaly, oxygen utilization, and creates technical report pages)	
	LIST (Creates station list)	TECHNICAL REPORT

Table 3. Cruise BF-38-77 Salinity Calibration Data.

Station No.	Depth (m)	Bottle ‰	CTD ‰	Difference Bottle-CTD (‰)
2C	14m	32.634	32.57	+.06
3C	13m	32.738	32.68	+.06
4C	14m	33.303	33.27	+.03
5C	15m	33.869	33.81	+.06
6C	24m	34.651	34.59	+.06
7C	28m	35.456	35.42	+.04
7C	16m	35.455	34.42	+.04
8C	31m	35.810	35.75	+.06
9C	34m	36.026	35.94	+.09
10C	40m	36.095	36.02	+.08
11C	41m	36.116	36.06	+.06
13C	53m	36.316	36.27	+.05
14C	74m	36.316	36.27	+.05
16C	10m	32.513	32.45	+.06

Table 4. Cruise BF-57-77 Salinity Calibration Data.

Station No.	Depth (m)	Bottle ‰	CTD ‰	Difference Bottle-CTD (‰)
1C	138m	36.191	36.074	+.117
2C	16m	36.268	36.151	+.117
3C	18m	32.218	36.101	+.117
4C	22m	36.219	36.111	+.108
5C	26m	36.229	36.126	+.103
6C	28m	36.238	36.138	+.100
7C	31m	36.250	36.154	+.096
8C	33m	36.228	36.135	+.093
9C	37m	36.327	36.218	+.109
10C	40m	36.325	36.242	+.083
12C	196m	35.034	35.015	+.019

Table 5. CTD Salinity Offset Equation

Cruise	Date	Data Source	‰ Offset Equation
BF-38-77	5/26-27/77	HP-Cartridge	$+0.06 \pm 0.015$
BF-57-77	9/13-14/77	Magnetic Tape	$* S = S_0 + .118 - 5.19 \times 10^{-4} D$

S_0 = Uncorrected CTD Salinity
 D = Depth

* It was necessary to apply an additional correction of -0.11 ‰ to Station 16-C after processing.

The magnetic tape data were normally our primary data source at this stage in the development of our acquisition system. However, the HP cartridge data were used for cruise BF-38-77 because a defective frequency plug resulted in erroneous magnetic tape data. The absence of an apparent depth effect for this same cruise is attributed to the shallowness of the samplings (deepest was 74 meters). Here, the normal instabilities of the instrumentation prohibit the determination of any discernible depth relationship. (See CTD Error Analysis).

The temperature of the CTD system was checked against reversing thermometers (Tables 6 and 7). Since the CTD temperature sensor agreed with protected reversing thermometers within the range of accuracy ($\pm 0.02^\circ\text{C}$), no offset was applied (Table 8). A +2.29 meter depth offset was applied to both sets of CTD data.

Table 8. CTD Temperature Calibration Check.

Cruise	Date	Mean Difference Reversing Thermometer - CTD	Standard Deviation
BF-38-77	5/26-27/77	+.018	.009
BF-57-77	9/13-14/77	+.006	.010

The XBT system was checked for proper calibration before and during each cruise with a test canister and periodically with surface bucket and/or near bottom reversing thermometer readings. These indicated that the system operated within acceptable error ($\pm 0.1^\circ\text{C}$).

CTD Error Analysis

The Plessey Model 9400 CTD system has the following rated accuracy, resolution, and time constants (Table 9).

Table 6. Cruise BF-38-77. Temperature Calibration Data.

Station No.	Depth (m)	REVERSING THERMOMETER TEMPERATURE (°C)			CTD Temperature (°C)	Difference (°C)
		1	2	Ave		
2C	14m	24.17	24.15	24.160	24.14	+ .020
4C	14m	23.74	23.74	23.740	23.73	+ .010
5C	15m	23.48	23.45	23.465	23.43	+ .035
6C	24m	22.65	22.66	22.655	22.64	+ .015
10C	40m	23.90	23.88	23.890	23.88	+ .010
11C	41m	23.91	23.90	23.905	23.89	+ .015

Table 7. Cruise BF-57-77. Temperature Calibration Data.

Station No.	Depth (m)	REVERSING THERMOMETER TEMPERATURE (°C)			CTD Temperature (°C)	Difference (°C)
		1	2	Ave		
1C	14m	28.41	28.42	28.415	28.41	+ .005
2C	16m	28.24	28.22	28.230	28.22	+ .010
3C	18m	28.00	28.02	28.010	28.00	+ .010
4C	22m	27.91	27.93	27.920	27.92	0.000
5C	26m	27.81	27.81	27.810	27.78	+ .030
6C	28m	27.48	27.46	27.470	27.48	- .010
7C	31m	26.50	26.49	26.495	26.49	+ .005
8C	33m	25.48	25.48	25.480	25.48	0.000
9C	37m	24.59	24.58	24.585	24.59	- .005
10C	40m	23.85	23.85	23.850	23.84	+ .010
12C	196m	8.42	8.42	8.420	8.41	+ .010

Table 9. Specifications for Plessey Model 9400 CTD System

	Conductivity	Temperature	Depth
Accuracy	± 0.03 mmho/cm	$\pm 0.02^{\circ}\text{C}$	± 1.5 m
Resolution	0.0001 mmho/cm	0.0001 $^{\circ}\text{C}$	0.0012 m
Time Constant	0.1 sec	0.35 sec	0.1 sec

Since salinity is not measured directly, it must be calculated from the above parameters, resulting in the composite errors of the C, T and D sensors and the salinity equation.

By varying "real" C, T and D by the rated sensor accuracies in the Broenkow CTD salinity equation (see Chandler *et al.* 1978, and Tables 10 and 11) the maximum error attributable to each sensor can be determined. The composite maximum error is approximately $\pm 0.06^{\circ}/_{\text{oo}}$ for "real" data sets. However, the standard deviation of all mixed layer samples taken for salinity calibration implies greater accuracy, namely $\pm 0.02^{\circ}/_{\text{oo}}$ after offset. We believe this value is a more realistic measure of the quality of the data set.

METEOROLOGICAL CONDITIONS

Wind and temperature data from Savannah, Georgia are presented in Figures 5-8. These data were derived from the monthly summaries for the respective months (U.S. Department of Commerce: March 1977, May 1977, September 1977 and January 1978) and are plotted in GMT at three-hour intervals. Additional meteorological data, collected by the ships personnel, are presented with the hydrographic data.

Table 10. Broenkow's Salinity Equations.

$$\begin{aligned}
 R_Z &= 1 + .01\{(1.551 - .0453T + 59 \times 10^{-5}T^2) \\
 &\quad + \frac{1}{4}(35-S)(.043 - .0017T + 23 \times 10^{-6}T^2)\}\{1.037 \times 10^{-3}Z \\
 &\quad - 32 \times 10^{-9}Z^2\} \\
 A_T &= (676547 + 20131.5T + 99.89T^2 - .1943T^3 - .00672T^4) 10^{-6} \\
 R_T &= \frac{C(S,T,Z)}{R_Z A_T 42.896} \\
 \Delta_{15} &= R_T(R_T-1)(T-15) \{96.7 - 72R_T + 37.3R_T^2 \\
 &\quad - (.63 + .21R_T^2)(T-15)\}10^{-5} \\
 R_{15} &= R_T + \Delta_{15} \\
 S^{0/00} &= .08996 + 28.2972R_{15} + 12.80832R_{15}^2 - 10.67869R_{15}^3 \\
 &\quad + 5.98624R_{15}^4 - 1.32311R_{15}^5
 \end{aligned}$$

where: R = conductivity ratio

Z = depth (meters)

T = temperature ($^{\circ}$ C)

C = measured conductivity (mmhos/cm)

S = salinity ($^0/00$)

Table 11. Flow Using Broenkow's Salinity Equation

*without the R_Z term

R_Z = pressure effect on conductivity

A_T = temperature effect

R_T = $R(S, t, p)$ conductivity ratio

Δ_{15} = t_{15} correction (International Oceanographic Tables, 1966)

R_{15} = $R(S, 15^\circ\text{C}, 0)$

RESULTS AND DISCUSSION

Savannah Section, 8-9 March 1977. (Figure 9)

Deep upwelling at the shelf break is indicated, and there is the appearance of cascading along the mid to outer shelf (stations 8X and 9X). This, however, may be due to by warmer offshore waters. No nutrient data were collected.

Brunswick Section, 9 March 1977. (Figure 9)

Upwelling is occurring at the shelf break. The 21°C lobe at stations 25X and 26X suggests that the upwelling may have resulted from an eddy. Note the differences in the vertical structure on the shelf between this section and the Savannah section, a horizontal distance of less than 60 nautical miles (111 kilometers). No nutrient data were collected.

Savannah Section, 26-27 May 1977. (Figures 10-11)

The temperature and sigma-t plots reveal an upwelling regime centered around station 13X/C. The nutrient data, however, reveal that significant nutrient concentrations did not occur in the surface waters because of the high temperatures.

The warm surface lobe at stations 11C and 12X with cooler waters at stations 13X/C and 14C, and then warmer waters again at station 15X suggest an eddy. A similar trend is seen in the density field where density increases and then decreases moving offshore at the shelf break.

Brunswick Section, 13-14 September 1977. (Figures 12-13).

A strong upwelling regime has been established at the shelf break with significant nutrient enrichment of the surface waters. The upwelling is evident in all parameters. Cooler, high nutrient waters are producing an "intrusion" on the shelf.

Savannah Section, 14 September 1977. (Figures 14-15)

Upwelling similar to that shown for the Brunswick section on 13-14 September is evident. However, nutrient concentrations in the shallower waters are not as great.

Savannah Section, 23-24 January, 1978. (Figures 16-17)

There is an overriding of shelf waters by warmer offshore waters with the 20°C isotherm roughly depicting the western wall of the Gulf Stream. Deep upwelling is apparent at the shelf break and high levels of nitrate, phosphate and silicate have reached the surface. In addition, there are extremely high chlorophyll concentrations in the surface waters at the shelf break, a further indication of strong upwelling.

Brunswick Section 24-25 January 1978. (Figures 18-19)

Strong upwelling at the shelf break is indicated by the nitrate and silicate data. This upwelling feature is less obvious in plots of the other parameters.

SUMMARY

Upwelling was observed at the shelf break during each of the cruises in March, May, September and January. This resulted in significant nutrient enrichment of surface and shelf waters. Nutrient concentrations as high as 5 μM nitrate, .2 μM phosphate and 2 μM silicate were observed in the top 30 m.

Gulf Stream eddies and meanders are probable explanations for at least some of the observed upwelling. However, confirmation will depend upon analysis of current meter data from moorings placed in the study area by the University of Miami (Dr. Tom Lee).

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FIGURES

Figure 1. Station locations (March 1977)

Figure 2. Station locations (May 1977)

Figure 3. Station locations (September 1977)

Figure 4. Station locations (January 1978)

Figure 5. Meteorological Data from Savannah, Georgia (March 1977).

Figure 6. Meteorological Data from Savannah, Georgia (May 1977).

Figure 7. Meteorological Data from Savannah, Georgia (September 1977).

Figure 8. Meteorological Data from Savannah, Georgia (January 1978).

Figure 9. Vertical temperature structure for the Savannah and Brunswick sections, 8-9 March 1977.

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Figure 17. Vertical nitrate, phosphate, silicate and chlorophyll-a structure for the Savannah section, 23-24 January 1978.

Figure 18. Vertical temperature, salinity and sigma-t structure for the Brunswick section, 24-25 January 1978.

APPENDIX

Hydrographic Data

HYDROGRAPHIC DATA

Vertical profiles of salinity, temperature, sigma-t, DO and nutrients

The symbols used in the following listings are defined as follows:

Header Data: Times are GMT (EST + 5 or EDT + 4)
Latitude and Longitude are from Loran C

Weather Data: These data are taken from the ship's log.

Wind speed (knots)
Wind direction (degrees)
Air temperature (°C)
Weather (WMO code 4501)
Barometric pressure (mb)
Sea state (WMO 3700)
Wave direction (degrees)
Cloud type (not given)
Cloud amount (not given)
Visibility code (not given)

Observations: Z = Depth in meters
T = Temperature in °C
S = Salinity in ‰
D = Density in sigma-t units
SVA = Specific volume anomaly $\times 10^5$
O₂ = Dissolved oxygen in ml/liter
O₂' = Oxygen saturation in ml/liter
AOU = Apparent oxygen utilization in ml/liter
PO₄ = Phosphate concentration in $\mu\text{mole/liter}$
NO₃ = Nitrate concentration in $\mu\text{mole/liter}$
Si = Silicate concentration in $\mu\text{mole/liter}$

BF-14-77

8-9 March 1977

STATION SUMMARY FOR BLUE FIN CRUISE 14

CRUISE	STATION	LATITUDE	LONGITUDE	YR	MM	DAY	HR	DEPTH	CONSEC
							GMT	M	NUMBER
014	001X	31 57.2N	80 40.8W	77	3	8	16.2	16	1
014	002X	31 54.9N	80 34.3W	77	3	8	16.9	16	2
014	003X	31 53.4N	80 29.2W	77	3	8	17.5	19	3
014	004X	31 51.4N	80 23.4W	77	3	8	18.1	25	4
014	005X	31 49.6N	80 17.3W	77	3	8	18.8	24	5
014	006X	31 48.1N	80 11.0W	77	3	8	19.4	27	6
014	007X	31 45.8N	80 5.3W	77	3	8	20.0	33	7
014	008X	31 44.3N	79 59.4W	77	3	8	20.7	36	8
014	009X	31 42.4N	79 54.5W	77	3	8	21.3	42	9
014	010X	31 40.8N	79 47.6W	77	3	8	22.0	44	10
014	011X	31 38.7N	79 41.7W	77	3	8	23.0	52	11
014	012X	31 36.9N	79 35.8W	77	3	8	23.5	85	12
014	013X	31 35.2N	79 29.8W	77	3	9	1.0	252	13
014	014X	31 33.3N	79 23.9W	77	3	9	1.7	608	14
014	015X	31 29.7N	79 28.3W	77	3	9	4.5	563	15
014	016X	31 26.2N	79 33.6W	77	3	9	5.5	263	16
014	017X	31 22.4N	79 38.2W	77	3	9	6.3	260	17
014	018X	31 18.8N	79 42.9W	77	3	9	7.4	157	18
014	019X	31 14.6N	79 47.8W	77	3	9	8.2	79	19
014	020X	31 9.5N	79 49.5W	77	3	9	8.9	88	20
014	021X	31 4.5N	79 51.2W	77	3	9	9.5	108	21
014	022X	30 59.4N	79 52.5W	77	3	9	10.1	168	22
014	023X	30 54.2N	79 54.1W	77	3	9	10.7	234	23
014	024X	30 45.7N	79 57.0W	77	3	9	11.7	256	24
014	025X	30 47.5N	80 2.6W	77	3	9	13.0	102	25
014	026X	30 49.7N	80 8.3W	77	3	9	13.5	46	26
014	027X	30 52.2N	80 12.8W	77	3	9	14.1	44	27
014	028X	30 54.1N	80 19.0W	77	3	9	14.6	38	28
014	029X	30 56.5N	80 25.2W	77	3	9	15.2	35	29
014	030X	30 58.7N	80 31.3W	77	3	9	15.8	32	30
014	031X	31 9.8N	80 35.2W	77	3	9	17.3	28	31
014	032X	31 20.5N	80 40.4W	77	3	9	18.6	25	32
014	033X	31 31.4N	80 44.5W	77	3	9	19.9	21	33
014	034X	31 41.9N	80 48.4W	77	3	9	21.5	13	34
014	035B	31 51.7N	80 52.5W	77	3	9	22.7	4	35

BLUE FIN CRUISE 14 STA 1X 8/ III/77 16.2 GMT CONSEC STA 1

LAT 31 57.2N LONG 80 40.8W DEPTH = 16M DIST LAST STA = 0.0KM

WEATHER DATA

WIND SPEED = 18 KTS
WIND DIRECTION = 050
AIR TEMP = . C
WEATHER CODE = X0
BAROMETRIC PRESSURE = 1027.8 MB

SEA STATE = 3
WAVE DIRECTION =
CLOUD TYPE =
CLOUD AMOUNT =
VISIBILITY CODE =

OBSERVATIONS

Z	T	S	D	SVA	O2	O2'	AOU	P04	M03	SI
1.0	11.50	.	.	.	.	.	.	.	.	.
8.5	11.50	.	.	.	.	.	.	.	.	.
9.0	11.40	.	.	.	.	.	.	.	.	.
16.0	11.40	.	.	.	.	.	0.13	00.1	03.1	.

STATION 001X

BLUE FIN CRUISE 14 STA 2X 8/ III/77 16.9 GMT CONSEC STA 2

LAT 31 54.9N LONG 80 34.3W DEPTH = 16M DIST LAST STA = 11.1KM

WEATHER DATA

WIND SPEED = 18 KTS
WIND DIRECTION = 050
AIR TEMP = . C
WEATHER CODE = X0
BAROMETRIC PRESSURE = 1027.8 MB

SEA STATE = 3
WAVE DIRECTION =
CLOUD TYPE =
CLOUD AMOUNT =
VISIBILITY CODE =

OBSERVATIONS

Z	T	S	D	SVA	O2	O2'	AOU	P04	M03	SI
1.0	11.70	.	.	.	.	.	.	.	.	.
11.0	11.70	.	.	.	.	.	.	.	.	.
14.0	11.60	.	.	.	.	.	.	.	.	.
16.0	11.60	.	.	.	.	.	.	.	.	.

STATION 002X

BLUE FIN CRUISE 14 STA 3X 8/ III/77 17.5 GMT CONSEC STA 3

LAT 31 53.4N LONG 80 29.2W DEPTH = 19M DIST LAST STA = 8.5KM

WEATHER DATA

WIND SPEED = 18 KTS
WIND DIRECTION = 050
AIR TEMP = . C
WEATHER CODE = X0
BAROMETRIC PRESSURE = 1027.8 MB

SEA STATE = 3
WAVE DIRECTION =
CLOUD TYPE =
CLOUD AMOUNT =
VISIBILITY CODE =

OBSERVATIONS

Z	T	S	D	SVA	O2	O2'	AOU	P04	M03	SI
1.0	12.20	.	.	.	.	.	.	.	.	.
2.0	12.10	.	.	.	.	.	.	.	.	.
3.0	12.00	.	.	.	.	.	.	.	.	.
6.0	12.00	.	.	.	.	.	.	.	.	.
7.0	12.20	.	.	.	.	.	.	.	.	.
19.0	12.20	.	.	.	.	.	.	.	.	.

STATION 003X

A map of the Georgia Bight coastline, showing the intricate network of rivers and bays. The map is framed by a coordinate grid with latitude lines at 31 and 32, and longitude lines at 81 and 82. The coastline is depicted in white against a dark background.

Technical Report Series
Number 79-5

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IN THE GEORGIA BIGHT
(APRIL 1978)

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and
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Georgia Marine Science Center
University System of Georgia
Skidaway Island, Georgia

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July 1979

The Technical Report Series of the Georgia Marine Science Center is issued by the Georgia Sea Grant Program and the Marine Extension Service of the University of Georgia on Skidaway Island (P.O. Box 13687, Savannah, Georgia 31406). It was established to provide dissemination of technical information and progress reports resulting from marine studies and investigations mainly by staff and faculty of the University System of Georgia. In addition, it is intended for the presentation of techniques and methods, reduced data and general information of interest to industry, local, regional, and state governments and the public. Information contained in these reports is in the public domain. If this prepublication copy is cited, it should be cited as an unpublished manuscript.

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ACKNOWLEDGEMENTS

The following people participated in the cruise and their help was appreciated: T. Lee, C. Pattison, D. Raffo, P. Bedard, T. Tankard, L. Brincko, B. Strahle, J. West, R. Watts, R. Guest, and L. Cunningham. We would also like to thank to Captain and crew of the R/V ISELIN for their efforts and Lucretia Garrigan for the nutrient analysis. Linda Land is thanked for typing this report.

Funding for this research and report is provided by the Department of Energy (under Contract EY-76-S-09-0889) and the Bureau of Land Management to L.P. Atkinson.

This report is published as a part of the Georgia Marine Science Center's Technical Report series issued by the Georgia Sea Grant Program under NOAA Office of Sea Grant #04-7-158-44126.

ABSTRACT

During a cruise in the Georgia Bight in April 1978, one onshore-offshore hydrographic section was repeated five times over a five-day period. Temperature, salinity, dissolved oxygen and nutrient (NO_3 , PO_4 , and SiO_2) data were collected.

The shelf waters were vertically well mixed with horizontal gradients being apparent only for temperature, salinity, and sigma-t. Initially, an upwelling velocity of $-4.3 \times 10^{-3} \text{ cm sec}^{-1}$ was observed at the shelf break in conjunction with a 10.8 cm sec^{-1} offshore meander of the Gulf Stream. By the third day, the Gulf Stream had started to move onshore at velocities as high as 7.9 cm sec^{-1} . Subsequently, downwelling velocities as high as $8.2 \times 10^{-3} \text{ cm sec}^{-1}$ were observed.

INTRODUCTION

This report contains chemical and physical data obtained during Georgia Bight Cruise CI-04-78 (10-23 April 1978) aboard the R/V COLUMBUS ISELIN. The investigation was part of a larger multi-institutional Department of Energy (DOE) program to understand event scale, physical, chemical and biological processes of the South Atlantic Bight, the continental shelf region from Cape Hatteras to Cape Canaveral. The study reported here is concentrated in the Georgia Bight near Brunswick, Georgia. Specifically, the objective was to collect physical and chemical data such that three-dimensional quasi-synoptic measurements of the interactions of shelf and Gulf Stream waters could be made. In addition, the hydrographic data were used to compare with those of moored instruments deployed by the University of Miami (Dr. Tom Lee).

This report also includes background hydrographic data from a Bureau of Land Management (BLM) cruise which occurred in conjunction with the DOE-sponsored Georgia Bight Cruise.

METHODS

Five onshore-offshore hydrographic sections (Figure 1) were completed as part of the BLM sampling grid. Stations 1C through 43C were occupied from 12-18 April, and stations 105C to 118C were completed between 22-23 April. Stations on this grid were sampled using CTD (conductivity/temperature/depth) Rosette casts. An exception was station 35X, and XBT (expendable bathythermograph) cast.

From 18-21 April, 27 stations were occupied as part of the DOE

Figure 1. BLM Station Grid.

sampling grid. One longshore section along the 50m isobath and four onshore-offshore hydrographic sections across the shelf break off of Brunswick, Georgia were completed. On 18 April, stations 47X-51X were occupied (Figure 2); the next day these stations were reoccupied (stations 62X-66X). All stations in these two sections were completed using XBTs. On 20 April, stations 71C-75C were occupied (Figure 2); the next day these stations were reoccupied (stations 93C-97C). All stations in these two sections were completed using CTD casts. The two CTD sections are further offshore than the two XBT sections. On 21 April, a north-south alongshore section was completed along the 50m isobath at the shelf break (Figure 3). One CTD and 6 XBT stations were occupied in this section. Upon completion of the DOE sampling grid, stations 105C to 118C of the BLM grid were then completed.

At CTD stations, a General Oceanics Model 1015 Mark 5 Rosette multi-bottle array with 5-liter Niskin Bottles and a Plessey Model 9400 CTD sensor system were used for water sampling. Niskin sampling depths were determined from the temperature structure obtained from the CTD. Samples were taken near the surface, just above or below the thermocline, at the bottom, and occasionally at other depths. Samples were analyzed for salinity, nitrate, phosphate, silicate, and dissolved oxygen.

CTD Data Acquisition and Processing

The CTD Data Acquisition System (Figure 4) consists of a Plessey Model 9400 CTD sensor system, a Model 8400 Digital Logger, and a Hewlett-Packard 9825A Calculator. Data were stored on cartridge tape and redundant

Figure 2. DOE Station Grid. Onshore-offshore Sections.

Figure 3. DOE Station Grid. Longshore Section on Shelf Break 50m Isobath.

Figure 4. CTD Data Acquisition System.

plots were produced for each cast on a Hewlett-Packard XXX' Plotter and Model 9862A Plotter.

Digitized data were collected as the CTD sensor unit was lowered at 15 m/min. on a four conductor cable. All three parameters (C,T, and D) were sampled once each 405 milliseconds or every 10 cm at the 15 m/min. lowering rate. For primary calibration of temperature and salinity, a Niskin Bottle equipped with paired protected deep-sea reversing thermometers was tripped after a four-minute equilibration period at the maximum sample depth in mixed layers. Other water samples were collected during ascent at depths selected after examination of the downcast temperature structure.

All data recorded on HP cartridge tape were processed according to the methods described by Chandler, et al. (1978) in the sequence shown in Table 1. Salinity was calculated from conductivity according to the equations of Broenkow, et al. (1977). Broenkow's equation and a flow diagram showing its use is presented in Figure 5.

The CTD system was calibrated only against bottle samples in mixed layers to insure that the sensors and the bottles were sampling the same water. However, since a mixed layer was not always observed, comparisons could not be made at every station. Salinity and temperature calibration data are included in Appendix I.

For the salinity calibration, time-dependent and depth-dependent offsets were determined. The time-dependent plot of bottle-CTD salinity shows no appreciable time-dependent change (Figure 6). This constant offset was

Table 1. CTD/Data Flow. Shipboard Acquisition to NODC Submission.

Data Source/Disposition	Program	Data File
HP Cartridge Tapes	*CTDACQ (CTD sensor controller and data acquisition)	ACQ
	*CTDAVE (Raw data processed for temperature lag, depth latch and meter averaging immediately after each cast)	AVE
Primary Calibration from Bottle Casts	*HP/CTD (Calculates salinity, converts to NODC format, and transfers the data to Cyber)	
Type in Headers on File Head		NODC + HEAD
	**NUTMERG (Merges NODC data with headers and chemical data)	
Submission to NODC		CI-04
	**CEMLIST (Calculates sigma-t, specific volume anomaly, oxygen utilization and prints technical report pages)	
	and	
	**STALIST (Prints station list for technical report)	
		TECHNICAL REPORT
*HP		
**Cyber		

$$\begin{aligned}
 R_2 &= 1 + .01[(1.551 - .0453T + 59 \times 10^{-5}T^2) \\
 &\quad + \frac{1}{2}(35-S)(.43 - .0017T + 23 \times 10^{-6}T^2)][1.037 \times 10^{-32} \\
 &\quad - 32 \times 10^{-9}Z^2] \\
 A_T &= (676547 + 20131.5T + 99.89T^2 - .1943T^3 - .00672T^4) 10^{-6} \\
 R_T &= \frac{C(S,T,Z)}{R_2 A_T 42.896} \\
 \Delta_{15} &= R_T(R_T - 1)(T - 15) [96.7 - 72R_T + 37.3R_T^2 \\
 &\quad - (.63 + .21R_T^2)(T - 15)] 10^{-5} \\
 R_{15} &= R_T + \Delta_{15} \\
 S^{0/00} &= .08996 + 28.2972R_{15} + 12.80832R_{15}^2 - 10.67869R_{15}^3 \\
 &\quad + 5.98624R_{15}^4 - 1.32311R_{15}^5
 \end{aligned}$$

where: R = conductivity ratio
 Z = depth (meters)
 T = temperature (°C)
 C = measured conductivity (nmhos/cm)
 S = salinity (°/oo)

*without the R_2 term

R_2 = pressure effect on conductivity

A_T = temperature effect

R_T = $R(S, t, p)$ conductivity ratio

Δ_{15} = t_{15} correction (International Oceanographic Tables, 1986)

R_{15} = $R(S, 15^\circ C, 0)$

Figure 5. Broenkow Salinity Equation and Flow Diagram.

Figure 6. Top: Time-dependent plot of bottle-CTD salinity. Bottom: Depth-dependent plot of bottle-CTD salinity.

determined to be .124 ‰ with a standard deviation of 0.012 ‰.

The depth-dependent plot of bottle-CTD salinity indicates no significant depth-dependent offset (Figure 6).

The mean difference between CTD and reversing thermometers was +0.020°C with a standard deviation of $\pm$ of 0.009°C. This offset was not considered significant, and no systematic correction was applied to the data.

The CTD depth sensor when compared to wire out under conditions of zero wire angle indicated no offset was necessary.

XBT Data Acquisition and Processing

A Sippican Model LM3A handheld launcher and a MK2A-1 recorder were used for XBT casts. The temperature/depth plots were manually digitized, and these data were placed in NODC format and merged with processed CTD data. Depths at which temperature is a whole or half degree are reported as are depths at which a significant mixed layer begins and ends.

During this cruise, the XBT system was not calibrated against CTD casts. Previous comparisons yielded a 0.2°C offset which is insignificant compared to the stated accuracies of the XBT system.

Physical and Chemical Procedures

Salinity samples collected for calibrating the CTD system were analyzed ashore using a Plessey Model 6230N induction salinometer.

Dissolved oxygen samples were analyzed during the cruise by the modified Winkler method outlined by Strickland and Parsons (1965).

The nutrient analysis was performed at Duke University Marine Laboratory

using Technicon Autoanalyzer procedures. The procedures are based on the manual methods of Murphy and Riley (1962) for reactive phosphate and Armstrong, Stearns, and Strickland (1967) for dissolved silicate, nitrate, and nitrite. The automated methods have been described by Friedrich and Whitledge (1972).

Chlorophyll-a was determined fluorometrically by the methods outlined by Strickland and Parsons (1965).

RESULTS AND DISCUSSION

Gulf Stream meandering has been related to upwelling at the shelf break with easterly movements of the stream related to lower temperatures at the shelf break (Atkinson, 1977). Thus, any observed offshore meander should coincide with upwelling. Conversely, the onshore movement of the Gulf Stream would result in downwelling and a rise in temperature at the shelf break. The five onshore-offshore sections completed off Brunswick clearly show vertical advection in association with the meander of the Gulf Stream. The following is a description of each section:

Section 1, Stations 33C to 43C, 17-18 April. (Figures 7-8).

The shelf waters were well mixed with well-defined horizontal gradients apparent only in the temperature, salinity and sigma-t distributions. The temperature, salinity, nutrient and oxygen distributions all indicated strong upwelling at the shelf break. The isotherm positions showed the Gulf Stream to be offshore of the shelf break.

Section 2, Stations 47X-51X, 18 April. (Figure 9).

The isotherms continued to indicate strong upwelling at the shelf break. The Gulf Stream was still offshore of the shelf.

Section 3, Stations 62X-66X, 19 April. (Figure 9).

Upwelling was apparent at the shelf break but had decreased in intensity. A general lowering of shelf break isotherms indicated downward advectons of warmer surface waters.

Section 4, Stations 71C to 75C, 20 April. (Figures 10-11).

The onshore meander of the Gulf Stream, as indicated by the isotherm positions, resulted in downwelling at the shelf break. Warmer, low-nutrient

Figure 7. Brunswick section temperature, salinity, and sigma-t, 17 April.

Figure 8. Brunswick section nitrate, phosphate, silicate and dissolved oxygen. 17 April. Nutrients are in μM and oxygen in ml/l.

Figure 9. Temperature profile for stations 47X - 51X, 18 April and 62X - 66X, 19 April.

Figure 10. Stations 71C - 75C temperature, salinity, sigma-t, 20 April.

Figure 11. Stations 71C - 75C nitrate, phosphate, silicate and dissolved oxygen, 20 April. Nutrients are in μM and oxygen in ml/l .

water dominated at the surface.

Section 5, Stations 93C to 97C, 21 April. (Figures 12-13).

Warm, low-nutrient water continued to be found at the surface at the shelf break. The onshore movement of the 25°C isotherm indicated further westward meander of the Gulf Stream.

Onshore-offshore Meanders.

The onshore-offshore velocities were determined from the distance the 19°C isotherm moved during the five observation periods (Table 2). Determination of horizontal advection through the first two sections showed an offshore flow of 10.8 cm sec^{-1} . By the third section, this offshore flow had reversed and the Gulf Stream was moving shoreward at -7.9 cm sec^{-1} . This onshore advection or westward meander of the Gulf Stream continued through the remainder of the study.

Vertical Advection.

Vertical advection at the shelf break was determined from the change in the depth of the 19°C isotherm through the five hydrographic sections (Table 2).

An upwelling velocity of $-4.3 \times 10^{-3} \text{ cm sec}^{-1}$ was observed through the first two onshore-offshore sections. This period of upwelling corresponded to the observed offshore movement of the Gulf Stream. Downwelling velocities of 2.0×10^{-3} and $8.2 \times 10^{-3} \text{ cm sec}^{-1}$ were observed during the third and fourth sections. This downwelling was associated with the westward meander of the Gulf Stream during the same period.

The final section (Section 5) revealed the resumption of upwelling, but at a lesser velocity than in the initial sections. The

Figure 12. Stations 93C - 97C temperature, salinity and sigma-t, 21 April.

Figure 13. Stations 93C - 97C nitrate, phosphate, silicate and dissolved oxygen. Nutrients are in μM and oxygen in ml/l .

Table 2. Vertical and onshore-offshore velocities of the 19° isotherm off Brunswick: (+down, offshore; - up, onshore).

Section	1	2	3	4	5
Station	37C	49X	64X	73C	95C
Time (d/h)	18/0.1	18/12.9	19/16.9	20/13.1	21/14.5
Vertical Velocities:					
Depth (19°C)(m)	29	27	29	35	32
Δ time (h)	12.8	28.0	20.2	25.4	
Δ depth (m)	-2	+2	+6	-3	
$\bar{w}$ (cm sec ⁻¹)	-4.3×10^{-3}	$+2.0 \times 10^{-3}$	$+8.2 \times 10^{-3}$	-3.3×10^{-3}	
Onshore - Offshore Velocities:					
Δ time (h)	12.8	28	20.2	25.4	
Δ distance (km)	+5	-8	-3	-1	
Velocity (cm sec ⁻¹)	+10.8	-7.9	-4.1	-1.1	

east-west currents were still onshore during the final period but at a considerably reduced rate as compared to the previous sections. The resumption of upwelling and slacking of the westward flow during the fifth section suggests the imminent reversal of the onshore-offshore flow to an eastward direction with the resumption of upwelling.

One alongshore XBT section on the 50m isobath was completed on 21 April after section 5 of the onshore-offshore time series grid (Figure 14). This north-south section crossed the onshore-offshore section. Figure 14 reveals a mass of cooler upwelled water north of the time series grid at station 87X. This mass of cool water corresponds with the existence of upwelling four days earlier at a position 76 km south on the time series section. Stations south of 87X showed lower isotherms which slowly moved upward as Station 91C was approached. These depressed isotherms correspond well with the downwelling and onshore flow several days before at the time series grid stations. The elevated isotherms seen at Station 90X generally conform to the observed upwelling seen the day before along the final time series section.

A consideration of temperature at one position on the shelf break (Figure 15) through the five time series sections reflects trends visible in the cross shelf section plots (Figures 7-13). The isotherms were elevated during the upwelling/offshore flow period at the beginning of the study and lowered as downwelling and onshore flow came to dominate the shelf break area. The slight rise of the isotherms on the last days can be attributed to the modest resumption of upwelling.

Figure 14. Alongshore section on 50m isobath from 87X (north) to 102X (south). Station 91C is on the onshore-offshore time series grid.

Figure 15. Temperature time series at 40m station L on shelf break, 18-21 April, 1978.

Temperature-Salinity Relationship.

A plot of temperature vs. salinity for all BLM-DOE stations (1C-118C) during 10-23 April 1978 revealed two distinctive water masses (Figure 16). Low-salinity, thermally mixed waters can be seen on the shelf, while high-salinity, thermally stratified water was found in the offshore Gulf Stream waters.

Figure 16. Temperature-salinity diagram of all BLM-DOE stations (1C-118C) 10-23 April 1978. T-S points for each station are connected.

SUMMARY

The shelf waters were vertically well mixed with horizontal stratification apparent only in the temperature, salinity, and sigma-t distributions. A Gulf Stream meander was observed at the shelf break which, at first, moved offshore at 10.8 cm sec^{-1} . The meander then reversed, moving onshore with an initial velocity of -7.9 cm sec^{-1} . This shoreward advection continued through the remainder of the study but at a decreasing velocity. An upwelling velocity of $-4.3 \times 10^{-3} \text{ cm sec}^{-1}$ was observed in association with the offshore meander of the Gulf Stream. The onshore meander resulted in downwelling at the shelf break with vertical velocities as high as $8.2 \times 10^{-3} \text{ cm sec}^{-1}$. The final day showed weak onshore movement and a resumption of upwelling, though at a lower velocity than observed initially in the study.

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APPENDIX I

Calibration Data

SALINITY CALIBRATION DATA:

Station	Depth	Bottle Salinity	CTD Salinity	Difference
2C	94	36.384	36.271	+ .113
2C	2	36.370	36.248	+ .122
3C	200	35.820	36.705	+ .115
3C	87	36.350	36.231	+ .119
4C	206	35.952	35.838	+ .114
5C	47	36.399	36.283	+ .116
7C	32	36.185	36.072	+ .113
8C	27	36.092	35.983	+ .109
20C	18	34.901	34.779	+ .122
22C	35	36.280	36.141	+ .139
24C	102	35.943	35.826	+ .117
25C	224	35.632	35.521	+ .111
26C	40	36.202	36.094	+ .108
33C	8	36.174	36.045	+ .129
36C	54	36.069	35.945	+ .124
37C	39	36.272	36.151	+ .121
39C	35	36.343	36.230	+ .113
40C	31	36.081	35.978	+ .103
41C	22	35.442	35.327	+ .115
42C	16	34.434	34.308	+ .126
60C	41	36.211	36.105	+ .106
60C	28	36.235	36.104	+ .131
67C	40	36.183	36.065	+ .118
69C	4	36.354	36.207	+ .147
71C	4	36.253	36.104	+ .149
72C	4	36.279	36.131	+ .148
73C	4	36.323	36.175	+ .148
75C	189	35.679	35.553	+ .126
94C	36	36.244	36.105	+ .139
97C	197	35.864	35.738	+ .126
105C	253	35.975	35.849	+ .126
108C	43	36.066	35.929	+ .137
109C	38	36.093	35.957	+ .136
110C	26	36.312	36.179	+ .133
113C	17	36.336	36.197	+ .139
114C	23	36.289	36.147	+ .142
115C	25	36.126	36.001	+ .125
116C	59	35.918	35.794	+ .124
117C	85	35.827	35.714	+ .113

TEMPERATURE CALIBRATION DATA

Station	Depth	Reversing Thermometer Temperature			CTD Temperature	Difference
		1	2	Ave		
7C	32	17.40	17.41	17.41	17.39	+.02
8C	27	17.29	17.31	17.30	17.27	+.03
36C	54	16.02	16.02	16.02	16.00	+.02
39C	35	20.64	20.63	20.64	20.62	+.02
40C	31	20.50	20.49	20.50	20.47	+.03
41C	22	19.73	19.71	19.72	19.70	+.02
42C	16	18.52	18.52	18.52	18.52	0.00
105C	253	14.93	14.94	14.94	14.93	+.01
111C	27	20.85	20.84	20.85	20.83	+.02
113C	17	21.13	21.11	21.12	21.09	+.03

APPENDIX II

Hydrographic Data

STATION SUMMARY FOR ISELIN CRUISE CI-04

CRUISE	STATION	LATITUDE	LONGITUDE	YR	MN	DY	HOUR GMT	DEPTH M	CONSEC NUMBER
004	001C	32 5.2N	78 7.7W	78	4	12	5.7	515	1
004	002C	32 12.0N	78 16.0W	78	4	14	6.7	373	2
004	003C	32 19.3N	78 24.5W	78	4	14	9.8	290	3
004	004C	32 26.1N	78 32.8W	78	4	14	12.1	248	4
004	005C	32 29.7N	78 37.2W	78	4	14	16.9	240	5
004	006C	32 33.3N	78 41.3W	78	4	15	5.4	46	6
004	007C	32 40.5N	78 49.3W	78	4	15	6.9	35	7
004	008C	32 47.2N	78 58.5W	78	4	15	8.3	29	8
004	009C	32 54.2N	79 6.8W	78	4	15	9.7	19	9
004	018CU	31 59.1N	80 44.8W	78	4	16	16.0	12	18
004	019C	31 54.3N	80 35.6W	78	4	16	18.3	16	19
004	020C	31 49.5N	80 24.5W	78	4	16	20.5	20	20
004	021C	31 45.0N	80 13.0W	78	4	16	22.8	25	21
004	022C	31 42.4N	80 9.9W	78	4	17	.7	37	22
004	023C	31 36.1N	79 50.6W	78	4	17	2.7	44	23
004	024CU	31 30.0N	79 38.0W	78	4	17	5.2	123	24
004	025C	31 29.0N	79 30.5W	78	4	17	6.9	337	25
004	026C	31 22.5N	79 22.0W	78	4	17	9.9	460	26
004	033C	30 45.8N	79 42.0W	78	4	17	23.0	525	33
004	034C	30 49.6N	79 54.4W	78	4	18	1.7	280	34
004	035X	30 52.0N	79 59.4W	78	4	18	3.6	117	35
004	036C	30 52.7N	80 1.2W	78	4	18	4.0	55	36
004	037C	30 54.6N	80 7.0W	78	4	18	5.1	41	37
004	038X	30 56.0N	80 13.4W	78	4	18	5.9	39	38
004	039C	30 57.6N	80 20.0W	78	4	18	6.5	39	39
004	040C	31 2.0N	80 30.5W	78	4	18	7.8	34	40
004	041CU	31 6.0N	80 42.0W	78	4	18	9.3	26	41
004	042C	31 10.0N	80 54.0W	78	4	18	10.7	18	42
004	043C	31 15.0N	81 8.0W	78	4	18	12.2	12	43
004	047X	30 57.0N	80 19.4W	78	4	18	17.1	35	47
004	048X	30 55.0N	80 12.6W	78	4	18	17.5	40	48
004	049X	30 54.0N	80 7.3W	78	4	18	17.8	42	49
004	050X	30 53.0N	80 2.2W	78	4	18	18.5	50	50
004	051X	30 52.0N	79 57.2W	78	4	18	18.9	250	51
004	053X	30 53.5N	00 5.0W	78	4	18	20.6	43	53
004	057C	30 53.4N	80 5.4W	78	4	19	1.6	44	57
004	060C	30 53.5N	80 4.1W	78	4	19	13.0	44	60
004	062X	30 57.7N	80 19.5W	78	4	19	19.9	38	62
004	063X	30 55.4N	80 12.6W	78	4	19	21.0	40	63
004	064X	30 53.5N	80 7.5W	78	4	19	21.8	42	64
004	065X	30 52.5N	80 2.5W	78	4	19	22.6	68	65

ISELIN CRUISE CI-04

[CONTINUED]

CRUISE	STATION	LATITUDE	LONGITUDE	YR	MN	DY	HOUR GMT	DEPTH M	CONSEC NUMBER
004	066X	30 51.8N	79 57.6W	78	4	19	23.0	173	66
004	067C	30 53.5N	80 4.0W	78	4	20	.9	44	67
004	069C	30 53.5N	80 4.0W	78	4	20	13.0	44	69
004	071C	30 56.9N	80 15.7W	78	4	20	15.9	36	71
004	072CU	30 55.3N	80 10.4W	78	4	20	17.0	40	72
004	073CU	30 53.3N	80 5.0W	78	4	20	18.0	45	73
004	074C	30 51.7N	79 59.5W	78	4	20	19.2	112	74
004	075C	30 49.6N	79 54.5W	78	4	20	20.4	244	75
004	077C	30 53.4N	79 36.8W	78	4	20	23.9	44	77
004	087X	31 32.1N	79 45.8W	78	4	21	10.1	52	87
004	088X	31 23.4N	79 50.5W	78	4	21	11.1	48	88
004	089X	31 14.0N	79 54.0W	78	4	21	12.1	49	89
004	090X	31 3.0N	79 57.6W	78	4	21	13.1	49	90
004	091C	30 53.5N	80 4.0W	78	4	21	14.6	44	91
004	093C	30 56.8N	80 15.5W	78	4	21	17.5	38	93
004	094C	30 55.5N	80 11.0W	78	4	21	18.3	39	94
004	095C	30 53.5N	80 5.4W	78	4	21	19.5	43	95
004	096C	30 51.5N	79 59.0W	78	4	21	20.6	123	96
004	097C	30 49.5N	79 54.5W	78	4	21	21.6	245	97
004	099C	30 55.3N	80 2.1W	78	4	21	23.9	46	99
004	101X	30 42.8N	80 9.0W	78	4	22	4.5	44	101
004	102X	30 32.0N	80 13.8W	78	4	22	5.5	45	102
004	103C	30 53.0N	80 5.0W	78	4	22	12.5	44	103
004	105C	30 4.0N	80 2.2W	78	4	22	19.9	430	105
004	106C	30 2.5N	80 11.0W	78	4	22	21.8	240	106
004	107C	30 2.1N	80 16.0W	78	4	22	23.2	55	107
004	108CU	30 1.5N	80 22.0W	78	4	23	.1	45	108
004	109C	30 0.0N	80 33.1W	78	4	23	1.3	41	109
004	110C	29 58.2N	80 43.0W	78	4	23	2.4	28	110
004	111C	29 56.8N	80 53.9W	78	4	23	3.7	29	111
004	112C	29 55.2N	81 5.0W	78	4	23	4.8	19	112
004	113C	29 6.0N	80 42.7W	78	4	23	9.6	19	113
004	114C	29 8.0N	80 33.0W	78	4	23	10.7	26	114
004	115C	29 8.8N	80 23.0W	78	4	23	11.8	26	115
004	116C	29 9.9N	80 12.9W	78	4	23	13.0	63	116
004	117C	29 11.2N	80 7.0W	78	4	23	14.2	130	117
004	118CU	29 11.9N	80 2.1W	78	4	23	15.7	350	118

HYDROGRAPHIC DATA

Vertical profiles of salinity, temperature, sigma-t, DO, and nutrients

The symbols used in the following listings are defined as follows:

- Header Data: Times are GMT (EST + 5)
 Latitude and Longitude are from Loran C
- Weather Data: These data are taken from the ship's log.
- Wind speed (knots)
 Wind direction (degrees)
 Air temperature (°C)
 Weather (WMO code 4501)
 Barometric pressure (mb)
 Sea State (WMO 3700)
 Wave direction (degrees)
 Cloud type (not given)
 Cloud amount (not given)
 Visibility code (not given)
- Observations: Z = Depth in meters
 T = Temperature in °C
 S = Salinity in ‰
 D = Density in sigma-t units
 SVA = Specific volume anomaly $\times 10^5$
 O₂ = Dissolved oxygen in ml/liter
 O₂' = Oxygen saturation in ml/liter
 AOU = Apparent oxygen utilization in ml/liter
 PO₄ = Phosphate concentration in $\mu\text{mole/liter}$
 NO₃ = Nitrate concentration in $\mu\text{mole/liter}$
 Si = Silicate concentration in $\mu\text{mole/liter}$

ISELIN CRUISE CI-04 STA 001C 12/ IV/78 5.7 GMI CONSEC STA 1

LAT 32 5.2N LONG 78 7.7W DEPTH =515M DIST LAST STA = 0.0KM

WEATHER DATA

WIND SPEED = 22 KTS

WIND DIRECTION = 210

AIR TEMP = 22.8C

WEATHER CODE =

BAROMETRIC PRESSURE = 1013.8 MB

SEA STATE =

WAVE DIRECTION =

CLOUD TYPE =

CLOUD AMOUNT =

VISIBILITY CODE =

OBSERVATIONS

Z	T	S	D	SVA	O2	O2'	AOU	P04	N03	S1
2.0	23.69	36.41	24.81	314	.	.	.	.	.	.
3.0	23.69	36.41	24.81	315	.	.	.	.	.	.
4.0	23.69	36.41	24.81	315	.	.	.	.	.	.
5.0	23.69	36.42	24.82	314	.	.	.	.	.	.
6.0	23.69	36.41	24.81	315	.	.	.	.	.	.
7.0	23.69	36.41	24.81	315	.	.	.	.	.	.
8.0	23.69	36.41	24.81	315	.	.	.	.	.	.
9.0	23.69	36.42	24.82	314	.	.	.	.	.	.
10.0	23.68	36.41	24.81	315	.	.	.	.	.	.
11.0	23.69	36.41	24.81	315	.	.	.	.	.	.
12.0	23.69	36.41	24.81	315	.	.	.	.	.	.
13.0	23.69	36.41	24.81	315	.	.	.	.	.	.
27.0	23.61	36.41	24.83	313	.	.	.	.	.	.
28.0	23.61	36.40	24.82	314	.	.	.	.	.	.
29.0	23.61	36.41	24.83	313	.	.	.	.	.	.
30.0	23.60	36.41	24.84	313	.	.	.	.	.	.
31.0	23.60	36.41	24.84	313	.	.	.	.	.	.
32.0	23.59	36.42	24.85	312	.	.	.	.	.	.
33.0	23.58	36.41	24.84	313	.	.	.	.	.	.
34.0	23.55	36.42	24.86	311	.	.	.	.	.	.
35.0	23.49	36.44	24.89	308	.	.	.	.	.	.
36.0	23.45	36.44	24.90	307	.	.	.	.	.	.
37.0	23.46	36.42	24.88	309	.	.	.	.	.	.
38.0	23.46	36.42	24.88	309	.	.	.	.	.	.
39.0	23.46	36.42	24.88	309	.	.	.	.	.	.
40.0	23.45	36.44	24.90	307	.	.	.	.	.	.
41.0	23.44	36.43	24.90	308	.	.	.	.	.	.
42.0	23.38	36.41	24.90	307	.	.	.	.	.	.
43.0	23.33	36.43	24.93	305	.	.	.	.	.	.
44.0	23.29	36.41	24.93	305	.	.	.	.	.	.
45.0	23.24	36.43	24.96	302	.	.	.	.	.	.
46.0	23.20	36.42	24.96	302	.	.	.	.	.	.
47.0	23.21	36.40	24.94	304	.	.	.	.	.	.
48.0	23.19	36.43	24.97	301	.	.	.	.	.	.
49.0	23.08	36.43	25.00	298	.	.	.	.	.	.
50.0	23.04	36.43	25.01	297	.	.	.	.	.	.
51.0	22.99	36.42	25.02	296	.	.	.	.	.	.
52.0	22.86	36.43	25.07	292	.	.	.	.	.	.
53.0	22.70	36.47	25.14	285	.	.	.	.	.	.
54.0	22.55	36.49	25.20	279	.	.	.	.	.	.
55.0	22.34	36.49	25.26	273	.	.	.	.	.	.
56.0	22.28	36.44	25.24	275	.	.	.	.	.	.
57.0	22.25	36.44	25.25	275	.	.	.	.	.	.
58.0	22.18	36.43	25.26	274	.	.	.	.	.	.
59.0	22.15	36.43	25.27	273	.	.	.	.	.	.
60.0	22.14	36.44	25.28	272	.	.	.	.	.	.
61.0	22.13	36.44	25.28	272	.	.	.	.	.	.
62.0	22.07	36.45	25.31	269	.	.	.	.	.	.
63.0	22.04	36.45	25.32	269	.	.	.	.	.	.
64.0	21.95	36.46	25.35	265	.	.	.	.	.	.
65.0	21.81	36.45	25.38	262	.	.	.	.	.	.
66.0	21.76	36.46	25.40	260	.	.	.	.	.	.
67.0	21.72	36.46	25.41	259	.	.	.	.	.	.
68.0	21.65	36.45	25.43	258	.	.	.	.	.	.
69.0	21.62	36.45	25.43	258	.	.	.	.	.	.
70.0	21.54	36.46	25.46	255	.	.	.	.	.	.
71.0	21.48	36.44	25.47	255	.	.	.	.	.	.
72.0	21.41	36.45	25.49	252	.	.	.	.	.	.
73.0	21.36	36.44	25.50	252	.	.	.	.	.	.
74.0	21.32	36.44	25.51	251	.	.	.	.	.	.
75.0	21.28	36.44	25.52	250	.	.	.	.	.	.
76.0	21.27	36.43	25.52	250	.	.	.	.	.	.
77.0	21.26	36.44	25.53	249	.	.	.	.	.	.
78.0	21.22	36.44	25.54	248	.	.	.	.	.	.
79.0	21.18	36.43	25.54	248	.	.	.	.	.	.
80.0	21.12	36.43	25.56	246	.	.	.	.	.	.
81.0	21.04	36.43	25.58	244	.	.	.	.	.	.
82.0	21.01	36.43	25.59	243	.	.	.	.	.	.
83.0	20.97	36.42	25.59	243	.	.	.	.	.	.
84.0	20.94	36.43	25.61	242	.	.	.	.	.	.
85.0	20.93	36.43	25.61	241	.	.	.	.	.	.
86.0	20.90	36.43	25.62	241	.	.	.	.	.	.
87.0	20.89	36.42	25.61	241	.	.	.	.	.	.
88.0	20.86	36.43	25.63	240	.	.	.	.	.	.
89.0	20.85	36.42	25.62	240	.	.	.	.	.	.
90.0	20.83	36.43	25.64	239	.	.	.	.	.	.
91.0	20.78	36.44	25.66	237	.	.	.	.	.	.
92.0	20.72	36.43	25.67	236	.	.	.	.	.	.
93.0	20.67	36.43	25.68	235	.	.	.	.	.	.

94.0	20.63	36.43	25.69	234	.	.	.	.	.	.
95.0	20.55	36.43	25.71	232	.	.	.	.	.	.
96.0	20.51	36.43	25.72	231	.	.	.	.	.	.
97.0	20.49	36.43	25.73	230	.	.	.	.	.	.
98.0	20.48	36.43	25.73	230	.	.	.	.	.	.
99.0	20.49	36.42	25.72	231	.	.	.	.	.	.
100.0	20.49	36.42	25.72	231	.	.	.	.	.	.
101.0	20.48	36.42	25.72	231	.	.	.	.	.	.
102.0	20.47	36.42	25.73	231	.	.	.	.	.	.
103.0	20.47	36.42	25.73	231	.	.	.	.	.	.
104.0	20.43	36.43	25.74	229	.	.	.	.	.	.
105.0	20.24	36.43	25.80	225	.	.	.	.	.	.
106.0	19.94	36.44	25.88	216	.	.	.	.	.	.
107.0	19.75	36.44	25.93	212	.	.	.	.	.	.
108.0	19.70	36.44	25.95	211	.	.	.	.	.	.
109.0	19.60	36.44	25.97	208	.	.	.	.	.	.
110.0	19.25	36.43	26.06	201	.	.	.	.	.	.
111.0	18.93	36.44	26.15	192	.	.	.	.	.	.
112.0	18.77	36.41	26.17	191	.	.	.	.	.	.
113.0	18.72	36.40	26.17	190	.	.	.	.	.	.
114.0	18.68	36.40	26.18	189	.	.	.	.	.	.
115.0	18.68	36.42	26.20	188	.	.	.	.	.	.
116.0	18.66	36.40	26.19	189	.	.	.	.	.	.
117.0	18.63	36.39	26.19	190	.	.	.	.	.	.
118.0	18.61	36.41	26.21	188	.	.	.	.	.	.
119.0	18.36	36.40	26.26	183	.	.	.	.	.	.
120.0	18.17	36.37	26.29	180	.	.	.	.	.	.
121.0	17.90	36.37	26.35	174	.	.	.	.	.	.
122.0	17.69	36.35	26.39	171	.	.	.	.	.	.
123.0	17.43	36.33	26.44	166	.	.	.	.	.	.
124.0	17.16	36.30	26.48	162	.	.	.	.	.	.
125.0	17.03	36.27	26.49	162	.	.	.	.	.	.
126.0	16.94	36.25	26.50	161	.	.	.	.	.	.
127.0	16.83	36.24	26.51	160	.	.	.	.	.	.
128.0	16.60	36.23	26.56	155	.	.	.	.	.	.
129.0	16.40	36.18	26.57	154	.	.	.	.	.	.
130.0	16.35	36.17	26.57	154	.	.	.	.	.	.
131.0	16.21	36.19	26.62	150	.	.	.	.	.	.
132.0	16.02	36.15	26.64	149	.	.	.	.	.	.
133.0	15.68	36.12	26.69	143	.	.	.	.	.	.
134.0	15.24	36.04	26.73	140	.	.	.	.	.	.
135.0	14.84	35.99	26.78	135	.	.	.	.	.	.
136.0	14.68	35.97	26.80	133	.	.	.	.	.	.
137.0	14.60	35.94	26.79	134	.	.	.	.	.	.
138.0	14.54	35.94	26.81	133	.	.	.	.	.	.
139.0	14.48	35.93	26.81	132	.	.	.	.	.	.
140.0	14.44	35.91	26.80	133	.	.	.	.	.	.
141.0	14.40	35.91	26.81	132	.	.	.	.	.	.
142.0	14.29	35.90	26.83	131	.	.	.	.	.	.
143.0	14.25	35.89	26.83	131	.	.	.	.	.	.
144.0	14.13	35.88	26.85	129	.	.	.	.	.	.
145.0	13.99	35.85	26.86	129	.	.	.	.	.	.
146.0	13.77	35.83	26.89	126	.	.	.	.	.	.
147.0	13.44	35.79	26.92	122	.	.	.	.	.	.

A map of the Georgia Bight coastline, showing the intricate network of rivers and bays. The map is oriented with North at the top. The coastline is depicted in white against a dark background. The map is framed by a grid with latitude and longitude markings. Latitude 32 is marked on the left and right sides, and latitude 31 is marked on the left and right sides. Longitude 81 is marked at the top and bottom center.

Technical Report Series

Number 79-3

HYDROGRAPHIC OBSERVATIONS
IN THE GEORGIA BIGHT (JULY 1977)

by

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February 1979

The Technical Report Series of the Georgia Marine Science Center is issued by the Georgia Sea Grant Program and the Marine Extension Service of the University of Georgia on Skidaway Island (P. O. Box 13687, Savannah, Georgia 31406). It was established to provide dissemination of technical information and progress reports resulting from marine studies and investigations mainly by staff and faculty of the University System of Georgia. In addition, it is intended for the presentation of techniques and methods, reduced data, and general information of interest to industry, local, regional, and state governments and the public. Information contained in these reports is in the public domain. If this prepublication copy is cited, it should be cited as an unpublished manuscript.

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ACKNOWLEDGEMENTS

The authors thank Dr. Jack Blanton, Pat O'Malley, Lee Bailey, Eileen Hofmann, and Lynn Rubicam for their participation in the study. We also thank the Captain, mates and crew of the R/V COLUMBUS ISELIN. Dan McIntosh provided graphics assistance and Cindy Miller typed the text.

Funding for this research and report preparation was provided by the Department of Energy, under contracts EY-76-S-09-0889 to Dr. Atkinson and EY-76-S-09-0936 to Dr. Paffenhofer.

This report is published as a part of the Georgia Marine Science Center's Technical Report series issued by the Georgia Sea Grant Program under NOAA Office of Sea Grant #04-7-158-44126.

ABSTRACT

From 4 to 8 July, 1977, five hydrographic sections and one temperature section were made in the Georgia Bight between Savannah, Georgia and Jacksonville, Florida. Salinity, temperature, dissolved oxygen, nutrient (NO_3 , PO_4 , SiO_2) and chlorophyll data were collected.

Nutrient rich intrusions of cold, deep Gulf Stream waters were observed off Savannah and Jacksonville.

INTRODUCTION

This report covers Georgia Bight cruise CI-03-77 (4 to 10 July 1977) aboard the R/V COLUMBUS ISELIN. Geographically, the cruise included the continental shelf region from Savannah, Georgia south to Jacksonville, Florida. The objective was to collect physical and chemical data for correlation with biological data and current/temperature/pressure data from moored instruments deployed by the University of Miami (Dr. Tom Lee) (Fig. 1). In addition, temperature and conductivity data from the hydrographic work are used to intercompare with the moored instruments. Correlation of the hydrographic/chemical observations with the current meter data will be made at a later time. The data will provide information about the Georgia Bight for intrusion studies and frontal mappings.

Five onshore-offshore Conductivity/Temperature/Depth (CTD) sections and one Expendable Bathythermograph (XBT) section were completed during the cruise (Fig. 2). The XBT section repeated the Brunswick CTD section (stations 29X-37X). The Jacksonville section included three XBT stations (50X, 51X, and 52X) and eleven CTD stations.

The St. Simons XBT section was taken to locate sites for drogues which were to be deployed by the biological group. During drogue tracking, XBT and CTD stations alternated at 90 minute intervals (Fig. 3). After the drogues were retrieved a final XBT section (AX, BX, CX, DX) was run. Table 1 summarizes the events.

The processed hydrographic data are available from the National Oceanographic Data Center (NODC).

METHODS

At CTD stations a General Oceanics Model 1015 Mark 5 Rosette Multi-Bottle Array (equipped with 1.7 liter Niskin Bottles) and a Plessey CTD Sensor System were used. Bottle sampling depths were determined by examination of the downcast temperature profile. During the upcast, samples were taken near surface, just above or below the thermocline, at the bottom and at other selected depths. The samples were analyzed for salinity, nitrate, phosphate, silicate, dissolved oxygen, and chlorophyll.

Chemical and Physical Procedures

In the lab, salinity samples were analyzed conductometrically using a Plessey Model 6230N Lab Salinometer. These samples were used to calibrate the CTD system. A separate section of this report deals with the CTD calibration procedure. Temperature was determined with deep sea reversing thermometers, XBT's, and the CTD system.

Oxygen samples were analyzed within 24 hours of collection using a modification of the Strickland and Parsons (1965) method.

Nutrient samples were frozen in polyethylene bottles and stored in the dark until thawed for analysis onshore. Colorimetric

Table 1. Sampling Events.

Event	Station Designation	Consecutive #	Time (GMT) (h/d/m/y)
Savannah Section	1C- 13C	1-13	18.8/4/7/77-10.2/5/7/77
Ossabaw Section	14C- 19C	14-19	14.7/5/7/77-23.3/5/7/77
Sapelo Section	21C- 26C	20-25	1.5/6/7/77-8.5/6/7/77
St. Simons Section	27C- 37C	26-36	13.0/6/7/77-5.3/7/7/77
Station 37	38C	37	9.0/7/7/77
Jacksonville Section	40C- 53C	38-51	11.8/7/7/77-6.2/8/7/77
St. Simons Section	29X- 37X	52-59	14.2/8/7/77-17.9/8/7/77
Drogue Location XBT's	D1X- D2X	60-61	22.1/8/7/77-22.8/8/7/77
Drogue Tracking Stations	101X-126X	62-87	23.7/8/7/77-13.8/10/7/77
XBT Section (Drogue to Savannah)	AX- DX	88-91	15.5/10/7/77-18.5/10/7/77

determinations of the nutrient concentrations were made using a Bausch and Lomb Spectronic 88 Spectrophotometer. Silicate was determined by the method of Mullin and Riley (1955) as modified by Strickland and Parsons (1965), phosphate by the method of Murphy and Riley (1962) and nitrate by the cadmium column reduction technique of Gardner, et al. (1976).

XBT Data Acquisition and Processing

A Sippican Model LM3A Handheld Launcher equipped with T10 (for 200 m casts) or T6 (for 450 m casts) probes and Model MK2A-1 Recorders were used for XBT casts. The temperature versus depth plots were digitized on a Hewlett-Packard (H-P) Model 9864A Digitizer interfaced with an H-P Model 9825A Calculator. The digitized data was stored on H-P cartridge tapes, transferred to Texas Instruments cassette tapes, entered into the University of Georgia Cyber 70 computer, formatted for NODC, and merged with the CTD data, producing a final tape copy and printout for this report.

CTD Data Acquisition and Processing

The CTD system consists of: 1) a Plessey Model 9400 Conductivity/Temperature/Depth System; 2) a Plessey Model 8400 Digital Data Logger (DDL); 3) an H-P 9825A Calculator, to control the casts and record the data; 4) a Kennedy Model 1600 Incremental Magnetic Tape Recorder for data storage; 5) an H-P 7046 XYY' Recorder, to plot temperature and conductivity versus depth; and 6) an H-P 9862A Plotter, to plot temperature versus depth and other plots. The use of this system, and copies of the Hewlett-Packard programs can be found in Chandler, et al. (1978). A diagram of this system and general data flow are presented in Figure 4.

Plots from both the H-P 9862A and H-P 7046A plotters were logged and stored with their respective station sheets. The H-P system was still in an experimental stage during this cruise; subsequently, H-P data are reported only for stations 1C-13C, where the data recorded on the Kennedy magnetic tape was inaccurate, due to a faulty temperature board in the DDL. The remainder of the data were extracted from data stored on the magnetic tape. Further computation and data manipulation were performed on a CDC Cyber 70 computer. The extraction and processing was done according to the methods described by Chandler, et al. (1978), as summarized in Table 2. Upcasts data from the CTD sensor are reported for stations 1C-13C, 32C and 126C, where the downcast data was faulty.

CTD Calibration and Error Analysis

The CTD system was calibrated against samples taken in mixed layers. Because the conductivity sensor is affected by increased pressure at depth, regression analyses were performed (Fig. 5 for

Table 2. Data Flow. Shipboard Acquisition to NODC Submitted.

Data Source/Disposition	Program	Data File
Station 14C-53C Tape from data logger	CTDRUN (Copies tape data to computer file)	IS77
	MAGREAD (Converts binary coded data to decimal)	BIRANG
Enter depth offset	CTDUNIT (Converts decimal units to engineering units; eliminates upcast data)	LAG
Readdition of upcast data Stations 32C,49C,126C	LAGFILT (Coarse filters and temperature lag)	SWIT
From HP9825A data cassette Station 1C-13C	SWITCH (Turns upcast data around for station 1C-13C,32C,49C,126C)	LATCH
	DLATCH (Removes decreasing and repeated depths)	CTDATA
Primary calibration from bottle casts and enter salinity offset	CTDAVE5 (One meter average data)	AVE
	BROENK (Calculates salinity and sigma-t)	SGSA
Type in headers on file HEAD	NODCF0 (Converts to NODC format)	NODC
	XBTMERG (Merges headers and XBT data)	NODC + HEAD
Submitted to NODC	NUTMERG (Merges headers, NODC data and chemical data)	FINAL
	CEMBELL (Calculates specific volume anomaly, oxygen utilization and creates technical report pages)	
	and	
	STABELL (Creates station list)	TECHNICAL REPORT

H-P data and Fig. 6 for magnetic tape data) and the resulting expressions ($S = S_0 + 0.102 - 3.67 \times 10^{-4}D$ and $S = S_0 + .101 - 3.05 \times 10^{-4}D$ where S is the corrected salinity, S_0 is the salinity without calibration offset and D is the depth of the sample) were applied to generate corrected salinities for both forms of collected data. These expressions have a $0.012^{\circ}/\text{oo}$ difference at a depth of 200 m due to differences in the number of deep data points available for comparison. The calibration data used to generate both the original offsets and the formulated expressions for the effect of depth are listed in Tables 3 and 4. CTD salinities for the same stations may vary in these tables due to slight differences in the acquisition systems.

A depth offset of + 2.29 meters was applied to zero the depth sensor. The temperature sensor agreed with protected reversing thermometers within the range of accuracy ($\pm 0.02^{\circ}\text{C}$); therefore, no temperature offset was applied.

The composite maximum error of the conductivity, temperature, and depth sensors rated accuracy, resolution, and time constants and the Broenkow (1977) equations for salinity is approximately $\pm 0.06^{\circ}/\text{oo}$. However, the standard deviation of all mixed layer samples taken for salinity calibration after offset is .02.

METEOROLOGICAL CONDITIONS

Wind data from the Savannah Navigational Light Tower ($31^{\circ}57'N$, $80^{\circ}41'W$) are presented in Figure 7. Winds were mostly from the south with increasing strength and there was no precipitation.

Air temperature (Fig. 8) ranged from 29.2°C to 31.5°C and averaged 30.5°C . The daily highs and nightly lows increased 0.8°C and 1.2°C , respectively, during the 5-day period.

Additional data collected by the ship's personnel at each station are presented with the data (Appendix I).

RESULTS AND DISCUSSION

Horizontal Distributions

Surface temperatures (Fig. 9) varied from 28 to 29°C with warmest waters at the shelf break. There were no significant horizontal gradients. Near bottom temperatures (Fig. 10) decreased towards offshore with strongest gradients between 20 - 23°C . The near bottom isotherms trended southwest indicating a large subsurface intrusion to the south of the observation area.

Surface salinity (Fig. 11) was lowest off the Savannah River and maximums were found mid-shelf and to the south. Near-bottom salinity (Fig. 12) was similar in trend but higher than surface salinity.

Surface density (Fig. 13) reflected the rather chaotic thermal distribution; however, near-bottom density (Fig. 14) increased offshore in response to the decreasing temperature.

Table 3. Salinity calibration of Hewlett Packard data
(Cruise CI-03-77).

Consecutive Cast No.	Station No.	Depth (m)	Bottle ‰	CTD ‰	Difference Bottle-CTD ‰
2	2CU	13	34.910	34.832	+ .078
3	3CU	17	35.136	35.001	+ .135
4	4CU	18	35.353	35.231	+ .122
5	5CU	21	35.693	35.579	+ .114
7	7CU	34	36.150	36.078	+ .078
8	8CU	38	36.200	36.138	+ .062
9	9CU	40	36.220	36.148	+ .072
12	12CU	113	35.784	35.742	+ .042
14	14C	274	35.096	35.069	+ .027
15	15C	63	36.117	36.034	+ .083
16	16C	41	36.274	36.196	+ .078
17	17C	33	36.162	36.067	+ .095
18	18C	23	35.988	35.888	+ .100
19	19C	19	35.477	35.380	+ .097
20	21C	17	35.803	35.706	+ .097
21	22C	25	36.027	35.908	+ .119
22	23C	40	36.202	36.103	+ .099
23	24C	43	36.300	36.217	+ .083
24	25C	45	36.196	36.128	+ .068
25	26C	232	34.938	34.901	+ .037
28	29C	58	36.216	36.105	+ .111
29	30C	38	36.281	36.202	+ .079
30	31C	34	36.267	36.183	+ .084
31	32C	33	36.304	36.218	+ .086
32	33C	32	36.294	36.218	+ .076
33	34C	27	36.282	36.197	+ .085
34	35C	28	36.271	36.191	+ .080
36	37C	18	36.132	36.031	+ .101
37	38C	22	36.343	36.247	+ .096
39	41C	27	36.306	36.217	+ .089
40	42C	28	36.289	36.205	+ .084
41	43C	28	36.255	36.161	+ .094
42	44C	31	36.265	36.171	+ .094
43	45C	36	36.254	36.145	+ .109
47	49C	206	34.987	34.933	+ .054
65	104C	36	36.273	36.177	+ .096
67	106C	38	36.268	36.183	+ .085
71	110C	40	36.250	36.158	+ .092
73	112C	41	36.253	36.168	+ .085
75	114C	41	36.260	36.173	+ .087

Table 3. Continued

Consecutive Cast No.	Station No.	Depth (m)	Bottle ‰	CTD ‰	Difference Bottle-CTD ‰
79	118C	43	36.213	36.130	+ .083
81	120C	43	36.213	36.124	+ .089
83	122C	39	36.227	36.150	+ .077
85	124C	43	36.249	36.166	+ .083
87	126C	45	36.222	36.147	+ .075

Table 4. Salinity calibration of magnetic tape data
(Cruise CI-03-77).

Consecutive Cast No.	Station No.	Depth (m)	Bottle ‰	CTD ‰	Difference Bottle-CTD ‰
14	14C	274	35.096	35.062	+ .034
15	15C	63	36.117	36.035	+ .082
16	16C	41	36.274	36.191	+ .083
17	17C	33	36.162	36.060	+ .102
18	18C	23	35.988	35.886	+ .102
19	19C	19	35.477	35.375	+ .102
20	21C	17	35.803	35.708	+ .095
21	22C	25	36.027	35.927	+ .100
22	23C	40	36.202	36.109	+ .093
23	24C	43	36.300	36.227	+ .073
24	25C	45	36.196	36.126	+ .070
25	26C	232	34.938	34.905	+ .033
28	29C	58	36.216	36.103	+ .113
29	30C	38	36.281	36.199	+ .082
30	31C	34	36.267	36.174	+ .093
31	32C	33	36.304	36.215	+ .089
32	33C	32	36.294	36.210	+ .084
33	34C	27	36.282	36.195	+ .087
34	35C	28	36.271	36.180	+ .091
36	37C	18	36.132	36.028	+ .104
37	38C	22	36.343	36.243	+ .100
39	41C	27	36.306	36.218	+ .088
40	42C	28	36.289	36.204	+ .085
41	43C	28	36.255	36.157	+ .098
42	44C	31	36.265	36.173	+ .092
43	45C	36	36.254	36.139	+ .115
47	49C	206	34.987	34.934	+ .053
65	104C	36	36.273	36.181	+ .092
67	106C	38	36.268	36.181	+ .087
71	110C	40	36.250	36.153	+ .097
73	112C	41	36.253	36.163	+ .090
75	114C	41	36.260	36.170	+ .090
79	118C	42	36.213	36.131	+ .082
81	120C	42	36.213	36.120	+ .093
83	122C	40	36.227	36.154	+ .073
85	124C	44	36.249	36.152	+ .097
87	126C	43	36.222	36.141	+ .081

Near-bottom nutrient concentrations (Figs. 15-17) were very high in outer shelf waters in response to the assumed influx of deeper Gulf Stream waters. Low surface silicate concentrations (Fig. 18), which indicate runoff distribution, were generally low.

Surface chlorophyll concentrations (Fig. 19) were highest nearshore off Jacksonville while near-bottom concentrations (Fig. 20) were high nearshore off Savannah. A mid-shelf maximum of $4\mu\text{g l}^{-1}$ was found off Jacksonville.

Vertical Distributions

The vertical sections (Figs. 21-31) clearly show the apparent active advection of deeper Gulf Stream water onto the shelf. These waters are characteristically colder, saltier and contain high nutrient concentrations and low oxygen.

The core of high density water ($> 36.50^\circ/\text{oo}$), which indicates the Gulf Stream core, was further offshore off Savannah (Fig. 21) and Jacksonville (Fig. 29) relative to the area between (Figs. 23, 25, and 27). This observation is confirmed in the lower temperatures at the shelf break off Savannah and Jacksonville.

Mid-shelf upwelling appeared to be occurring mid-shelf at all sections except Jacksonville. The result was a lower temperature, higher salinity band that isolated a lens of warm lower salinity water over the outer shelf. One result was a maximum in pycnocline strength over that outer shelf. Off Jacksonville no outer shelf low salinity band was observed although the density section indicates slight erosion of the thermocline.

The only time series observations made, excluding the drogue tracking experiment, were the St. Simons section which was run on 6-7 July (Fig. 27-28) and again on 8 July (Fig. 31). As stated previously, the St. Simons section was between the two zones of Gulf Stream intrusion. On 6-7 July the Gulf Stream was near the shelf break and the 24°C water was apparently stranded on the outer shelf. On 8 July the inner shelf waters appeared to be unchanged but 18°C water invaded the outer shelf waters replacing the $24\text{-}25^\circ\text{C}$ water previously there. This observation confirms the hypothesis of northerly propagation of Gulf Stream meanders and eddies.

To place the hydrographic situation in relation to nutrient distribution and chlorophyll concentrations composite plots were made (Figs. 32-35). Fig. 32 shows the relative position of the sections. The temperature-nitrate composite (Fig. 33) shows the greatest intrusion of $2\mu\text{M NO}_3$ water off Savannah and Jacksonville and the least penetration off St. Simons. Temperature-chlorophyll comparisons (Fig. 34) suggest that chlorophyll production occurs at the "leading edge" of the intruding water.

NUTRIENT RELATIONSHIPS

The relationships between nutrient, temperature and salinity are useful for data quality assessment and elucidation of certain biological and physical interactions.

The nitrate-phosphate plot (Fig. 36) shows the typical 16:1 nitrate to phosphate ratio. At low concentrations phosphate was disproportionately higher than nitrate possibly because of faster release of phosphate in surface and shelf waters.

The silicate-nitrate plot (Fig. 37) shows direct correlation between the two.

The nutrient-temperature plots (Figs. 38-40) show the linear relation that exists in these waters. The nitrate-temperature and phosphate-temperature plots (Figs. 38-39) are quite linear up to 23°C above which non-conservative processes prevail. The silicate-temperature plot (Fig. 40) is not linear but does behave similarly to nitrate and phosphate above 23°C. The non-linearity is a result of mixing of several water types in the 5-15°C temperature range (Stefánsson and Atkinson, 1971).

Temperature-Salinity

The composite T-S plot for all samples (Fig. 41) is typical of summer conditions in the Bight. There were considerable amounts of water between 15 and 23°C that were slightly lower in salinity than normal Gulf Stream waters and represent mixtures of shelf and Gulf Stream waters. Waters greater than 27°C varied in salinity from 33.8 to 36.4‰ with lower values from nearshore off Savannah.

A T-S analysis of each section indicated that the shelf was flooded with waters of dominant Gulf Stream characteristics except nearshore off Savannah.

The salinity maximum appeared at station 53C, Jacksonville section, with values of 36.80‰ (see data in Appendix and Fig. 29).

Oxygen Anomaly

The oxygen anomaly (Richards and Redfield, 1955) (Fig. 42) indicates whether the observed Gulf Stream waters are of Caribbean or Antilles origin. Waters of Caribbean origin generally have anomalies greater than 0.5 or 1.0 ml l⁻¹ while water of Antilles origin has no anomaly. Anomalies less than 0.5 ml l⁻¹ are not significant and those in waters less dense than $\sigma_T = 25$ are not included because of non-conservative processes. The largest anomalies (+ 0.99 to 1.32) were found mid-depth at station 26C in the Sapelo section and stations 27C and 28C in the St. Simons section. These sections are also where the Gulf Stream was furthest west.

Since essentially all samples greater than $\sigma_T = 25$ had a significant anomaly, we conclude that the sampled waters were of Caribbean rather than Antilles origin.

DROGUE OBSERVATIONS

A drogue was launched at 23.7 (GMT) on 8 July and tracked until 13.8 on 10 July. The drogue sail was placed at a depth of 24-26 meters which was below the thermocline. During the drogue tracking experiment, XBT and CTD samples were taken alternately every 90 minutes. CTD casts

also included nutrient and chlorophyll samples. These data are included in Appendix II.

The drogue track (Fig. 43) was to the northeast with a tidal onshore/offshore drift. The net drogue movement coincided with the mean wind.

Figure 44 is a time series of parameters measured during the drogue drift. The 3 hour wave feature noticeable in the thermocline is partly due to different response times of the CTD and XBT's. The drogue apparently did not track the same water mass. Bottom temperatures decreased from 23°C to 21°C and then warmed again towards the end of the sampling period. The presence of water approaching 21°C is critical since at that temperature, nitrate concentrations increase dramatically. With the increase in nutrients, chlorophyll increased.

SUMMARY

1. During the sampling period subsurface intrusions of Gulf Stream water penetrated partly across the shelf off Savannah; however, off Jacksonville the intrusion of nutrient rich water extended across the shelf to within ca. 20 km of the coast. Between the Savannah and Jacksonville sections, the Gulf Stream was nearer shore and relatively warmer water was found in that area. It is concluded that either a Gulf Stream meander or eddy was present north of Savannah and likewise off Jacksonville. There are not sufficient data to determine whether a meander or eddy was present.

2. Off St. Simons 23.5°C water was apparently stranded on the shelf by a shoreward migration of the Gulf Stream.

3. Chlorophyll concentrations were generally high in nearshore areas and at the leading edge of subsurface Gulf Stream intrusions.

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FIGURES

Fig. 1. Georgia Bight, Current/Temperature/Pressure moorings designated A-G.

Fig. 2. Georgia Bight, station locations, Cruise CI-03-77, hydrographic leg.

Fig. 3. Drogue tract. In 8 July 23.7 GMT, out 10 July 18.8 GMT, samples taken every 90 minutes.

Fig. 4. Schematic of CTD acquisition system.

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Fig. 8. Air temperature ($^{\circ}\text{C}$) data, Savannah Navigational Light Tower, 4-8 July 1977, at one hour intervals (Blanton, Bailey and Hayes, 1978)).

Fig. 9. Horizontal surface temperature ($^{\circ}\text{C}$) distribution.

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Fig. 11. Horizontal surface salinity (‰) distribution.

Fig. 12. Horizontal bottom salinity (‰) distribution.

Fig. 13. Horizontal surface sigma-t distribution.

Fig. 14. Horizontal bottom sigma-t distribution.

Fig. 15. Horizontal bottom nitrate (μM) distribution.

Fig. 16. Horizontal bottom phosphate (μM) distribution.

Fig. 17. Horizontal bottom silicate (μM) distribution.

Fig. 18. Horizontal surface silicate (μM) distribution.

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Fig. 43. Drogue tract. In 8 July 23.7 GMT, out 10 July 18.8 GMT, samples taken every 90 minutes.

Fig. 44. Time series of parameters measured during the drogue drift. (stations 101x-126c). In the same area marked "see caption," salinities are not contoured because of extreme scatter.

APPENDIX I:
Hydrographic Data

STATION SUMMARY FOR ISELIN CRUISE CI-03									ISELIN CRUISE CI-03									(CONTINUED)											
CRUISE	STATION	LATITUDE	LONGITUDE	YR	MM	DT	HOUR	DEPTH	CONSEC	CRUISE	STATION	LATITUDE	LONGITUDE	YR	MM	DT	HOUR	DEPTH	CONSEC	CRUISE	STATION	LATITUDE	LONGITUDE	YR	MM	DT	HOUR	DEPTH	CONSEC
							GMT	M	NUMBER								GMT	M	NUMBER								GMT	M	NUMBER
003	001CU	31 55.0N	80 42.0W	77	7	4	18.8	14	1	003	050X	30 14.9N	80 4.1W	77	7	8	2.8	347	48	003	051X	30 14.7N	79 52.0W	77	7	8	3.9	570	49
003	002CU	31 53.0N	80 36.1W	77	7	4	19.9	13	2	003	052X	30 15.0N	79 39.9W	77	7	8	4.8	826	50	003	053C	30 14.5N	79 27.6W	77	7	8	6.2	734	51
003	003CU	31 51.0N	80 30.0W	77	7	4	20.8	17	3	003	029X	30 51.0N	80 4.5W	77	7	8	14.2	44	52	003	030X	30 53.3N	80 10.0W	77	7	8	14.7	40	53
003	004CU	31 49.0N	80 24.5W	77	7	4	22.1	18	4	003	031X	30 55.0N	80 15.5W	77	7	8	15.1	37	54	003	032X	30 57.0N	80 21.5W	77	7	8	15.6	33	55
003	005CU	31 47.0N	80 18.5W	77	7	4	23.3	21	5	003	034X	31 1.5N	80 32.4W	77	7	8	16.5	29	56	003	035X	31 3.5N	80 38.5W	77	7	8	17.0	26	57
003	006CU	31 45.4N	80 12.4W	77	7	5	1.0	29	6	003	036X	31 5.7N	80 44.5W	77	7	8	17.5	21	58	003	037X	31 7.5N	80 50.0W	77	7	8	17.9	20	59
003	007CU	31 43.5N	80 6.5W	77	7	5	2.3	34	7	003	001X	30 59.2N	80 27.3W	77	7	8	22.1	34	60	003	002X	31 1.4N	80 33.1W	77	7	8	22.8	28	61
003	008CU	31 42.0N	80 .9W	77	7	5	4.1	38	8	003	003X	31 1.4N	80 33.1W	77	7	8	23.7	34	62	003	101X	30 56.3N	80 14.9W	77	7	9	1.5	33	63
003	009CU	31 39.6N	79 54.6W	77	7	5	5.0	40	9	003	102C	30 56.2N	80 14.4W	77	7	9	3.0	37	64	003	103X	30 56.2N	80 14.4W	77	7	9	3.0	37	64
003	010CU	31 38.2N	79 49.4W	77	7	5	6.7	41	10	003	104C	30 56.7N	80 14.9W	77	7	9	4.7	37	65	003	105X	30 57.5N	80 15.0W	77	7	9	6.0	39	66
003	011CU	31 36.0N	79 43.0W	77	7	5	7.6	54	11	003	106C	30 57.5N	80 15.1W	77	7	9	7.5	38	67	003	107X	30 58.4N	80 14.7W	77	7	9	9.0	38	68
003	012CU	31 34.5N	79 37.5W	77	7	5	9.0	113	12	003	108C	30 59.1N	80 14.0W	77	7	9	10.4	39	69	003	109X	30 59.0N	80 12.5W	77	7	9	12.0	43	70
003	013CU	31 32.8N	79 31.5W	77	7	5	10.2	241	13	003	110C	30 59.3N	80 12.5W	77	7	9	13.5	40	71	003	111X	30 59.5N	80 12.2W	77	7	9	15.0	39	72
003	014C	31 21.6N	79 35.9W	77	7	5	14.7	274	14	003	112C	30 59.4N	80 12.7W	77	7	9	16.5	42	73	003	113X	31 .9N	80 13.4W	77	7	9	18.0	41	74
003	015C	31 25.0N	79 47.7W	77	7	5	17.2	63	15	003	114C	31 2.0N	80 13.0W	77	7	9	19.5	42	75	003	115X	30 50.4N	80 12.0W	77	7	9	21.0	40	76
003	016C	31 28.6N	79 59.8W	77	7	5	18.6	41	16	003	116C	31 .5N	80 12.5W	77	7	9	22.5	43	77	003	117X	31 2.5N	80 9.4W	77	7	10	0.0	44	78
003	017C	31 32.5N	80 11.5W	77	7	5	20.5	33	17	003	118C	31 2.2N	80 8.7W	77	7	10	1.5	43	79	003	119X	31 2.4N	80 9.8W	77	7	10	3.0	43	80
003	018C	31 36.0N	80 23.5W	77	7	5	21.9	23	18	003	120C	31 3.0N	80 10.0W	77	7	10	4.5	44	81	003	121X	31 1.4N	80 10.7W	77	7	10	5.0	42	82
003	019C	31 39.5N	80 35.0W	77	7	5	23.3	19	19	003	122C	31 3.3N	80 11.2W	77	7	10	7.5	43	83	003	123X	31 4.5N	80 10.3W	77	7	10	9.0	43	84
003	021C	31 25.0N	80 44.9W	77	7	6	1.5	17	20	003	124C	31 4.9N	80 11.0W	77	7	10	10.5	46	85	003	125X	31 3.7N	80 12.0W	77	7	10	12.0	44	86
003	022C	31 21.9N	80 32.9W	77	7	6	3.0	25	21	003	126CU	31 3.7N	80 12.0W	77	7	10	13.8	45	87	003	00AX	31 18.0N	80 18.3W	77	7	10	15.5	36	88
003	023C	31 18.5N	80 21.0W	77	7	6	4.4	40	22	003	00BX	31 28.0N	80 25.0W	77	7	10	16.5	29	89	003	00CX	31 38.7N	80 32.0W	77	7	10	17.7	21	90
003	024C	31 15.5N	80 9.0W	77	7	6	5.9	43	23	003	00DX	31 49.2N	80 38.2W	77	7	10	18.5	17	91										
003	025C	31 12.5N	79 57.0W	77	7	6	7.2	45	24																				
003	026C	31 9.0N	79 45.0W	77	7	6	8.5	232	25																				
003	027C	30 47.0N	79 52.8W	77	7	6	13.0	588	26																				
003	028C	30 49.0N	79 58.5W	77	7	6	16.6	190	27																				
003	029C	30 51.0N	80 4.5W	77	7	6	18.4	58	28																				
003	030C	30 53.3N	80 10.0W	77	7	6	20.7	38	29																				
003	031C	30 55.0N	80 15.5W	77	7	6	21.9	34	30																				
003	032CU	30 57.0N	80 21.5W	77	7	6	23.3	33	31																				
003	033C	30 59.2N	80 27.3W	77	7	7	.2	32	32																				
003	034C	31 1.4N	80 33.1W	77	7	7	1.8	27	33																				
003	035C	31 3.5N	80 38.8W	77	7	7	2.8	28	34																				
003	036C	31 5.5N	80 44.5W	77	7	7	4.2	21	35																				
003	037C	31 7.4N	80 50.0W	77	7	7	5.3	18	36																				
003	038C	30 41.5N	80 58.5W	77	7	7	9.0	22	37																				
003	040C	30 15.0N	80 6.5W	77	7	7	11.8	20	38																				
003	041C	30 15.2N	81 .4W	77	7	7	13.2	27	39																				
003	042C	30 15.0N	80 54.1W	77	7	7	14.2	28	40																				
003	043C	30 15.0N	80 47.9W	77	7	7	15.9	28	41																				
003	044C	30 15.0N	80 41.7W	77	7	7	16.8	31	42																				
003	045C	30 15.0N	80 35.0W	77	7	7	19.8	36	43																				
003	046C	30 15.0N	80 29.0W	77	7	7	21.0	38	44																				
003	047C	30 15.0N	80 23.0W	77	7	7	22.5	39	45																				
003	048C	30 15.0N	80 16.5W	77	7	7	23.8	43	46																				
003	049C	30 14.9N	80 10.2W	77	7	8	1.1	206	47																				

Table 5. Station Summary for Iselin Cruise CI-03-77.

HYDROGRAPHIC DATA

Vertical profiles of salinity, temperature, sigma-t, DO, and nutrients

The symbols used in the following listings are defined as follows:

Header Data: Times are CMT (EDT + 4)
 Latitude and Longitude are from Loran C

Weather Data: These data are taken from the ship's log.

Wind speed (knots)
 Wind direction (degrees)
 Air temperature (°C)
 Weather (WMO code 4501)
 Barometric pressure (mb)
 Sea State (WMO code 3700)
 Wave direction (degrees)
 Cloud type (not given)
 Cloud amount (not given)
 Visibility code (not given)

Observations:

Z = Depth in meters
 T = Temperature in °C
 S = Salinity in ‰
 D = Density in sigma-t units
 SVA = Specific volume anomaly $\times 10^5$
 O₂ = Dissolved oxygen in ml/liter
 O₂' = Oxygen saturation in ml/liter
 AOU = Apparent oxygen utilization in ml/liter
 PO₄ = Phosphate concentration in $\mu\text{mole/liter}$
 NO₃ = Nitrate concentration in $\mu\text{mole/liter}$
 Si = Silicate concentration in $\mu\text{mole/liter}$

A map of the Georgia Bight coastline, showing the intricate network of rivers and bays. The map is oriented with North at the top. Latitude lines are marked at 31 and 32 degrees North, and longitude lines are marked at 81 and 82 degrees West. The coastline is detailed, showing major rivers like the Savannah, Altamaha, and Ogeechee, and bays like the Chatham and Pamlico.

Technical Report Series

Number 79-1

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January 1979

The Technical Report Series of the Georgia Marine Science Center is issued by the Georgia Sea Grant Program and the Marine Extension Service of the University of Georgia on Skidaway Island (P. O. Box 13687, Savannah, Georgia 31406). It was established to provide dissemination of technical information and progress reports resulting from marine studies and investigations mainly by staff and faculty of the University System of Georgia. In addition, it is intended for the presentation of techniques and methods, reduced data and general information of interest to industry, local, regional, and state governments and the public. Information contained in these reports is in the public domain. If this prepublication copy is cited, it should be cited as an unpublished manuscript.

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Acknowledgements

The authors thank Drs. J. O. Blanton and D. W. Menzel for critically reading the manuscript.

The following people participated in the cruise and their help was appreciated: D. Gregory, R. Findley, O. Guest, L. Quad, D. Huntley, A. Brinko, N. Chalker, P. Thompson, and M. Kelley. We would also like to thank the Captain and crew of the R/V ISELIN for their efforts. Dan McIntosh and Cindy Miller are thanked for graphics and typing, respectively.

Funding for this research and report is provided by the Department of Energy, under contract EY-76-S-09-0889 to L. P. Atkinson, and contract EY-76-S-05-5163 to T. N. Lee.

This report is published as a part of the Georgia Marine Science Center's Technical Report series issued by the Georgia Sea Grant Program under NOAA Office of Sea Grant #04-7-158-44126.

Abstract

During a cruise in the Georgia Bight in December 1976 two onshore-offshore hydrographic sections were repeated three times over a four-day period. Temperature, salinity, dissolved oxygen, and nutrient (NO_3 , PO_4 , and SiO_2) data were collected.

The shelf waters were vertically well mixed with horizontal gradients typical of winter conditions. A Gulf Stream meander was observed near the shelf break with upwelling velocities as high as $2.8 \times 10^{-2} \text{ cm sec}^{-1}$ and an along stream propagation of 31 cm/sec (26.8 km/day).

Introduction

This report contains chemical and physical data obtained during Georgia Bight cruise CI-12-76 (9-15 December 1976) aboard the R/V COLUMBUS ISELIN. The investigation was part of a larger multi-institutional Department of Energy program to understand event scale, physical, chemical, and biological processes of the South Atlantic Bight, the continental shelf region from Cape Hatteras to Cape Canaveral. The study reported here is concentrated in the Georgia Bight near Savannah, Georgia. Specifically, the objective was to collect physical and chemical data such that 3-dimensional, quasi-synoptic measurements of the interactions of shelf and Gulf Stream waters could be made. In addition, the hydrographic data were used to compare with moored instruments deployed by the University of Miami (Dr. Tom Lee). The hydrographic data sets are available from the National Oceanographic Data Center (NODC).

Methods

Two onshore-offshore hydrographic sections were repeated three times (Figure 1) between 10 and 14 December. Between stations a thermosalinograph was operated to obtain a detailed map of surface temperatures and salinities.

A typical hydrographic section consisted of alternate CTD (conductivity/temperature/depth) Rosette casts and XBT (expendable bathythermograph) casts at approximately 10 kilometer intervals. The Brunswick section (14-15 December) consisted exclusively of XBT stations 10 kilometers apart.

At CTD stations, a General Oceanics Model 1015 Mark 5 Rosette multi-bottle array with 1.7 liter Niskin Bottles and a Plessey Model 9400 CTD sensor system were used for water sampling. Niskin sampling depths were determined from the temperature structure obtained from the CTD. Samples were taken near the surface, just above or below the thermocline, at the bottom, and occasionally at other depths. Samples were analyzed for salinity, nitrate, phosphate, silicate, and dissolved oxygen.

Chemical and Physical Procedures

Salinity samples were analyzed conductometrically using a Plessey Model 6230N salinometer. Values obtained were used to calibrate the Plessey Model 9400 CTD system. A separate section of this report details the CTD calibration procedure. Temperature was determined with deep sea reversing thermometers, XBT's, and the CTD system.

Dissolved oxygen analyses were performed within 24 hours of collection using a modified Winkler procedure (Strickland and Parsons, 1965).

Nutrient samples were immediately frozen in polyethylene bottles and stored in the dark until thawed and analyzed ashore. Colorimetric

Figure 1. Location of Stations on Cruise CI-12-76.

determinations of nutrient concentrations were made utilizing a Bausch and Lomb Spectronic 88 spectrophotometer with a sample sipper. Silicate was determined by the method of Mullin and Riley (1955) as modified by Strickland and Parsons (1965), phosphate by the method of Murphy and Riley (1962), and nitrate by the cadmium column reduction technique as modified by Gardner, et al. (1976).

XBT Data Acquisition and Processing

A Sippican Model LM3A handheld launcher and an MK2A-1 recorder were used for XBT casts. The temperature/depth plots were manually digitized and these data were placed in NODC format and merged with processed CTD data. Depths at which temperature is a whole or half degree are reported as are depths at which a significant mixed layer begins or ends.

CTD Data Acquisition

The CTD unit consists of a Plessey Model 9400 CTD sensor system with a Model 8400 digital data logger and Kennedy Model 1600 incremental magnetic tape recorder for data acquisition and storage. A redundant 'YYY' plot was made of all casts using a Hewlett-Packard Model 7046 X-Y-Y recorder which was calibrated with a precision 10VDC source.

Digitized data were collected as the CTD sensor unit was lowered at 15m/min on a two conductor cable. All three parameters (C, T, and D) were sampled once each 229 milliseconds or every 6 cm at the 15m/min lowering rate. For primary calibration of temperature and salinity, a Niskin bottle equipped with paired protected deep sea reversing thermometers was tripped after a four minute equilibration period at the maximum sample depth in mixed layers. Other water samples were collected during ascent at depths selected after examination of the downcast temperature structure. The average time for stations less than 100 meters in depth was 25 minutes; for those greater than 100 meters, average time was 48 minutes, with a maximum of 65 minutes at station 20C.

CTD Data Processing

CTD plots were logged and stored with their respective station sheets. All data recorded on magnetic tape were extracted and processed according to the flow scheme shown in Table 1. Computation and data manipulation were performed on a CDC Cyber 70/74 computer. All CTD data were acquired and processed according to the methods described by Chandler, et al. (1978).

CTD Calibration

The CTD system was calibrated only against bottle samples in mixed layers to insure that the sensors and the bottles were sampling

Table 1. CTD/Data Flow. Shipboard Acquisition to NODC Submission.

Data Source/Disposition	Program	Data File
Tape from Data Logger	MAGREAD	(Converts binary coded data to decimal)
		BIRANG
	CTDUNIT	(Converts decimal units to engineering units)
		LAG
	LAGFILT	(Course filters and temperature lag)
		LATCH
	DLATCH	(Removes decreasing and repeated depths)
Primary Calibration from Bottle Casts		CTDATA
	CTDAVE5	(One meter average data less than 100 meters and 5 meter average data after 100 meters)
		AVE
	BROENK	(Calculates salinity and sigma-t)
		SGSA
	NODCFO	(Converts to NODC format)
		NODC + HEAD
Submission to NODC	NUTMERG	(Merges NODC data with headers and chemical data)
		FINAL (CTD)
	STAMERG	(Merges CTD and XBT data)
		CI012
	CEMLIST	(Calculates specific volume anomaly, oxygen utilization, etc.)
		TECHNICAL REPORT

the same water. However, since a mixed layer was not always observed, comparisons could not be made at every station. The resulting mean offset, + 0.020‰ (Figure 2) was applied to all stations at which the maximum sampling depth was less than 50m. At depths greater than 50m, it was found that the effects of pressure could not be neglected. For these stations a regression analysis was performed (Figure 3) and an expression ($S = S_0 + 0.023 - 1.57 \times 10^{-4}D$ where S is the corrected salinity, S_0 is the calculated salinity without a calibration offset and D is the depth of the sample) was obtained. This expression was applied to generate corrected salinities at all CTD stations at which the maximum depth was greater than 50m.

After the entire data set was treated with the derived offset equation, + 0.10‰ was added to the salinities from casts 49C, 64C, and 99C. It is thought that powering up operations may be the cause of these higher offsets as 2 of the 3 problem casts (49C and 99C) were at the beginning of sections. The calibration data used to generate both the original offset and the subsequent expression for the depth effect are listed in Table 2. (Station numbers are discontinuous since thermosalinograph stations were established at intervals between hydrographic sections). Calibration data for stations 49C, 64C, and 99C were rejected in establishing the original offset equations.

No depth offset was necessary, and no temperature offset was applied since the CTD temperature sensor agreed with protected reversing thermometers within the range of accuracy ($\pm 0.02^\circ\text{C}$).

CTD Error Analysis

The Plessey Model 9400 CTD system has the following rated accuracy, resolution, and time constants (Table 3).

Table 3. Specifications for Plessey Model 9400 CTD System.

	Conductivity	Temperature	Depth
Accuracy	± 0.03 mmho/cm	$\pm 0.02^\circ\text{C}$	± 1.5 m
Resolution	0.0001 mmho/cm	0.0001 $^\circ\text{C}$	0.0012 m
Time Constant	0.1 sec	0.35 sec	0.1 sec

Since salinity is not measured directly, it must be calculated from the above parameters, resulting in the composite errors of the C, T, and D sensors and the salinity equation.

By varying "real" C, T, and D by the rated sensor accuracies in the salinity equation (Tables 4 and 5), the maximum error

Figure 2. Mean offset for salinities at stations at which the maximum sampling depth was less than 50m (—— mean offset;-----standard deviation).

Figure 3. Regression analysis of salinity offset versus depth of sample.

Table 2. Cruise CI-12-76 Salinity Calibration Data.

Consecutive Cast No.	Station No.	Depth (m)	Bottle ‰	CTD ‰	Difference Bottle-CTD(‰)
1	20C	402	35.163	35.188	- .025
2	21C	13	33.878	33.869	+ .009
3	22C	20	35.020	34.962	+ .058
4	23C	21	35.894	35.907	- .013
5	24C	29	36.103	36.076	+ .027
6	26C	38	36.094	36.070	+ .024
7	28C	44	36.129	36.087	+ .042
8	30C	136	36.162	36.139	+ .023
9	32C	438	34.969	35.012	- .043
11	50C	19	35.585	35.577	+ .008
12	51C	24	35.878	35.911	- .033
14	56C	28	36.066	36.062	+ .004
15	58C	34	36.109	36.079	+ .030
16	60C	38	36.100	36.065	+ .035
19	75C	19	35.672	35.667	+ .005
20	77C	27	36.081	36.055	+ .026
21	79C	39	36.107	36.087	+ .020
22	81C	44	36.146	36.114	+ .032
23	83C	140	36.123	36.157	- .034
24	85C	379	34.997	35.047	- .050
26	101C	31	36.048	36.027	+ .021
27	103C	34	36.098	36.056	+ .042
28	105C	40	36.076	36.069	+ .007
30	109C	432	34.995	35.043	- .048
31	134C	18	35.675	35.685	- .010
32	136C	26	36.099	36.046	+ .053
33	138C	37	36.096	36.076	+ .020
34	141C	42	36.115	36.093	+ .022
35	143C	102	36.096	36.097	- .001

Table 4. Broenkow's Salinity Equations.

$$\begin{aligned}
 R_Z &= 1 + .01\{(1.551 - .0453T + 59 \times 10^{-5}T^2) \\
 &\quad + \frac{1}{4}(35-S)(.043 - .0017T + 23 \times 10^{-6}T^2)\}\{1.037 \times 10^{-3}Z \\
 &\quad - 32 \times 10^{-9}Z^2\} \\
 A_T &= (676547 + 20131.5T + 99.89T^2 - .1943T^3 - .00672T^4) 10^{-6} \\
 R_T &= \frac{C(S,T,Z)}{R_Z A_T 42.896} \\
 \Delta_{15} &= R_T(R_T-1)(T-15) \{96.7 - 72R_T + 37.3R_T^2 \\
 &\quad - (.63 + .21R_T^2)(T-15)\}10^{-5} \\
 R_{15} &= R_T + \Delta_{15} \\
 S^{0/00} &= .08996 + 28.2972R_{15} + 12.80832R_{15}^2 - 10.67869R_{15}^3 \\
 &\quad + 5.98624R_{15}^4 - 1.32311R_{15}^5
 \end{aligned}$$

where: R = conductivity ratio

Z = depth (meters)

T = temperature ($^{\circ}\text{C}$)

C = measured conductivity (mmhos/cm)

S = salinity ($^{\circ}/00$)

Table 5. Flow Using Broenkow's Salinity Equations.

*without the R_Z term

R_Z = pressure effect on conductivity

A_T = temperature effect

R_T = $R(S, t, p)$ conductivity ratio

Δ_{15} = t_{15} correction (International Oceanographic Tables, 1966)

R_{15} = $R(S, 15^\circ\text{C}, 0)$

attributable to each sensor can be determined. The composite maximum error is approximately $\pm 0.06^{\circ}/\text{oo}$ for "real" data sets. However, the standard deviation of all mixed layer samples taken for salinity calibration purposes implies greater accuracy, namely $\pm 0.02^{\circ}/\text{oo}$ after offset for this data set. We believe this value is a more realistic measure of the quality of the data set.

Meteorological Conditions

Wind data from Savannah, Georgia are presented in Figure 4. These data are derived from the monthly summary for December 1976 (U.S. Department of Commerce, December 1976) and are plotted in GMT at three-hour intervals.

Winds were generally northeasterly from 9-15 December with a southerly interruption on 11 and 12 December. The strongest winds were observed on 13 December averaging 9.0 knots.

Air temperature at the Savannah station ranged from 9°C to 22°C during the cruise period. Additional meteorological data, collected by the ship's personnel, are presented with the data.

Figure 4. Wind speed and direction recorded at Savannah Airport.

Results and Discussion

The results of the synoptic mapping are shown in Figures 5-16 in both horizontal and vertical planes.

Surface Temperature Distributions

Included with the three surface temperature maps is the map obtained by the Coast Guard Airborne Radiation Thermometer flight on 9 December 1976 (Figure 5). Surface temperature over the time period increased towards the offshore with isotherms paralleling the coast. The Stream was, as determined by the 21-24°C isotherm, meandering with the maximum offshore position in the southern part of the area on 10-11 December, and, with time, migrating north until the 14th when the offshore meander was apparently north of the observation area. The ART flight data indicates that on 9 December the Stream was relatively far to the west. The strongest thermal gradients were observed on 12-13 December when the Stream was advancing again to the west.

Subsurface Distributions

Gulf Stream meandering has been related to upwelling at the shelf break with easterly movements of the stream related to lower temperatures at the shelf break (Atkinson, 1977). Thus the observed offshore meander should coincide with observed upwelling. The vertical sections (Figures 6-16) clearly show upwelling and downwelling associated with the meander. Following is a description of each section:

Savannah Section, 10-11 December 1976. (Figures 6-7) The shelf water was well mixed vertically with horizontal gradients. Offshore, upwelling can be seen in the isotherms positions as well as the distribution of nitrate and phosphate. Upwelling in this region is typical when the Gulf Stream is offshore of the shelf break.

Savannah Section, 12 December 1976. (Figures 8-9) The shelf waters were well mixed with horizontal gradients and once again upwelling can be seen in the temperature, nitrate and oxygen data. Elevated nutrient concentration at the shelf break indicate that upwelling reach the surface. The Gulf Stream was closer to shore than on 10-11 December.

Savannah Section, 14 December 1976. (Figures 10-11) The shelf waters were unstratified with high nitrate and phosphate waters at the shelf break indicative of recent upwelling. The Gulf Stream was further onshore (24°C isotherm).

Brunswick Section, 11-12 December 1976. (Figures 12-13) Typical winter conditions persisted on the shelf. The isotherms indicate some upwelling, but as the Savannah section on these dates, this feature is weak. Nitrate, phosphate, and silicate plots also indicate upwelling.

Brunswick Section, 13 December 1976. (Figures 14-15) Typical winter conditions persisted over the shelf. The Gulf Stream moved onshore a distance of approximately 12 km and downwelling occurred along the slope to a depth of ca. 175 m.

Brunswick Section, 14-15 December 1976. (Figure 16) There was little change from the profile made on 13 December. The Gulf Stream moved offshore (compare with 24°C isotherm for 13 December; Figure 14) and some upwelling was present as shown by the positions of the 20°C and 21°C isotherms. No salinity or nutrient data are available.

Onshore/Offshore Motions

The onshore-offshore velocities were determined from the distance the 21°C and 24°C isotherms moved during the three observation periods. The isotherm positions are summarized in Figure 17 and the calculations are as follows:

Table 6. Onshore/offshore velocities off Savannah and Brunswick (+ offshore, - onshore).

		21°C			24°C		
	Grid	1	2	3	1	2	3
Savannah	Distance (km)	-15	+11		+4	-17	
	Elapsed Time (h)	40	42		39	29	
	Velocity(cm sec ⁻¹)	-10.4	+7.3		+2.8	-16.3	
Brunswick	Distance (km)	+3	+3		-6	+7	
	Elapsed Time (h)	33	42		33	44	
	Velocity(cm sec ⁻¹)	+2.5	+2.0		-5.0	+4.4	

The 24°C isotherm appears to be a better indicator of the meander motion. Onshore velocities were first observed off Brunswick between the first two grids and then off Savannah between the second and third grids.

Vertical Motions

Vertical motions were determined from the variation in the minimum depth of the 19°C isotherm. The calculation and results are given in Table 7.

Table 7. Vertical velocities off Savannah and Brunswick (+ down).

Savannah	Grid	1	2	3
	Station	30C	83C	143C
	Time (d/h)	11/0.3	12/16.1	14/9.8
	Depth(19°C)(m)	170	130	150
	Δ time (h)	39.8	41.7	
	Δ depth (m)	-40	+20	
	$\bar{w}$ (cm sec ⁻¹)	-2.8×10^{-2}	$+1.3 \times 10^{-2}$	
Brunswick	Station	62C	107C	171X
	Time (d/h)	12/0.6	13/9.3	15/4.2
	Depth(19°C)(m)	130	152	126
	Δ time (h)	32.7	42.9	
	Δ depth (m)	+22	-16	
	$\bar{w}$ (cm sec ⁻¹)	$+1.9 \times 10^{-2}$	-1.0×10^{-2}	

These velocities are typical of upwelling situations. Interestingly, the upwelling occurred first off Savannah leading the offshore motion.

Propagation Rate

The rate at which the meander moves downstream can be estimated from the surface isotherm positions. The amplitude of the meander was ca. 15 km and typical onshore/offshore velocities were 10 cm sec⁻¹ thus the period is 3.4 days. The observed length is 93 km so the phase speed would be 31 cm sec⁻¹ (0.6 knot). This rate is similar to the 39 cm sec⁻¹ observed by Legeckis (1975).

T-S Relationship

The T-S plot for all data is in Figure 18. The group of points at ca. 20°C/34‰ are from Station 207 which is considerably south of the existing hydrogrid (see Figure 1).

Figures 19-23 are T-S plots for each individual section. They show the transition from shelf to Gulf Stream water in each of the onshore-offshore sections. At some deep stations (i.e., 54-62) mixing of shelf waters with Gulf Stream water is apparently active.

Nitrate-Phosphate-Silicate-Temperature Relationships

Various relationships between nitrate, phosphate, silicate and temperature are useful to assess the quality of the data and to elucidate some of the chemical, biological, and physical processes.

For deeper waters the ratio of nitrate to phosphate is typically 16:1 and is derived from the decomposition of organic matter. All nitrate and phosphate data for this cruise appear in Figure 24 with a line representing the 16:1 N:P ratio. At low nutrient concentrations, an excess of phosphate over nitrate is observed. Stations with excess phosphate are generally in shallow areas where any free nitrogen is released more quickly than nitrate, leading to an apparent excess of phosphate.

Temperature-nutrient plots (Figures 25-27) show the inverse relationship between temperature and nutrient concentration. The scatter at low concentrations represents samples taken over the shelf with temperature decreasing towards shore.

A plot of silicate versus salinity is presented in Figure 28. Higher salinity and silicate concentrations are representative of Gulf Stream waters. Other values correspond to shelf waters.

Oxygen-Density Correlation

Figure 29 plots oxygen versus sigma-t. The curve is typical of normal Sargasso Sea water. Points above the curve are from surface Gulf Stream and shelf waters. Points below the curve with a sigma-t of 25 to 26 are a Caribbean component of the Gulf Stream (Richards and Redfield, 1955).

Summary

In summary, the following observations were made:

1. The shelf waters were well mixed with horizontal stratification, typical of winter conditions.
2. A meander was observed at the shelf break and passed through the area of this study.
3. The vertically induced component of velocity (upwelling) associated with this meander was as high as $2.8 \times 10^{-2} \text{ cm sec}^{-1}$.
4. The meander moved northward at a rate of 31 cm sec^{-1} , a velocity comparable to the 39 cm sec^{-1} reported by Legeckis (1975).

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FIGURES

(5 - 29)

Figure 5. Surface temperature distribution. The 9 December data are from a Coast Guard Airborne Radiation Thermometer flight. Dashed line is cruise track.

Figure 6. Savannah section temperature, salinity and sigma-t, 10-11 December.

Figure 7. Savannah section nitrate, phosphate, silicate and dissolved oxygen, 10-11 December.

Figure 8. Savannah section temperature, salinity, and sigma-t, 12 December.

Figure 9. Savannah section nitrate, phosphate, silicate and dissolved oxygen, 12 December.

Figure 10. Savannah section temperature, salinity and sigma-t, 14 December.

Figure 11. Savannah section nitrate, phosphate, silicate and dissolved oxygen, 14 December.

Figure 12. Brunswick section temperature, salinity and sigma-t, 11-12 December.

Figure 13. Brunswick section nitrate, phosphate, silicate and dissolved oxygen, 11-12 December.

Figure 14. Brunswick section salinity and sigma-t, 13 December.

Figure 15. Brunswick section nitrate, phosphate, silicate and dissolved oxygen, 13 December.

Figure 16. Brunswick section temperature, 14-15 December.

Figure 17. Time series of the 21°C and 24°C isotherms (—— 10-12 December, -----12-13 December, -·-·-·-14-15 December).

Figure 18. Temperature-salinity diagram, Cruise CI-12-76, December 1976.

Figure 19. Savannah Section, 10-11 December.

Figure 20. Brunswick Section, 10-11 December.

Figure 21. Savannah Section, 12 December.

Figure 22. Brunswick Section, 13 December.

Figure 23. Savannah Section, 14 December.

Figure 24. Nitrate vs. phosphate with line representing the 16:1 (N:P) ratio.

Figure 25. Nitrate vs. temperature.

Figure 26. Phosphate vs. temperature.

Figure 27. Silicate vs. temperature.

Figure 28. Silicate vs. salinity.

Figure 29. Oxygen versus sigma-t with line representing normal Sargasso Sea water.

DATA

Table 8. STATION SUMMARY FOR ISELIN CRUISE CI-12

CRUISE	STATION	LATITUDE	LONGITUDE	YR	MM	DAY	HOUR	DEPTH	CONSEC
							GMT	M	NUMBER
012	020C	31 28.1N	79 7.6W	76	12	9	4.0	500	20
012	021C	31 56.4N	80 41.0W	76	12	10	14.7	16	21
012	022C	31 52.0N	80 30.1W	76	12	10	15.7	23	22
012	023C	31 48.2N	80 20.0W	76	12	10	17.3	22	23
012	024C	31 45.2N	80 8.4W	76	12	10	18.7	30	24
012	025X	31 43.0N	80 2.0W	76	12	10	20.0	42	25
012	026C	31 40.9N	79 57.5W	76	12	10	20.5	41	26
012	027X	31 39.0N	79 52.5W	76	12	10	21.2	41	27
012	028C	31 37.1N	79 47.5W	76	12	10	22.0	46	28
012	029X	31 35.0N	79 41.6W	76	12	10	23.5	67	29
012	030C	31 33.5N	79 36.0W	76	12	11	.3	136	30
012	031X	31 31.6N	79 30.3W	76	12	11	1.6	259	31
012	032C	31 29.8N	79 24.6W	76	12	11	2.5	510	32
012	033X	31 27.8N	79 19.1W	76	12	11	6.0	480	33
012	049C	31 11.5N	81 2.5W	76	12	11	14.0	18	49
012	050C	31 7.9N	80 50.5W	76	12	11	15.3	22	50
012	051C	31 4.0N	80 40.6W	76	12	11	16.8	25	51
012	052C	31 6.0N	80 46.0W	76	12	11	17.8	23	52
012	054X	31 4.5N	80 42.0W	76	12	11	19.1	25	54
012	055X	31 2.6N	80 35.0W	76	12	11	19.6	29	55
012	056C	31 1.0N	80 29.5W	76	12	11	20.2	30	56
012	057X	30 58.5N	80 24.5W	76	12	11	21.0	34	57
012	058C	30 57.0N	80 19.5W	76	12	11	21.6	38	58
012	059X	30 54.9N	80 14.5W	76	12	11	22.4	42	59
012	060C	30 52.7N	80 8.8W	76	12	11	23.0	40	60
012	061X	30 50.7N	80 3.5W	76	12	12	0.0	50	61
012	062C	30 49.0N	79 57.0W	76	12	12	.6	206	62
012	063X	30 47.2N	79 52.9W	76	12	12	2.6	291	63
012	064C	30 45.4N	79 47.4W	76	12	12	3.2	429	64
012	075C	31 48.2N	80 19.0W	76	12	12	9.9	22	75
012	076X	31 46.5N	80 13.8W	76	12	12	11.0	25	76
012	077C	31 45.0N	80 8.2W	76	12	12	11.5	30	77
012	078X	31 43.0N	80 2.8W	76	12	12	12.4	35	78
012	079C	31 41.1N	79 56.9W	76	12	12	13.2	42	79
012	080X	31 39.1N	79 50.6W	76	12	12	14.2	46	80
012	081C	31 37.5N	79 45.4W	76	12	12	14.8	46	81
012	082X	31 35.8N	79 40.3W	76	12	12	15.6	55	82
012	083C	31 34.1N	79 34.6W	76	12	12	16.1	146	83
012	084X	31 33.0N	79 32.1W	76	12	12	17.0	247	84
012	085C	31 32.0N	79 26.8W	76	12	12	17.5	507	85
012	099C	31 4.1N	80 40.8W	76	12	13	3.7	25	99

Table 8. ISELIN CRUISE CI-12

[CONTINUED]

CRUISE	STATION	LATITUDE		LONGITUDE		YR	MN	DAY	HOUR	DEPTH	CONSEC
									GMT	M	NUMBER
012	100X	31	2.0N	80	35.3W	76	12	13	4.6	25	100
012	101C	31	0.0N	80	30.0W	76	12	13	5.2	33	101
012	102X	30	58.0N	80	24.0W	76	12	13	6.0	37	102
012	103C	30	56.0N	80	19.2W	76	12	13	6.8	38	103
012	104X	30	54.4N	80	13.5W	76	12	13	7.5	41	104
012	105C	30	52.5N	80	8.5W	76	12	13	8.0	43	105
012	106X	30	50.5N	80	3.4W	76	12	13	8.8	49	106
012	107C	30	48.7N	79	58.0W	76	12	13	9.3	214	107
012	108X	30	46.6N	79	52.5W	76	12	13	10.7	292	108
012	109C	30	44.5N	79	46.6W	76	12	13	11.3	443	109
012	134C	31	48.2N	80	19.0W	76	12	14	1.6	23	134
012	135X	31	46.4N	80	13.5W	76	12	14	2.7	28	135
012	136C	31	44.9N	80	8.4W	76	12	14	3.7	30	136
012	137X	31	43.0N	80	3.4W	76	12	14	4.9	36	137
012	138C	31	41.4N	79	57.8W	76	12	14	5.9	41	138
012	139X	31	39.6N	79	52.0W	76	12	14	7.1	51	139
012	141C	31	38.0N	79	47.0W	76	12	14	8.1	53	141
012	142X	31	36.0N	79	41.0W	76	12	14	9.0	64	142
012	143C	31	34.0N	79	35.0W	76	12	14	9.8	118	143
012	144X	31	32.5N	79	28.2W	76	12	14	11.5	330	144
012	145C	31	30.5N	79	24.0W	76	12	14	12.2	520	145
012	146X	31	30.3N	79	23.8W	76	12	14	14.2	485	146
012	163X	31	4.5N	80	40.5W	76	12	14	22.2	25	163
012	164X	31	2.5N	80	35.0W	76	12	14	23.0	30	164
012	165X	31	.5N	80	29.6W	76	12	14	23.6	29	165
012	166X	30	58.5N	80	24.5W	76	12	15	.3	35	166
012	167X	30	57.2N	80	19.6W	76	12	15	.9	35	167
012	168X	30	54.6N	80	13.9W	76	12	15	1.7	38	168
012	169X	30	52.9N	80	8.6W	76	12	15	2.6	41	169
012	170X	30	51.0N	80	3.1W	76	12	15	3.4	52	170
012	171X	30	50.0N	79	59.0W	76	12	15	4.2	147	171
012	172X	30	49.2N	79	57.4W	76	12	15	4.6	198	172
012	173X	30	49.5N	79	50.5W	76	12	15	5.6	300	173
012	207C	28	59.3N	80	24.6W	76	12	15	21.3	26	207

HYDROGRAPHIC DATA

Vertical profiles of salinity, temperature, sigma-t, D0, and nutrients

The symbols used in the following listings are defined as follows:

Header Data: Times are GMT (EST + 5)
 Latitude and Longitude are from Loran C

Weather Data: These data are taken from the ship's log.

Wind speed (knots)
Wind direction (degrees)
Air temperature (°C)
Weather (WMO code 4501)
Barometric pressure (mb)
Sea State (WMO code 3700)
Wave direction (degrees)
Cloud type (not given)
Cloud amount (not given)
Visibility code (not given)

Observations: Z = Depth in meters
 T = Temperature in °C
 S = Salinity in ‰
 D = Density in sigma-t units
 SVA = Specific volume anomaly $\times 10^5$
 O₂ = Dissolved oxygen in ml/liter
 O₂' = Oxygen saturation in ml/liter
 AOU = Apparent oxygen utilization in ml/liter
 PO₄ = Phosphate concentration in $\mu\text{mole/liter}$
 NO₃ = Nitrate concentration in $\mu\text{mole/liter}$
 Si = Silicate concentration in $\mu\text{mole/liter}$

A map of the Georgia coast and the Atlantic Ocean. The map shows the coastline of Georgia, with major rivers like the Savannah, Altamaha, and Ogeechee. The ocean is to the east. The map is framed by a coordinate grid with latitude and longitude markings. Latitude 31 and 32 are marked on the left and right sides. Longitude 81 is marked at the top and bottom.

Technical Report Series
Number 78-7

A CTD SYSTEM:
DESCRIPTION, OPERATION,
DATA ACQUISITION AND PROCESSING

by
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October 1978

The Technical Report Series of the Georgia Marine Science Center is issued by the Georgia Sea Grant Program and the Marine Extension Service of the University of Georgia on Skidaway Island (P. O. Box 13687, Savannah, Georgia 31406). It was established to provide dissemination of technical information and progress reports resulting from marine studies and investigations mainly by staff and faculty of the University System of Georgia. In addition, it is intended for the presentation of techniques and methods, reduced data and general information of interest to industry, local, regional, and state governments and the public. Information contained in these reports is in the public domain. If this prepublication copy is cited, it should be cited as an unpublished manuscript.

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ACKNOWLEDGEMENTS

The development of this system is the result of the cooperation of many people. The initial effort was inspired by the success of Dr. William W. Broenkow, Moss Landing Laboratories, Moss Landing, California, and his assistance is appreciated. We also thank Mr. Lee Knight, engineer, Skidaway Institute, for his assistance in the development. Others who assisted through direct effort or helpful comments included Drs. Tom Curtin and T. N. Lee. Mrs. Cindy Miller typed the manuscript. Funding support for the system was and is provided by the Department of Energy (Contract No. EY-76-S-09-0889) to Dr. L. P. Atkinson.

This report is published as a part of the Georgia Marine Science Center's Technical Report series issued by the Georgia Sea Grant Program under NOAA Office of Sea Grant #04-8-MO-175.

INTRODUCTION

The level of sophistication of today's marine research dictates the need for a rapid, reliable and accurate system for acquiring and processing temperature and salinity data.

In order to meet these needs, we at the Skidaway Institute of Oceanography have acquired a conductivity/temperature/depth (CTD) system. With principal support from the U. S. Department of Energy, we have developed the software and made numerous modifications to the hardware of the system, facilitating the principal task of investigating and explaining the chemical and physical processes in the South Atlantic Bight.

The purpose of this report is to describe our CTD system, document the developments and improvements we have made thus far, and relate our practical experience. It is hoped this report will be useful to oceanographers who now have, or will in the future have, a CTD system. The system is in a continual state of upgrading and modification, so this report represents the state of our system as of May 1978. Recent additions to the system are an HP Flexible Disk Unit (0.5 megabyte) and an HP-BCD Interface Bus. The XBT has also been interfaced to the HP 9825A.

DESCRIPTION OF THE SYSTEM

The CTD system, shown schematically in Figure 1, has four major components: 1) the underwater unit, consisting of the depth, conductivity, and temperature sensors, and a mixer that powers the sensors and multiplexes the signals; 2) the winch, conductor wire, and Rosette Multi-Bottle Array fitted with a variety of Niskin sampling bottles; 3) the deck unit that powers the rosette and the CTD sensors and filters and digitizes the multiplexed CTD signal; and 4) the data processing system. The data processing system is actually two separate systems, one which records the raw data digitally on magnetic tape and another that performs real-time data processing and stores and displays the data in a variety of ways (i.e., Hewlett-Packard (HP) tape cartridge, calculator plotter, printer and analog plotter). All components of the CTD system are listed in Table 1. In the following discussion, the hardware components, the shipboard operating procedure, and the software of the system will be described, some in more detail than others. Troubleshooting problems, causes, and repairs for those problems that we have encountered are listed in Appendix I.

The CTD Sensor System

The CTD unit consists of the three sensors powered by a 120 ma constant current supply in the mixer. The sensors output AC signals of frequencies that are proportional to the parameters being sensed (Table 2). The AC signals from these sensors are multiplexed by the mixer and transmitted through a single conductor to the deck unit. Thus, only one conductor is required by the CTD for input power and an output multiplexed signal. To

Figure 1. Schematic of CTD System.

Table 1. Component List of the CTD System.

Plessey Model 9400 System
Plessey Model 6500 Conductivity Sensor
Plessey Model 4500 Temperature Sensor
Plessey Model 4600 Pressure Sensor
Plessey Model 4400 Mixer
General Oceanics Rosette Multi-Bottle Array Model 1015 Mark V
Plessey Model 7400 Winch

Plessey Model 8400 Digital Data Logger
HP 7046A X-Y Recorder
Kennedy Model 1600 Incremental Magnetic Tape Recorder
HP 59307A VHF Switch
HP 98034A HP-IB Interface
HP 5328A Universal Counter
HP 59309A HP-IB Digital Clock
HP 9825A Calculator
HP 9862A Calculator Plotter
Texas Instruments Silent 700 ASR Electronic Data Terminal

guard against applying reverse voltage to the CTD sensors, a reverse biased diode is installed on the input power line to the mixer. Our system is dismantled and reassembled frequently and such protection is good insurance against damaging the sensors.

Table 2. Parameters Measured and Sensor Ranges.

Parameter	Frequency Range	Sensor Range
Temperature	2127-4193 hz	-2-35°C
Conductivity	4995-7901 hz	0-60 mmhos/cm
Depth	9712-11288 hz	0-600 m

The pressure vessels housing the sensors protect the sensors to 600 meters; however, flooding of the vessels, even at shallow depths, has been a problem. According to Plessey, Inc., replacing the plastic endcaps with stainless steel endcaps has solved the flooding problem. When our system is not functioning properly and flooding is suspected, the sensors are disassembled and dried out. Pins in the connectors are also examined and dried out when wet. Care should be exercised when handling the O-ring seals for the connectors. Silicone grease is used to seal the connections. It should be used sparingly to avoid insulating the electrical connecting pins.

We have spare C, T, and D sensors, connectors, Scotchcast electrical splicing kits, and wire harnesses so that any malfunctioning part can be replaced on board, allowing sampling to proceed after repairs are made.

The Winch and Rosette Multi-Bottle Array

The winch should be equipped with at least two conductor oceanographic electromechanical cables and the appropriate slip rings. One conductor is for the CTD and the other for the rosette. The winch should be capable of lowering and raising at rates of 15 m/min or less. This low winch speed is necessary so that enough data points are collected to average over one meter increments, especially in strong thermoclines such as those encountered in the South Atlantic Bight.

Most oceanographic ships are equipped with conductor winches. However, the wire and/or slip rings are often in disrepair and should be checked out beforehand. We bring a portable winch for backup. Our portable winch (Plessey Model 7400) has 250 m of 4-conductor wire and runs on 110 Volts AC power at a constant speed of 15 m/min. It handles a maximum load of 200 pounds, which is of minimum acceptable capability. Changes have been made to improve the operation of the winch. The operating switch installed by Plessey, Inc. burned out after very little use, so a heavy duty switching

relay was installed. The new switch also increases safety since a spring returns it to the off position upon release; therefore, the operator cannot leave the switch unattended while the CTD is being raised or lowered. Solid state relays will be installed soon in order to minimize the electrical noise that spikes the data signals. An occasional overhaul and repainting of the winch housing is necessary due to corrosion from salt spray. It should also be disassembled, cleaned, and lubricated regularly.

The Rosette Multi-Bottle Array is manufactured by General Oceanics, Inc. as are the Niskin bottles mounted on it. The rosette is mounted on a frame which encloses the CTD sensor system (Figure 2). Reference to the "Fish" includes the sensors and rosette as one unit. The sensors are located beneath the rosette so that they are not in the wake of the rosette as the Fish is lowered through the water column. Conversely, during the upcast the sensors are in the wake of the rosette, degrading the data. During the upcast, the Niskin bottles are triggered serially on command from the deck unit at desired depths.

Plessey, Inc. had designed the system so that the sea cable from the winch's single slip ring entered the rosette deck unit, then continued on to the digital data logger (DDL). The wire harness connected to the winch wire went through the rosette, then to the sensors. With only one path as such, powering the rosette with the high voltage required to trip a bottle interrupted the connection to the sensors.

We have modified the system and now use multi-conductor wire, allowing separate rosette and sensor operation. A branching cable connects the slip ring wires to the rosette deck unit and the DDL. An underwater harness branches from the winch wire connector to the rosette and to the CTD sensors.

The rosette requires continual maintenance to perform reliably. After every cast the cam/trip mechanism should be washed with fresh water and sprayed with a penetrating lubricant such as CRC. Recommended spare parts are appropriate relays for the winch, rosette, and rosette deck unit and SCR for the rosette deck unit.

A Helle pinger is mounted on the frame of the Fish to aid in recovery if the Fish becomes severed from the conductor wire. A buoy, chain, and anchor are also kept ready to use to mark a lost instrument.

The Deck Unit and Data Processing System

The Plessey Model 8400 Digital Data Logger (DDL) provides power to the CTD sensors, receives and demultiplexes the CTD signal, and determines the frequencies for depth, conductivity, and temperature for output to recording devices.

Several modifications were made to the DDL that make control of the system more convenient. An on-off switch for power to the Fish, as well as voltage and current meters, were installed in the front panel of the DDL that readily indicate the power status of the Fish. Thus, an opened, closed, or shorted circuit in the system can easily be detected. One input

Figure 2. Underwater Assembly.

and two outputs may be connected to one of the three channels, and a switch and porter LEDs for selecting a channel also were installed in the front panel of the DDL. The two outputs allow an oscilloscope and frequency counter to monitor any one channel at a time. A signal generator can be attached to the input. When using a winch with a short wire, a capacitor is put on the DDL input line to attenuate the signal, simulating a longer wire, and thus preventing interference of one channel with another. Another modification was the replacement of the 741 operational amplifier in the DDL with a higher grade ultra-linear operational amplifier.

Spare parts for the DDL include spare counting and digitizing boards. D, C, or T counting and digitizing boards are essentially interchangeable. The plastic integrated circuits (ICs) that Plessey, Inc. used on our unit are less reliable than ceramic ICs and do not stand up to the humid, salt-air environment. Consequently, our boards have been sprayed with a sealer to reduce failure. The newer Plessey, Inc. units, however, are equipped with ceramic ICs.

The digital signal output from the DDL is recorded on a Kennedy Model 1600 Incremental Magnetic Tape Recorder. The digital-to-analog converter in the DDL outputs an analog voltage proportional to the input range which drives an HP-XXX' Recorder (Model 7046A). The DDL folds the signals proportional to 0 to 10 Volts full scale (Table 3). We have found that ship-board generators are not stable, therefore, a line conditioner is required. The greatest problem caused by a power failure is that the magnetic tape must be started up again and the lack of continuity will cause tape reading errors when it is played back.

Table 3. Analog Characteristics.

	D	C	T
Full Scale	0-600	0-80 mmhos/cm	-5-35°C
Ranges	4	8	8
Folded Range Scale	0.06666 v/m	1 v/mmhos/cm	2 v/°C
Scale on Paper	0.25 cm/m	2.5 cm/mmhos/cm	5.0 cm/°C
Finest Line Reading	0.4 m	0.2 mmhos/cm	0.02°C

After this CTD system was in use for one year, an HP 9825A Calculator and peripherals were added which decreased the time and cost of data acquisition. The HP recording devices are the 9862A Plotter and the tape cartridge and printer in the 9825A Calculator.

CTD Assembly

Loading and assembling the components of the CTD system aboard various ships can become routine, as it has for us. The deck unit must be situated in a dry, preferably air-conditioned lab. Most of the HP components are rack-mounted, and the racks are bolted to lab tables. Everything that is not in a rack is secured with rope or tape.

A full complement of tools and spare electronic parts is necessary (see Appendix II for a complete list). If the ship does not have adequate communications between the lab, deck, and bridge, a portable intercom system is placed so that the deck unit operator can talk with the winch operator. The CTD sea cable must reach the deck, where it is affixed to the slip rings on the winch. Enough conductor wire is unspooled from the winch to reach the Fish after it is put through a block or metering wheel on an A-frame or boom that can be extended away from the ship. A splice must be made to join the Envirocon underwater connector that mates the two pin connectors on the wire harness of the Fish to the conductor wire used on most ships' winches. Using Scotchcast over the spliced wire is a convenient method of waterproofing underwater connections. Scotchcast is mechanically and electrically sound because of its rigidity, unlike underwater tape that can bend and break. Our small winch is equipped with the connector that joins the conductor wire and Fish.

Niskin bottles appropriate for the anticipated sampling are mounted on the rosette. Invariably, a rack to hold three reversing thermometers (two of the protected type and one unprotected) is put on the bottle that will be tripped at the deepest sampling depth. Expendable Bathythermograph (XBT) pins (one ground to a point and another to a flat blade) are convenient tools to cock the bottles on the rosette and to rotate the cam/trip mechanism. While not in use, the Fish should be secured in a shaded place to protect the rosette's rubber pressure-compensating diaphragm and reversing thermometers.

Early CTD tests indicated that the pendulum motion of the Fish while in the air between the deck and the water should be dampened by weight suspended from a rope harness beneath the Fish. In practice, the pendulum motion ceases as the weight enters the water. In calm-to-moderate seas, a 10-pound weight is used. In heavy seas more weight is added in accordance with the capacity of the winch. Our winch can support 30 pounds in addition to the weight of the Fish.

OPERATING PROCEDURE

To utilize ship time to the fullest, the CTD should be ready for a cast before arriving on station. The sensors are powered up for a short time on deck, and the frequencies for D and C are recorded to use as offsets from the manufacturer's zero D and C frequencies during the ensuing cast. In order to prevent accidents, power to the Fish is on only during a cast. The rest of the deck unit has power to it throughout the cruise to insure electronic stability.

The HP plotter is programmed for 5 to 30°C and 0 to 400 meters full scale and the XYY' recorder plots conductivity and temperature-versus-depth proportional to the analog voltage output by the DDL (Table 3). The XYY' recorder must be calibrated often with a precision 10 Volt source to check the 0 to 10 Volts full scale. Both plotters are made ready before arriving on station.

Operating the CTD recording devices requires a complex system of button-pushing. Explicit instructions are displayed on the front of the deck unit (Table 4). Any deviation from this procedure produces a non-standardized tape recording, making processing costly and time consuming. The standard tape recording for the Kennedy should have an identification (header) for each station cast followed by a file gap (blank mark of a specific length) and the cast data followed by a file gap. Missing or extra file gaps must be reported so that tape errors can be found and corrected.

A minimum of two people can operate the CTD. One person on deck runs the winch and guides the Fish into the water while the second person in the lab operates the data acquisition system and fills in the station sheets (Figure 3). Prior to lowering the Fish, the depth at a station should be determined by a depth sounding device, either on the bridge or in the lab. The data acquisition operator instructs the winch operator when to put the Fish in the water and when to lower and raise it. At the beginning of a cast, all of the data-recording devices should be simultaneously set into action. During the downcast, the HP Calculator is programmed to display depth so that the data acquisition operator can tell the winch operator when to stop lowering the Fish. Then the plotter pens are raised, and the programming is switched to a soak routine. After four minutes (to allow the reversing thermometers to equilibrate), the bottom sample bottles are tripped from the rosette deck unit. During the upcast, new plotter paper is used or the pens are raised to trace over the downcast plot. The vertical temperature plot is used to decide where to stop and trip bottles on the upcast (Table 5). While the Fish is stopped at the predetermined sampling depths, the rate of data acquisition is slowed down by using a mid-depth soak program.

After the surface sample bottles are tripped, power to the Fish is turned off, and the Fish is brought on deck and secured. The rest of the CTD operation may be carried out while the ship is steaming towards the next station. Dissolved oxygen, nutrient, salinity and other samples are drawn from the Niskin bottles into appropriate collecting bottles, treated, and stored as needed. The data acquisition operator records the bottle numbers for the samples taken on the station sheets. The reversing thermometers are read, and temperatures are recorded on the station sheets for calibration of the CTD temperature sensor. After the samples are taken, the rosette cam/trip mechanism should be rinsed with fresh water and sprayed with a marine lubricant. Then the cam must be reset and the Niskin bottles cocked in preparation for the next cast. The station sheets and plots are filed, and all data acquisition devices are made ready for the next station.

Examples of other forms we use are in Appendix VI.

Table 4. CTD Operating Procedure.

-
1. Determine the depth of the water column.
 2. Turn Rosette ON (Small button under "8400 DIGITAL").
 3. Set heading data. (10(00)) for upcasts; 00(00) for downcasts).
 - *4. Push "ENTER" five times; push "FILE GAP" once.
 5. Set up HP programming (trkl, ldf0, RUN). Try to time the readiness of the HP to receive data so that steps 6 and 7 can immediately be completed.
 6. When ready to begin cast push "START" on recording control (tape should begin moving in short increments). Turn on recorder "SERVO" and ~~put pen-on "RECORD".~~
-
7. Lower CTD (stop 2-3 meters from the bottom).
 8. Change to scan 10 at bottom of cast. LIFT PEN.
 9. Follow the 4 minute soak instructions on the HP.
 10. Push "STOP" after soak. Change back to scan 0.
 11. Push "FILE GAP" once.
 12. Follow steps 3-6 for upcast.
 13. Raise CTD to desired depths and "FIRE" Niskin bottles. (Change to scan 1 while firing bottles).
 14. Turn Rosette off (small button under "8400 DIGITAL").
 15. For the next cast, repeat procedure with step 1.
 16. When tape is completed change header to 9999 and push "ENTER" five times, then push "FILE GAP" three times, rewind and remove tape.
- *IF "FILE GAP" IS PUSHED TWICE IN A ROW OR NEGLECTED AT ANY TIME, PLEASE NOTE THIS ON THE RESPECTIVE STATION SHEET. DO NOT "ENTER" A HEADER AND "FILE GAP" MORE THAN ONCE. JUST NOTE THE ERRONEOUS HEADER NUMBER.
-

CRUISE _____ GRID STATION _____ CONSECUTIVE STATION _____

MAGNETIC TAPE NO. _____ KEYWORD _____

HEADER (d) _____ SCAN RATE (d) _____
(u) _____ (u) _____

SURFACE FREQ: DEPTH _____ COND. _____ TEMP. _____
 BOTTOM FREQ: DEPTH _____ COND. _____ TEMP. _____
 MID DEPTH FREQ: DEPTH _____ COND. _____ TEMP. _____
 MID DEPTH FREQ: DEPTH _____ COND. _____ TEMP. _____
 MID DEPTH FREQ: DEPTH _____ COND. _____ TEMP. _____
 SURFACE FREQ: DEPTH _____ COND. _____ TEMP. _____

MIXER
407 411
COND
615 660
TEMP
720 737
DEPTH
817 837

THERMAL TEMP. _____
SURF. BUCKET TEMP. _____
TIME OUT _____

[illegible]

V_0 , I and G_f are obtained from specifications for thermometers

$$C = \frac{(T_{\text{obs}} + V_0) (T_{\text{obs}} - T_{\text{aux}})}{1/G_f - 100}$$

*Depth Freq. on deck _____
 *Cond. Freq. in air _____
 O.K. for T calib. (B) _____
 O.K. for S calib. (B) _____ (M) (S)

Figure 3. Station sheet.

Table 5. Suggested Sampling Depths.

Depth less than 50 m:

Mixed - Surface and bottom
 Two-Layer - Surface, above or below the
 thermocline and bottom

Depth greater than 50 m and less than 100 m:

0, 25, 50, 75, 100 (or bottom)

Depth greater than 100 m:

0, 50, 100, 150, 200, 300, 400 (or bottom)

Cyber Processing

After a cruise, the magnetic tape is sent to the University of Georgia Computer Center and stored in their tape library. The tape is then processed at Skidaway where there is access to interactive time-sharing of the University's Control Data Corporation Cyber 70 through a telephone link.

During the shipboard CTD operations, binary coded frequencies are recorded on 7-track magnetic tapes by the Kennedy recorder. The processing of tape data has been adapted from that described by Scarlet (1975). Table 6 shows the basic data flow, though program modifications are necessary for the special situations that arise for each new data set. The programs are listed in Appendix III. The final programming step, NUTMERG, merges additional station data, i.e., nutrients, weather, latitude, longitude, etc., to the CTD data for submission to the NODC. This final product is stored on magnetic tape in our computer system and all data, i.e., CTD, XBT, chemical, etc., are available from the NODC.

Another program, CEMLIST, calculates specific volume anomaly, oxygen saturation and apparent oxygen utilization (from the International Oceanographic Tables, 1966), and the distance between successive stations from the NODC formatted data. CEMLIST reformats the NODC data for presentation in a technical report.

Temperature Lag. The Plessey temperature sensor time constant is reported to be 0.35 seconds. The depth and conductivity sensors each have a reported 0.1 second time constant, so that temperature lags behind depth and conductivity. Therefore, the "real" T at the time that D and C are sampled must be calculated from the "indicated" T. From Scarlet, 1975:

Table 6. Cyber CTD Data Flow: Shipboard Acquisition to NODC Submission.

Data Source/Disposition	Program	Data File
Digital Data Logger to Tape	CTDRUN (Copies tape data to a computer file)	
		KEYWORD
	MAGREAD (Converts binary coded data to decimal)	
		BIRANG
	CTDUNIT (Converts decimal units to engineering units)	
Primary Calibration from Bottle Casts		LAG
	LAGFILT (Temperature lag and course filter)	
		CAL
	BROENK (Calculates salinity and sigma-t)	
		LATCH
	DLATCH (Removes decreasing and repeated depths)	
		CTDATA
	CTDAVE (One meter averaged data)	
		AVE
	NODCF0 (Converts to NODC format)	
Submission to NODC		NODC + HEAD
	NUTMERG (Merges NODC data with headers and chemical data)	
		FINAL
	CEMLIST (Calculates specific volume anomaly, oxygen utilization, etc.)	
		TECHNICAL REPORT

$$T_{R(n)} = T_{I(n)} + \frac{\tau (T_{I(n+1)} - T_{I(n-1)})}{2 \sigma}$$

where: T_R = real T

T_I = indicated T

τ = sensor time constant

σ = sampling rate

$n = 1, 2, 3, \dots$ (each CTD scan)

The sensor with the slowest time constant determines the fastest rate at which a CTD scan can be updated by the digital-to-analog converter in the DDL. The T time constant of 0.229235 seconds governs the fastest rate for this system. Setting the scan interval to 00 provides the fastest rate. The scan interval can be set as high as 99, with each of the 100 increments slowing the sampling rate down by multiples of 0.229235 seconds. The temperature lag of this system can be calculated from:

$$T_{R(n)} = T_{I(n)} + \frac{0.35 (T_{I(n+1)} - T_{I(n-1)})}{(2)(0.229235)(\text{Scan} + 1)}$$

Offsets and Course Filter. Depth and temperature offsets (Table 7), determined by the on-deck frequencies for depth and temperature, are applied in program CTDUNIT. The offsets correct for the deviation of the zero depth and temperature frequency readings from the frequencies preset by the manufacturer. Our temperature sensor has shown no signs of drift or offset with age when compared with protected reversing thermometer readings, so no offset has been applied. In addition, no offset is determined for conductivity though it, like depth, has been observed to drift slightly with age. This drift is compensated for in BROENK by a salinity offset from a comparison of bottle salinity with CTD salinity. This salinity offset may be depth dependent due to the effect of pressure on the conductivity sensor. A simple test for this is a linear regression analysis of bottle salinity less CTD salinity versus depth. When sampling at depths less than 50 meters or when no pressure effect is apparent, the mean offset from bottle salinities less CTD salinities for all stations is most appropriate.

LAGFILT course filters electronic, slip ring, and winch noise. The windows for the filter are ± 5 m, ± 0.8 mmhos/cm and $\pm 0.5^\circ\text{C}$.

Depth Latch and Averaging. The normal descent rate of 0.25 meters/second and scan rate of 0.229 seconds should provide 17 scans/meter. The number of scans/meter varies because the motion of the Fish reflects ship roll. Repeated depths are removed by the DLATCH program. The average number of scans (remaining) through a 1 meter interval is 10 ± 7 . Scans of data 0.5 meters above and below each 1 meter are averaged for depths less than 100 meters and data 2.5 meters above and below each 5 meters are averaged for depths greater than 100 meters.

Table 7. CTD Offsets.

Cruise	D(m)	T(°C) S/N 720	S(%) (Bottle-CTD) or equation	Sal. Eq. (from)	Data Source	Deepest Calib. depth
OBIS V (July-Aug. 1976):						
Hydro 1	None	None	+ .138 ± .030	Knowles	XYX	55m
			+ .333 ± .023	Knowles	XYX	55m
Bio 1	None	None	+ .099 ± .008	Knowles	XYX	55m
Hydro/Bio 2	None	None	+ .090 ± .017	Knowles	XYX	55m
Aborted Hydro 3	None	None	+ .101 ± .022	Knowles	Mag tape	55m
Bio 3	None	None	+ .073 ± .025	Knowles	Mag tape	55m
Hydro 4	None	None	+ .064 ± .021	Knowles	Mag tape	55m
Bio 4	None	None	+ .019 ± .008	Knowles	Mag tape	55m
Hydro 5	None	None	+ .068 ± .009	Knowles	Mag tape	55m
CI 12 (December, 1976)	None	None	$S = S_0 + 0.023 - 1.57 \times 10^{-4}D$	Broenkow	Mag tape	438m
AD 477 (April, 1977)	+1.714	None	$S = S_0 + .007 - 4.97 \times 10^{-4}D$	Bennett	Mag tape	192m
BF 38 (May, 1977)	+2.29	None	+ .06 ± .015	Broenkow	HP	74m
CI 03 (July, 1977)	+2.29	None	$S = S_0 + .101 - 3.05 \times 10^{-4}D$	Broenkow	Mag tape	204m
BF 57 (September, 1977)	+2.29	None	$S = S_0 + .113 - 5.19 \times 10^{-4}D$	Broenkow	Mag tape	196m
CI 07 (November, 1977)	+3.24	None	Not determined*	Broenkow	XYX	
BF 07 (February, 1978)		None	- .003 ± .004	Broenkow	HP	209m
PIERCE (March, 1978)	+4.57 (-1.14)**	None	+ .042 ± .013	Broenkow	HP	398m
CI 01 (April, 1978)		None	+ .125 ± .013	Broenkow	HP	253m
BF 21 (May, 1978)		None	+ .136 ± .011	Broenkow	HP(& XYX)	15m

*Change C sensor (S/N 615 replaced with S/N 660); **change D sensor (S/N 817 replaced with S/N 837)

Salinity. Salinity is calculated from CTD scans using shortened equations adapted from those of Bradshaw and Schleicher (1965) and Cox et al. (1967) by Broenkow (1977) (Table 8). To determine the effects of pressure and temperature on the conductivity sensor, uncorrected and then corrected salinity calculations are required according to the steps in Table 9.

CTD Calibration. The CTD system is calibrated against water samples from rosette bottles tripped in mixed layers to insure that the sensors and the bottles are both sampling the same water. When a mixed layer is not observed, a comparison cannot be made at that station. Consequently, an offset equation is derived from the available data and applied to the entire cruise (Table 7). A Plessey Model 6230N Lab Salinometer is used to determine the salinity of water samples from the rosette bottles.

The Onslow Bay 1976 project was an exception. Each leg of the project had its own offset. At times, more than one offset was necessary during a single leg because of repairs to the CTD system. Many problems were encountered during this initial break-in period. Modifications to the system, as described on pages 1-7 of this report, overcame many of the problems.

Upcasts. Our original Plessey CTD system was set up using a one-conductor wire that would carry the multiplexed C, T, and D and rosette bottle tripper signals. Sending the signal to trip a bottle interrupted the data reception from the CTD (actually sending spiked signals). For this reason, only downcast data was recorded on tape, and bottles were tripped on the upcasts.

The system has since been modified. Two wires and the shield (used for a ground wire) of a four-conductor wire are used, separating the CTD and rosette signals. Upcast data is recorded, unaffected by bottle tripping. However, the sensors lie in the wake of the rosette during upcasts and this causes turbulent disturbance of the water being sampled; therefore, the data reported to NODC and in technical reports are the downcasts only, except where downcast data is lost or incomplete.

CTD Error Analysis. The Plessey Model 9400 CTD system has the following rated accuracy, resolution, and time constants (Table 10). Since salinity is not measured directly, it has to be calculated from the parameters indicated in Table 10, resulting in the composite errors of the C, T, and D sensors and the salinity equation.

Table 8. Broenkow's Salinity Equations.

$$\begin{aligned}
 R_Z &= 1 + .01\{(1.551 - .0453T + 59 \times 10^{-5}T^2) \\
 &\quad + \frac{1}{4}(35-S)(.043 - .0017T + 23 \times 10^{-6}T^2)\}\{1.037 \times 10^{-3}Z \\
 &\quad - 32 \times 10^{-9}Z^2\} \\
 A_T &= (676547 + 20131.5T + 99.89T^2 - .1943T^3 - .00672T^4) 10^{-6} \\
 R_T &= \frac{C(S,T,Z)}{R_Z A_T 42.896} \\
 \Delta_{15} &= R_T(R_T - 1)(T - 15)\{96.7 - 72R_T + 37.3R_T^2 \\
 &\quad - (.63 + .21R_T^2)(T - 15)\}10^{-5} \\
 R_{15} &= R_T + \Delta_{15} \\
 S^{0/00} &= .08996 + 28.2972R_{15} + 12.80832R_{15}^2 - 10.67869R_{15}^3 \\
 &\quad + 5.98624R_{15}^4 - 1.32311R_{15}^5
 \end{aligned}$$

where: R = conductivity ratio

Z = depth (meters)

T = temperature ($^{\circ}\text{C}$)

C = measured conductivity (mmhos/cm)

S = salinity ($^{\circ}/00$)

Table 9. Flow Using Broenkow's Salinity Equations.

*without the R_Z term

R_Z = pressure effect on conductivity

A_T = temperature effect

R_T = $R(S, t, p)$ conductivity ratio

Δ_{15} = t_{15} correction (International Oceanographic Tables, 1966)

R_{15} = $R(S, 15^{\circ}\text{C}, 0)$

Table 10. Specifications for Plessey Model 9400 CTD System.

	Conductivity	Temperature	Depth
Accuracy	± 0.03 mmho/cm	$\pm 0.02^{\circ}\text{C}$	± 1.5 m
Resolution	0.0002 mmho/cm	0.0001 $^{\circ}\text{C}$	0.0012 m
Time Constant	0.1 sec	0.35 sec	0.1 sec

We have progressively used several different compact sets of salinity equations in the HP calculator, going from Knowles (1973) to Bennett (1976) to Broenkow (1977). The Knowles equation does not consider the influence of depth on the calculation of salinity and, therefore, is not recommended. Both Bennett and Broenkow include depth dependence. The Bennett equations apparently have received considerable acceptance and use (Lewis and Perkin, 1978). We have gravitated further, now using the equations of Broenkow (1977). These equations give a better fit to Jaeger's (1973) table of salinities calculated from experimental conductivities, temperatures, and depths than Bennett for the temperature, depth, and salinity ranges we experience in our work (Table 11). This in turn gives a better real time look at the salinity structure before introducing the salinity calibration data.

By varying "real" C, T, and D by the rated sensor accuracies in the salinity equation, the maximum error attributable to each sensor can be determined. Those stations with deep casts that have a low conductivity and temperature have been found to cause the maximum error, therefore, those "real" data are used to determine each parameters' effect on the salinity equation. The composite maximum error has been approximately ± 0.06 ‰ for the "real" data sets. However, the standard deviation of all mixed layer samples taken for salinity calibration purposes implies greater accuracy, namely ± 0.03 ‰ after offset. We believe this value is a more realistic measure of the quality of the data set, except in strong thermoclines ($\Delta T > 1^{\circ}\text{C/m}$).

Hewlett-Packard System

The previously described digital magnetic tape recording has many advantages. However, there are several serious disadvantages. The principal weaknesses are the lack of onboard confirmation of data acquisition, no real time presentation of data, and costly computer analysis. In an effort to avoid these disadvantages and provide a more redundant system, we have assembled a data acquisition system based on a Hewlett-Packard 9825A calculator.

Presently, our HP-CTD data acquisition system is in the final developmental stages. The remaining problems are principally with software. Our intentions are to use the HP tape cartridge or flexible disk as a primary

Table 11. Jaeger Pressure, Conductivity, Temperature, Salinity Table.

Depth	Pressure	Conductivity	Temperature	Experimental	Knowles	Bennett	Broenkow
m	dbar	mmhos/cm ²	°C	Salinity ppt	Salinity ppt	Salinity ppt	Salinity ppt
0.00	0.00	25.381	0.00	30.200	30.163	30.186	30.183
0.00	0.00	29.267	5.00	30.200	30.177	30.188	30.186
0.00	0.00	33.340	10.00	30.200	30.184	30.187	30.192
0.00	0.00	37.582	15.00	30.200	30.187	30.188	30.196
0.00	0.00	41.977	20.00	30.200	30.189	30.188	30.197
0.00	0.00	46.510	25.00	30.200	30.193	30.187	30.199
0.00	0.00	51.149	30.00	30.200	30.188	30.186	30.197
1714.00	1723.00	39.146	15.00	31.000	-	30.989	31.003
1714.00	1723.00	43.629	20.00	31.000	-	30.988	31.004
0.00	0.00	38.606	15.00	31.118	31.105	31.105	31.113
0.00	0.00	38.094	13.80	31.619	31.610	31.611	31.619
0.00	0.00	44.580	20.90	31.619	31.610	31.608	31.618
0.00	0.00	50.571	27.20	31.619	31.611	31.605	31.618
0.00	0.00	29.021	0.00	35.000	34.976	34.992	35.000
1714.00	1723.00	29.779	0.00	35.000	-	34.993	35.007
3427.99	3446.00	30.451	0.00	35.000	-	34.996	35.023
5141.99	5169.00	31.035	0.00	35.000	-	34.995	35.040
6855.98	6892.00	31.541	0.00	35.000	-	34.993	35.069
0.00	0.00	33.443	5.00	35.000	34.987	34.995	34.998
0.00	0.00	38.073	10.00	35.000	34.989	34.990	34.999
0.00	0.00	42.896	15.00	35.000	34.990	34.991	35.000
1714.00	1723.00	43.623	15.00	35.000	-	34.987	35.004
3427.99	3446.00	44.269	15.00	35.000	-	34.988	35.012
5141.99	5169.00	44.838	15.00	35.000	-	34.993	35.025
0.00	0.00	47.891	20.00	35.000	34.989	34.989	34.998
0.00	0.00	53.046	25.00	35.000	34.993	34.988	35.000
1714.00	1723.00	53.746	25.00	35.000	-	34.985	35.000
0.00	0.00	58.324	30.00	35.000	34.989	34.988	34.999
0.00	0.00	47.186	15.00	38.951	38.944	38.945	38.956
1714.00	1723.00	48.020	15.00	39.000	-	38.989	39.008
1714.00	1723.00	53.495	20.00	39.000	-	38.989	39.009
0.00	0.00	46.290	13.80	39.333	39.319	39.320	39.330
0.00	0.00	54.130	20.90	39.333	39.321	39.320	39.331
0.00	0.00	61.369	27.20	39.333	39.322	39.315	39.331
0.00	0.00	32.880	0.00	40.196	40.178	40.192	40.205
0.00	0.00	37.869	5.00	40.196	40.192	40.198	40.203
0.00	0.00	43.090	10.00	40.196	40.194	40.194	40.205
0.00	0.00	48.524	15.00	40.196	50.192	40.193	40.203
0.00	0.00	54.151	20.00	40.196	40.188	40.188	40.199
0.00	0.00	59.961	25.00	40.196	40.193	40.187	40.202
0.00	0.00	65.911	30.00	40.196	40.190	40.186	40.201

data storage device, with the Kennedy tape recorder and HP XYY' recorder available as backup units. The expanded scale of the HP XYY' recorder (0.20/cm, 0.4 (mmhos/cm)/cm, 4 m/cm) still makes it valuable for determining at which depths to trip Niskin bottles on the upcast, having plotted T and C versus D during the downcast.

A single HP tape cartridge, which is structured with two parallel tracks, contains programs for the CTD acquisition on one track and has space for data storage for as many as 30 stations on the other. The programs are listed in Appendix IV. The master program instructs the operator how to initiate a CTD cast. Special function keys are defined by this program that enable interactive control of data acquisition modes, i.e., downcast, upcast, soak routines. All subsequent programs prompt the operator on procedures and ask for the necessary variable entries, i.e., offsets, data storage, file numbers. An example of the internal printer output is shown in Appendix V.

The data acquired by the HP is treated using a software scheme similar to the Cyber programming but is real time (Table 12). While the CTD is on the deck of the ship the frequencies for D and C are entered following the station number. These variables are used in the frequency to engineering unit conversion as the frequencies for zero D and C.

Three scans of CTD are acquired and the temperature lag is calculated similar to the Cyber programming:

$$T_{R(n)} = T_{I(n)} + \frac{0.35(T_{I(n+1)} - T_{I(n-1)})}{2(0.405)}$$

The difference is the sampling rate; 0.405 seconds are required for the HP to acquire and process a CTD scan. The length and complexity of the HP data acquisition program governs the sampling rate. Further data processing is done after data is acquired and recorded on preliminary tape cartridge files at this fastest sampling rate. A T-versus-D plot is done in real time.

After the CTD Fish is lowered to within 3 meters of the bottom, data collection is stopped and a soak routine begins. Depth, temperature, and salinity are displayed and printed during the four minutes that the reversing thermometers remain at a constant depth for equilibration. T and S printed during the soak are used to calibrate the CTD against the reversing thermometers and salinity bottle samples taken at that depth.

The preliminary down cast data is then averaged for each meter and recorded permanently on the HP tape cartridge. Data collection during upcasts is taken in the same manner. If calibration is to be done at depths other than the deepest sample depth, a mid-depth soaking routine is used to print D, T, and S while a rosette bottle is being tripped. The mid-depth soak can be used at any time the CTD Fish is stopped, so that excessive data is not recorded. At the end of the upcast the preliminary data is averaged to meter increments and recorded on a permanent file.

Table 12. HP-CTD Data Acquisition Scheme.

Our HP calculator was purchased with 8k bytes of core memory. With the program taking up one-fourth of the core, only 100 CTD scans could be input before the array had to be recorded on a preliminary file. The core was then free to receive 100 more CTD scans. As much as two meters of data were missed while the calculator stopped to record each 100 scans. Sixteen k bytes of memory were recently added. Initial tests indicate that 80 m can be stored in an array before copying to the tape cartridge. Use of disk would eliminate this problem.

Further data processing is done aboard ship. Salinity (preferably from downcast data) is plotted versus depth. Until calibration data becomes available, plots are made using uncorrected salinity values. Temperature and salinity onshore-offshore transects are plotted in vertical cross section as well as horizontal plots and station locations. The HP software for this was developed at Skidaway Institute.

SUMMARY

The system described herein is a powerful tool for hydrographic data collection and reduction. Over 900 vertical CTD profiles and 45 hours of horizontal profiling (pumping water over the sensors in a bucket on deck) have been successfully completed in the two years since purchasing the initial system components. Through the first year, a 96% success rate was achieved while the system was being tried and upgraded. The success rate improved in the second year and continues to do so.

The portability of the system has allowed us to work from many of the ships available for research in the South Atlantic Bight. We take part in cooperative cruises and can operate on a minimum of manpower.

Real time data processing aboard ship has been achieved. The HP programmed plotter provides immediate visual presentation of the data. The sensors show drift with time; therefore, an extension calibration scheme is performed for every cruise. Once calibrated and formatted for NODC, cruise data is presented in technical report form.

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APPENDIX I.

Troubleshooting

This section summarizes some of our problems and cures in a troubleshooting chart. This is not an attempt to list every possible problem nor the probable remedy.

CTD TROUBLESHOOTING

PROBLEM	PROBABLE CAUSE	CORRECTION
*No C, T, and D signals in air	1) Have not made all connections (DDL-slip rings - CTD) 2) Bad ground 3) Short in armored cable 4) Bad mixer 5) Bad connection to C, T, and D sensors from mixer	1) Check connections 2) Check ground 3) Cut off bad part of cable and re-sotchcast 4) Replace or repair mixer 5) Check connection for too much dielectric grease
Loss of C, T, or D signal in air	1) Bad counter or digitizing board in DDL 2) Bad connection to sensor	1) Replace or repair board 2) Check connection for too much dielectric grease
Loss of C, T, or D signal or some combination of signals in air but recovery of signal with depth	1) Too much silicone dielectric grease in connection	1) Clean connector pins and sleeves
Loss of all signals as Fish enters water	1) Bad ground 2) Leak in C, T, D, or mixer pressure housings containing electronics 3) Leak in 9 pin or 3 pin plugs to sensors	1) Check ground 2) Disassemble and dry with alcohol and Q-tips 3) Dry and seal with silicone dielectric grease
Loss of C, T, and D signals at depth but recovery with return to ship	1) Wire crimped and wedged in pressure housing of mixer	1) Replace or repair wire

*See "Volt-Amp Meter Readings" for troubleshooting problems (page 30).

PROBLEM	PROBABLE CAUSE	CORRECTION
Occasional spiking (blinking) in C, T, and D signals	1) Fluctuation in AC system 2) Wet or bad connection to slip rings 3) Loose ground 4) Some stress on a connector (on ship or on Fish) 5) Wet 9 pin or 3 pin connectors on sensors	1) Use different wall sockets for power cords 2) Check slip ring wiring 3) Check ground 4) Check all connectors 5) Dry pins
Spiking of C, T, and D signals when winch is turned on or off	1) Relays to winch	1) Solid state relays would be an improvement
Occasional D spiking beginning at a particular depth from one cast to the next	1) Bad armored conductor cable	1) Inspect cable and cut off bad section
Spiking (blinking) of C signal in high salinity water but O.K. in air or in low salinity water. Also note on XYY' that while signal occasionally spikes, conductivity remains too constant (false reading)	1) Defective frequency plug on C board in DDL (Changes the limit of acceptable frequencies which it will allow to pass into DDL for processing)	1) Replace plug or capacitor on plug
Blinking C and analog (XYY') spikes	1) Capacitor to attenuate Fish power to DDL when using a short conductor wire is not in place	1) Connect capacitor
Severe noise on XYY' and/or HP 9825A and Plotter in air or at depth	1) Plotter picking up stray radio frequency from radio communications (Single Side Band) 2) Data lines too near AC power lines	1) Prohibit radio communications while doing CTD cast 2) Separate Data lines from AC power lines

PROBLEM	PROBABLE CAUSE	CORRECTION
Good signals to DDL but nothing to XYY' plotter	1) S3 switch on back of DDL in wrong position	1) Flick switch to proper position
Good signals to DDL but nothing to frequency counter	1) Bad conductor between the two	1) Repair or replace conductor
Not tripping bottles in air	1) Incorrect armored cable hookup 2) Bad ground 3) Loose or wet connection on Fish 4) Bad relays in deck box 5) Bad step motor 6) Bad cold solders in deck unit	1) Check hookup 2) Check ground 3) Check connections 4) Replace relays 5) Repair or replace step motor 6) Check solders
Bottles trip in air but not in water	1) Leakage in armored conductor cable	1) Cut off bad cable and re-sotchcast (entire cable may be bad)

Our Plessey 8400 Digital Data Logger, which also powers the CTD, was modified to indicate sea cable voltage and amperage on the front panel. The following table is very useful for troubleshooting.

Volt-Amp Meter Readings

Problem	Indication of Problem
CTD on Deck:	
Open Circuit	high voltage, low amperage*
Short Circuit:	low voltage, correct amperage
Short is in deck unit	2 Volts
Short is in Fish	5 Volts
During CTD cast:	
Short Circuit	voltage decrease
Corrosion	voltage increase

*For our 250 meter, 4-conductor wire the normal readings are 30 Volts and 135 milliamps.

APPENDIX II.

Cruise Supplies

CRUISE SUPPLIES

General

Drafting supplies

Ruler

Dividers

10 point dividers

Rubber station stamp and ink pad

Stop watch

HP-55 hand held calculator and power cord

Meter-fathoms-feet disc

2 boxes of pencils (#2)

2 magic markers (black)

Graph paper for XY' and 9862A plotters (25 x 38 cm)

15 legal size white envelopes

2 clip boards

10 large plastic bags

Spare tubing for Niskin Bottles

2 spare Niskin end caps (tops)

Spare landyards and micro-press clamps for Niskin Bottles

Pair of stainless steel wing bolts for each Niskin Bottle (in tool box)

2 scotch cast (type 82-A1) (2 others in electronics box)

1 box scotch auto-electric sealing compound (live rubber tape)

5 G.O. messengers (for Niskins in case of CTD failure)

Inclinometer (wire angle)

Bicycle stretch straps

3 - radiator specialty straps (black rubber) for CTD

1 pair of gloves

50' 1/8" nylon line (for tying down)

50' 1/4" clothes line (for tying down)

2 cans of CRC spray

4 nutrient freezing boxes

2 ice chests (if entering another port)

Nutrient Bottles

Large dissolved oxygen (B.O.D. Bottles)

2 boxes of large salinity bottles (70 total)

1 box of small salinity bottles (50 total)

2 black pails with attached rope

Bucket thermometer and spare thermometer (0.1°C increments)

Weather radio

Anchor, 500 ft. of line and buoy

Desk lamp

Lab stool

Lawn chairs

2 unprotected thermometers

4 protected thermometers (7715 and 7718 are best)

10 and 30 lb. weights

CTD weight harness

Thermometer reader-magnifier

7 small Niskin Bottles (1.7 liter) - 3 with thermometer racks

2 large (5.0 liter) Niskin Bottles

NODC sheets

Ringbinder reinforcers

Cruise Supplies - General (cont'd)

"Cruise Log" ring-binder notebook with: cruise plan, cruise log, data cassette logs (10), cruise section logs (10), station sheets (120), XBT event log (15), CTD procedure, D, C, T frequency conversion tables, protected and unprotected thermometer calibration sheets (copies), oxygen analysis procedure (3), oxygen data sheets (15)

XBT Tester

XBT test canister

XBT chart paper (0-200 m roll)

XBT's

XBT recorder

XBT gun

Plessey Lab Salinometer

Standard seawater

CTD-Rosette with Helle Pinger

CTD Winch + 3 welding brackets

CTD parts box

ELECTRONIC GEAR

EQUIPMENT MANUALS

OXYGEN ANALYSIS SUPPLIES

TOOL BOX

CRUISE SUPPLIES

ELECTRONIC GEAR

Electronics box

HP 9825A (calculator), power cord and packing box
HP 9862A (plotter), interface, power cord and packing box
HP 59307A (VHF switch), *Interface HP-IB and power cord
HP 59309A (Clock), *Interface and power cord *connected piggyback
HP 5328A (Counter), *Interface and power cord
HP 204C (Frequency oscillator) and power cord and leads
Plessey DDL
Kennedy Recorder and power cord
HP 7046A (XYY') and power cord
DDL - Recorder Interface
DDL - (XYY' Plotter) Interface
3 leads: DDL from switch
1 lead: switch from counter
G.O. Rosette Tripper Box
4 conductor sea cable: (Winch to DDL and Rosette Tripper Box)
Spare harness (9 pin with 3 three pin connectors for C, T, and D) - (in CTD Parts Box)
Assorted spare wires and connectors for CTD (in CTD Parts Box)
Mounting board (for calculator and plotter)
2 multiterminal power strips (be sure they have fuses in them)
Voltmeter and leads (check that it is operational)
Solder iron and solder
Spare mixer, conductivity, temperature, and depth sensors (in CTD Parts Box)
Data Cassettes
Program Cassettes
Rolls of printing paper
Pens for plotters (9862A and 7046A XYY')
HP Tape head cleaner
Kennedy tape head cleaner kit
Check output on 10 volt calibration of XYY' plotter (is it 10 volts?)
Labels for magnetic tapes
3 or 4 magnetic tapes for Kennedy tape drive
Intercom system (winch to DDL communications)
2 rolls of electric tape

CRUISE SUPPLIES

EQUIPMENT MANUALS

HP 9825A Calculator: Operating and Programming
HP 9825A Calculator: System Test Booklet and Test Cartridge 09825-90035
HP 9825A Calculator: Quick Reference Guide
HP 9825A Calculator: General I/O Programming
HP 9825A Calculator: Extended I/O Programming
HP 9825A Calculator and Plotter: Plotter Programming
HP 9825A Calculator: Advanced Programming
HP 9825A Calculator: String Variable Programming
HP 9825A Calculator: Systems Programming
HP 98034A HP-IB Interface: Installation and Service Manual
HP 59307A VHF Switch: Operating and Service Manual
HP 59309A ASCII Digital Clock: Operating and Service Manual
HP 7046A X-Y Recorder: Operating and Service Manual
HP 5328A Universal Counter: User and Service Manual
HP 204C/204D Oscillator: Operation and Service Manual
HP Option 020 Digital Voltmeter: Installation and Service Manual
HP Software General Statistics Binder with 3-tapes
Kennedy Model 1600 Incremental Tape Recorder: Operation and Maintenance Manual
G.O. Model 1015 Rosette: Instruction Manual
G.O. Model 3070 Film Recording Thermograph: Instruction Manual
Plessey Model 7400 Winch: Instruction Manual
Plessey Model 9400 CTD System: Instruction Manual
Plessey Model 8400 DDL: Instruction Manual
Sippican Model R-603 XBT System: Instruction Manual
Plessey Model 6230N Laboratory Salinometer

CRUISE SUPPLIES

OXYGEN ANALYSIS SUPPLIES

3 copies of Oxygen Analysis procedure (in "Cruise Log" notebook)
15 Oxygen Data Sheets (in "Cruise Log" notebook)
1 roll duct tape
1 roll masking tape
paper towels
2 boxes kimwipes
1 clip board
1 pipette bulb
2 - 50 ml Lowy pipettes (and tubing)
2 - 10 ml (.05 ml increment) burettes (and tubing)
2 clean 5.0 ml pipettes
2 clean 1.0 ml pipettes
1 clean 50.0 ml pipette
2 - 10 ml graduate cylinders
6 automatic pipettes (plunger type) with 6 to 10 dispensing tubes (preset 3 of them for 0.5 ml and 1 for 2.5 ml) - these are backup to Oxford Dispensers
4 clean erlenmeyer flasks (125 ml)
1 - 250 ml beaker
1 - 600 ml beaker
2 - 300 ml B.O.D. bottles
3 squeeze bottles of distilled water
1 squeeze bottle of acetone
titration lamp
3 - 0.5 ml Oxford Reagent Dispensers (check to see that they work)
2 extra dispenser bottles
Jug of distilled water
2 ring stands
4 clamps
4 pieces of tubing to cushion and secure burette and pipet with clamps
Vacuum pump (be sure it works)
Trap for vacuum pump (and tubing)
Magnetic stirrer and 2 stir bars
1 pair scissors
Box of Para Film
Sulfuric acid
Starch indicator solution (2 liter)
.01 N Iodate standard (at least 500 ml)
Alkaline Iodide Soln. (1 liter)
Manganous sulfate soln. (1 liter)
6 liters thiosulfate solution (+ stopper and tubing attachments)
300 ml BOD Bottles

CRUISE SUPPLIES

TOOL BOX

1 roll masking tape
 1 roll duct tape
 1 roll electric tape
 1 tube silicone lubricant, 1 tube silicone glue
 1 can PVC cement
 1 magic marker (black)
 1 hammer
 3 screw drivers
 2 phillips screw drivers (large and small handled)
 6 jewelers screw drivers
 Channel lock pliers
 Needle nose pliers
 Regular pliers
 Cutting pliers
 Vise grips
 Cable cutters (that don't fit in Tool Box)
 Allen wrenches
 Tape measure
 Small ratchet set
 *1 knife or cutting tool
 Triangle file for Copenhagen water
 Niskin bottle cocker and screw driver
 Electric drill (Separate from box)
 Drill bits
 *1 pair scissors
 8" adjustable wrench
 2 - 1/2"-9/16" open end wrenches
 1 - 1/2" wrench o/c
 1 - 9/16" wrench o/c
 2 - 3/8"-7/16" open end wrenches
 1 - 3/8" wrench o/c
 1 - 7/16" wrench o/c
 1 - 1/4"-5/16" open end wrench
 1 - 5/16" wrench o/c
 1 - 3/4" chisel
 Wire strippers

ACCESSORIES TO TOOL BOX

2 - 1/8" thimbles
 2 - 3/16" thimbles
 2 - 7/16" thimbles
 Pair of stainless wing bolts for each Niskin bottle
 Nuts and bolts for securing DDL and XYY' plotter
 2 shackles
 Hard wire (for securing shackles)
 Wire clamps (U-bolts)
 2" C-clamps
 Assorted bolts, wood screws, and screw eyes

APPENDIX III.

Cyber Programs

The following programs are written in CDC Fortran IV extended time sharing (FTNTS). The language is identical to Fortran IV except for the addition line numbers and the relaxed column requirements. These programs are stored and run in compiled (binary) form.

PROGRAM CTDRUN

```
SIO.  
USER,SIO3,****.  
SETUP,U3002=BF07.  
REQUEST,TAPE,VSU=U3002,HI,F=S,PO=R,LB=KU.  
DEFINE,BF07,BFCK.  
COPY,TAPE,BF07.  
REWIND,TAPE.  
COPY,TAPE,BFCK.  
REWIND,BF07,BFCK.  
VERIFY,BF07,BFCK,R.  
DAYFILE.  
REPLACE,OUTPUT=CK.  
EXIT.  
DAYFILE.  
REPLACE,OUTPUT=CK.
```

PROGRAM MAGREAD

```

00100 PROGRAM MAGREAD (BF07,BIRANG,OUTPUT,TAPE5=BF07,TAPE6=OUTPUT,
00110+ TAPE7=BIRANG)
00120C THIS PROGRAM IS DESIGNED TO CONVERT CTD DATA ON MAGNETIC TAPES
00130C TO A BINARY RECORD (PROPORTIONAL TO FREQUENCY) FOR FURTHER
00140C CALCULATION TO SALINITY,TEMPERATURE, AND DEPTH VALUES.
00150 INTEGER K(54),M(45),HEAD
00170 INTEGER I0,I1,I2,I3,I4,I5,I6
00180 INTEGER SCAN0,SCAN1,SCAN2,SCAN3,SCAN4,SCAN5,SCAN6
00190 INTEGER Z0,Z1,Z2,Z3,Z4,Z5,Z6
00200 INTEGER C0,C1,C2,C3,C4,C5,C6
00210 INTEGER T0,T1,T2,T3,T4,T5,T6
00215 ISTA=0
00222C MASK WITH J
00225 J=0000 0000 0000 0000 0001 B
00230 28 BUFFER IN (5,1) (M(1),M(45))
00240 IF (UNIT(5)) 25,24,13
00250 25 N=M(1)
00260 HEAD=AND(SHIFT(N,3),J)*8000 +AND(SHIFT(N,4),J)*4000
00270+ +AND(SHIFT(N,5),J)*2000 +AND(SHIFT(N,6),J)*1000
00280+ +AND(SHIFT(N,9),J)*800 +AND(SHIFT(N,10),J)*400
00290+ +AND(SHIFT(N,11),J)*200 +AND(SHIFT(N,12),J)*100
00300+ +AND(SHIFT(N,15),J)*80 +AND(SHIFT(N,16),J)*40
00310+ +AND(SHIFT(N,17),J)*20 +AND(SHIFT(N,18),J)*10
00320+ +AND(SHIFT(N,21),J)*8 +AND(SHIFT(N,22),J)*4
00330+ +AND(SHIFT(N,23),J)*2 +AND(SHIFT(N,24),J)*1
00334C HOPEFULLY 9999 WAS ENTERED ON THE MAGNETIC TAPE AFTER THE LAST CAST.
00335 IF (HEAD.EQ.9999) GO TO 8
00340 WRITE (7,23)HEAD
00345 23 FORMAT ("9999",/,I4)
00346 GO TO 28
00348 24 WRITE (6,26)HEAD
00350 26 FORMAT (/"***",I4,"***=THE HEADER NUMBER")
00351C COUNT THE NUMBER OF STATIONS
00352 ISTA=ISTA+1
00355 ICOUNT=0
00360 9 BUFFER IN(5,1)(K(1),K(54))
00370 IF(UNIT(5))15,14,13
00380 15 CONTINUE
00390C COUNT THE NUMBER OF RECORDS OF DATA
00400 ICOUNT=ICOUNT+1
00410 5 DO 2 L=1,7
00420 I0=K(7*L-6)$I1=K(7*L-5)$I2=K(7*L-4)$I3=K(7*L-3)$I4=K(7*L-2)$I5=K(7*L-1)
00430 I6=K(7*L)
00460 SCAN0=AND(SHIFT(I0,3),J)*80+
00470+ AND(SHIFT(I0,4),J)*40+
00480+ AND(SHIFT(I0,5),J)*20+
00490+ AND(SHIFT(I0,6),J)*10+
00500+ AND(SHIFT(I0,9),J)*8+
00510+ AND(SHIFT(I0,10),J)*4+
00520+ AND(SHIFT(I0,11),J)*2+
00530+ AND(SHIFT(I0,12),J)*1
00540 Z0=AND(SHIFT(I0,15),J)*32768 +AND(SHIFT(I0,16),J)*16384
00550+ +AND(SHIFT(I0,17),J)*8192 +AND(SHIFT(I0,18),J)*4096

```

```

00560+ +AND(SHIFT(I0,21),J)*2048 +AND(SHIFT(I0,22),J)*1024
00570+ +AND(SHIFT(I0,23),J)*512 +AND(SHIFT(I0,24),J)*256
00580+ +AND(SHIFT(I0,27),J)*128 +AND(SHIFT(I0,28),J)*64
00590+ +AND(SHIFT(I0,29),J)*32 +AND(SHIFT(I0,30),J)*16
00600+ +AND(SHIFT(I0,33),J)*8 +AND(SHIFT(I0,34),J)*4
00610+ +AND(SHIFT(I0,35),J)*2 +AND(SHIFT(I0,36),J)*1
00620 C0=AND(SHIFT(I0,39),J)*32768 +AND(SHIFT(I0,40),J)*16384
00630+ +AND(SHIFT(I0,41),J)*8192 +AND(SHIFT(I0,42),J)*4096
00640+ +AND(SHIFT(I0,45),J)*2048 +AND(SHIFT(I0,46),J)*1024
00650+ +AND(SHIFT(I0,47),J)*512 +AND(SHIFT(I0,48),J)*256
00660+ +AND(SHIFT(I0,51),J)*128 +AND(SHIFT(I0,52),J)*64
00670+ +AND(SHIFT(I0,53),J)*32 +AND(SHIFT(I0,54),J)*16
00680+ +AND(SHIFT(I0,57),J)*8 +AND(SHIFT(I0,58),J)*4
00690+ +AND(SHIFT(I0,59),J)*2 +AND(SHIFT(I0,60),J)*1
00700 T0=AND(SHIFT(I1,3),J)*32768 +AND(SHIFT(I1,4),J)*16384
00710+ +AND(SHIFT(I1,5),J)*8192 +AND(SHIFT(I1,6),J)*4096
00720+ +AND(SHIFT(I1,9),J)*2048 +AND(SHIFT(I1,10),J)*1024
00730+ +AND(SHIFT(I1,11),J)*512 +AND(SHIFT(I1,12),J)*256
00740+ +AND(SHIFT(I1,15),J)*128 +AND(SHIFT(I1,16),J)*64
00750+ +AND(SHIFT(I1,17),J)*32 +AND(SHIFT(I1,18),J)*16
00760+ +AND(SHIFT(I1,21),J)*8 +AND(SHIFT(I1,22),J)*4
00770+ +AND(SHIFT(I1,23),J)*2 +AND(SHIFT(I1,24),J)*1
00780 SCAN1=AND(SHIFT(I1,27),J)*80 +AND(SHIFT(I1,28),J)*40
00790+ +AND(SHIFT(I1,29),J)*20 +AND(SHIFT(I1,30),J)*10
00800+ +AND(SHIFT(I1,33),J)*8 +AND(SHIFT(I1,34),J)*4
00810+ +AND(SHIFT(I1,35),J)*2 +AND(SHIFT(I1,36),J)*1
00820 Z1=AND(SHIFT(I1,39),J)*32768 +AND(SHIFT(I1,40),J)*16384
00830+ +AND(SHIFT(I1,41),J)*8192 +AND(SHIFT(I1,42),J)*4096
00840+ +AND(SHIFT(I1,45),J)*2048 +AND(SHIFT(I1,46),J)*1024
00850+ +AND(SHIFT(I1,47),J)*512 +AND(SHIFT(I1,48),J)*256
00860+ +AND(SHIFT(I1,51),J)*128 +AND(SHIFT(I1,52),J)*64
00870+ +AND(SHIFT(I1,53),J)*32 +AND(SHIFT(I1,54),J)*16
00880+ +AND(SHIFT(I1,57),J)*8 +AND(SHIFT(I1,58),J)*4
00890+ +AND(SHIFT(I1,59),J)*2 +AND(SHIFT(I1,60),J)*1
00900 C1=AND(SHIFT(I2,3),J)*32768 +AND(SHIFT(I2,4),J)*16384
00910+ +AND(SHIFT(I2,5),J)*8192 +AND(SHIFT(I2,6),J)*4096
00920+ +AND(SHIFT(I2,9),J)*2048 +AND(SHIFT(I2,10),J)*1024
00930+ +AND(SHIFT(I2,11),J)*512 +AND(SHIFT(I2,12),J)*256
00940+ +AND(SHIFT(I2,15),J)*128 +AND(SHIFT(I2,16),J)*64
00950+ +AND(SHIFT(I2,17),J)*32 +AND(SHIFT(I2,18),J)*16
00960+ +AND(SHIFT(I2,21),J)*8 +AND(SHIFT(I2,22),J)*4
00970+ +AND(SHIFT(I2,23),J)*2 +AND(SHIFT(I2,24),J)*1
00980 T1=AND(SHIFT(I2,27),J)*32768 +AND(SHIFT(I2,28),J)*16384
00990+ +AND(SHIFT(I2,29),J)*8192 +AND(SHIFT(I2,30),J)*4096
01000+ +AND(SHIFT(I2,33),J)*2048 +AND(SHIFT(I2,34),J)*1024
01010+ +AND(SHIFT(I2,35),J)*512 +AND(SHIFT(I2,36),J)*256
01020+ +AND(SHIFT(I2,39),J)*128 +AND(SHIFT(I2,40),J)*64
01030+ +AND(SHIFT(I2,41),J)*32 +AND(SHIFT(I2,42),J)*16
01040+ +AND(SHIFT(I2,45),J)*8 +AND(SHIFT(I2,46),J)*4
01050+ +AND(SHIFT(I2,47),J)*2 +AND(SHIFT(I2,48),J)*1
01060 IF (L.EQ.7)6,12
01070 12 CONTINUE
01080 SCAN2=AND(SHIFT(I2,51),J)*80 +AND(SHIFT(I2,52),J)*40
01090+ +AND(SHIFT(I2,53),J)*20 +AND(SHIFT(I2,54),J)*10
01100+ +AND(SHIFT(I2,57),J)*8 +AND(SHIFT(I2,58),J)*4
01110+ +AND(SHIFT(I2,59),J)*2 +AND(SHIFT(I2,60),J)*1

```



```

01120 Z2=AND(SHIFT(I3,3),J)*32768 +AND(SHIFT(I3,4),J)*16384
01130+ +AND(SHIFT(I3,5),J)*8192 +AND(SHIFT(I3,6),J)*4096
01140+ +AND(SHIFT(I3,9),J)*2048 +AND(SHIFT(I3,10),J)*1024
01150+ +AND(SHIFT(I3,11),J)*512 +AND(SHIFT(I3,12),J)*256
01160+ +AND(SHIFT(I3,15),J)*128 +AND(SHIFT(I3,16),J)*64
01170+ +AND(SHIFT(I3,17),J)*32 +AND(SHIFT(I3,18),J)*16
01180+ +AND(SHIFT(I3,21),J)*8 +AND(SHIFT(I3,22),J)*4
01190+ +AND(SHIFT(I3,23),J)*2 +AND(SHIFT(I3,24),J)*1
01200 C2=AND(SHIFT(I3,27),J)*32768 +AND(SHIFT(I3,28),J)*16384
01210+ +AND(SHIFT(I3,29),J)*8192 +AND(SHIFT(I3,30),J)*4096
01220+ +AND(SHIFT(I3,33),J)*2048 +AND(SHIFT(I3,34),J)*1024
01230+ +AND(SHIFT(I3,35),J)*512 +AND(SHIFT(I3,36),J)*256
01240+ +AND(SHIFT(I3,39),J)*128 +AND(SHIFT(I3,40),J)*64
01250+ +AND(SHIFT(I3,41),J)*32 +AND(SHIFT(I3,42),J)*16
01260+ +AND(SHIFT(I3,45),J)*8 +AND(SHIFT(I3,46),J)*4
01270+ +AND(SHIFT(I3,47),J)*2 +AND(SHIFT(I3,48),J)*1
01280 T2=AND(SHIFT(I3,51),J)*32768 +AND(SHIFT(I3,52),J)*16384
01290+ +AND(SHIFT(I3,53),J)*8192 +AND(SHIFT(I3,54),J)*4096
01300+ +AND(SHIFT(I3,57),J)*2048 +AND(SHIFT(I3,58),J)*1024
01310+ +AND(SHIFT(I3,59),J)*512 +AND(SHIFT(I3,60),J)*256
01320+ +AND(SHIFT(I4,3),J)*128 +AND(SHIFT(I4,4),J)*64
01330+ +AND(SHIFT(I4,5),J)*32 +AND(SHIFT(I4,6),J)*16
01340+ +AND(SHIFT(I4,9),J)*8 +AND(SHIFT(I4,10),J)*4
01350+ +AND(SHIFT(I4,11),J)*2 +AND(SHIFT(I4,12),J)*1
01360 SCAN3=AND(SHIFT(I4,15),J)*80 +AND(SHIFT(I4,16),J)*40
01370+ +AND(SHIFT(I4,17),J)*20 +AND(SHIFT(I4,18),J)*10
01380+ +AND(SHIFT(I4,21),J)*8 +AND(SHIFT(I4,22),J)*4
01390+ +AND(SHIFT(I4,23),J)*2 +AND(SHIFT(I4,24),J)*1
01400 Z3=AND(SHIFT(I4,27),J)*32768 +AND(SHIFT(I4,28),J)*16384
01410+ +AND(SHIFT(I4,29),J)*8192 +AND(SHIFT(I4,30),J)*4096
01420+ +AND(SHIFT(I4,33),J)*2048 +AND(SHIFT(I4,34),J)*1024
01430+ +AND(SHIFT(I4,35),J)*512 +AND(SHIFT(I4,36),J)*256
01440+ +AND(SHIFT(I4,39),J)*128 +AND(SHIFT(I4,40),J)*64
01450+ +AND(SHIFT(I4,41),J)*32 +AND(SHIFT(I4,42),J)*16
01460+ +AND(SHIFT(I4,45),J)*8 +AND(SHIFT(I4,46),J)*4
01470+ +AND(SHIFT(I4,47),J)*2 +AND(SHIFT(I4,48),J)*1
01480 C3=AND(SHIFT(I4,51),J)*32768 +AND(SHIFT(I4,52),J)*16384
01490+ +AND(SHIFT(I4,53),J)*8192 +AND(SHIFT(I4,54),J)*4096
01500+ +AND(SHIFT(I4,57),J)*2048 +AND(SHIFT(I4,58),J)*1024
01510+ +AND(SHIFT(I4,59),J)*512 +AND(SHIFT(I4,60),J)*256
01520+ +AND(SHIFT(I5,3),J)*128 +AND(SHIFT(I5,4),J)*64
01530+ +AND(SHIFT(I5,5),J)*32 +AND(SHIFT(I5,6),J)*16
01540+ +AND(SHIFT(I5,9),J)*8 +AND(SHIFT(I5,10),J)*4
01550+ +AND(SHIFT(I5,11),J)*2 +AND(SHIFT(I5,12),J)*1
01560 T3=AND(SHIFT(I5,15),J)*32768 +AND(SHIFT(I5,16),J)*16384
01570+ +AND(SHIFT(I5,17),J)*8192 +AND(SHIFT(I5,18),J)*4096
01580+ +AND(SHIFT(I5,21),J)*2048 +AND(SHIFT(I5,22),J)*1024
01590+ +AND(SHIFT(I5,23),J)*512 +AND(SHIFT(I5,24),J)*256
01600+ +AND(SHIFT(I5,27),J)*128 +AND(SHIFT(I5,28),J)*64
01610+ +AND(SHIFT(I5,29),J)*32 +AND(SHIFT(I5,30),J)*16
01620+ +AND(SHIFT(I5,33),J)*8 +AND(SHIFT(I5,34),J)*4
01630+ +AND(SHIFT(I5,35),J)*2 +AND(SHIFT(I5,36),J)*1
01640 SCAN4=AND(SHIFT(I5,39),J)*80 +AND(SHIFT(I5,40),J)*40
01650+ +AND(SHIFT(I5,41),J)*20 +AND(SHIFT(I5,42),J)*10
01660+ +AND(SHIFT(I5,45),J)*8 +AND(SHIFT(I5,46),J)*4

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01670+ +AND(SHIFT(I5,47),J)*2 +AND(SHIFT(I5,48),J)*1
01680 Z4=AND(SHIFT(I5,51),J)*32768 +AND(SHIFT(I5,52),J)*16384
01690+ +AND(SHIFT(I5,53),J)*8192 +AND(SHIFT(I5,54),J)*4096
01700+ +AND(SHIFT(I5,57),J)*2048 +AND(SHIFT(I5,58),J)*1024
01710+ +AND(SHIFT(I5,59),J)*512 +AND(SHIFT(I5,60),J)*256
01720+ +AND(SHIFT(I6,3),J)*128 +AND(SHIFT(I6,4),J)*64
01730+ +AND(SHIFT(I6,5),J)*32 +AND(SHIFT(I6,6),J)*16
01740+ +AND(SHIFT(I6,9),J)*8 +AND(SHIFT(I6,10),J)*4
01750+ +AND(SHIFT(I6,11),J)*2 +AND(SHIFT(I6,12),J)*1
01760 C4=AND(SHIFT(I6,15),J)*32768 +AND(SHIFT(I6,16),J)*16384
01770+ +AND(SHIFT(I6,17),J)*8192 +AND(SHIFT(I6,18),J)*4096
01780+ +AND(SHIFT(I6,21),J)*2048 +AND(SHIFT(I6,22),J)*1024
01790+ +AND(SHIFT(I6,23),J)*512 +AND(SHIFT(I6,24),J)*256
01800+ +AND(SHIFT(I6,27),J)*128 +AND(SHIFT(I6,28),J)*64
01810+ +AND(SHIFT(I6,29),J)*32 +AND(SHIFT(I6,30),J)*16
01820+ +AND(SHIFT(I6,33),J)*8 +AND(SHIFT(I6,34),J)*4
01830+ +AND(SHIFT(I6,35),J)*2 +AND(SHIFT(I6,36),J)*1
01840 T4=AND(SHIFT(I6,39),J)*32768 +AND(SHIFT(I6,40),J)*16384
01850+ +AND(SHIFT(I6,41),J)*8192 +AND(SHIFT(I6,42),J)*4096
01860+ +AND(SHIFT(I6,45),J)*2048 +AND(SHIFT(I6,46),J)*1024
01870+ +AND(SHIFT(I6,47),J)*512 +AND(SHIFT(I6,48),J)*256
01880+ +AND(SHIFT(I6,51),J)*128 +AND(SHIFT(I6,52),J)*64
01890+ +AND(SHIFT(I6,53),J)*32 +AND(SHIFT(I6,54),J)*16
01900+ +AND(SHIFT(I6,57),J)*8 +AND(SHIFT(I6,58),J)*4
01910+ +AND(SHIFT(I6,59),J)*2 +AND(SHIFT(I6,60),J)*1
01920 WRITE (7,7)SCAN0,Z0,C0,T0,SCAN1,Z1,C1,T1,SCAN2,Z2,C2,T2,SCAN3,
01930+ Z3,C3,T3,SCAN4,Z4,C4,T4
01940 7 FORMAT (4(I4,1X,I5,1X,I5,1X,I5,/),I4,1X,I5,1X,I5,1X,I5)
01950 2 CONTINUE
01960 6 WRITE (7,3)SCAN0,Z0,C0,T0,SCAN1,Z1,C1,T1
01970 3 FORMAT (I4,1X,I5,1X,I5,1X,I5,/,I4,1X,I5,1X,I5,1X,I5)
01980 GO TO 9
01990 13 WRITE (6,16)
02000 16 FORMAT (/"THERE IS A PROBLEM. THE DATA IS NOT BEING READ RIGHT."/)
02010 14 WRITE (6,10)ICOUNT
02020 10 FORMAT ("*****",I3,"*****=THE NUMBER OF RECORDS")
02030 GO TO 28
02040 8 WRITE(7,77)
02045 77 FORMAT("9999")
02046 WRITE(6,78)ISTA
02047 78 FORMAT("###",I6,"###=THE NUMBER OF CASTS NOW ON TAPE7.")
02048 STOP
02050 END

```

PROGRAM CTDUNIT

```

00100 PROGRAM CTDUNIT(INPUT,BIRANG,OUTPUT,LAG,TAPE5=BIRANG,TAPE7=LAG,
00110+ TAPE4=INPUT,TAPE6=OUTPUT)
00120C THIS PROGRAM READS FREQUENCIES (BINARY RANGE,BR) FROM BIRANG,
00130C   CONVERTS THEM TO DEPTH, CONDUCTIVITY, AND TEMPERATURE, AND
00140C   WRITES THE NEW DATA SET ON A FILE DESIGNATED BY TAPE7.
00150 INTEGER HEAD,SCAN,W
00160 INTEGER ZBR,CBR,TBR
00170 REWIND 5
00180 I=0
00185 WRITE(6,8)
00187 READ(4,9)COR
00190C   W IS THE PRE-HEADER WRITTEN ONTO BIRANG TO IDENTIFY NEW CASTS.
00200C   W=9999. THE HEADER NUMBER FOLLOWS.
00210 10 READ (5,11)W
00220 12 READ(5,13)HEAD
00230 IF(EOF(5))6,16
00235 16 CONTINUE
00240 WRITE(7,14)HEAD
00250C   I COUNTS THE NUMBER OF CASTS.
00260 I=I+1
00270 J=0
00280 2 IF(EOF(5))6,7
00290 7 READ (5,3)SCAN,ZBR,CBR,TBR
00300 IF (SCAN.EQ.9999) GO TO 12
00310C   J COUNTS THE NUMBER OF LINES PER CAST.
00320 J=J+1
00330 Z=0.036621094*ZBR
00335 Z=Z+COR
00340 C=0.002441406*CBR
00350 T=0.001220679*TBR-4.999208208
00360 WRITE (7,5)J,SCAN,Z,C,T
00370 GO TO 2
00380 6 WRITE (6,4) I
00390 WRITE(7,1)
00400C   THE FORMAT SECTION FOLLOWS
00410 1 FORMAT("9999")
00420 3 FORMAT (I4,1X,I5,1X,I5,1X,I5)
00430 4 FORMAT ("*****",I6,"*****=THE NUMBER OF CASTS NOW ON TAPE7.")
00440 5 FORMAT (I4,1X,I2,1X,F6.2,1X,F6.3,1X,F5.2)
00445 8 FORMAT("ENTER THE DEPTH CORRECTION FACTOR FOR THE CTD",/,
00446+ "IN THE FORMAT +X.XXX OR -X.XXX")
00447 9 FORMAT(F6.3)
00450 11 FORMAT (I2)
00460 13 FORMAT (I4)
00470 14 FORMAT ("9999",/,I4)
00480 STOP
00490 END

```

```

00100 PROGRAM LGFILT(LAG,OUTPUT,LATCH,TAPE5=LAG,TAPE6=OUTPUT,
00110+ TAPE7=LATCH)
00120C THIS PROGRAM READS D, C, AND T FROM LAG, COURSE FILTERS THE DATA,
00130C CALCULATES THE TEMPERATURE SENSOR LAG, AND WRITES THE NEW DATA
00140C SET ONTO A FILE DESIGNATED BY TAPE7.
00150 INTEGER W,HEAD
00160 REWIND 5
00170 I=0
00180 READ(5,10)W
00190 GO TO 1
00200 2 WRITE(6,19)HEAD,M
00210 1 READ(5,10)HEAD
00220 IF(EOF(5))4,5
00230 5 WRITE(7,15)HEAD
00240 M=0
00250C I COUNTS THE NUMBER OF CASTS.
00260 I=I+1
00290 READ(5,12)J1,S1,D1,C1,T1
00300 READ(5,12)J2,S2,D2,C2,T2
00310 3 IF(EOF(5))4,23
00320 23 READ(5,12)J3,S3,D3,C3,T3
00325 IF(EOF(5))4,28
00330 28 L=0
00340 IF(J3.EQ.9999)GO TO 2
00350 IF(D3.GE.D2+5.OR.D3.LE.D2-5)GO TO 30
00360 IF(C3.GE.C2+0.8.OR.C3.LE.C2-0.8)GO TO 30
00370 IF(T3.GE.T2+0.5.OR.T3.LE.T2-0.5)GO TO 30
00380 T=.76341*(T3-T1)/(S2+1)+T2
00390 WRITE(7,12)J2,S2,D2,C2,T
00400 J1=J2*J2=J3*S1=S2*S2=S3*D1=D2*D2=D3*C1=C2*C2=C3*T1=T2*T2=T3
00410 GO TO 3
00420 30 READ(5,12)J4,S4,D4,C4,T4
00423 IF(J4.EQ.9999)GO TO 2
00425 IF(EOF(5))4,26
00430C M COUNTS THE NUMBER OF LINES OF DATA REMOVED BY THE COURSE FILTER.
00440 26 M=M+1
00445 L=L+1 $ IF(L.EQ.5)GO TO 33
00460 IF(D4.GE.D2+5.OR.D4.LE.D2-5)GO TO 30
00470 IF(C4.GE.C2+0.8.OR.C4.LE.C2-0.8)GO TO 30
00480 IF(T4.GE.T2+0.5.OR.T4.LE.T2-0.5)GO TO 30
00490 31 READ(5,12)J5,S5,D5,C5,T5
00495 IF(J5.EQ.9999)GO TO 2
00497 IF(EOF(5))4,27
00500 27 IF(D5.GE.D4+5.OR.D5.LE.D4-5)GO TO 32
00510 IF(C5.GE.C4+0.8.OR.C5.LE.C4-0.8)GO TO 32
00520 IF(T5.GE.T4+0.5.OR.T5.LE.T4-0.5)GO TO 32
00530 J1=J4*J2=J5*S1=S4*S2=S5*D1=D4*D2=D5*C1=C4*C2=C5*T1=T4*T2=T5
00540 GO TO 23
00542 32 L=0 $ GO TO 30
00544 33 IF(D4.GE.D2+20.OR.D4.LE.D2-20)GO TO 32
00546 GO TO 31
00550 4 WRITE(7,16)
00560 WRITE(6,17)I
00570C FORMATS ARE AS FOLLOWS:
00580 10 FORMAT(I4)
00590 12 FORMAT(I4,1X,I2,1X,F6.2,1X,F6.3,1X,F5.2)
00600 15 FORMAT("9999",/,I4)
00610 16 FORMAT("9999")
00620 17 FORMAT(/,"**",I6,"**=THE NUMBER OF CASTS NOW ON TAPE7.")
00630 19 FORMAT("CAST",I4," LOST",I4," DATA PTS. THRU COURSE FILTERING.")
00640 STOP
00650 END

```

```

00100 PROGRAM BROE (INPUT,AVE,OUTPUT,SGSA,TAPE4=INPUT,
00110+ TAPE5=AVE,TAPE6=OUTPUT,TAPE7=SGSA)
00120C THIS PROGRAM READS D, C, AND T FROM AVE, CALCULATES SALINITY
00130C AND SIGMAT, AND WRITES THOSE PARAMETERS ONTO A FILE
00140C DESIGNATED BY TAPE7. THE SALINITY CALCULATION IS FROM
00141C BROENKOW.
00150 INTEGER W,HEAD
00160 C1=.03895414
00170 C2=-2.2584586
00180 REWIND 5
00190 WRITE(6,37)
00210 READ(4,36)COR
00230 I=0
00240 READ (5,12)W
00250 13 READ (5,12)HEAD
00260 IF(EOF(5))5,4
00270C I COUNTS THE NUMBER OF CASTS.
00280 4 I=I+1
00290 WRITE (7,21)HEAD
00300 7 IF(EOF(5))5,9
00310 9 READ(5,10)J,SCAN,D2,CSTP,T,M
00320 IF (J.EQ.9999) GO TO 13
00330 K=0
00332 AT=(676547+20131.5*T+99.89*T**2-0.1943*T**3-0.00672*T**4)*1.0E-6
00340 RT=CSTP/(AT*42.896)
00420 100 D15=RT*(RT-1)*(T-15)*(96.7-72.0*RT+37.3*RT**2-
00430+(0.63+0.21*RT**2)*(T-15))*1.0E-5
00440 R15=RT+D15
00450 S=-0.08996+28.29720*R15+12.80832*R15**2-10.67869*R15**3+
00460+5.98624*R15**4-1.32311*R15**5
00462 IF(K.EQ.1)GO TO 101
00464 RZ=1.0+0.01*(1.551-0.0453*T+0.00059*T**2+0.25*(35-S)*(0.043-0.0017*T
00465+ 2.3E-5*T**2))*(1.037E-3*D2-3.2E-8*D2**2)
00466 RT=CSTP/(RZ*AT*42.896)
00467 K=1 $ GO TO 100
00470C A CORRECTION FACTOR FOR SALINITY(BOTTLE)-SALINITY(CTD) IS ADDED
00480C TO ALL SALINITY VALUES.
00490C (IT MUST BE CALCULATED FOR EVERY CRUISE)
00500 101 S=S+COR
00510 F1=((T-3.98)**2)*(T+283.)/((503.57)*(T+67.26))
00520 F2=(T**3)*(1.0843E-6)-(T*T)*(9.8185E-5)+T*4.7867E-3
00530 F3=(T**3)*(1.667E-8)-(T*T)*(8.164E-7)+T*1.803E-5
00540 FS=(S**3)*(6.76786136E-6)-(S*S)*(4.8249614E-4)+S*.814876577
00550 SIG=-F1+(FS+C1)*(1.-F2+(F3)*(FS+C2))
00560 WRITE (7,20)J,SCAN,D2,CSTP,T,M,S,SIG
00570 6 GO TO 7
00580 5 WRITE(6,38)I
00590 WRITE(7,39)
00600C THE FORMAT SECTION FOLLOWS
00610 3 FORMAT (3X,I4,2X,F6.2,6X,F6.3,8X,F5.2,6X,F6.3)
00620 10 FORMAT(I4,1X,I2,1X,F6.2,1X,F6.3,1X,F5.2,1X,I4)
00630 12 FORMAT (I4)
00640 15 FORMAT (/,"HEADER NUMBER=",I4,/)
00650 21 FORMAT ("9999",/,I4)
00660 20 FORMAT (I4,1X,I2,1X,F6.2,1X,F6.3,1X,F5.2,1X,I4,2X,F6.3,1X,F5.2)
00670 36 FORMAT(F6.3)
00680 37 FORMAT("A SALINITY CORRECTION FACTOR FOR SAL(BOTTLE)-SAL(CTD)",/,
00690+ "SHOULD BE ENTERED IN THE FORMAT +X.XXX OR -X.XXX")
00700 38 FORMAT("****",I6,"****=THE NUMBER OF CASTS NOW ON TAPE7.")
00710 39 FORMAT("9999")
00720 50 STOP
00730 END

```

PROGRAM DLATCH

```

00100 PROGRAM DLATC (LATCH,OUTPUT,CTDATA,TAPE5=LATCH,TAPE6=OUTPUT,
00110+ TAPE7=CTDATA)
00120C THIS PROGRAM READS D, C, AND T FROM LATCH, REMOVES LINES HAVING
00130C     ASCENDING DEPTHS, AND WRITES THE NEW DATA SET ONTO A FILE
00140C     DESIGNATED BY TAPE7.
00150 DIMENSION J(6000),S(6000),D(6000),C(6000),T(6000)
00160 INTEGER HEAD,W
00170 REWIND 5
00180 I=0
00190 READ(5,10)W
00200 2 READ(5,10)HEAD
00210 IF(EOF(5))3,4
00220 4 WRITE(7,15)HEAD
00230C     I COUNTS THE NUMBER OF CASTS.
00240 I=I+1
00250 READ(5,12)JOUT,SCAN,DOUT,COUT,TOUT
00260 READ(5,12)J1,S1,D1,C1,T1
00270 DO 1,K=1,6000
00280 READ(5,12)J(K),S(K),D(K),C(K),T(K)
00290 IF(J(K).EQ.9999)GO TO 2
00300 IF(EOF(5))3,5
00320 5 IF(D(K).LE.D1)GO TO 1
00330 WRITE(7,12)J1,S1,D1,C1,T1
00340 J1=J(K)$S1=S(K)$D1=D(K)$C1=C(K)$T1=T(K)
00350 1 CONTINUE
00355 WRITE(6,18)HEAD $ GO TO 222
00360 3 WRITE(7,16)
00370 WRITE(6,17)I
00380C     FORMATS ARE AS FOLLOWS:
00390 10 FORMAT(I4)
00400 12 FORMAT(I4,1X,I2,1X,F6.2,1X,F6.3,1X,F5.2)
00410 15 FORMAT("9999",/,I4)
00420 16 FORMAT("9999")
00430 17 FORMAT("*,I6,"*=THE NUMBER OF CASTS NOW ON TAPE7.")
00435 18 FORMAT("STATION",I6," HAS OVER 6000 LINES:THE PROG. STOPPED.")
00440 222 STOP
00450 END

```

PROGRAM CTDAVE

```
00100 PROGRAM CTDAV (CTDATA,AVE,OUTPUT,TAPE5=CTDATA,TAPE7=AVE,
00110+ TAPE6=OUTPUT)
00120C THIS PROGRAM READS D, C, AND T FROM CTDATA, CALCULATES THE AVERAGE
00130C VALUES FOR POINTS FROM .5 TO .5 METERS, AND WRITES THE NEW
00140C DATA SET ONTO A FILE DESIGNATED BY TAPE7.
00150 DIMENSION J(100),S(100),D(100),C(100),T(100)
00160 INTEGER HEAD,W,S,Q,R
00170 REWIND 5
00180 I=0
00190 READ(5,1)W
00200 17 READ(5,1)HEAD
00210 IF(EOF(5))18,15
00220 15 WRITE(7,2)HEAD
00230C I COUNTS THE NUMBER OF CASTS.
00240 I=I+1
00250 DX=1.5
00260 13 N=0 $ P=0 $ F=0 $ G=0
00270 DO 10 K=1,100
00280 READ(5,3)J(K),S(K),D(K),C(K),T(K)
00290 IF(EOF(5))11,12
00300 12 Q=J(K) $ R=S(K)
00310 IF(D(K).GE.DX)GO TO 11
00320 IF(Q.EQ.9999)GO TO 11
00330 M=Q
00340C N COUNTS THE NUMBER OF POINTS TO BE AVERAGED.
00350 N=N+1
00360 P=P+D(K) $ F=F+C(K) $ G=G+T(K)
00370 10 CONTINUE
00380 11 IF(N.EQ.0)GO TO 22
00390 A=P/N $ B=F/N $ E=G/N
00400 GO TO 23
00410 22 IF(Q.EQ.9999)GO TO 17
00420 A=D(K) $ B=C(K) $ E=T(K)
00430 M=Q
00440 N=1
00450 23 WRITE(7,3)M,R,A,B,E,N
00460 IF(Q.EQ.9999)GO TO 17
```

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00470C  DX STEPS TO THE NEXT DEPTH FOR AVERAGING.
00480  DX=DX+1
00490  IF(DX.EQ.102.5)GO TO 30
00500  GO TO 13
00510  30 DX=DX+5
00520  N=0 $ P=0 $ F=0 $ G=0
00530  DO 31 K=1,100
00540  READ(5,3)J(K),S(K),D(K),C(K),T(K)
00550  IF(EOF(5))32,33
00560  33 Q=J(K) $ R=S(K)
00570  IF (D(K).GE.DX)GO TO 32
00575  IF(Q.EQ.9999)GO TO 32
00580  M=Q
00590  N=N+1
00600  P=P+D(K) $ F=F+C(K) $ G=G+T(K)
00610  31 CONTINUE
00620  32 IF(N.EQ.0)GO TO 34
00630  A=P/N $ B=F/N $ E=G/N
00640  GO TO 35
00650  34 IF(Q.EQ.9999)GO TO 17
00660  A=D(K) $ B=C(K) $ E=T(K)
00670  M=Q
00680  N=1
00690  35 IF(Q.EQ.9999)GO TO 17
00700  WRITE(7,3)M,R,A,B,E,N
00710  GO TO 30
00720  18 WRITE(7,4).
00730  WRITE(6,5)I
00740C  FORMAT SECTION:
00750  1 FORMAT(I4)
00760  2 FORMAT("9999",/,I4)
00770  3 FORMAT(I4,1X,I2,1X,F6.2,1X,F6.3,1X,F5.2,1X,I4)
00780  4 FORMAT("9999")
00790  5 FORMAT("**",I6,"**=THE NUMBER OF CASTS NOW ON TAPE7.")
00800  STOP
00810  END
```



```
00100 PROGRAM NODCFO(SGSA,OUTPUT,NODC,TAPE5=SGSA,TAPE6=OUTPUT,
00110+ TAPE7=NODC)
00120C THIS PROGRAM READS D,T AND S FROM THE CRUISE DATA FILE AND
00130C REWRITES THEM IN NODC FORMAT ON A FILE DESIGNATED BY TAPE7.
00140 INTEGER W,HEAD,X
00150 REWIND 5
00160 I=0 $ N=0
00170 READ(5,1)W
00180 10 READ(5,1)HEAD
00190 IF(EOF(5))20,21
00200 21 WRITE(7,2)HEAD
00205 WRITE(6,1)HEAD
00210 N=N+1
00220 X=0
00230 11 READ(5,3)J,D,T,S
00240 IF(J.EQ.9999)GO TO 10
00250 IF(D.GE.INT(D)+0.5)GO TO 24
00251 IF(T*10.GE.INT(T*10)+0.5)GO TO 25
00252 IF(S*100.GE.INT(S*100)+0.5)GO TO 26
00254 K=D $ L=T*100 $ M=S*100
00255 GO TO 23
00256 26 K=D $ L=T*100 $ M=S*100+1
00257 GO TO 23
00258 25 IF(S*100.GE.INT(S*100)+0.5)GO TO 27
00259 K=D $ L=T*100+1 $ M=S*100
00260 GO TO 23
00261 27 K=D $ L=T*100+1 $ M=S*100+1
00262 GO TO 23
00263 24 IF(T*10.GE.INT(T*10)+0.5)GO TO 28
00270 IF(S*100.GE.INT(S*100)+0.5)GO TO 29
00271 K=D+1 $ L=T*100 $ M=S*100
00280 GO TO 23
00281 29 K=D+1 $ L=T*100 $ M=S*100+1
00282 GO TO 23
00283 28 IF(S*100.GE.INT(S*100)+0.5)GO TO 30
00284 K=D+1 $ L=T*100+1 $ M=S*100
00285 GO TO 23
00286 30 K=D+1 $ L=T*100+1 $ M=S*100+1
00290 23 IF(K.EQ.X)GO TO 11
00300 WRITE(7,4)K,L,M
00310 I=I+1
00320 X=K
00330 GO TO 11
00340 20 WRITE(6,5)N
00345 WRITE(7,6)
00350C THIS IS THE FORMAT SECTION:
00360 1 FORMAT(I4)
00370 2 FORMAT("9999",/,I4)
00380 3 FORMAT(I4,4X,F6.2,8X,F5.2,7X,F6.3)
00390 4 FORMAT(26X,I5,I5,I5)
00400 5 FORMAT("***",I4,"***=THE NUMBER OF CASTS NOW ON TAPE7.")
00405 6 FORMAT("9999")
00410 STOP
00420 END
```

PROGRAM NUTMERG

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00100 PROGRAM MERGEIT(INPUT,NOD,HEA,OUTPUT,FINAL,TAPE4=INPUT,
00110+ TAPE5=NOD,TAPE6=OUTPUT,TAPE7=FINAL,TAPE8=HEA)
00115+ THIS PROGRAM MERGES HEADER AND NUTRIENT DATA TO CAST DATA IN NODC FORMAT.
00120 DIMENSION IH(10)
00130 INTEGER W,HEAD,X,CT,Z
00140 REWIND5 $ REWIND8
00150 I=0 $ N=0
00160 READ(5,1)W
00170 41 BACKSPACE 8
00180 10 READ(5,1)HEAD
00185 IF(EOF(5))20,21
00187 21 READ(8,6)(IH(I),I=1,9),IP,IHEAD,IR
00190 IF(EOF(8))20,29
00200 29 CONTINUE
00210 22 WRITE(7,6)(IH(I),I=1,9),IP,IHEAD,IR
00219 N=N+1
00221 12 READ(8,9)Z
00222 IF(EOF(8))13,14
00223 14 IF(Z.EQ.31)GO TO 13
00224 BACKSPACE 8
00230 READ(8,7)KK,ISAL,02,P04,N03,SIO3,CT
00232 GO TO 11
00234 13 KK=999
00240 11 READ(5,3)J,K,L,M
00250 IF(J.EQ.9999)GO TO 40
00255 IF(K.GT.100.)GO TO 60
00257 IF(KK.EQ.2)GO TO 43
00260 IF(KK.LE.K)GO TO 43
00263 GO TO 44
00265 60 IF(KK.LT.K+2.5)GO TO 43
00282 44 WRITE(7,4)K,L,M
00283 GO TO 11
00285 43 IF(ISAL.EQ.0)GO TO 48
00287 WRITE(7,5)K,L,ISAL,02,P04,N03,SIO3,CT
00288 GO TO 12
00290 48 WRITE(7,8)K,L,M,02,P04,N03,SIO3,CT
00300 GO TO 12
00310 40 IF(KK.EQ.999)GO TO 41
00315 IF(J.EQ.9999)WRITE(7,8)KK,L,M,02,P04,N03,SIO3,CT
00317 GO TO 47
00320 45 WRITE(7,7)KK,ISAL,02,P04,N03,SIO3,CT
00323 47 CONTINUE
00330 READ(8,9)Z
00335 IF(EOF(8))10,46
00340 46 IF(Z.EQ.31)GO TO 41
00345 BACKSPACE 8
00347 READ(8,7)KK,ISAL,02,P04,N03,SIO3,CT
00350 GO TO 45
00360 20 WRITE(6,5)N
00370C THIS IS THE FORMAT SECTION:
00380 1 FORMAT(I4)
00390 2 FORMAT("9999",/,I4)
00400 3 FORMAT(I4,22X,I5,A5,A5)
00410 4 FORMAT(26X,I5,A5,A5,38X,"3")
00420 5 FORMAT("***",I4,"***=THE NUMBER OF CASTS NOW ON TAPE7.")
00430 6 FORMAT(9A8,A4,I3,A1)
00440 7 FORMAT(26X,I5,5X,I5,9X,A3,A3,6X,A3,A3,11X,I1)
00450 8 FORMAT(26X,I5,A5,A5,9X,A3,A3,6X,A3,A3,11X,I1)
00452 9 FORMAT(I2)
00453 51 FORMAT(26X,I5,A5,I5,9X,A3,A3,6X,A3,A3,11X,I1)
00455 52 FORMAT(30X,I3)
00460 STOP
00470 END

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PROGRAM CENLIST

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00100 PROGRAM CENLIST(PIERC,TEC,OUTPUT,INPUT,TAPE5=PIERC,TAPE6=TEC,
00102+  TAPE8=OUTPUT,TAPE7=INPUT)
00104C
00105C   MODIFIED FEB. 1978 FOR CI-12 (DEC 76) CRUISE AND ON.  W.S.C.
00106C
00110C THIS PROGRAM CREATES OUTPUT FROM NATIONAL OCEANOGRAPHIC DATA CENTER
00120C INPUT FROM DIRECT ACCESS FILES. INPUT MUST BE NODC FORMATTED
00130C 80 CHARACTER CARD IMAGES. OUTPUT IS A COMPLETE LIST OF THE DATA
00140C IN TECHNICAL REPORT FORMAT. L.P. ATKINSON
00150 REAL NO3,RLAT(2),RLONG(2)
00160 INTEGER PO41,PO42,NO31,NO32,SI1,SI2
00170 REWIND5
00180 DATA C1,C2,C3,C4,D1,D2,D3/-173.4292,249.6339,143.3483,-21.8492
00190+,-.033096,.014259,-.0017/
00200 DATA AS1,AS2,AS3,AS4/1D-09,4886.,1.83E-05,.001/
00210 DATA A31,A32,A33,A34,A35,A36/.97264298,1E-09,4886.,1.83E-05,
00220+.01059094,-228.86167/
00230 DATA A1,A3,A3,A4,A5,A6,A7,A8,A9/1E-04,105.5,9.5,-.158,-1.5E-04,227.,
00240+28.33,-.551,.004/
00250 DATA B1,B2,B3,B4,B5,B6,B7,B8,B9,B10,B11,B12/10.,147.3,2.72,.04,
00260+.0001,32.4,.87,.02,4.5,0.1,1.8,.06/
00270 DATA O/-28.1324/
00280 DATA FS1,FS2,FS3/6.76786136E-06,-4.8249614E-04,8.14876577E-01/
00290 WRITE(8,10)
00300 10 FORMAT("ENTER CRUISE HEADER, 20 SPACES MAX")
00310 READ(7,11)HEAD1,HEAD2
00320 11 FORMAT(A10,A10)
00330 WRITE(8,12)
00340 12 FORMAT("IF YOU WANT SIGMA CALCULATED TYPE YES OR NO")
00350 READ(7,13)SIGCAL
00359 13 FORMAT(A3)
00360 READ(5,79)NCONS
00361 79 FORMAT(T76I4)
00362 BACKSPACE 5 $ IF(NCONS.EQ.1)GO TO 60
00363 WRITE(8,72)
00364 72 FORMAT("ENTER THE LAT. AND LONG. (DEG. & MIN.) OF THE LAST STATION ",
00365+ " IN NODC FORMAT:","/", " _____XXXXXXXX (4X,I2,I3,I3,I3)")
00366 READ(7,73)NLAT,NLATD,NLONG,NLONGD
00367 73 FORMAT(4X,I2,3(I3))
00368 ALAT=NLATD/10. $ ALONG=NLONGD/10.
00369 RLAT(2)=NLAT+ALAT/60. $ RLONG(2)=NLONG+ALONG/60.
00370 60 IPG=IPG+1
00371 IF(ISEC.EQ.0)GO TO 83
00372 IF(IPG.LT.50)GO TO 61
00373 83 IF(IPG.LT.42)GO TO 61
00374 WRITE(6,62)NSTA,NLTR,NIDY,MONTH,NYR,AHR,NCONS $ IPG=0 $ ISEC=ISEC+1
00375 62 FORMAT(/,/,,12X," STA ",I3,A1,1X,I2"/",A4,"/",I2,2X,F4.1," GMT",1X,
00376+ "CONSEC STA",I4," [CONTINUED]",/,,38X,"OBSERVATIONS",/,

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00377+ T14"Z",T19"T",T25"S",T31"D",T36"SVA",T42"02",T48"02'",T53"AOU",
00378+ T59"PO4",T65"N03",T72"SI")
00379 61 READ(5,1)LD
00380 IF(E0F(5))70,71
00390 71 CONTINUE
00400 IF(LD.EQ.4)GO TO 70$IF(LD.EQ.1)GO TO 80$IF(LD.EQ.6)GO TO 60
00410 IF(LD.EQ.3)GO TO 50
00420 80 BACKSPACE 5
00425 IPG=0 $ ISEC=0
00430 READ(5,2)NLAT,NLATD,NLONG,NLONGD,NYR,NMN,NDY,NHR,NCRU,NSTA,NZ
00440+,NWAD,NWHT,NWID,NWFO,NBAR,NAT2,NAT1,NWC,NCT,NCA,NVIS,NLTR,NCONS
00450 ALAT=NLATD/10.$ALONG=NLONGD/10.$AHR=NHR/10.
00600C WIND SPEED IS AS SPEED
00610C BAROMETER CALCULATION
00620 BAR=NBAR/10.
00630 IF(BAR.GE.0)GO TO 700
00640 BAR=BAR+900.$GO TO 701
00650 700 BAR=BAR+1000.
00660 701 CONTINUE
00690C WEATHER CODE IS AS IS
00700C CLOUD TYPE AS IS
00710C VISIBILITY AS IS
00720C MONTH TO ROMAN NUMERAL
00730 GOTO(751,752,753,754,755,756,757,758,759,760,761,762),NMN
00740 751 MONTH=# I#$GO TO 770
00750 752 MONTH=# II#$GO TO 770
00760 753 MONTH=# III#$GO TO 770
00770 754 MONTH=# IV#$GO TO 770
00780 755 MONTH=# V#$GO TO 770
00790 756 MONTH=# VI#$GO TO 770
00800 757 MONTH=# VII#$GO TO 770
00810 758 MONTH=#VIII#$GO TO 770
00820 759 MONTH=# IX#$GO TO 770
00830 760 MONTH=# X#$GO TO 770
00840 761 MONTH=# XI#$GO TO 770
00850 762 MONTH=# XII#$GO TO 770
00860 770 CONTINUE
00870C CLOUD AMOUNT CODE 9
00880 IF(NCA.EQ.9)NCA=1H*
00890C
00900C
00910C *****HEADER PRINTOUTS*****
00920 RLAT(1)=NLAT+ALAT/60.$RLONG(1)=NLONG+ALONG/60.
00930 IF(NCONS.GT.1)GO TO 2000
00940 DIST=0.$GO TO 2001
00950 2000 DELAT=ABS(RLAT(1)-RLAT(2))
00960 DELLON=ABS(RLONG(1)-RLONG(2))
00970 P=DELLON*COS((RLAT(1)+RLAT(2))*0.087265)
00980 DIST=111.2*(P*P+DELLAT*DELLAT)**.5
00990 2001 RLAT(2)=RLAT(1)$RLONG(2)=RLONG(1)
01000 WRITE(6,550)HEAD1,HEAD2,NSTA,NLTR,NDY,MONTH,NYR,AHR,NCONS

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01010 550 FORMAT(///10X,A10,A10,1X," STA ",I3,A1,1X,I2"/",
01020+A4,"/",I2,1X,F4.1," GMT",1X,"CONSEC STA",I4)
01025 INO=INO+1
01030 WRITE(6,551)NLAT,ALAT,NLONG,ALONG,NZ,DIST
01040 551 FORMAT(/10X,"LAT ",I2,1X,F4.1,"N",2X,"LONG ",I2,1X,F4.1,"W",
01050+2X,"DEPTH =",I3,"M",2X,"DIST LAST STA =",F5.1,"KM")
01055 IF(NWFO.EQ.0)WRITE(6,549)NWHGT
01060 IF(NWFO.NE.0)WRITE(6,552)NWFO,NWHGT
01070 552 FORMAT(/,10X,"WEATHER DATA",/,12X,"WIND SPEED      = ",I2,1X,"KTS",16X
01071+"SEA STATE          = ",A2)
01074 549 FORMAT(/,10X,"WEATHER DATA",/,12X,"WIND SPEED      = CALM",
01075+ 18X,"SEA STATE          = ",A2)
01077 IF(NWID.EQ.2H00)WRITE(6,74)
01078 74 FORMAT(12X,"WIND DIRECTION =          ",14X,"WAVE DIRECTION = ")
01081 IF((NWID.EQ.2H99).AND.(NWAD.EQ.2H ))WRITE(6,75)
01082 75 FORMAT(12X,"WIND DIRECTION = VARIABLE",14X,"WAVE DIRECTION = ")
01083 IF((NWID.EQ.2H99).AND.(NWAD.NE.2H ))WRITE(6,76)
01084 76 FORMAT(12X,"WIND DIRECTION = VARIABLE",14X,"WAVE DIRECTION = ",
01085+ A2,"0 DEGR")
01090 IF((NWID.EQ.2H ).AND.(NWAD.EQ.2H ))WRITE(6,1002)
01100 1002 FORMAT(12X,"WIND DIRECTION = ",22X,"WAVE DIRECTION = ")
01110 IF((NWID.NE.2H ).AND.(NWAD.EQ.2H ).AND.(NWID.NE.2H99))WRITE(6,1003)NWID
01120 1003 FORMAT(12X,"WIND DIRECTION = ",A2,"0",19X,"WAVE DIRECTION = ")
01130 IF((NWID.NE.2H ).AND.(NWAD.NE.2H ).AND.(NWID.NE.2H99))WRITE(6,1004)
01135+NWID,NWAD
01140 1004 FORMAT(12X,"WIND DIRECTION = ",A2,"0"," DEGR",13X,
01145+"WAVE DIRECTION = ",A2,"0"," DEGR")
01150 IF((NWID.EQ.2H ).AND.(NWAD.NE.2H ))WRITE(6,1005)NWAD
01160 1005 FORMAT(12X,"WIND DIRECTION = ",22X,"WAVE DIRECTION = ",
01165+A2,"0 DEGR")
01170 553 CONTINUE
01300 WRITE(6,554)NAT2,NAT1,NCT
01310 554 FORMAT(12X,"AIR TEMP          = ",A2,1H.,A1,"C",17X,"CLOUD TYPE      = ",
01320+A1)
01330 WRITE(6,555)NWC,NCA
01340 555 FORMAT(12X,"WEATHER CODE      = ",A2,20X,"CLOUD AMOUNT      = ",A2)
01347C IF THERE IS VISABILITY DATA, PUT "NVIS" AFTER BAR IN LINE 1350
01350 WRITE(6,556)BAR
01360 556 FORMAT(12X,"BAROMETRIC PRESSURE = ",F6.1," MB",8X,
01370+"VISIBILITY CODE = ",A1,"/10")
01380C WRITE OBSERVED HEADER CARD
01390 WRITE(6,3)
01400 3 FORMAT(/,38X,"OBSERVATIONS",/,T14"Z",T19"T",T25"S",T31"D",T36"SVA",
01410+T42"02",T48"02'",T53"AOU",T59"PO4",T65"NO3",T72"SI")
01420 GO TO 60
01430 50 BACKSPACE 5
01440 READ(5,4)NDEPTH,NDEF,NTEMP,NSAL,NSIGMA,NOXY,PO41,PO42,NO31,NO32,SI1,SI2
01450 TEMP=NTEMP/100.$SAL=NSAL/100.$SIGMA=NSIGMA/100.
01460+$TK=TEMP+273.18$OXY=NOXY/100.
01470C***CALCULATE SIGMA T***
01480 IF(SIGCAL.NE.3HYES)GO TO 3000

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```

01490 T=TEMP$SIGF1=((T-3.98)**2)*(T+283.)/((503.57)*(T+67.26))
01500 SIGF2=(T**3)*(1.0843E-6)-(T*T)*(9.8185E-5)+T*4.7867E-3
01510 SIGF3=(T**3)*(1.667E-8)-(T*T)*(8.164E-7)+T*1.803E-5
01520 SIGS=(SAL**3)*(6.767861E-6)-(SAL*SAL)*(4.82496E-4)+SAL*.814877
01530 SIGMA=-SIGF1+(SIGS+.03895414)*(1.-SIGF2+(SIGF3)*(SIGS-2.258458))
01540 3000 CONTINUE
01550C CALCULAT SVA(SPECIFIC VOLUME ANOMALY)
01560 FS=FS1*SAL**3+FS2*SAL**2+FS3*SAL
01570 A=NDEPTH*A1*(A2+A3*TEMP+A4*TEMP**2+A5*NDEPTH*TEMP)-
01580+(A6+A7*TEMP+A8*TEMP**2+A9*TEMP**3)
01590 B=((FS+0)/B1)*(B2-B3*TEMP+B4*TEMP**2-NDEPTH*B5*(B6-B7*TEMP+B8*
01600+TEMP**2))*(-1.)+((FS+0)/B1)**2*(B9-B10*TEMP-(NDEPTH*B5)*
01610+(B11-B12*TEMP))
01620 A350P=A31*(1.-NDEPTH*A32*(A33/(1.+A34*NDEPTH)+A35*NDEPTH+A36))
01630 ASTP=(1.-NDEPTH*AS1*(AS2/(1.+AS3*NDEPTH)+(A+B)))/(1.+SIGMA*AS4)
01640 SVA=ASTP-A350P
01650 SVA=SVA*100000.
01660 NSVA=SVA
01670 OXYSAT=EXP(C1+C2*(100./TK)+C3*ALOG(TK/100.)+C4*TK/100.
01680++SAL*(D1+D2*TK/100.+D3*(TK/100.))**2))
01685 ADU=OXYSAT-OXY
01690 IF(SAL.GT.0.00)GO TO 200
01695 IF(TEMP.EQ.0.0)GO TO 311
01700 IF(OXY.EQ.0.00)GO TO 250
01710 WRITE(6,210)NDEPTH,NDEP,TEMP,OXY,PO41,PO42,NO31,NO32,SI1,SI2
01720 210 FORMAT(10X,I3,1H.,I1,1X,F5.2,19X,F4.2,3X,1H.,5X,1H.,4X,A1,1H.,A2,2X,
01721+ A2,1H.,A1,2X,A2,1H.,A1)
01730 GO TO 60
01731 311 IF(OXY.EQ.0.0)GO TO 313
01732 WRITE(6,312)NDEPTH,NDEP,OXY,PO41,PO42,NO31,NO32,SI1,SI2
01734 312 FORMAT(10X,I3,1H.,I1,25X,F4.2,3X,1H.,5X,1H.,4X,A1,1H.,A2,2X,A2,1H.,A1,
01735+ 2X,A2,1H.,A1)
01736 GO TO 60
01737 313 WRITE(6,314)NDEPTH,NDEP,PO41,PO42,NO31,NO32,SI1,SI2
01738 314 FORMAT(10X,I3,1H.,I1,26X,1H.,5X,1H.,5X,1H.,4X,A1,1H.,A2,2X,A2,1H.,A1,
01739+ 2X,A2,1H.,A1)
01740 GO TO 60
01741 250 WRITE(6,251)NDEPTH,NDEP,TEMP,PO41,PO42,NO31,NO32,SI1,SI2
01750 251 FORMAT(10X,I3,1H.,I1,1X,F5.2,3X,1H.,5X,1H.,5X,1H.,4X,1H.,5X,1H.,5X,
01751+ 1H.,4X,A1,1H.,A2,2(2X,A2,1H.,A1))
01760 GO TO 60
01770 200 IF(OXY.EQ.0.00)GO TO 300
01780 WRITE(6,5)NDEPTH,NDEP,TEMP,SAL,SIGMA,NSVA,OXY,OXYSAT,ADU,PO41,PO42,NO31,
01785+ NO32,SI1,SI2
01790 GOTO 60
01800 300 WRITE(6,6)NDEPTH,NDEP,TEMP,SAL,SIGMA,NSVA,PO41,PO42,NO31,NO32,SI1,SI2
01810 6 FORMAT(10X,I3,1H.,I1,3(1X,F5.2),2X,I3,3X,1H.,5X,1H.,5X,1H.,4X,A1,1H.,
01811+ A2,2X,A2,1H.,A1,2X,A2,1H.,A1)
01820 GO TO 60
01830 1 FORMAT(79X,I1)
01840 2 FORMAT(4X,I2,3I3,3X,3I2,I3,A3,I3,I4,8X,A2,A1,1X,A2,I2,I3,A2,A1,3X,A

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```
01850+2,A1,A1,A1,A1,7X,I4)
01860 4 FORMAT(28X,I3,I1,I4,1X,I4,1X,I4,4X,I3,A1,A2,6X,A2,A1,A2,A1)
01870 5 FORMAT(10X,I3,1H.,I1,3(1X,F5.2),2X,I3,2X,F4.2,2(1X,F5.2),2X,A1,1H.,
01880+ A2,2X,A2,1H.,A1,2X,A2,1H.,A1)
01890 70 WRITE(8,77)INO
01895 77 FORMAT("###",I4,"###=THE NUMBER OF CASTS NOW ON TAPE7.")
01898 STOP
01900 END
```

APPENDIX IV.

HP Programs

The following programs are written for the HP 9825A desktop computer with the following options:

98214A 9862A Plotter - General I/O -
Extended I/O ROM

98210A String-Advanced Programming ROM

98324A Systems Programming ROM

and

24K core

The 9825A internal printer is 16 characters wide. Using a RS-232C interface to a T.I. Silent 700 ASR terminal provides an 80 character printout. Some characters are not the same, such as:

<u>HP</u>	<u>T.I.</u>
→	}
Lower case	Little caps.
↑	^

The programs are stored by file on the internal cassette and are as follows:

<u>File</u>	<u>Name</u>
0	Master File
1	Special Function Keys
2	Taking a Cast
3	List D, C, T
4	Bottom Soak
5	Downcast Average
6	Mid-depth Soak
7	Upcast Average
8	Salinity Plot

The programs are stored on track 1, files 0-8. The preliminary data are stored on track 1 from file 10 on. The final data (filtered and meter averaged) is stored on track 0, file 0 on.

SPECIAL FUNCTIONS				SAL. PRINT	
S	END	END	START	NO	YES
S	CAST	SOAK	mid-D		
			SOAK		
0-380		380-760			
Cast D Scales					

Overlay used for Special Function Keys

MASTER PROGRAM

```

0: PRT " MASTER PROGRAM";PRT "  ♦♦♦♦♦♦♦♦";GTO +2
1: SFG 1
2: PRT "TYPE PROGRAM #  AND PRESS          CONTINUE TO RUN"
3: IF FLG1=1;CFG ;GTO 17
4: PRT "ONE OF THESE:";SPC 1
5: PRT "0 THIS ONE          STOPS THE          MASTER PROGRAM"
6: PRT "1 THIS ONE          ALREADY LOADED  THE SPECIAL  FUNCTION KEYS"
7: PRT "2  TAKING A CAST"
8: PRT "3      LIST D,C,T"
9: PRT "4      BOTTOM SOAK"
10: PRT "5 DOWNCAST AVER."
11: PRT "6 MID-DEPTH SOAK"
12: PRT "7  UPGAST AVER."
13: PRT "8  SALINITY PLOT"
14: PRT "9  TEMP. PLOT"
15: PRT "10 1ST DATA FILE"
16: PRT "  ♦♦♦♦♦♦♦♦";SPC 2
17: ENT "PROGRAM #",P
18: IF P=0;GTO 20
19: TRK 1;LDK 1;LDP P
20: END

```

TAKING A CAST

```

0: DIM A(3,799)
1: TRK 1;LDR 1
2: IF FLG2=1;GTO 24
3: SPC 2;PRT "MONTH DAY TIME"
4: RED 720,W;FXD 0;INT(W/1E8)M;(W/1E8-INT(W/1E8))*1E2D
5: (W/1E6-INT(W/1E6))*1E4H
6: FMT 2,1X,F2.0,4X,F2.0,1X,F4.0
7: WRT 16.2,M,D,H
8: IF Z#0;GTO 16
9: ENT "DEPTH FREQ. OF CTD IN AIR",Z
10: ENT "COND. FREQ. OF CTD IN AIR",E
11: ENT "STATION NUMBER?",P
12: PRT "STATION NUMBER=",P;PRT "D FREQ IN AIR=",Z,"*"
13: PRT "C FREQ IN AIR=",E,"*"
14: PRT "WHEN THE CTD CAST ENDS PRESS SPECIAL FUNCTIONKEY F0."
15: PRT "FOR MID-DEPTH SOAKING,PRESS SPECIAL FUNCTIONKEY F2."
16: PRT "*";SPC 1;DSP "WAIT FOR AXES PLOT."
17: SCL 0,380,5,30
18: AXE 0,5,20,5
19: DSP "PRESS CONTINUE WHEN IT'S ALL RDY";STP
20: ON;100K
21: 10M
22: GSB "READ"
23: FOR I=1 TO 799;O>A(1,I)>A(2,I)>A(3,I);NEXT I
24: GSB "READ"
25: GSB "CON"
26: D>P;O>Q;T>R
27: GSB "READ"
28: GSB "CON"
29: D>S;O>U;T>V>D
30: GSB "READ"
31: GSB "CON"
32: IF FLG1=1;GTO "REC"
33: IF FLG3=1;CFG 2;PEN;TRK 1;LDF 6,0,0
34: D>W;O>X;T>Y
35: V+.35(Y-R)/.810 3V
36: FXD 1;DSP "D=",S,"T=",V,M,K
37: FXD 3;PLT S,V
38: S>A(1,M);U>A(2,M);V>A(3,M)
39: S>P;W>S;U>Q;X>U;O>R;Y>V>D
40: IF M<799;M+1>M;GTO 30
41: DSP "STOP WINCH (STOPPED AT",S,"M)"
42: PEN;TRK 1;RCF K,A[*];K+1>K;GTO 21
43: "CON":
44: (1/D-Z)*.38071>D
45: (1/C-E)*.02065>C
46: (1/T-2127)*.01791-2>T
47: RET
48: "READ":
49: WRT 719,"B1";WRT 718,"PF762T";WAIT 30;RED 718,D

```

```
50: WRT 719,"B2";WRT 718,"PF762T";WAIT 30;RED 718,C
51: WRT 719,"B3";WRT 718,"PF763T";WAIT 30;RED 718,T
52: RET
53: "REC":
54: PEN;TRK 1;RCF K,A[*]
55: IF FLG2=1 OR D<5;GTO 57
56: DSP "NOW DO THE CALIBRATION SOAK.";GTO 60
57: FXD 0;PRT "THE FIRST AND LAST FILES OF THISCAST ARE      10 AND";K
58: PRT "      ♦♦♦♦♦♦♦♦♦♦";SPC 2
59: IF FLG2=1 OR D<5;CFG ;PRT "UPCAST AVER. IS #7";TRK 1;LDF 0,0,1
60: TRK 1;LDF 4,0,0
61: END
```

LIST D,C,T

```
0: DIM A[3,799]
1: DSP "MAKE SURE DATA TAPE IS IN PLACE!";WAIT 1000
2: ENT "STATION NUMBER=";P
3: FXD 0;PRT "STATION NUMBER=";P
4: ENT "WHICH TAPE TRACK?";Q
5: PRT "    D    C    T"
6: ENT "STARTING DATA FILE=";S
7: ENT "LAST DATA FILE=";N
8: FOR L=S TO N
9: TRK Q;LDP L,A[+]
10: FOR J=1 TO 799
11: IF A[2,J]=0;GTO 18
12: IF A[1,J]>99;GTO 15
13: FMT 1,F4.1,F6.2,F6.2
14: WRT 16.1,A[1,J],A[2,J],A[3,J];GTO 17
15: FMT 3,F4.0,F6.2,F6.2
16: WRT 16.3,A[1,J],A[2,J],A[3,J]
17: NEXT J
18: PRT " "
19: NEXT L
20: DSP "D,C,T LISTED, WHAT NEXT?"
21: SFG 2;TRK 1;LDP 0,0,1
22: END
```

BOTTOM SOAK

```

0: PRT "◆◆◆◆SOAKING◆◆◆◆"
1: PRT "MONTH DAY TIME"
2: RED 720,W;INT(W/1E8)X;(W/1E8-INT(W/1E8))◆1E2Y
3: (W/1E6-INT(W/1E6))◆1E4Q
4: FMT 2,1X,F2.0,4X,F2.0,1X,F4.0
5: WRT 16.2,X,Y,Q
6: PRT "   D       T       S"
7: O)P
8: GSB "READ"
9: GSB "READ"
10: GSB "CON"
11: D)F;C)G;T)H
12: I+1)I
13: GSB "READ"
14: IF FLG2=1;GTO 59
15: GSB "CON"
16: O)J
17: IF R3-Q=4;GSB "WARN"
18: IF P>3;O)P;SPC ;GTO 9
19: IF D>F+5 OR D<F-5;P+1)P;GTO 12
20: IF C>G+.05 OR C<G-.05;P+1)P;GTO 12
21: IF T>H+.05 OR T<H-.05;P+1)P;GTO 12
22: GSB "SAL"
23: FXD 1;DSP "D=",D,"T=",T,"S=",S,I,K
24: IF I>=5;O)I;GTO 26
25: GTO 12
26: FMT 3,F3.0,F6.2,F7.3
27: WRT 16.3,D,T,S
28: GTO 11
29: "WARN":
30: PRT "◆";PRT "THE CTD HAS SOAKED FOR 4 MINUTES◆◆TRIP BOTTLE◆◆";PRT "◆"
31: PRT "PRESS SPECIAL   FUNCTION KEY F1 AFTER THE TRIP. ◆"
32: RET
33: "SAL":
34: GTO +3
35: 1)J; .01(1.551-.0453T+5.9E-4T^2+.25(35-S)(.043-.0017T+2.3E-5T^2))B
36: 1+B◆(1.037E-3D-3.2E-8D^2)R4
37: (676547+20131.5T+99.89T^2-.1943T^3-.00672T^4)1E-6)U
38: IF J=1;GTO +2
39: C/42.896U)R1;GTO +2
40: C/(R4◆U+42.896)R1
41: R1(R1-1)(T-15)(96.7-72R1+37.3R1^2-(.63+.21R1^2)(T-15))1E-5)R2
42: R1+R2)R3
43: -.092+28.3R3+12.808R3^2-10.679R3^3+5.986R3^4-1.323R3^5)S
44: IF J=0;GTO 35
45: RET
46: "CON":
47: (1/D-Z)◆.38071)D
48: (1/C-E)◆.02065)C
49: (1/T-2127)◆.01791-2)T

```

```

50: INT(R0/1E8)R1;(R0/1E8-INT(R0/1E8))*1E2R2
51: (R0/1E6-INT(R0/1E6))*1E4R3
52: RET
53: "READ":
54: WRT 719,"B1";WRT 718,"PF7G2T";WAIT 35;RED 718,D
55: WRT 719,"B2";WRT 718,"PF7G2T";WAIT 35;RED 718,C
56: WRT 719,"B3";WRT 718,"PF7G3T";WAIT 35;RED 718,T
57: RED 720,R0
58: RET
59: PRT "      *****";SPC 1;FXD 0
60: PRT "THE FIRST AND LAST FILES OF THISCAST ARE      10 AND ",K;SPC 1
61: TRK 1;LDF 5,0,0
62: END

```


DOWNCAST AVERAGING

```

0: DIM A(3,799)
1: DIM B(3,80)
2: SPC 1;PRT "♦DOWNCAST AVER.♦"
3: ENT "LAST FILE OF PRELIM. DATA SET?";K
4: PRT "YOU TYPED";K
5: ENT "NEXT FILE FOR DATA STORAGE?";U;U>V
6: PRT "YOU TYPED";U
7: 1.53E
8: 13J
9: PRT "   D       C       T"
10: FOR L=10 TO K
11: TRK 1;LDF L,A[+]
12: 03P
13: FOR M=3 TO 799
14: P+13Q
15: IF P=3;03P
16: IF A(1,M)>A(1,M-Q)+5 OR A(1,M)<A(1,M-Q)-5;P+13P;GTO 24
17: IF A(2,M)>A(2,M-Q)+.8 OR A(2,M)<A(2,M-Q)-.8;P+13P;GTO 24
18: IF A(3,M)>A(3,M-Q)+.5 OR A(3,M)<A(3,M-Q)-.5;P+13P;GTO 24
19: IF A(1,M)<E-1;GTO 24
20: IF A(1,M)>=E;GSE "STOR"
21: IF L=K AND A(1,M)=0 AND A(3,M)=0;GSE "STOR"
22: F+A(1,M)>F;G+A(2,M)>G;H+A(3,M)>H
23: I+13I;03P
24: NEXT M
25: SPC 1;NEXT L
26: REW;TRK 0;RCF U,B[+]
27: FXD 0;PRT "THE FIRST AND   LAST FILES OF   SAVED DATA ARE";V," AND";U
28: DSP "NOW DO THE UPCAST";WAIT 1000
29: SPC 2;PRT "FOR SOAKING WHILE A BOTTLE TRIPS PRESS S.F.K. F2."
30: TRK 1;LDF 2,0,0
31: "STOR":
32: IF F=0;GTO 45
33: F/I3F;G/I3G;H/I3H
34: IF F<99.5;GTO +4
35: FMT 5,F3.0,F7.2,F6.2
36: WRT 16.5,F,G,H
37: GTO +3
38: FMT 1,F4.1,F6.2,F6.2
39: WRT 16.1,F,G,H
40: F>B(1,J);G>B(2,J);H>B(3,J)
41: IF J=80;GSE "REC"
42: J+13J
43: INT(F+.5)+1.53E
44: GTO 46
45: E+13E
46: 03F>6>H>I
47: RET
48: "REC":
49: TRK 0;RCF U,B[+]
50: FOR N=1 TO 80;03B(1,N)>B(2,N)>B(3,N);NEXT N
51: 03J;U+13U
52: RET
53: END

```

MID-DEPTH SOAK

```

0: SPC 1;PRT "♦♦♦♦SOAKING♦♦♦♦"
1: PRT "WHEN THE UPGAST IS TO BE RESUMEDPRESS SPECIAL FUNCTION KEY F1.♦"
2: PRT " D T S"
3: 00P
4: GSB "READ"
5: GSB "READ"
6: GSB "CON"
7: D>F;C>G;T>H
8: I+1>I
9: GSB "READ"
10: IF FLG2=1;GTO 47
11: GSB "CON"
12: 00J
13: IF P>3;00P;SPC ;GTO 5
14: IF D>F+5 OR D<F-5;P+1>P;GTO 8
15: IF C>G+.05 OR C<G-.05;P+1>P;GTO 8
16: IF T>H+.05 OR T<H-.05;P+1>P;GTO 8
17: GSB "SAL"
18: FXD 1;DSP "D=",D,"T=",T,"S=",S,I,K
19: IF I>=5;00I;GTO +2
20: GTO 8
21: FMT 3,F3.0,F6.2,F7.3
22: WRT 16.3,D,T,S
23: GTO 7
24: "SAL":
25: GTO +3
26: 1>J;(.01(1.551-.0453T+5.9E-4T^2+.25(35-S)(.043-.0017T+2.3E-5T^2)))>B
27: 1+B*(1.037E-3D-3.2E-8D^2)>R4
28: (676547+20131.5T+99.89T^2-.1943T^3-.00672T^4)1E-6>U
29: IF J=1;GTO +2
30: C/42.896U>R1;GTO +2
31: C/(R4+U+42.896)>R1
32: R1(R1-1)(T-15)(96.7-72R1+37.3R1^2-(.63+.21R1^2)(T-15))1E-5>R2
33: R1+R2>R3
34: -.092+28.3R3+12.808R3^2-10.679R3^3+5.986R3^4-1.323R3^5>S
35: IF J=0;GTO 26
36: RET
37: "CON":
38: (1/D-2)*.38071>D
39: (1/C-E)*.02065>C
40: (1/T-2127)*.01791-2>T
41: RET
42: "READ":
43: WRT 719,"B1";WRT 718,"PF762T";WAIT 30;RED 718,D
44: WRT 719,"B2";WRT 718,"PF762T";WAIT 30;RED 718,C
45: WRT 719,"B3";WRT 718,"PF763T";WAIT 30;RED 718,T
46: RET
47: PRT " ♦♦♦♦♦♦♦♦♦♦";SPC 1
48: CFG 1,3;TRK 1;LDF 2,0,1
49: END

```

UPCAST AVERAGING

```

0: DIM A(3,799)
1: DIM B(3,80)
2: SPC 1;PRT "◆◆UPCAST AVER.◆◆"
3: ENT "LAST FILE OF PRELIM. DATA SET?";K
4: PRT "YOU TYPED";K
5: ENT "NEXT FILE FOR DATA STORAGE?";U;U>V
6: PRT "YOU TYPED";U
7: 500E
8: 1J
9: PRT "    D    C    T"
10: FOR L=10 TO K
11: TRK 1;LDF L,A[+]
12: 0P
13: FOR M=3 TO 799
14: P+1J
15: IF P=3;0P
16: IF A(1,M)>A(1,M-1)+5 OR A(1,M)<A(1,M-1)-5;P+1J;GTO 24
17: IF A(2,M)>A(2,M-1)+.8 OR A(2,M)<A(2,M-1)-.8;P+1J;GTO 24
18: IF A(3,M)>A(3,M-1)+.5 OR A(3,M)<A(3,M-1)-.5;P+1J;GTO 24
19: IF A(1,M)>E+1;GTO 24
20: IF A(1,M)<=E;GSE "STOR"
21: IF L=K AND A(1,M)=0 AND A(3,M)=0;GSE "STOR"
22: F+A(1,M)>F;G+A(2,M)>G;H+A(3,M)>H
23: I+1J;0P
24: NEXT M
25: SPC 1;NEXT L
26: REN;TRK 0;RCF U,B[+]
27: DSP "NEXT..PLOT SALINITY; UP OR DOWN."
28: FXD 0;PRT "THE FIRST AND LAST FILES OF SAVED DATA ARE";V;"AND";U
29: PRT "    ◆◆◆◆◆◆◆◆◆◆";SPC 2
30: PRT "SAL. PLOT IS    *8"
31: TRK 1;LDF 0,0,1
32: "STOR":
33: IF F=0;GTO 45
34: F/I>F;G/I>G;H/I>H
35: IF F<99.5;GTO +4
36: FMT 5,F3.0,F7.2,F6.2
37: WRT 16.5,F,G,H
38: GTO +3
39: FMT 1,F4.1,F6.2,F6.2
40: WRT 16.1,F,G,H
41: F>B(1,J);G>B(2,J);H>B(3,J)
42: IF J=80;GSE "REC"
43: J+1J
44: INT(F+.5)-1.5E
45: 0F>G>H>I
46: RET
47: "REC":
48: REN;TRK 0;RCF U,B[+]
49: FOR N=1 TO 80;0B(1,N)>B(2,N)>B(3,N);NEXT N
50: 0J;U+1J
51: RET
52: END

```

SALINITY PLOT

```

0: DIM K(3,80);SCL 0,380,32,37
1: DSP "DO YOU WANT THE PRINTOUT?";STP
2: SFG 4
3: ENT "FIRST FILE?";A
4: ENT "LAST FILE?";Z
5: FOR L=A TO Z
6: TRK 0;LDF L,K[*]
7: IF FLG4=1;GTO +2
8: FXD 0;SPC 1;PRT "◆◆◆FILE◆◆◆ ",L;PRT " D T S";FXD 2
9: FOR I=1 TO 80
10: 0)J
11: K(1,I)D;K(2,I)C;K(3,I)T
12: IF D=0 AND C=0;GTO 35
13: GTO +3
14: 1)J;.01(1.551-.0453T+5.9E-4T^2+.25(35-S)(.043-.0017T+2.3E-5T^2))B
15: 1+B*(1.037E-3D-3.2E-8D^2)R4
16: (676547+20131.5T+99.89T^2-.1943T^3-.00672T^4)1E-6)Z
17: IF J=1;GTO +2
18: C/42.896Z)R1;GTO +2
19: C/(R4+Z+42.896)R1
20: R1(R1-1)(T-15)(96.7-72R1+37.3R1^2-(.63+.21R1^2)(T-15))1E-5)R2
21: R1+R2)R3
22: -.092+28.3R3+12.808R3^2-10.679R3^3+5.986R3^4-1.323R3^5)S
23: IF J=0;GTO 14
24: IF D>99;GTO 30
25: FMT 1,F4.1,F6.2,F6.2
26: IF FLG4=1;GTO +2
27: WRT 16.1,D,T,S
28: FLT D,S
29: GTO 34
30: FMT 2,F4.0,F6.2,F6.2
31: IF FLG4=1;GTO +2
32: WRT 16.2,D,T,S
33: FLT D,S
34: NEXT I
35: NEXT L
36: PRT " ◆◆◆◆◆◆◆◆◆◆";SPC 1;PRT "PREP. FOR NEXT STATION";SPC
37: PEN;CPS 4;TRK 1;LDF 0,0,1
38: END

```

APPENDIX V.

Sample HP-CTD Cast Printout

The following is a sample listing of an HP-CTD cast. The various sections of the printout are as follows:

1. The Master Program (TRK1, FILE 0) provides access to the other programs. It also loads the special function keys.

2. Program 2 reads the clock and prints the month, day, and hour. It then asks for the station number followed by depth and conductivity zero frequencies.

*During the cast, both depth and temperature are displayed on the LED display. Special function key f0 ends the cast and puts the 9825A into a soak routine. The 9825A times the soak and after 4 minutes prints the time and continues. During the soak, 5 consecutive temperature values are averaged and printed unless one of the values varies by more than 0.05°C from others, in which case a space is printed. This visually displays the quality of the soak for calibration purposes.

*After the soak, program 4 prints the first and last preliminary data files, in this case files 10 and 13.

3. Program 4 loads and runs program 5 which prints the downcast one meter averaged data and asks where to store that data (files 8 and 9 in this case).

4. The upcast is similar to the downcast with final data stored on files 10 and 11.

5. Program 8 simultaneously prints and plots salinity values for the up and down cast if requested.

MASTER PROGRAM

Type program #
and press
CONTINUE to run
one of these:

- 0 this one
stops the
Master Program
1 this one
already loaded
the special
function keys
2 Taking a Cast
3 List D,C,T
4 Bottom Soak
5 Downcast Aver.
6 Mid-Depth Soak
7 Upcast Aver.
8 Salinity Plot
10 1st data file

Month Day Time
4 23 1046
Station number=
118
D freq in air=
9712
*
C freq in air=
5005
*

When the CTD
cast ends press
Special Function
Key f0.
*

For Mid-Depth
soaking, press
Special Function
Key f2.
*

****SOAKING****

Month Day Time
4 23 1107
D T S
145 13.40 35.600
145 13.42 35.601
145 13.46 35.610
144 13.50 35.602

142 13.64 35.627
142 13.64 35.619

144 13.50 35.629

146 13.26 35.627

The first and la
st files of this
cast are 10
and 13

DOWNCAST AVER.
you typed 13
you typed 8
D C T
2.7 55.38 25.81
3.8 55.37 25.82
5.0 55.36 25.82
:
:

147 41.87 13.19

148 41.77 13.10
149 41.65 13.06

The first and
last files of
saved data are 8
and 9

For soaking whil
e a bottle trips
press S.F.K. f2.

Month Day Time
4 23 1111
Station number=
118
D freq in air=
9712
*

C freq in air=
5005
*

When the CTD
cast ends press
Special Function
Key f0.
*

For Mid-Depth
soaking, press
Special Function
Key f2.
*

****SOAKING****

When the upcast
is to be resumed
press Special
Function Key f1.
*

3 25.00 36.092
4 25.80 36.097
4 25.80 36.086

4 25.80 36.132

4 25.80 36.093

4 25.80 36.085
3 25.80 36.084

The first and la
st files of this
cast are 10
and 12

Upcast Aver. is
#7
Type program #
and press
CONTINUE to run

UPCAST AVER.
you typed 12
you typed 10
D C T
157 40.85 12.34
156 40.86 12.36
155 40.98 12.48
:
:

3.3 44.38 25.80
1.8 55.39 25.80
1.1 55.32 25.80

The first and
last files of
saved data are
10
and 11

Sal. Plot is
#8

Type program #
and press
CONTINUE to run

File 8
D T S
2.7 25.81 36.09
3.8 25.82 36.07
5.0 25.82 36.07
:
:

80.9 19.53 36.24
81.9 19.41 36.23

File 9
D T S
82.9 19.30 36.21
:
:

147 13.19 35.64
148 13.10 35.63
149 13.06 35.56

prep. for
NEXT STATION

Type program #
and press
CONTINUE to run

APPENDIX VI.

Data Logging Forms

Country = 31

Ship = CI

C = CTD

X = XBT

CRUISE: _____

Page of

XBT - CTD BRIDGE LOG

[illegible]

SALINITY LOG SHEET

Cruise	Operators Name	Analysis Date	STANDARD Sea water Stock # and Year

[illegible]

CTD-SALINITY ERROR ANALYSIS

82

SENSOR (Accuracy)	Maximum ‰ Error	
	Shallow	Deep
Conductivity ($\pm .03$ mmho/cm)		
Temperature ($\pm .02^{\circ}\text{C}$)		
Depth (± 1.5 m)		
‰ Equation: _____		
Total		

DIGITIZING (RESOLUTION)	Maximum ‰ Error	
	Shallow	Deep
Conductivity ($\pm .01$ mmho/cm)		
Temperature ($\pm .005^{\circ}\text{C}$)		
Depth ($\pm .10$ m)		
Total		

(Values used for error analysis)	
SHALLOW	DEEP
Cond. _____	Cond. _____
Temp. _____	Temp. _____
Depth _____	Depth _____

SPECIF	

MAGNETIC TAPE LOG

84

A map of the Georgia Bight coastline, showing the intricate network of rivers and bays. The map is oriented with the coastline on the left and the open ocean on the right. The coastline is depicted with a thick black line, and the interior of the bays and rivers is filled with a light gray color. The map is framed by a double-line border. Latitude and longitude coordinates are marked along the border: 32 and 31 on the left and right sides, and 81 on the top and bottom sides.

Technical Report Series
Number 78-5

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IN THE GEORGIA BIGHT
(APRIL 1977)

by
P. G. O'Malley
L. P. Atkinson
J. J. Singer
W. S. Chandler
and
T. N. Lee

Georgia Marine Science Center
University System of Georgia
Skidaway Island, Georgia

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Savannah, Georgia 31406

July 1978

The Technical Report Series of the Georgia Marine Science Center is issued by the Georgia Sea Grant Program and the Marine Extension Service of the University of Georgia on Skidaway Island (P. O. Box 13687, Savannah, Georgia 31406). It was established to provide dissemination of technical information and progress reports resulting from marine studies and investigations mainly by staff and faculty of the University System of Georgia. In addition, it is intended for the presentation of techniques and methods, reduced data and general information of interest to industry, local, regional, and state governments and the public. Information contained in these reports is in the public domain. If this prepublication copy is cited, it should be cited as an unpublished manuscript.

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ACKNOWLEDGEMENTS

The authors thank Alex Brincko, Rich Findley, Dave Gregory, O. C. Guest and Dave Leach for their participation in the study. We also thank the Captains, mates, crew and students of the S/S ADVANCE II and the R/V BLUE FIN. Dan McIntosh provided graphics assistance and Cindy Miller typed the text.

Funding for this research and report preparation is provided by the Department of Energy, under Contract EY-S-76-09-0889.

This report is published as a part of the Georgia Marine Science Center's Technical Report series issued by the Georgia Sea Grant Program under NOAA Office of Sea Grant # 04-7-158-44126.

ABSTRACT

During two cruises in the Georgia Bight in April 1977, nine hydrographic and three XBT transects were conducted. Temperature, salinity, dissolved oxygen, and nutrient (NO_3 , PO_4 , and SiO_2) data were collected.

Generally, the continental shelf water was well mixed vertically and characterized by low nutrient concentrations and oxygen saturation. However, bottom and interlayering intrusions of Gulf Stream water onto the shelf were observed. Satellite thermal images revealed a Gulf Stream spin-off eddy which was subsequently mapped and intensively sampled. Strong upwelling of dense, cold, nutrient-rich, and oxygen depleted water was associated with the eddy event. It is likely that the regular occurrence of spin-off eddies provides a mechanism for significant nutrient enrichment of the continental shelf.

INTRODUCTION

This report contains chemical and physical data obtained during Georgia Bight cruises AD-4-77 and BF-29-77 aboard the S/S ADVANCE II and the R/V BLUE FIN from 8 to 20 April 1977. The investigation was part of a larger multi-institutional DOE program to describe and explain the physical, chemical, and biological processes of the South Atlantic Bight, the continental shelf region from Cape Hatteras to Cape Canaveral. The study reported here was concentrated in the Georgia Bight from Savannah, Georgia, south to Ormond Beach, Florida (Fig. 1).

Our object was to collect temperature and chemical data to correlate with other data from box arrays of current/temperature/pressure recording instruments (deployed by the University of Miami) concurrently operative in the study area (Fig. 1). Additionally, our temperature and conductivity data are used to calibrate the moored instruments. No attempt is made here to correlate the hydrographic/chemical observations with the current meter data. The latter will appear in a separate report edited by Dr. T. Lee of the University of Miami.

The processed hydrographic data set is available from the National Oceanographic Data Center (NODC).

METHODS

Nine onshore-offshore hydrographic transects and two XBT transects were conducted during the ADVANCE II cruise (Fig. 2). The first four transects were selected to provide chemical and physical data during recovery, servicing, and deployment of the current/temperature/pressure instruments of the box array off Savannah and St. Simons, Georgia. Later, we proceeded south to locate what appeared, in satellite thermal images, to be a Gulf Stream spin-off eddy (Lee, 1975).

Figure 1. The Georgia Bight. Current/Temperature/Pressure moorings are designated A through G.

Figure 2. The study area showing station locations for cruises AD-4-77 (numbered stations) and BF-29-77 (lettered stations).

Four hydrographic sections and one XBT transect were made adjacent to and through this event. The final two sections were made off St. Simons and Savannah to provide additional data in the area of the array. Throughout the ADVANCE II cruise, surface temperature/salinity distribution was mapped by means of a thermosalinograph. The BLUE FIN cruise on 19-20 April consisted of one onshore/offshore XBT section off Savannah (Fig. 2).

A typical hydrographic section consisted of alternate CTD (conductivity/temperature/depth) Rosette casts and XBT (expendable bathythermograph) firings at approximately 10 kilometer intervals. On occasion, specifically during investigation of the eddy event, sampling intensity was increased. Two sections, Jacksonville (North), 15 April 1977, and St. Simons, 16 April 1977, consisted exclusively of XBT stations at approximately 10 kilometer intervals. The average time required to complete a hydrographic section, excluding the first Savannah section which took 15 hours, was approximately 6 hours. The average time of an XBT section was 2 hours.

At CTD stations, a General Oceanics Model 1015 Mark 5 Rosette multi-bottle array was mated to the Plessey 9400 CTD sensor unit and equipped with 1.7 liter Niskin bottles for water sampling. Niskin sampling depths were determined from the temperature structure obtained from the CTD. Samples were taken near the surface, just above or below the thermocline, at the bottom, and occasionally at other depths. Samples were analyzed for salinity, nitrate, phosphate, silicate, and dissolved oxygen contents.

Chemical and Physical Procedures

Salinity samples were analyzed conductometrically using a Plessey Model 6230N portable laboratory salinometer. Values obtained were used

to calibrate the Plessey Model 9400 CTD system. A separate section of this report details the CTD calibration procedure. Temperature was determined with deep sea reversing thermometers, XBT's, and the CTD system.

Dissolved oxygen analyses were performed onboard the research vessel within 24 hours of collection using a modified Winkler procedure (Strickland and Parsons, 1965).

Nutrient samples were immediately frozen in polyethylene bottles and stored in the dark until thawed and analyzed ashore. Colorimetric determinations of nutrient concentrations were made utilizing a Bausch and Lomb Spectronic 88 spectrophotometer with a sample sipper. Silicate was determined by the method of Mullin and Riley (1955) as modified by Strickland and Parsons (1965), phosphate by the method of Murphy and Riley (1962), and nitrate by the cadmium column reduction technique as modified by Gardner et al. (1976)

XBT Data Acquisition and Processing

A Sippican Model LM3A handheld launcher equipped with type T10 probes (200 m), coupled to a Sippican Model MK2A-1 recorder, was used for XBT casts. The temperature/depth plots were digitized on a Hewlett-Packard Model 9864A digitizer interfaced to a Hewlett-Packard Model 9825A calculator. The digitized data was placed in NODC format and merged on magnetic tape with processed CTD data. Depths at which temperature was a whole or half degree are reported as are depths at which a significant mixed layer began or ended.

CTD Data Acquisition

The CTD unit consisted of a Plessey Model 9400 CTD sensor system with a Model 8400 digital data logger and Kennedy Model 1600 incremental

magnetic tape recorder for data acquisition and storage. A redundant 'XYZ' plot was made of all casts using a Hewlett-Packard Model 7046 X-Y recorder which was calibrated with a precision 10VDC source.

With the exception of two stations (53S and 54S), digitized data was collected as the CTD sensor unit was lowered at 15m/min on single conductor cable. All three parameters (C, T, and D) were sampled once each 229 milliseconds or every 6 cm at the 15m/min lowering rate. For primary calibration of temperature and salinity, a Niskin bottle equipped with paired protected deep sea reversing thermometers was tripped after a four minute equilibration period at the maximum sample depth. Other water samples were collected during ascent at depths selected after examination of the downcast temperature structure. The average time for stations less than 100 meters in depth was 16 minutes; for those greater than 100 meters, average time was 44 minutes, with a maximum of 60 minutes at station 65.

The acquisition of CTD data during the downcast and water samples during the upcast creates some problems:

- 1) CTD data is of higher quality during the down than up cast since the sensors are located at the bottom of the sub-surface unit to maximize response during the downward motion. During upward motion, the CTD sensors lie in the wake of the Rosette.

- 2) Water samples are taken during the upcast since surface water samples taken during the downcast may be diluted by deeper waters.

- 3) Although horizontal advection may alter the coherence of downcast CTD data versus upcast water sample data, the minor advective motions during the time of a station cause negligible mismatch of nutrient data

since horizontal gradients in nutrients are typically quite low.

Upcast CTD data is reported for stations 53S and 54S since those collected on the downcast were not recorded on magnetic tape.

CTD Data Processing

CTD plots were logged and stored with their respective station sheets. All data recorded on magnetic tape were extracted and processed according to the flow scheme (Scarlet, 1975) shown in Table 1. Computation and data manipulation were performed on a CDC Cyber 70 computer.

MAGREAD converts binary coded data to frequencies and CTDUNIT converts frequencies to engineering units. LAGFILT treats the data for the temperature lag of the temperature sensor and coarse filters the data for noise. Next, SIGSALP calculates uncorrected sigma-t and salinity values. At this stage, salinity and temperature offset corrections are made from the primary calibration data. Flow is then resumed by repeating SIGSALP with the added correction factors. DLATCH deletes lines with decreasing or repeated depths caused by ship roll and CTDAVE presents the data in average one meter increments. NODCFO converts the data to NODC format and NODMER merges additional data (i.e., nutrients, weather, latitude, longitude, etc.) for submission to NODC. CEMLIST calculates specific volume anomalies, oxygen saturation and apparent oxygen utilization (from the International Oceanographic Tables, 1973), the distance between successive stations, reads all other data and formats the data for presentation in a technical report. The final product is stored on magnetic tape in our computer system and all data (i.e., CTD, XBT, chemical, etc.) are available through NODC.

At the stations and to the depths listed in Table 2, a Hewlett-Packard Model 9825A calculator was used to record data on cassette tape because of a

Table 1. CTD/Data Flow. Shipboard acquisition to NODC submission.

Data Source/Disposition	Program	Data File
Tape from Data Logger	MAGREAD (Converts binary coded data to decimal)	
		BIRANG
	CTDUNIT (Converts decimal units to engineering units)	
		LAG
	LAGFILT (Course filter and temperature lag)	
		CAL
	SIGSALP (Calculates sigma-t and salinity)	
		LATCH
	DLATCH (Removes decreasing and repeated depths)	
		CTDATA
Primary calibration from bottle casts	CTDAVE (One meter average data)	
		AVE
	NODCFO (Converts to NODC format)	
		NODC + HEAD
	NODMER (Merges NODC data with Headers and chemical data)	
		NODCFNL
	CEMLIST (Calculates specific volume anomaly, oxygen utilization, etc.)	
		TECHNICAL REPORT
Submission to NODC		

Table 2. Stations at which Hewlett-Packard 9825A was used as the primary data acquisition system.

Stations Number	Depth Range (m)
65S	3-21
113S	4-29
182S	3-18
199S	3-36
220S	4-16
259S	3-84
261S	3-37

malfunction in the primary collection system. At the time, software for the HP system was being developed. These data were treated essentially in the same manner as described above. The correction for temperature sensor lag is not applied, however, since most of the data are from mixed layers where the lag effect is considered minimal.

The Hewlett-Packard system yielded a discrete data point at approximately 0.5 meter depth increments. This relatively infrequent sampling, compared to the primary acquisition system, resulted in considerable scatter ($\pm 0.09^{\circ}/\text{oo}$) in the salinity generated from the three parameters collected. Therefore, binomial smoothing was performed on salinity data after interpolation for values at whole meter increments.¹

CTD Calibration

The data derived from the CTD sensor system are critical to the correct interpretation of the oceanographic processes. To insure data of the highest possible quality, an extensive calibration was performed.

The CTD system was calibrated only against bottle casts in mixed layers to insure that the sensors and the bottles were sampling the same water. However, since a mixed layer was not always observed, comparisons could not be made at every station. Consequently, the resulting mean offset, $-0.010^{\circ}/\text{oo}$ (Figure 3), for the mixed layer salinity data was originally used for the entire data set. On later cruises, it became apparent that the head of the conductivity sensor was effected by increased pressure at depth. To further refine the data,

¹The expression used, as adapted from Broenkow et al. (1977), is:

$$S_F = (S_{D-2m} + 4S_{D-1m} + 6S_D + 4S_{D+1m} + S_{D+2m})/16$$

where S_F is the salinity reported at depth D and S_D is the unsmoothed salinity at depth D.

Figure 3. Salinity offset for cruise AD-4-77 (—— mean offset; ----- standard deviation).

a regression analysis was performed (Figure 4) and an expression ($S + S_0 + 0.007 - 4.97 \times 10^{-4}D$, where S is corrected salinity, S_0 is calculated salinity without calibration offset, and D is depth of sample) was obtained. This expression was applied to generate corrected salinities at all CTD stations at which the maximum sampling depth was greater than 50 meters. At other CTD stations, the original offset was preserved. The calibration data used to generate both the original offset and the subsequent expression for the depth effect are listed in Table 3. Station numbers are discontinuous since thermosalinograph stations were established at intervals between hydrographic sections.

A depth offset of -1.714 meters was applied to the entire data set as the depth sensor consistently recorded a depth of 1.714 meters at the surface. No temperature offset was necessary since the CTD temperature sensor agreed with the protected reversing thermometers within the range of accuracy ($\pm 0.02^\circ\text{C}$).

CTD Error Analysis

The Plessey Model 9400 CTD system has the following rated accuracy, resolution, and time constants (Table 4).

Table 4. Specifications for Plessey Model 9400 CTD system.

	Conductivity	Temperature	Depth
Accuracy	± 0.03 mmho/cm	$\pm 0.02^\circ\text{C}$	± 1.5 m
Resolution	0.0001 mmho/cm	0.0001 $^\circ\text{C}$	0.0012 m
Time Constant	0.1 sec	0.35 sec	0.1 sec

Figure 4. Regression analysis of salinity offset versus depth of sensor, cruise AD-4-77.

Table 3. Cruise AD-4-77 Salinity Calibration Data.

Consecutive Cast No.	Station No.	Depth (m)	Bottle ‰	CTD ‰	Difference Bottle-CTD(‰)
2	2S	14	32.897	32.899	-0.002
3	3S	18	34.005	34.008	-0.003
5	6S	27	35.154	35.158	-0.004
9	14S	192	35.930	36.020	-0.090
12	24S	34	35.297	35.322	-0.025
13	26S	38	36.006	36.027	-0.021
14	28S	39	36.251	36.252	-0.001
20	39S	38	35.549	35.552	-0.003
21	41S	28	34.973	34.974	-0.001
23	53S	13	32.902	32.908	-0.006
24	54S	17	33.955	33.971	-0.016
25	55S	22	34.679	34.695	-0.016
26	57S	29	35.042	35.044	-0.002
27	59S	38	35.509	35.518	-0.009
28	61S	43	35.528	35.530	-0.002
29	63S	69	35.807	35.826	-0.019
31	100S	15	35.263	35.254	+0.009
32	101S	23	35.623	35.624	-0.001
33	103S	26	35.724	35.725	-0.001
34	105S	32	35.927	35.949	-0.022
	105S	14	35.934	35.951	-0.017
36	109S	42	36.196	36.210	-0.014
37	111S	93	35.937	36.000	-0.063
39	174S	27	35.784	35.772	+0.012
40	176S	36	36.081	36.102	-0.021
41	177S	43	36.019	36.043	-0.024
	177S	33	36.022	36.038	-0.016
42	178S	63	35.587	35.616	-0.029
45	192S	22	35.958	35.974	-0.016
48	213S	38	36.151	36.150	+0.001
50	215S	42	36.140	36.149	-0.009
53	220S	95	35.439	35.478	-0.039
55	261S	73	35.980	36.005	-0.025
56	263S	43	36.100	36.097	+0.003
57	265S	38	35.736	35.731	+0.005

From the above parameters, and using the equation of Bennett (1976), the in situ conductivity, $C(S,t,p)$, was reduced to salinity.

- 1) The conductivity ratio is expressed as:

$$R(S,t,p) = C(S,t,p)/C(35^{\circ}/\text{oo}, 15^{\circ}\text{C}, 0)$$

where $C(S,t,p)$ is the in situ conductivity

and $C(35^{\circ}/\text{oo}, 15^{\circ}\text{C}, 0) = 42.906 \text{ mmho/cm}$.

- 2) A correction is made for the effect of pressure

$$R(S,t) = R(S,t,p)/(1 + F)$$

$$\text{where } F = \frac{1.60836 \times 10^{-5} p - 5.4845 \times 10^{-10} p^2 + 6.166 \times 10^{-15} p^3}{1 + 3.0786 \times 10^{-2} t + 3.169 \times 10^{-4} t^2}$$

F is the fractional increase in conductivity at pressure p dbar and temperature $t^{\circ}\text{C}$.

- 3) A correction is made for the effect of temperature

$$R(S) = R(S,t)/r_t$$

$$\begin{aligned} \text{where } r_t = & 0.676518 + 0.200402 \times 10^{-1} t \\ & + 0.122700 \times 10^{-3} t^2 - 0.218091 \times 10^{-5} t^3 \\ & + 0.663405 \times 10^{-7} t^4 - 0.95646 \times 10^{-9} t^5 \end{aligned}$$

- 4) The corrected conductivity ratio is converted to salinity

$$\begin{aligned} S = & -0.08996 + 28.8567R + 12.18882R^2 \\ & - 10.61869R^3 + 5.98624R^4 - 1.32311R^5 \\ & + R(R-1) \{0.442 \times 10^{-1} t - 0.46 \times 10^{-3} t^2 \\ & - 4 \times 10^{-3} R t + (1.25 \times 10^{-4} - 2.9 \times 10^{-6} t)p\} \end{aligned}$$

Bennett estimates the overall accuracy of this equation as $0.0042^{\circ}/\text{oo}$ r.m.s. Additional sources of error (summarized in Table 5) are attributed to the reported accuracy of the conductivity, temperature, and depth sensors. These values were obtained by varying observed extremes in C , T , and D data by the rated sensor accuracies.

Table 5: Sources of salinity error due to the reported accuracy of the sensors and the salinity equation.

Parameter	Maximum Error
Conductivity	± 0.032
Temperature	± 0.020
Depth	± 0.001
Equation	± 0.004
Total	± 0.057

The standard deviation of all mixed layer samples taken for salinity calibration purposes implies an accuracy, after offset, of ± 0.012 ‰. We believe this value is, except in strong thermoclines ($\Delta T > 1^\circ\text{C/m}$), a more realistic measure of the quality of the data set, particularly in mixed layers, than the composite maximum error of the sensor package reported above.

METEOROLOGICAL CONDITIONS

Wind data from Jacksonville, Florida, are presented in Figure 5. These data are derived from the monthly summary for April 1977 (U.S. Department of Commerce, April 1977) and are plotted in GMT at three hour intervals.

Winds in the first part of the month were generally southwesterly. April 6-9 was characterized by winds gradually changing from southwesterly to easterly. The easterly wind continued from April 10-18 when it changed to southeasterly and remained as such until April 21. Winds were strongest on April 4-5, averaging 6.2 m/sec.

The average daily air temperature of the study period ranged from 14.4°C to 21.1°C . There was no precipitation during the study.

Figure 5. Wind data, Jacksonville, Florida, 1-20 April, 1977 at three hour intervals (U.S. Dept. of Comm. April, 1977).

Meteorological data were also collected by the ship's personnel at each station. These additional data are presented with the data sheets.

The Jacksonville, Florida, weather station is located at International Airport, which is approximately 27 kilometers inshore. Consequently, the meteorological data presented in Figure 5 may not be indicative of the actual conditions at a particular hydrographic station.

RESULTS AND DISCUSSION

In the following figures, vertical temperature plots are derived from CTD and XBT data, salinity plots from CTD data, sigma-t from temperature and salinity and nutrients (NO_3 , PO_4 , and SiO_2), and dissolved oxygen from water samples collected at selected depths indicated by dots on the respective plots. Horizontal surface temperature plots are derived from continuous thermosalinograph mapping conducted during the ADVANCE II cruise.

On all vertical plots, except those for cruise BF-29-77, the "S" or "X" following the station number indicates a CTD or XBT station, respectively. The plots are arranged chronologically by section.

The Vertical Distribution of Physical and Chemical Properties

Savannah Section, 8-9 April 1977. (Figures 6-7) The temperature, salinity, and density structures seen in Figure 6 are indicative of typical continental shelf conditions expected in the Georgia Bight in April. Nearshore is cold, low salinity, low density water resulting from high spring runoff. Further offshore is warmer, more saline and denser continental shelf water. At the shelf break, the sharp horizontal thermal gradient indicates the thermal wall of the Gulf Stream with its characteristically higher salinity surface water (≥ 35.00 ‰). The 20.0°C isotherm and 36.00 ‰ isohaline at 35 meters showed an interlayering intrusion of the Gulf Stream onto the continental shelf as described by

Atkinson (1977), i.e., the shelf water was stratified with low salinity water lying on top of more saline, denser water, and intermediate density Gulf Stream water intruded between the two.

Phosphate and silicate plots of the same section (Figure 7) show elevated concentrations in both the nearshore runoff water and the deep, cold Gulf Stream water. These nutrients were fairly depleted in the shelf water. Nitrate was essentially depleted from shore out to the shelf break. As with the other nutrients, the Gulf Stream water below the euphotic zone had higher concentrations of nitrate.

St. Simons Section, 10 April 1977. (Figures 8-9) The St. Simons transect, 10 April 1977, (Figures 8-9) revealed well mixed water from nearshore almost to the shelf break. The temperature and density plots showed a possible Gulf Stream perturbation around station 28S, as temperature increased and then decreased and density correspondingly decreased and then increased from onshore to offshore. Additionally, isotherms which sloped down to the west (see 10.0° - 21.0°C isotherms, Figure 8) indicate an eddy event (Lee, 1975). Current meter data, now being processed at the University of Miami, should elucidate the nature of the event.

Savannah Sections, 11 and 12 April 1977. (Figures 10-13) A bottom intrusion of dense Gulf Stream water onto the shelf was observed during the Savannah sections of 11 and 12 April, 1977 (Figures 10-13). Note particularly the relatively high nutrient concentrations at depth at station 39S (Figure 11) and station 59S (Figure 12). Also, the presence of cool, nitrate-rich water at the shelf break (Figure 11) demonstrated the availability of this water as a potential source of nutrients to the continental shelf.

Jacksonville Section, 13-14 April 1977. (Figures 14-15) A bottom intrusion was observed during the Jacksonville section, 13-14 April 1977. Figure 14 shows that the 19.0°C isotherm was on the continental shelf. Associated with this cool water were high nutrient concentrations (Figure 15).

St. Augustine (South) Section, 14 April 1977. (Figures 16-17) The vertical plots (Figures 16-17) of the St. Augustine (South) section, 14 April 1977, reveal the presence of a Gulf Stream spin-off eddy. Taking temperature as an example, proceeding from onshore to offshore, an increase, then decrease, and finally an increase occurred. The first significant increasing horizontal temperature gradient resulted from the water being of Gulf Stream origin. This water spun off from the main body of the Stream and was transported as a cyclonic counter-current. Lee (1975) described a similar process in the Florida Current.

Strong upwelling was observed at stations 177S through 180S and, as can be seen in Figure 17, nutrients are advected upwards with the deep Gulf Stream water. The ratio between nitrate and phosphate at station 178S at a sample depth of 39 meters is 15.7:1, which suggests that the water is of deep origin. The low oxygen concentrations observed support this contention.

Ormond Beach Section, 15 April 1977. (Figures 18-19) During the Ormond Beach section, 15 April 1977, some upwelling was observed. The 17.0°C to 22.0°C isotherms (Figure 18) best demonstrated this feature as they curved downwards to the west. Comparison of the nutrient and oxygen plots (Figure 19) with those of the St. Augustine (South) section (Figure 17), however, confirms that the observed upwelling was not as strong as during the eddy event since nutrient concentrations were

significantly lower and dissolved oxygen concentrations higher at the shelf break.

St. Augustine (North) Section, 15 April 1977. (Figures 20-21)

Another hydrographic section, St. Augustine (North), 15 April 1977, was run through the eddy event. The results are presented graphically in Figures 20 and 21. Again, a strong upwelling of cold, nutrient-rich, low oxygen water was apparent. Note that this water extended well onto the shelf: the $1.0 \mu \text{ mole/l}$ nitrate isopleth extended almost to station 213S (Figure 21). Thus, assuming that the fate of a spin-off eddy is eventual dissipation in the shelf water, an eddy event can increase the supply of available nutrients on the shelf.

Jacksonville (North) Section, 15 April 1977. (Figure 24a) An XBT transect was conducted to the north of the eddy center (Jacksonville (North) 15 April 1977). Figure 24a shows the characteristic increase, decrease and increase in surface water temperature found during an eddy event. Upwelling of cold water at stations 233X and 234X was observed. No nutrient or oxygen data was collected.

St. Simons Section, 16 April 1977. (Figure 24b) The St. Simons XBT section, 16 April 1977, (Figure 24b) through the northern portion of the eddy also showed upwelling at the shelf break but this upwelling was not as strong as during the preceding section since the corresponding isotherms were not as shallow.

Savannah Section, 16 April 1977. (Figures 22-23) The results of the last hydrographic section occupied (Savannah, 16 April 1977) are shown graphically in Figures 22 and 23. The plots do not indicate an eddy; however, there was a bottom intrusion since high salinity water ($> 36.100/00$) was observed on the continental shelf at station 263S (Figure 22). Associated with this water was high nutrient and low oxygen concentrations (Figure 23).

Savannah Section, 19 April 1977. (Figure 24c) Changes which can occur over a short period of time are demonstrated by comparing Figure 24c, which presents the results of XBT Cruise BF-29, 19 April 1977, with Figure 22 (Savannah section, 16 April 1977). In three days, the upper 10 meters stratified, possibly as a result of surface heating in response to insolation, and a cold water core ($< 17.0^{\circ}\text{C}$ at the center) moved into the mid-shelf region. Since Gulf Stream spin-off eddies are advected northward (Lee, 1975), it is likely that this is the same water mass observed upwelling in response to the eddy mechanism but which later completely separated from the parent Gulf Stream. This is again evidence that spin-off eddies are a significant source of nutrients to the continental shelf.

The Horizontal Distribution of Temperature

The results of continuous mapping of surface temperature during the ADVANCE II cruise are presented graphically in Figures 25 (12-14 April 1977) and 26 (14-16 April 1977). Note in Figure 25 the cold water surface core ($< 21^{\circ}\text{C}$) of the eddy at a latitude of $29^{\circ}40'\text{N}$. To the west was a warmer tongue ($> 22^{\circ}\text{C}$) spun off from the Gulf Stream. Figure 26 reveals that the cold water core and the entire eddy increased in size. Also, the core center advected northward while water warmer than 23°C in the tongue extended more to the south. Additionally, water warmer than 24°C was evident in portions of the tongue. Clearly, these two figures, in combination with Figures 16 and 20 (St. Augustine (South) and (North)), provide a unique documentation of an eddy event.

T-S Relationship

The relation of temperature to salinity observed during cruise AD-4-77 is presented graphically in Figure 27. The nearshore and shelf waters are at the left and center of the plot, respectively. The generally vertical band at the right hand side of the plot is characteristic of the Gulf Stream T-S relationship. Within this band are found the T-S relationships of the waters at the shelf break during the eddy event, identifying their origin.

SUMMARY

During cruises AD-4-77 and BF-29-77 in April 1977, the following observations were made:

1. Water on the continental shelf was generally well mixed vertically. On the outer shelf, exceptions occurred when Gulf Stream water was deposited on the shelf in the form of an intrusion or as a spin-off eddy.

2. An interlayering intrusion of Gulf Stream water into the continental shelf water was seen at the shelf break off Savannah on April 8-9, 1977.

3. Bottom intrusions of cool, nutrient-rich water onto the shelf occurred during the Savannah transects of 11 and 12 April, the Jacksonville transect of 13-14 April, and the Savannah transect of 16 April, 1977.

4. A Gulf Stream spin-off eddy centered off St. Augustine and at the shelf break had associated with it cool, nutrient-rich, low oxygen water which was advected upward from its origin off the continental shelf. Within a week, this water was on the mid-shelf, isolated from the parent Gulf Stream. Therefore, a spin-off eddy can be identified as a mechanism for nutrient enrichment of the continental shelf waters.

FIGURES: 6 - 27

Figure 6. Vertical distribution of temperature, salinity, and sigma-t, Savannah section, 8-9 April 1977.

Figure 7. Vertical distribution of nutrients and oxygen, Savannah section, 8-9 April 1977.

Figure 8. Vertical distribution of temperature, salinity, and sigma-t, St. Simons section, 10 April 1977.

Figure 9. Vertical distribution of nutrients and oxygen, St. Simons section, 10 April 1977.

Figure 10. Vertical distribution of temperature, salinity, and sigma-t, Savannah section, 11 April 1977.

Figure 11. Vertical distribution of nutrients and oxygen, Savannah section, 11 April 1977.

Figure 12. Vertical distribution of temperature, salinity, and sigma-t, Savannah section, 12 April 1977.

Figure 14. Vertical distribution of temperature, salinity, and sigma-t, Jacksonville section, 13-14 April 1977.

Figure 15. Vertical distribution of nutrients and oxygen, Jacksonville section, 13-14 April 1977.

Figure 16. Vertical distribution of temperature, salinity, and sigma-t, St. Augustine (South) section, 14 April 1977.

Figure 17. Vertical distribution of nutrients and oxygen, St. Augustine (South) section, 14 April 1977.

Figure 18. Vertical distribution of temperature, salinity, and sigma-t, Ormond Beach section, 15 April 1977.

Figure 19. Vertical distribution of nutrients and oxygen, Ormond Beach section, 15 April 1977.

Figure 20. Vertical distribution of temperature, salinity, and sigma-t, St. Augustine (North) section, 15 April 1977.

Figure 21. Vertical distribution of nutrients and oxygen, St. Augustine (North) section, 15 April 1977.

Figure 22. Vertical distribution of temperature, salinity, and sigma-t, Savannah section, 16 April 1977.

Figure 23. Vertical distribution of nutrients and oxygen, Savannah section, 16 April 1977.

Figure 24. Vertical distribution of temperature, (a) Jacksonville (North) section, 15 April 1977, (b) St. Simons section, 16 April 1977, and (c) cruise BF-29-77 (Savannah), 19 April 1977.

Figure 25. Horizontal surface temperature distribution,
12-14 April 1977.

Figure 26. Horizontal surface temperature distribution, 14-16 April 1977.

Figure 27. Temperature-Salinity plot, cruise AD-4-77, April 1977.

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Appendix I.
Hydrographic Data

HYDROGRAPHIC DATA

The following printouts are from our CEMLIST programming of the data set. An explanation of the listing follows.

Header Data: Times are GMT (EST + 5 hours)
Latitude and Longitude are from Loran A or Loran C

Weather Data: These data are from the ship's log.

Wind speed (knots)
Wind direction (degrees)
Air temperature (degrees C)
Weather code (WMO code 4501)
Barometric pressure (millibars)
Sea state (WMO code 3700)
Wave direction (not given)
Cloud type (not given)
Cloud amount (not given)
Visibility code (not given)

Observations: Z = Depth in meters
T = Temperature in °C
S = Salinity in ‰
D = Sigma-t
SVA = Specific volume anomaly $\times 10^5$
O₂ = Dissolved oxygen in milliliters/liter
O₂' = Oxygen saturation value (from International
Oceanographic Tables, Vol. 2 (1973))
AOU = Apparent oxygen utilization (O₂ - O₂')
PO₄ = Phosphate concentration in $\mu\text{mole/liter}$
NO₃ = Nitrate concentration in $\mu\text{mole/liter}$
Si = Silicate concentration in $\mu\text{mole/liter}$

STATION SUMMARY FOR ADVANCE II CRUISE

CRUISE	STATION	LATITUDE	LONGITUDE	YR	MN	DAY	HOUR GMT	DEPTH M	CONSEC NUMBER
4	1	31 56.7N	80 46.3W	77	4	8	14.8	12	1
4	2	31 54.2N	80 36.0W	77	4	8	15.8	15	2
4	3	31 51.0N	80 26.5W	77	4	8	17.0	19	3
4	4	31 48.0N	80 17.5W	77	4	8	21.4	24	4
4	5	31 46.5N	80 13.0W	77	4	8	22.1	29	5
4	6	31 46.0N	80 9.0W	77	4	8	22.4	33	6
4	7	31 43.6N	80 3.6W	77	4	8	23.6	38	7
4	8	31 42.0N	79 58.9W	77	4	9	.1	43	8
4	9	31 40.5N	79 54.0W	77	4	9	.9	46	9
4	10	31 39.0N	79 49.3W	77	4	9	1.4	46	10
4	11	31 37.5N	79 45.0W	77	4	9	2.3	55	11
4	12	31 36.0N	79 40.0W	77	4	9	2.9	84	12
4	13	31 34.7N	79 35.5W	77	4	9	4.0	172	13
4	14	31 33.4N	79 30.5W	77	4	9	4.4	338	14
4	21	31 7.7N	80 45.8W	77	4	10	1.4	19	21
4	22	31 4.0N	80 36.5W	77	4	10	2.7	28	22
4	23	31 2.3N	80 32.0W	77	4	10	3.4	31	23
4	24	31 1.0N	80 28.0W	77	4	10	3.9	37	24
4	25	30 58.5N	80 23.0W	77	4	10	4.8	37	25
4	26	30 57.0N	80 18.0W	77	4	10	5.3	40	26
4	27	30 55.4N	80 13.2W	77	4	10	6.0	41	27
4	28	30 53.7N	80 9.1W	77	4	10	6.5	42	28
4	29	30 52.2N	80 3.9W	77	4	10	7.2	48	29
4	30	30 50.9N	79 59.8W	77	4	10	7.8	113	30
4	31	30 49.3N	79 53.8W	77	4	10	8.8	261	31
4	32	30 47.0N	79 50.5W	77	4	10	9.4	351	32
4	33	31 33.4N	79 30.8W	77	4	11	3.1	329	33
4	34	31 35.0N	79 36.0W	77	4	11	5.0	124	34
4	35	31 36.6N	79 40.8W	77	4	11	5.7	68	35
4	36	31 38.2N	79 45.4W	77	4	11	6.5	46	36
4	37	31 39.0N	79 49.9W	77	4	11	7.0	46	37
4	38	31 40.3N	79 54.4W	77	4	11	7.6	44	38
4	39	31 42.0N	79 58.7W	77	4	11	8.2	40	39
4	40	31 43.4N	80 4.1W	77	4	11	9.1	37	40
4	41	31 45.0N	80 9.0W	77	4	11	9.6	33	41
4	42	31 46.1N	80 13.5W	77	4	11	10.2	27	42
4	43	31 47.7N	80 17.5W	77	4	11	10.6	22	43
4	53	31 54.0N	80 36.2W	77	4	12	15.4	15	53
4	54	31 51.0N	80 26.3W	77	4	12	16.5	19	54
4	55	31 47.4N	80 17.5W	77	4	12	17.6	24	55
4	56	31 46.0N	80 13.0W	77	4	12	18.3	26	56
4	57	31 45.0N	80 8.4W	77	4	12	18.8	31	57
4	58	31 43.5N	80 3.2W	77	4	12	19.6	37	58
4	59	31 41.8N	79 58.8W	77	4	12	20.0	42	59
4	60	31 40.4N	79 53.2W	77	4	12	20.8	44	60

ADVANCE II CRUISE

[CONTINUED]

CRUISE	STATION	LATITUDE		LONGITUDE		YR	MN	DAY	HOUR	DEPTH	CONSEC
									GMT	M	NUMBER
4	61	31	39.2N	79	48.9W	77	4	12	21.2	46	61
4	62	31	37.5N	79	44.6W	77	4	12	22.0	47	62
4	63	31	36.1N	79	39.8W	77	4	12	22.4	71	63
4	64	31	34.9N	79	35.1W	77	4	12	23.4	132	64
4	65	31	33.4N	79	30.0W	77	4	12	23.8	238	65
4	100	30	15.3N	81	10.4W	77	4	13	17.7	16	100
4	101	30	14.9N	81	.8W	77	4	13	18.9	27	101
4	102	30	15.2N	80	55.8W	77	4	13	19.5	29	102
4	103	30	14.9N	80	51.4W	77	4	13	19.9	29	103
4	104	30	15.0N	80	45.8W	77	4	13	20.7	29	104
4	105	30	15.0N	80	41.8W	77	4	13	21.1	34	105
4	106	30	15.3N	80	36.2W	77	4	13	22.0	35	106
4	107	30	15.0N	80	31.6W	77	4	13	22.4	37	107
4	108	30	15.0N	80	27.0W	77	4	13	23.1	40	108
4	109	30	15.0N	80	22.0W	77	4	13	23.5	44	109
4	110	30	15.4N	80	17.6W	77	4	14	.1	46	110
4	111	30	15.1N	80	12.2W	77	4	14	.6	102	111
4	112	30	14.7N	80	10.3W	77	4	14	1.7	185	112
4	113	30	15.1N	80	5.2W	77	4	14	2.1	329	113
4	174	29	40.0N	80	35.0W	77	4	14	19.1	28	174
4	175	29	40.5N	80	29.3W	77	4	14	19.9	33	175
4	176	29	40.5N	80	25.0W	77	4	14	20.4	41	176
4	177	29	39.8N	80	20.8W	77	4	14	21.2	48	177
4	178	29	39.8N	80	15.3W	77	4	14	22.0	68	178
4	179	29	40.2N	80	15.4W	77	4	14	22.6	68	179
4	180	29	40.1N	80	14.1W	77	4	14	23.0	104	180
4	181	29	40.2N	80	11.8W	77	4	14	23.7	200	181
4	182	29	41.0N	80	8.2W	77	4	15	.1	388	182
4	192	29	25.2N	80	35.5W	77	4	15	4.1	26	192
4	193	29	25.3N	80	29.7W	77	4	15	5.0	33	193
4	194	29	25.0N	80	25.0W	77	4	15	5.4	29	194
4	195	29	26.4N	80	19.9W	77	4	15	6.3	43	195
4	196	29	25.2N	80	16.9W	77	4	15	6.6	48	196
4	197	29	25.5N	80	15.7W	77	4	15	6.9	55	197
4	198	29	25.2N	80	9.9W	77	4	15	7.8	125	198
4	199	29	25.6N	80	7.3W	77	4	15	8.1	370	199
4	213	30	0.0N	80	35.0W	77	4	15	12.1	41	213
4	214	30	.1N	80	29.5W	77	4	15	12.9	42	214
4	215	30	0.0N	80	25.1W	77	4	15	13.3	44	215
4	216	30	0.0N	80	20.0W	77	4	15	14.0	42	216
4	217	30	0.0N	80	18.0W	77	4	15	14.2	50	217
4	218	30	0.0N	80	14.8W	77	4	15	14.9	146	218
4	219	30	0.0N	80	11.0W	77	4	15	16.2	270	219
4	220	30	1.2N	80	7.5W	77	4	15	16.6	370	220
4	229	30	31.6N	80	31.7W	77	4	15	20.8	36	229
4	230	30	31.2N	80	30.0W	77	4	15	21.0	35	230

ADVANCE II CRUISE

[CONTINUED]

CRUISE	STATION	LATITUDE	LONGITUDE	YR	MN	DY	HOUR GMT	DEPTH M	CONSEC NUMBER
4	231	30 29.5N	80 25.2W	77	4	15	21.3	38	231
4	232	30 29.4N	80 20.0W	77	4	15	21.7	42	232
4	233	30 29.7N	80 15.0W	77	4	15	22.1	48	233
4	234	30 30.0N	80 9.7W	77	4	15	22.4	73	234
4	235	30 30.2N	80 5.0W	77	4	15	22.8	240	235
4	236	30 30.5N	80 1.1W	77	4	15	23.0	283	236
4	249	31 2.5N	80 32.0W	77	4	16	2.7	26	249
4	250	31 .8N	80 27.0W	77	4	16	3.1	33	250
4	251	30 59.0N	80 22.5W	77	4	16	3.4	33	251
4	252	30 57.2N	80 18.0W	77	4	16	3.7	40	252
4	253	30 55.5N	80 13.3W	77	4	16	4.1	40	253
4	254	30 53.8N	80 8.9W	77	4	16	4.4	41	254
4	255	30 52.2N	80 4.0W	77	4	16	4.7	48	255
4	256	30 50.5N	79 59.4W	77	4	16	5.1	148	256
4	257	30 48.5N	79 54.7W	77	4	16	5.4	236	257
4	258	30 49.1N	79 50.0W	77	4	16	5.7	370	258
4	259	31 33.0N	79 29.6W	77	4	16	8.7	200	259
4	260	31 34.6N	79 34.6W	77	4	16	10.3	132	260
4	261	31 35.9N	79 39.3W	77	4	16	10.8	77	261
4	262	31 38.2N	79 44.0W	77	4	16	11.7	48	262
4	263	31 39.1N	79 49.2W	77	4	16	12.1	46	263
4	264	31 41.4N	79 53.0W	77	4	16	12.8	43	264
4	265	31 42.2N	79 58.8W	77	4	16	13.3	41	265
4	266	31 43.8N	80 3.8W	77	4	16	14.0	38	266
4	267	31 45.5N	80 8.2W	77	4	16	14.4	31	267

A map of the Georgia Bight coastline, showing the intricate network of rivers and bays. The map is oriented with the coastline on the left and the open ocean on the right. The coastline is depicted with black lines on a light background. The ocean area is a solid dark gray. The map is framed by a coordinate grid with latitude and longitude markings.

Technical Report Series
Number 78-1

THE RESULTS OF
FOUR OCEANOGRAPHIC CRUISES
IN THE GEORGIA BIGHT

by
L. P. Atkinson

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THE RESULTS OF FOUR OCEANOGRAPHIC CRUISES
IN THE GEORGIA BIGHT

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INTRODUCTION

During 1973 and 1974 we conducted four oceanographic cruises in the Georgia Bight with the purpose of gaining background seasonal data with which to plan more specific experiments. In this technical report the data are presented in graphical form with interpretation. The data itself was published in two technical reports (Atkinson, 1975 and 1976). Some of the interpretations in this report will be given in more detail in published journal articles.

RESULTS OF FOUR SEASONAL CRUISES

Data

The basic station grid was sampled four times as shown in Figures 1-4. In addition to the onshore/offshore line of stations samples were occasionally taken between sections.

The dates and sampling activities for the four Georgia Bight cruises are summarized in the following table:

Table 1. Sample Inventory

Cruise Name Date (Inclusive)	<u>Dates</u>			
	E-13-73 4-11/IX/73	E-19-73 8-15/XII/73	E-3-74 23-30/IV/74	E-12-74 23-30/VII/74
# Stations	55	62	63	68
# Sample Depths	278	239	215	296
# Salinity Samples	274	233	213	288
# Oxygen Samples	256	135	207	291
# Temperature Observations	278	238	212	295
# Nitrate Samples	276	199	180	244
# Phosphate Samples	276	198	204	291
# Silicate Samples	260	200	208	293
Drift Bottles Released (#/Stations)	60/15	60/15	36/18	36/18

All of the hydrographic data and bathythermograph profiles are stored with the National Oceanographic Data Center and are available under the appropriate cruise name.

The horizontal plots are presented first, followed by the vertical plots. Cruises are referred to by the name (e.g., E-19-73) or the month during which the cruise took place.

Horizontal Distributions

Surface Temperature. Surface temperatures (Figure 5) were observed to range from less than 14°C to greater than 29°C . The higher temperatures are always found in the vicinity of the Gulf Stream. During the summer (E-13-73 and E-12-74) solar heating is effective in raising the surface temperature of the Bight uniformly. Thus the horizontal temperature gradients are minimal during the summer. During the winter and spring (E-19-73 and E-3-74) a definite offshore gradient in temperature occurs. On E-19-73 the waters are cooling in response to lower air temperatures. During E-3-74 the shelf waters are generally warmer in response to warmer air temperatures and solar insolation. In the spring (E-3-74) horizontal gradients are minimal except in the vicinity of the Gulf Stream.

Bottom Temperature. The bottom temperature distributions (Figure 6) must be compared to the surface temperature distributions. In three cases (upper and lower left, and lower right) bottom temperatures decrease towards the offshore. This is in contrast to the surface water temperatures that increase in the offshore direction. This occurs because relatively cold, deep, Gulf Stream water is moving onshore along the bottom. This is normally referred to as the intrusion process. This process is very important because it brings new water onto the shelf, replacing what was there. The intrusion process is also evident in the December cruise (upper right) but because the shelf waters are relatively cold ($15\text{--}20^{\circ}\text{C}$) the intruding Gulf Stream water appears warm.

Surface Salinity. Surface salinities (Figure 7) range from 31 to greater than $36^{\circ}/\text{oo}$. The lower salinities are found near the shore as

expected. In general the $35^0/00$ isohaline follows the 18 m (10 fathom) isobath. However south of the Altamaha River the isohalines begin to intersect the coast. The surface shelf water salinities generally are greater than $36^0/00$ with a tendency for higher salinities to the south and lower salinities to the north at the same isobath.

During cruise E-13-73 a special situation existed. The low surface salinities on the outer shelf were hypothesized to originate from the Mississippi River during periods of high runoff. See Atkinson and Wallace (1975) for additional discussion.

Surface Density. The surface density plots (Figure 8) show the effect of low salinity water lying along the coast. The central shelf waters are quite often of higher density than inner or outer shelf waters because of the combination of relative high salinities and low temperatures in contrast to higher offshore salinities (and temperatures).

Nearshore geostrophic currents to the south are indicated in all cruises except E-19-73.

Bottom Nutrients. The intrusion of deeper-nutrient rich water onto the shelf is one of the principal sources of phytoplankton nutrients. One way of identifying intruding waters is by looking at the near bottom concentrations of the phytoplankton nutrients and especially nitrate (Figure 9).

As Figure 9 demonstrates nitrate is usually at very low concentrations in the shelf waters, typically being less than $1 \mu\text{m}$. However, in the vicinity of an intrusion it is higher, often reaching $10 \mu\text{m}$. The figures show a steady increase in the nitrate concentration in the near bottom waters towards the offshore with the only variant being where the increase starts in the cross-shelf direction.

The wave-like structures in these plots are not significant since they could reflect the bias in the time required for sampling. It is significant however that there always appeared to be an intrusion of nitrate-rich water off the St. Johns River.

Vertical Sections

The vertical sections indicate, when combined with the horizontal data, a three dimensional view of the shelf. The data presented are sample location and depth, temperature, salinity, sigma-t (density), oxygen, phosphate, nitrate and silicate.

The legend above the section refer to station numbers. The Roman numerals inset in the section refer to the onshore/offshore sections, I being the most northerly and VI the most southerly. Since station numbers, locations and sections were nearly invariant during the cruises the reader may easily compare various stations and sections. For each cruise the sections proceed from north to south. The stations in a section were either 5, 10, or 15 nautical miles (9.3, 18.5 or 27.8 km) apart.

Cruise E-13-73, 5-10 September 1973. (Figures 10-14) On all sections a strong thermocline extended to varying distances across the shelf. If one compares the vertical temperature profiles with the horizontal distribution of bottom temperatures the cause of the cold bottom waters becomes evident. The steeply sloping isotherms can expose cold water to very shallow depths. For example on Section V (Figure 14) at station 54 18°C water is found at about 220 m, whereas at station 51, which is 25 nautical miles (46 km) to the west, 18°C water is found at 50 m: a rise of 3.7 m per km.

The intense thermocline in the outer shelf waters caused by the invasion of deeper, cold Gulf Stream waters has many important consequences.

The outer shelf is extremely stable because of the extreme vertical density gradients. The cold water contains many dissolved constituents that are lacking in shelf water and thus becomes an important source of these constituents.

Nitrate, phosphate and silicate are quite high on the outer shelf in relation to the lower temperatures because their source is cold, deep water. The onshore movement of nutrient-rich water is especially noticeable in Section V (Figure 14).

An area of maximum salinity is always found at depths of 100-300 meters. In this area salinities often reach $36.5^{\circ}/\text{oo}$ and occasionally $36.7^{\circ}/\text{oo}$. Nearshore salinities progressively decrease. As the near-shore is approached the surface salinity is nearly always less than the bottom salinity. This is expected since fresher water flows out at the surface and salt water flows shoreward to replace that entrained in the surface flow. Silica and phosphate also increase towards the coast with higher concentrations usually found at the surface. This is because the river water carries high concentrations of these nutrients.

The lens of low salinity water that appears in the surface waters near the shelf break, which is especially noticable in sections III, IV, and V (Figures 12-14), represents water that we hypothesized is of Mississippi River origin.

An oxygen minimum is associated with the zone of high salinity. Concentrations often are less than $3.5 \text{ ml O}_2/\text{l}$.

Cruise E-19-73, 10-15 December 1973. (Figures 15-20) This cruise was during a period of strong winds and cooling and the data reflect that. Nearly all isolines are vertical which indicate the complete absence of vertical gradients in the shelf waters.

Temperature and salinity progressively decrease towards the coast indicative of atmospheric cooling and the influence of river runoff, respectively. In all sections the colder deep water is poised at the shelf edge and nutrient concentrations are higher in that area. In fact in spite of the intense wind mixing the temperature and nutrient profiles at the shelf break look much like Cruise E-13-73.

Temperature data indicates the Gulf Stream lies nearer to the shelf break in the southern part of the study area relative to the northern sections.

Cruise E-3-74, 24-29 April 1974 (Figures 21-26). This cruise was during a time of moderation of the stronger winter winds and seasonal heating. Shelf water temperatures are 18-21°C with little horizontal or vertical structure. The outer shelf waters on section VI (Figure 26) are significantly affected by an intrusion of colder Gulf Stream water. This results in the coldest shelf waters being in the most southerly section.

Salinities in the shelf waters decrease towards the coast and exhibit estuarine type structure with higher salinities near bottom. A salinity maximum usually occurs well east of the shelf break at depths of 100-200 m.

The isotherms in deeper water slope up to the east in section I and II then down (Figures 21-22). At other more southerly sections, they slope down to the east. This implies a counter-current near the shelf break in the northern part of the area: isotherms sloping down to the west indicate the possible presence of a southerly flowing current (flowing counter to the Gulf Stream).

The nutrient concentrations reflect the presence of colder water at the shelf break and are relatively high. Sections I and VI (Figures 21, 26) show an especially active intrusion of deeper Gulf Stream water into the outer shelf waters.

Oxygen concentrations show a consistent minimum at 100-200 m.

Cruise E-12-74, 23-30 July 1974 (Figures 27-32). This cruise was in July during the typical summer season. The area is dominated by southerly winds. In all sections there was a significant intrusion of colder water onto the shelf.

On section I (Figure 27) water of 20°C is present at the shelf break. This cold water was accompanied by nutrient concentrations of .3, 2 and 2 μm for phosphate, nitrate and silicate, respectively. There is an indication of a counter-current at 200- to 300 m in the slope of the isotherms and isopycnals. Low salinity water is present in the nearshore surface waters implying an offshore movement of surface waters. No salinity maxima is observed which implies that the Gulf Stream lies farther to the east as is also implied by the isotherm slopes.

Section II is similar to section I with 20°C water at the shelf break. And again this water is accompanied by high nutrient concentrations. The lack of a well-developed salinity maximum and the isotherm position indicates that the Gulf Stream is well to the east of our stations. Salinities decrease near the coast. There is also an indication of offshore flow of low salinity water at mid-depth in the middle shelf. There are no well-developed oxygen minima.

In Section III (Figure 29) there are indications that the Gulf Stream is near the shelf break. None of the isopycnals or isotherms

slope down to the west and the presence of a salinity maximum indicate that the Gulf Stream is closer to the shelf. 20°C water is still at the shelf break and accompanied by high nutrient concentrations.

In Section IV (Figure 30) the position of the isohalines indicates that the Stream is still near the shelf break. Nutrient concentrations are low because of the Gulf Stream position.

In Section V (Figure 31) a current reversal is indicated near the shelf break. The isotherms and isopycnals dip at about 100 m near the shelf break. Nutrient concentrations are higher.

Section VI (Figure 32) represents an eastern movement of the Stream with a current reversal indicated. This could be caused by an eddy like feature. The presence of high salinity water (36.50/00) at shallow depths (Stations 58 and 59) confirms this conclusion. High nutrient concentrations also accompany the high salinity water and nutrient concentrations in the shelf waters have been raised. It is concluded that water had intruded into these shelf waters and then was cut off, which is typical for the intrusion process.

DISCUSSION

In the previous sections the data were examined by plotting in horizontal and vertical planes. In this section, we will look at the relationship between the parameters, such as the temperature-salinity relationship. In addition we will calculate new parameters based on the original observations.

Freshwater Volume

The offshore distribution of river runoff (freshwater) is a useful indicator of the potential distribution of a river borne pollutant and of the gross circulation and diffusive characteristics of shelf waters.

Freshwater volume is the amount of freshwater ($S^0/00 = 0$) in m^3 required to reduce the salinity of a water column ($1 m^2$) at $36^0/00$ to the observed salinity. The key assumption is that Georgia Bight waters would have a salinity of $36.0^0/00$ if no runoff waters were present. At any geographic location the amount of required freshwater to affect the observed salinity reduction is:

$$\text{freshwater volume} = \sum_{i=1}^{n-1} \left[\frac{72 - (S_i + S_{i+1})}{72} \right] \cdot (Z_i - Z_{i+1})$$

where n = number of depths sampled
 72 = twice the base salinity
 S_i = observed salinity at depth Z_i
 Z_i = depth of sample i

This calculation is made for each oceanographic station yielding a set of values for freshwater volume in m^3/m^2 that can be plotted and contoured as shown in Figure 33.

Drift Bottle Returns

The drift bottle returns (Figure 34) essentially confirm the results of Bumpus (1973). The offshore releases were within 45 km of the coast and not subject to the direct influence of the Gulf Stream which dominates flow at the shelf break. Thus these returns indicate the general direction of circulation of the shelf waters.

The September returns (E-13-73) all indicate a southerly flow with velocities greater than 20 km/day. The very high return rate and consistent southern direction implies a strong coherent flow during this time.

The December 1973 release had no returns although the release pattern was similar to the September release.

The April 1974 returns were also sparse with only two bottles returned. They indicated a weak northerly flow.

The July 1974 returns were high with a strong northerly flow in the northern part of the Georgia Bight and a southerly flow indicated in the inshore part of the southern part of the Bight. The July data may indicate the transition from a predominant northward flow in the winter, spring and early summer to a southerly flow in later summer and fall.

Apparent Oxygen Utilization

In deeper ocean waters the decomposition of plant and animal tissue produces higher concentrations of phosphate, nitrate, and silicate and reduces the amounts of oxygen present: the oxidation process consumes oxygen. The loss of oxygen is measured by subtracting the measured amount (O_2) from that which should be there if no oxidation had occurred. The amount of O_2 that should be in solution is the saturation value (O_2^s) which is the amount of O_2 that dissolved in seawater if that water is equilibrated with air at the observed temperature and salinity. The apparent oxygen utilization (AOU) is $O_2^s - O_2$. Since the oxygen loss (AOU) is dependent on biological oxidative processes it is proportional to the nitrate, phosphate, and silicate produced. The high AOU (low oxygen) water (Figures 35-38) usually inclined with depth as did the isotherms. These values, although low, are not in any way restrictive to biological activity. The initial oxygen concentrations are 5-6 ml O_2 /l so even an AOU of 3 ml O_2 /l leaves 2-3 ml O_2 /l in the water. While the AOU is an interesting parameter the oxygen anomaly is in many ways more useful.

Oxygen Anomaly

The water flowing north in the Gulf Stream has at least two origins. One is the Florida Strait between Florida and Cuba. The second is the Antilles current which flows northward in the area east of the Bahamas. These waters have a common origin in the central north Atlantic Ocean, however, the path for some water is more circuitious than others. The waters that emerge from the Straits of Florida have spent much time in the Caribbean Sea and the Gulf of Mexico and their chemical characteristics have changed. The Gulf Stream water that traveled through the Caribbean and Gulf of Mexico has lower oxygen content than water of an identical temperature that moved in the Antilles current. The amount of this difference is the oxygen anomaly. Thus this tracer is useful to define the two water masses and was originally discussed by Rossby (1936). Since the tracer indicates water of tropical origin it is useful in the interpretation of the shelf flora and fauna which often has tropical components.

During the September cruise (E-13-73) (Figure 39) the zones of high oxygen anomaly coincided with temperatures of ca. 22°C. In Sections I through IV the oxygen anomaly water is not abundant; however, Section V shows large amounts and what appears to be two masses. This correlates with the temperature and density structure which indicates an eddy feature.

During the December cruise (E-19-73) (Figure 40) the oxygen anomaly occurs in large quantities in Section VI which coincides with high nutrient concentrations. Contrasting Section II and VI temperatures and oxygen anomaly the oxygen anomaly occurs when the isotherms tilt up steeply to the continental slope. This condition corresponds to an east position of the Gulf Stream with no eddy structures present.

The E-3-74 data (April) (Figure 41) shows the pattern displayed previously. Where the isotherms indicate an eddy structure we find oxygen anomaly water at the shelf break.

Data from Cruise E-12-74 (July) (Figure 42) shows the most amounts of oxygen anomaly. This correlates with the eddy structure present in many of the sections (I, III, V, and VI).

The distribution of the anomaly is difficult to predict although it does correlate with the presence of eddies (isotherms tilting down to the west) and possibly with Gulf Stream positions. The important observation is the extreme variability of the position and amount of anomalous water. This could be partly due to bias induced by our discrete sampling, however we feel more is indicated. It is indicated that the amounts of various water masses vary with time in the Gulf Stream.

Summarized Horizontal Effect of Runoff and Intrusions.

The offshore extent of runoff and the onshore extent of intrusions were determined from all the data to see if a pattern exists. The composite data (Figures 43-46) for the four cruises are summarized in Table 2. Runoff averages 56 km offshore in the north but less than 3 km in the south. Conversely intrusions extend onshore an average of 20 km but extend much further onshore in the south than the northern part of the area.

The Ranges of Temperature

The annual range in water temperature is important since it will effect animal growth rates or, in extreme cases, the survival rate. While the nearshore waters have an annual range of 12.3°C the offshore surface waters have an average range of 6.4°C and the shelf break bottom waters an annual range of 4.2°C . This results from the influence

TABLE 2

Average offshore extent of runoff

Section I	56.5 ± 33.3	n=4
II	42.3 ± 23.6	n=4
III	33.8 ± 15.0	n=4
IV	37.8 ± 23.0	n=4
V	19.5 ± 1.3	n=4
VI	2.7 ± 4.6	n=3
Average for all sections	33.4 ± 24.7 km	n=23

Average inshore extent of intrusions

Section I	15.5 ± 17.2	n=4
II	12.8 ± 10.5	n=4
III	27.3 ± 9.5	n=4
IV	11.5 ± 1.3	n=4
V	13.5 ± 13.4	n=4
VI	40.0 ± 30.8	n=3
Average for all sections	19.2 ± 16.6 km	n=23

of the Gulf Stream. The nearshore waters are subject to extreme cooling and heating causing the large annual range. The offshore surface waters, while also subject to seasonal heating and cooling are moderated by the consistently warm Gulf Stream waters. The deep waters offshore are not subject to atmospheric cooling or heating, but only minor variations caused by Gulf Stream meandering.

These results are important to fisheries since many tropical species cannot tolerate the large temperature ranges observed in the nearshore waters. However they can tolerate the minor temperature ranges in the deeper waters at the shelf break.

T-S Relationship

The relationship of temperature to salinity, a T-S plot, is a standard oceanographic procedure used to analyze data. In the central oceans the TS plot is very characteristic for each ocean and each depth in that ocean (i.e., water of 10°C always has a salinity of about 35.0⁰/oo). The relationship is very predictable for subsurface waters. However, surface waters can easily change temperature because of atmospheric conditions, and the salinity may change as a result of runoff, rain, or evaporation. Therefore, while the T-S relationship of deeper waters such as the deeper Gulf Stream waters is constant, the T-S relationship of Georgia shelf waters is quite variable depending on the season. Figure 47 shows the T-S plots for the four cruises.

The early winter cruise is a time of minimum temperatures and low runoff, consequently observed temperatures were at a minimum and salinities were relatively high.

During April 1974, which is during the high runoff and warming season, higher temperatures were observed and the lowest salinities of any cruise.

In July 1974, during a period of highest temperatures and decreasing runoff, higher temperatures were observed and lower salinities than in September 1973 when runoff is lower.

The T-S relationship of shelf water closely reflects the runoff and air temperature. That relationship is shown in the following schematic (Figure 48). This diagram was made by taking the minimum observed salinities and temperature for the four cruises, plotting them (heavy dots) and then connecting the dots. This represents the seasonal cycle of salinity and temperature in the nearshore zone for the whole coast. The pattern reflects the combined effect of seasonally varying temperatures and runoff that peaks in the late winter and again in the late summer. Thus from January to April the water continues to warm, but the runoff decreases causing salinity to increase. From July to September the temperatures stabilize while runoff increases, decreasing the salinity. Finally, from October to December the temperature decreases, because of lowering air temperature, while salinity increases because of decreased runoff. This is caused by the subtropical runoff pattern: the runoff pattern in most temperate areas is unimodal.

Nitrate-Phosphate-Silicate-Temperature Relationships

The various relationships between nitrate, phosphate, silicate and temperature are useful to confirm the quality of the data and to elucidate some of the chemical, biological, and physical processes at work.

The ratio between nitrate and phosphate concentrations in deeper water is usually 16:1. This results from the 16:1 ratio of N to P in phytoplankton tissue. The subsequent bacterial mineralization of this tissue in deep water produces the observed 16:1 ratio. All of our

nitrate-phosphate data is plotted in Figure 49. The theoretical 16 to 1 line is also shown. Note that at low concentrations there is usually excess phosphate with respect to nitrate. These samples are from shallow areas where nitrate is consumed and not quickly released while phosphate is quickly released.

The plot of nitrate vs AOU (apparent oxygen utilization; Figure 50) demonstrates that nitrate is produced at the expense of oxygen: an oxidation/reduction reaction.

Since all nutrient concentrations generally increase with depth and temperature decreases one may expect a relationship between these parameters. Figure 51 shows a nitrate-temperature plot of all of our data. At lower temperatures the relationship is very consistent and essentially allows one to predict nitrate given the water temperature.

CONCLUSIONS

The preceding data presentation and discussions make many points. It should be apparent that many things about the Georgia Bight are predictable. Temperature-salinity relationships and patterns are consistent and reasonably predictable as are the nutrient relationships. Knowledge of the processes that control these is where we fall short. Intrusions, although easily recognized, are not understood. We do not know to what extent they occur or how often. The distribution of freshwater in the offshore waters is also easily detected but we do not understand the forces that disperse the waters and produce the distribution we observe.

The understanding of these processes is more important in many cases than knowing the distribution of some compound resulting from the process. We must know the process if we are to make reasonable judgments concerning the effects of man's activities on the ocean system.

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FIGURES

Figure 1. Station locations, Cruise E-13-73

Figure 2. Station Locations, Cruise E-19-73

Figure 3. Station Locations, Cruise E-3-74

Figure 4. Station Locations, Cruise E-12-74

Figure 5. Surface Temperature

Figure 6. Bottom Temperature

Figure 7. Surface Salinity

Figure 8. Surface Density

Figure 9. Bottom Nitrate

Figure 10. Vertical Section, Cruise E-13-73, Section I

Figure 11. Vertical Section, Cruise E-13-73, Section II

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Figure 33. Distribution of Freshwater

Figure 34. Drift Bottle Trajectories

Figure 35. Apparent Oxygen Utilization, Cruise E-13-73

Figure 36. Apparent Oxygen Utilization, Cruise E-19-73

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Figure 39. Oxygen Anomaly ($\text{ml O}_2/\text{L}$), Cruise E-13-73.

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Figure 43. Summarized Horizontal Extent of Runoff and Intrusions E-13-73

Figure 44. Summarized Horizontal Extent of Runoff and Intrusions E-19-73

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Figure 47. Temperature-Salinity Plot

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Figure 49. Phosphate-Nitrate Plot

Figure 50. Nitrate-Apparent Oxygen Utilization Plot

Figure 51. Nitrate-Temperature Plot