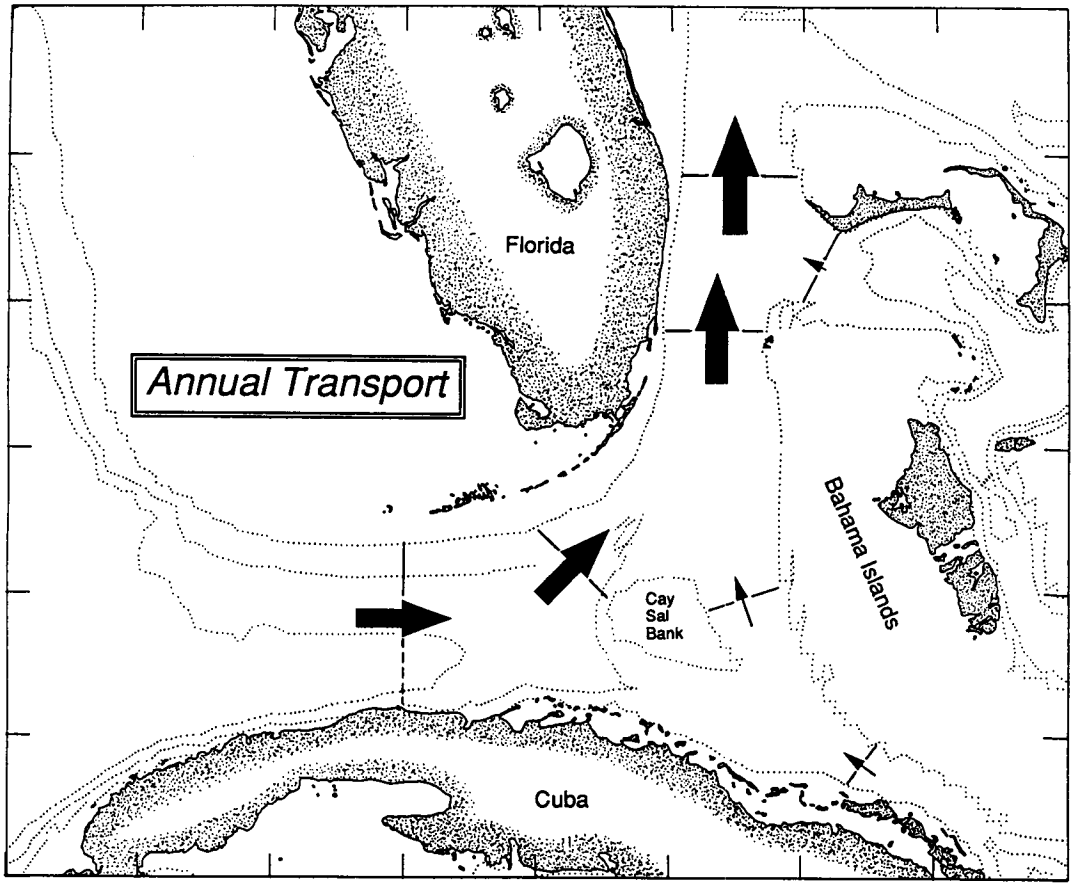
OCS Report
MMS 92-0024

Straits of Florida
Physical Oceanographic Field Study

Data Report



U.S. Department of the Interior
Minerals Management Service
Atlantic OCS Region

OCS Report
MMS 92-0024

Straits of Florida Physical Oceanographic Field Study

Data Report

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ABSTRACT

A one-year field measurement program in the Straits of Florida was initiated in November 1990. Field observations included:

- Subsurface currents, temperature and conductivity
- Hydrographic profiles (CTD and XBT)
- Lagrangian drifters trajectories
- PEGASUS velocity profiles
- Water levels

These were supplemented by data taken by NOAA at sites on or adjacent to the coast as part of their normal observational activities. Data obtained from NOAA included:

- Water levels
- Wind velocity
- Air temperature
- Atmospheric pressure
- Satellite thermal imagery

Observations were made on eight transects covering all primary and lateral channels in the study area. Twenty one moorings containing 63 instruments were deployed during the program. Data return was excellent with only one instrument being lost. Meteorological data was obtained for seven CMAN and NWS stations. Water levels were obtained for four NOS sites to supplement the program measurements.

All field activities occurred during five seasonal mooring/ hydrography/drifter release cruises and four separate PEGASUS profiling cruises. Approximately 60 casts were made on each mooring/ hydrographic cruise. PEGASUS profiles were made at 17 stations across three key transects. During the mooring cruises, a total of 15 ARGOS drifters were released and tracked. Release sites were dependent on the circulation patterns expected in the study area.

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I. INTRODUCTION

1.1 Study Area Description

The Gulf Stream (GS) has a major role in maintaining a meridional heat transport as well as being a primary influence on circulation patterns along the Atlantic coast of the United States (US). The precursor of the Gulf Stream, the Loop Current, enters the Gulf of Mexico via the Yucatan Straits and exits by the Straits of Florida. While in the Straits of Florida (SoF), this major western boundary current is called both the Florida Current (FC) and the GS. The study area for the present program is the SoF, and the primary oceanographic features to be documented are the Gulf Stream and related circulation patterns in the region.

The southern or western end of the SoF is a 150 km wide, steep-sided channel between the Florida Keys and Cuba. In this approach, water depths shoal until they are approximately 1500m on a line between Key West and Havana. Further eastward, the main channel turns 90° to the north. In this area of channel curvature, maximum water depths continue to shoal with the deepest part of the channel skewed to the offshore.

After the northward turn, the main GS channel remains steep-sided with the Florida Keys and mainland Florida on the west and the Bahama Islands to the east. Northwest Providence Channel (NWPC), which opens into this channel at about 26°N, connects the SoF with the Atlantic. Water depths in this northern section of the SoF are generally less than 800 m or about half that found at 82°N.

In the area where the main channel turns to the north is Cay Sal Bank, a large but shallow (water depths $\leq$ 30m) reef whose presence creates two other channels - Nicolas Channel toward Cuba and Santaren Channel towards the Bahamas Islands (Great Bahama Bank). Southeast of Cay Sal Bank is the Old Bahama Channel (OBC), a narrow passage separating Great Bahama Bank and Cuba and connecting the SoF to the Caribbean Sea.

1.2 Background

The Minerals Management Service (MMS), through its Outer Continental Shelf (OCS) Environmental Studies Program, funds various projects that support the MMS's statutory requirement to understand and describe "environmental impacts on the human, marine, and coastal environments of the OCS and coastal areas that might be affected by oil and gas development (43 U.S.C. 1346). It is in this context that the MMS contracted with Science Applications International Corporation (SAIC) to conduct the Physical Oceanographic Field Study of the Straits of Florida.

The specific objectives of this study were twofold:

1) To acquire data sets that provide initial and boundary conditions for a numerical circulation model as well as information that can be used for model validation and verification.

2) To develop an improved understanding of primary circulation patterns in the study area and the responsible forcing mechanisms.

The overall rationale for the SoF project, which both these objectives support, is development of a numerical circulation model that will provide improved input to and hence reliability of the Oil Spill Risk Assessment (OSRA) model results.. OSRA is used to provide a probabilistic characterization of potential adverse impacts of activities linked directly to offshore oil and gas development, production, and transportation.

The study area is the path followed by the Florida Current/Gulf Stream. Effective and compatible modeling of the Loop Current and the Gulf Stream is essential to a proper characterization of linked circulation patterns in the Gulf of Mexico and the South Atlantic Bight. This points to the importance of having a circulation model that can adequately reflect conditions and patterns in this key waterway. An improved documentation and understanding of the expected transport and current patterns is also important to the overall MMS objectives since knowledge of the dynamics governing circulation provides guidance in developing an appropriate model and provides a basis for evaluating model performance (skill assessment).

1.3 General Program Scope

The SoF Physical Oceanography Study involved one year of coordinated observations of those variables determined to be of key importance to subsequent circulation modeling and to the present and any future process synthesis. The specific experimental design was developed in keeping with the RFP requirements and after discussion with numerical circulation modelers as well as this program's principal investigators.

Of primary concern to the modelers, and hence a major thrust of this study, is documentation of volume transport as it varies in time at the boundaries of the study area, in particular along 82°W and 27°N. In addition, water level gradients along and across the primary and secondary channels are of interest to support modeling. To document mass transport requires information on the time varying density and current velocity fields at the domain boundaries.

The following primary and ancillary variables were either measured as part of the field program or acquired from other sources:

1) Subsurface currents (velocity, temperature)

2) Surface currents velocity (lagrangian)

3) Hydrographic measurements - temperature and salinity

4) Ancillary Data

- Satellite thermal imagery
- Meteorological observation (wind velocity, air temperature, and atmospheric pressure).
- Water levels

The above data were supplemented with detailed vertical profiles of horizontal velocity as determined with PEGASUS technology.

Generally, field activities occurred as follows: Five seasonal cruises were made during which all field equipment (current meters and water level sensors) were either deployed, rotated or retrieved. On each cruise, conductivity, temperature and depth profiler (CTD) and expendable bathythermograph (XBT) profiles were used to measure profiles along each mooring transect in such a way as to support and complement subsurface current velocity data. During each cruise, three ARGOS-tracked surface drifters were to be released and tracked for 50 days. PEGASUS-based velocity profiles were measured during four separate cruises, which occurred approximately quarterly. Satellite thermal imagery was obtained for the study area. The meteorological observations were obtained from existing NOAA measurement sites as were some of the water level data.

Transport time series were computed using subsurface current data. These estimates were compared with transport computed using PEGASUS velocity profiles, which were made on three key cross-channel transects.

The project schedule called for one year of field activities to begin three months following contract award. Following completion of seasonal cruises, data obtained was processed and as appropriate provided to the program principal investigators. Approximately four months following the end of field measurements, a draft Interpretive Report is to be submitted to the MMS. The remaining portion of the program is to be devoted to document review and finalization, and preparation of two journal manuscripts.

Key program scientific participants are:

Dr. L. Atkinson (Old Dominion University)
Dr. T. Berger (SAIC)
Dr. P. Hamilton (SAIC)
Dr. K. Leaman (U. of Miami)
Dr. T. Lee (U. of Miami)

Primary program support personnel from SAIC include:

Dr. E. Waddell, Program Manager
Mr. J. Singer, Logistics Manager
Dr. R. Wayland, Data Manager

II. FIELD MEASUREMENT PROGRAM

2.1 Summary of Program Sampling Design

2.1.1 Subsurface Currents

Moored current meter arrays were placed on four approximately equally spaced cross-channel transects (A, B, C and D) as well as in NWPC (E), Santaren Channel (F) and ODC (G) as shown in Figure 2.1-1. An additional mooring (H) was placed between the Dry Tortugas and the Marquesas Keys to provide an indication of the flow through the deeper portion of the intervening channel.

These instrumented transects provide the velocity data that was used to estimate transport through the main and lateral channels as well as providing information needed to document Gulf Stream dynamics better. The various sectional transport estimates can be combined to compute and check input and outputs for the total study area as well as subunits (control volumes). The approximate along-channel separation of Transects A, B, C and D is 60 to 80 nautical miles, which provides appropriate resolution of the expected wave length of meanders that occur in the SoF. This distribution of transects also provides two sets of observations on both sides of the northward 90° turn of the main channel in the middle of the study area. The location of Transects A and B also allows coordination and incorporation of selected data with an overlapping NOAA-funded study (SEFCAR) being conducted by Dr. T. Lee (U. of Miami), a principal investigator on the present study.

2.1.2 PEGASUS Profiling

A key element in the present study was development of methods by which measured velocity time series could be used to estimate the volume of water being transported through each instrumented transect. On Transect D, voltage, which was measured on an abandoned phone cable, was calibrated using PEGASUS technology during the Subtropical Atlantic Circulation Study (STACS) to provide sectional transport estimates. Via an Interagency Agreement with NOAA, the MMS arranged for Dr. J. Larsen to provide these cable-based transport estimates as well as those for a cable between Key West and Havana for the present study period. During the present study, PEGASUS was again used to provide accurate transport estimates through Transects B, E and F (Figure 2.1-1). With these and cable data from Transect D, transports computed from current meter time series through all key transects could be calibrated/evaluated.

2.1.3 Drifters

Three ARGOS-tracked, near-surface drifters, which were to be released during each of the five quarterly mooring deployment, rotation or recovery cruises, provided information having several uses. The resulting drifter trajectories are a good indicator of the movement of a surface-constrained water parcel as it responds to the time varying balance of forces. They also provide information which, when combined with subsurface current data, may enhance documentation of the vertical structure of the velocity field.

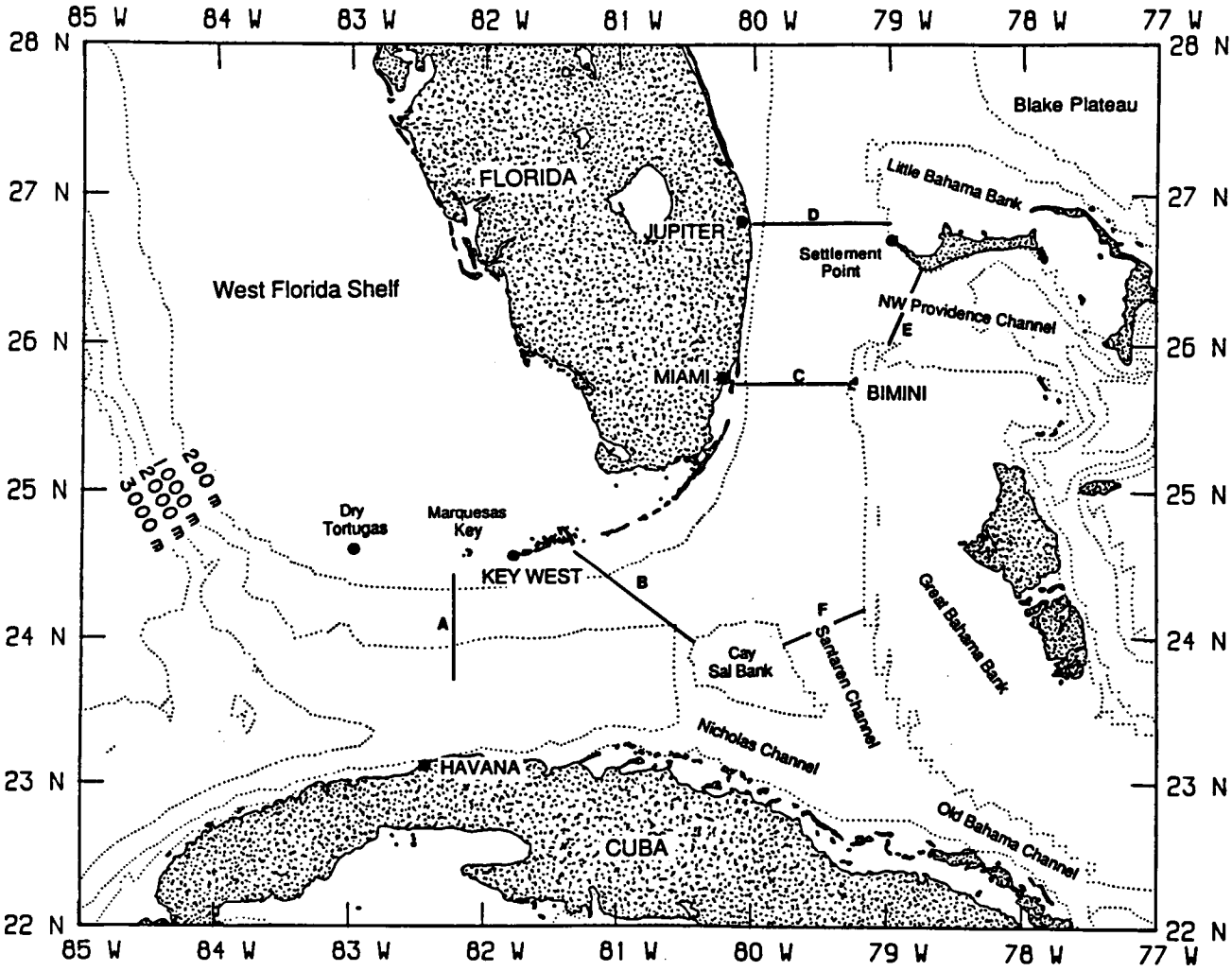


Figure 2.1-1 Map showing labeled instrument transects.

2.1.4 Hydrography

During each of the five quarterly mooring cruises, hydrographic profiles were measured along all of the mooring transects (Figure 2.1-1). These profiles were obtained with either a CTD profiler or XBTs. An examination of the temperature/salinity (TS) structure within the LC and GS shows the consistency of the correlation of these two variables (Figure 2.1-2). Within the LC/GS, knowledge of temperature provides an excellent indication of salinity. With this understanding, SAIC proposed to rely more on XBTs at stations well inside the main LC/GS water mass. CTD observations were used more extensively near the GS boundary, especially near the surface, where water masses may not conform to the documented TS correlation.

A simple rationale was used in deciding which subsurface instruments would have a conductivity sensor. Those current meters with conductivity cells were at positions nearer the surface on the onshore ends of Transect A and B where the TS correlation might be expected to be least stable.

2.1.5 Ancillary Data

2.1.5.1 Satellite Imagery

During part of each year, sea surface temperature fields reflect some of the characteristics of the underlying water mass distribution. This is particularly true along the northern side of the Gulf Stream during the cooler months. During these periods the GS boundary at the surface can be located by looking for a marked temperature gradient between the GS and the cooler water to the north. These data are more useful for the region south or west of the northward channel curvature, where the west Florida shelf water tends to be cooler and the GS boundary position has substantial N-S variability in response to passage of features such as meanders.

2.1.5.2 Meteorological Observation

Previous studies, e.g. STACS, have shown some relationship between local currents and transport, and wind stress on the water surface (Lee and Williams, 1988). Consequently, local wind data was to be acquired from sites where observations were already being made. Of particular interest were those measurements made immediately adjacent to or over the water at the coast. This coastal proximity was important so the observations more adequately reflected conditions that existed over the water in the study area. A number of NOAA-maintained sites exist along the U.S. coast between Key West in the south and Jupiter, Florida, in the north.

2.1.5.3 Water Level Observations

The potential relation between transport and water level gradients was the rationale for these measurements. A series of existing NOAA-maintained measurement sites was located along the Florida Key and at one site in the Bahama Islands. These were supplemented with water level measurement at two sites as part of the present program. When the entire set of water level observations is grouped, water level gradients can be computed across many of the major channels (Transects B, C, D and E). Current meter-based transport estimates are also

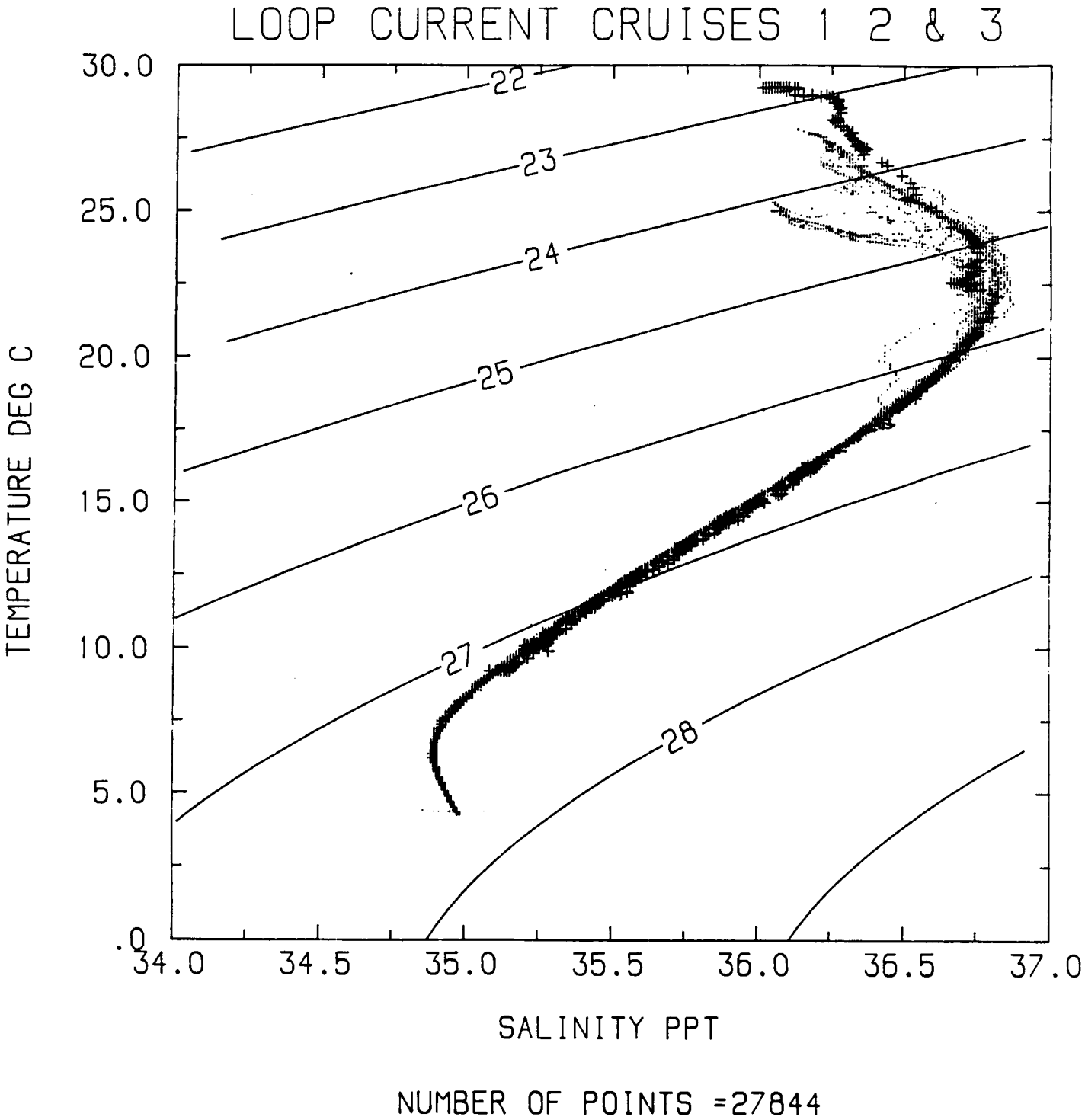


Figure 2.1-2 Correlation of temperature and salinity in LC/GS area.

being made on all four of these channels with PEGASUS or cable calibration data being available for three transects (B, D and E).

2.2 Field Measurement Program

2.2.1 Subsurface Currents and Temperature

Specific mooring locations and identification codes are shown in Figure 2.2-1. A brief rationale for the mooring positions has been given in Section 2.1.1. Table 2.2-1 provides a listing of the geographic position of each mooring and the approximate vertical position of each instrument. Figure 2.2-2 shows the instrument positions on each transect.

2.2.2 PEGASUS Profiling Stations

The locations of PEGASUS profiling stations on Transects B, E and F are shown in Figure 2.2-3, and presented in Table 2.2-2. The cross-stream spacing was dictated by experience developed during STACS and the estimated horizontal scale of variability and shear on the present transects. An additional consideration was the amount of time required to complete a transect since an effort was made to account for tides partially by using a tidal and half-tidal interval between reoccupying each station during a given series of transect measurements.

PEGASUS profiles were taken on these three transects during four separate cruises. Being seasonal, these cruises were sufficiently far apart in time that the transport estimates should be relatively independent. Note that during each of the four cruises, each transect was occupied more than once.

2.2.3 Lagrangian Drifters

The location of drifter release was not constant but rather was determined from an evaluation of possible or expected circulation patterns. The final pattern of deployment had most drifters being released in the vicinity of Cay Sal Bank or in and around Old Bahama Channel.

2.2.4 Surface Currents

During various station activities such as mooring retrieval or a CTD cast, a Neil Brown direct reading current meter (DRCM) was suspended over the side of the vessel at a depth of 10m. During the deployed period, the precise vessel location and vector averaged currents were recorded so that estimates of local surface currents could be reconstructed. These observations provide surface current estimates; however, there is on the order of 16 days between the first and last station, which will not satisfy a criteria for synopticity over the study area.

2.2.5 Hydrography

As indicated previously, hydrographic measurements were made on each mooring transect (Figure 2.1-1) during each of five quarterly cruises. The originally expected station spacing was guided by the rationale that closer interval profiles would occur where sharper horizontal gradients might reasonably be expected. On different cruises some shifts between XBT and CTD profiles occurred

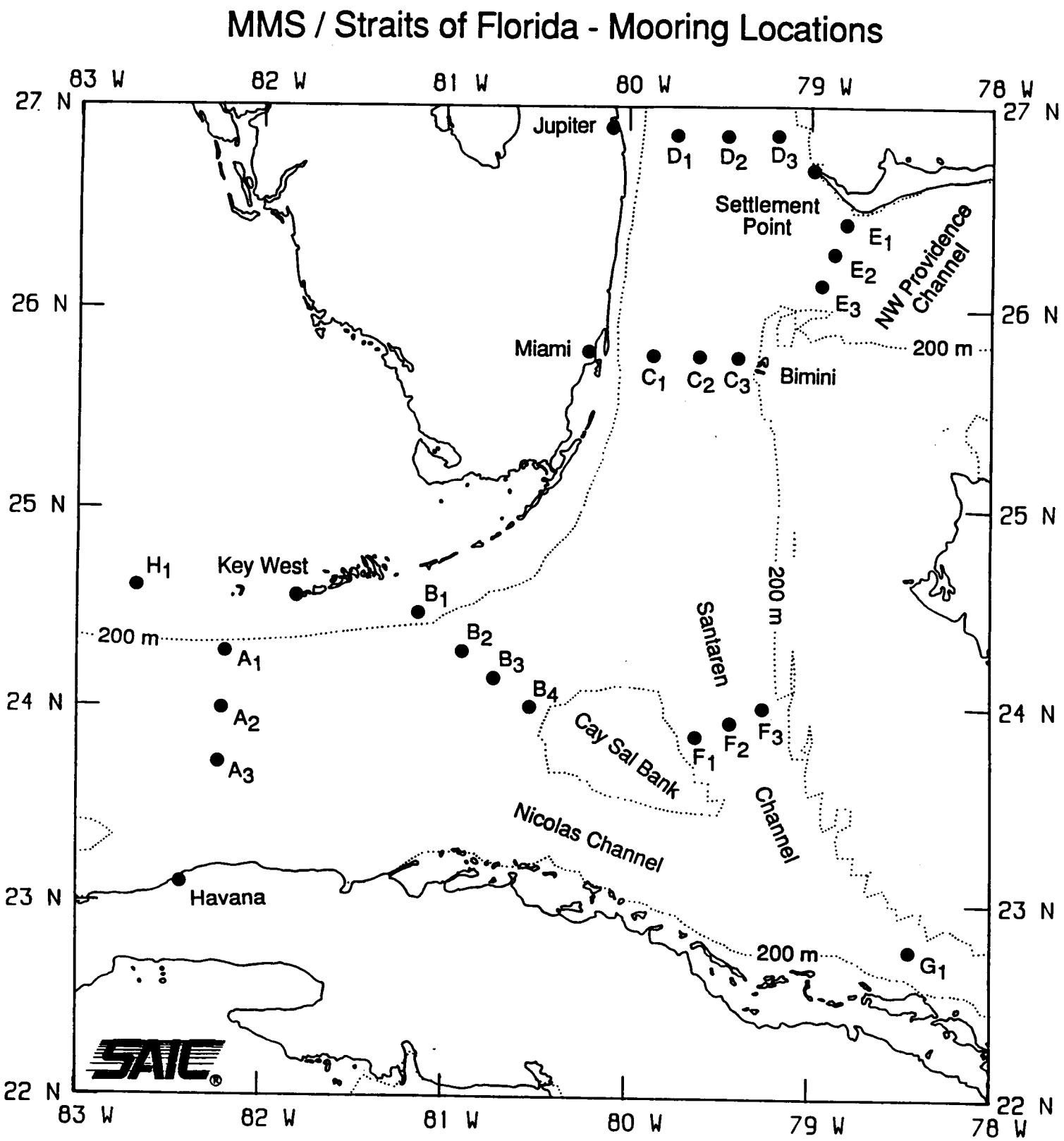
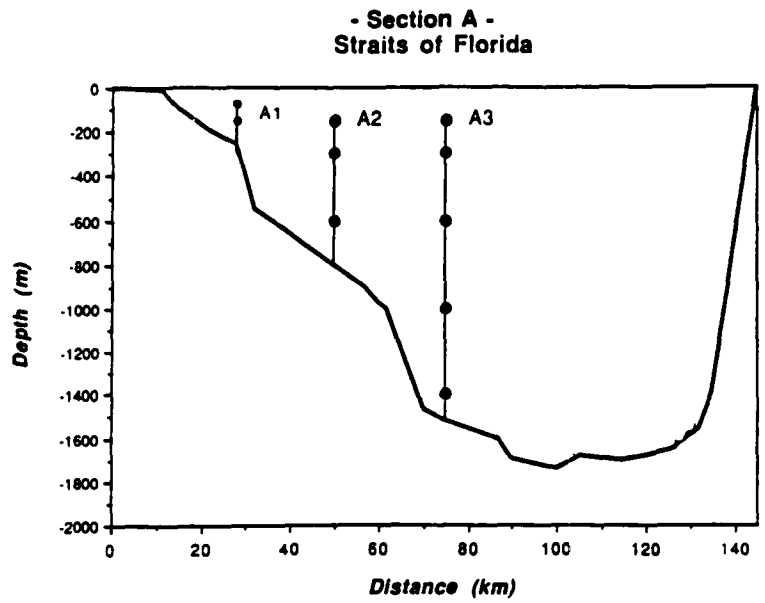


Figure 2.2-1 Map showing mooring locations and mooring identifiers.

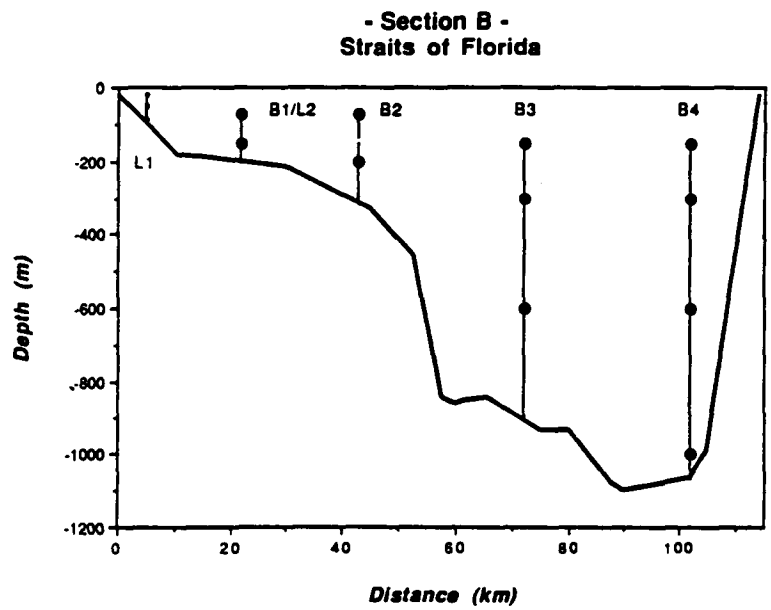
Table 2.2-1 Listing of all subsurface mooring and instrument IDs, locations and depths.

Mooring ID	Latitude/ Longitude	Inst. ID	Depth (m)
A1	24°17.7'N 82°12.2'W	A11	75
		A12	150
A2	24°03.2'N 82°09.7'W	A21	145
		A22	300
		A23	600
A3	23°49.7'N 82°11.8'W	A31	145
		A32	300
		A33	600
		A34	1000
		A35	1400
B1	24°27.1'N 81°07.9'W	B11	75
		B12	150
B2	24°18.1'N 80°57.6'W	B21	75
		B22	200
B3	24°10.5'N 80°47.6'W	B30	145
		B31	293
		B32	300
		B33	600
		B34	805
B4	24°00.0'N 80°35.1'W	B40	288
		B41	145
		B42	300
		B43	600
		B44	1000
B5	23°58.0'N / 80°26.8'W	B51*	17
C1	25°48.3'N 79°51.8'W	C11	100
		C12	250
C2	25°48.5'N 79°38.7'W	C21	145
		C22	300
		C23	600
C3	25°48.3'N 79°23.8'W	C31	145
		C32	300
		C33	600
		C34*	718
D1	26°49.5'N 79°48.2'W	D11	145
		D12	300
D2	26°51.0'N 79°29.8'W	D21	145
		D22	300
		D23	600
D3	26°51.1'N 79°14.0'W	D31	145
		D32	300
		D33	600
E1	26°20.8'N 78°42.6'W	E11	100
		E12	300
		E13	600
E2	26°13.9'N 78°46.2'W	E21	100
		E22	300
		E23	450
E3	26°07.2'N 78°49.9'W	E31	100
		E32	200
		E33	300
F1	23°51.8'N 79°36.9'W	F11	50
		F12	300
		F13	500
F2	23°55.0'N 79°26.3'W	F21	50
		F22	300
		F23	500
F3	23°57.0'N 79°14.5'W	F31	50
		F32	300
		F33	500
G1	22°44.5'N 78°31.8'W	G11	50
		G12	250
		G13	435
H1	26°36.4'N 82°41.8'W	H11	17

*=Water level only

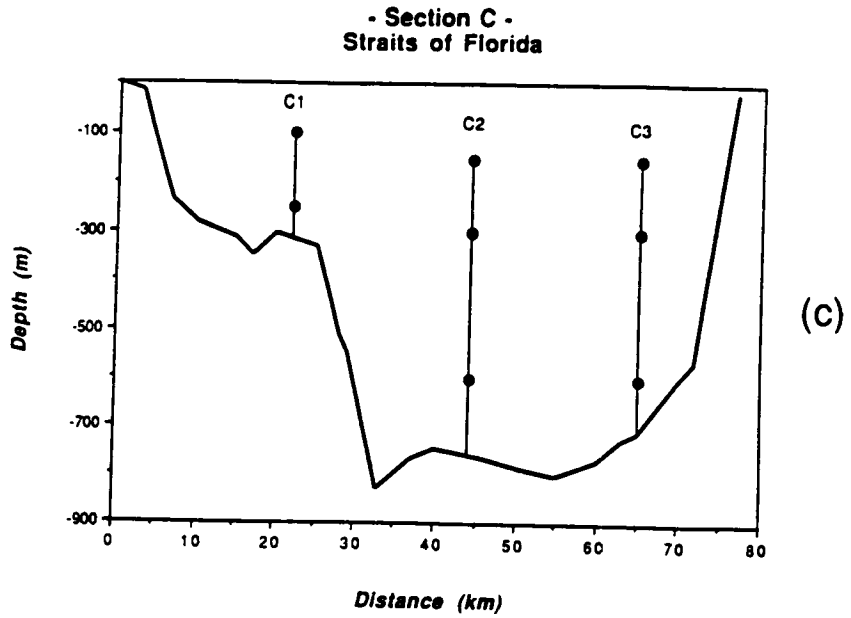


(a)

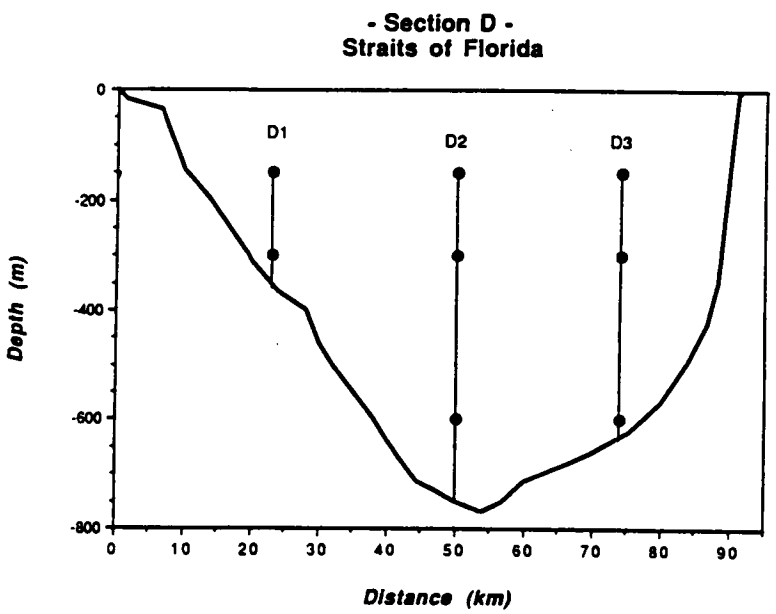


(b)

Figure 2.2-2 Schematic scaled drawings showing locations of current meters relative to channel geometry, a) Transect A, b) Transect B.

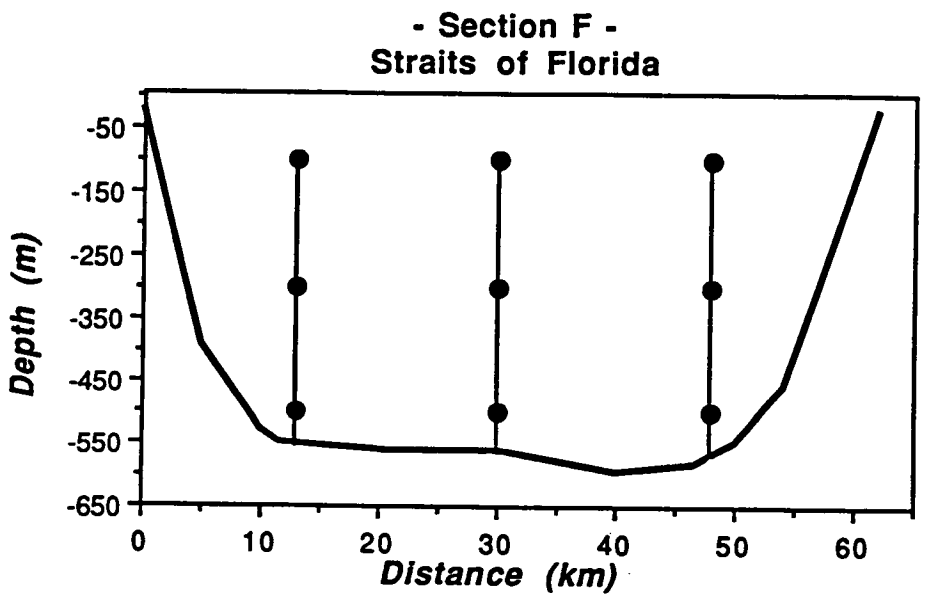


(c)



(d)

Figure 2.2-2 Schematic scaled drawings showing locations of current meters relative to channel geometry, c) Transect C, d) Transect D.



(e)

Figure 2.2-2 Schematic scaled drawings showing locations of current meters relative to channel geometry, e) Transect F.

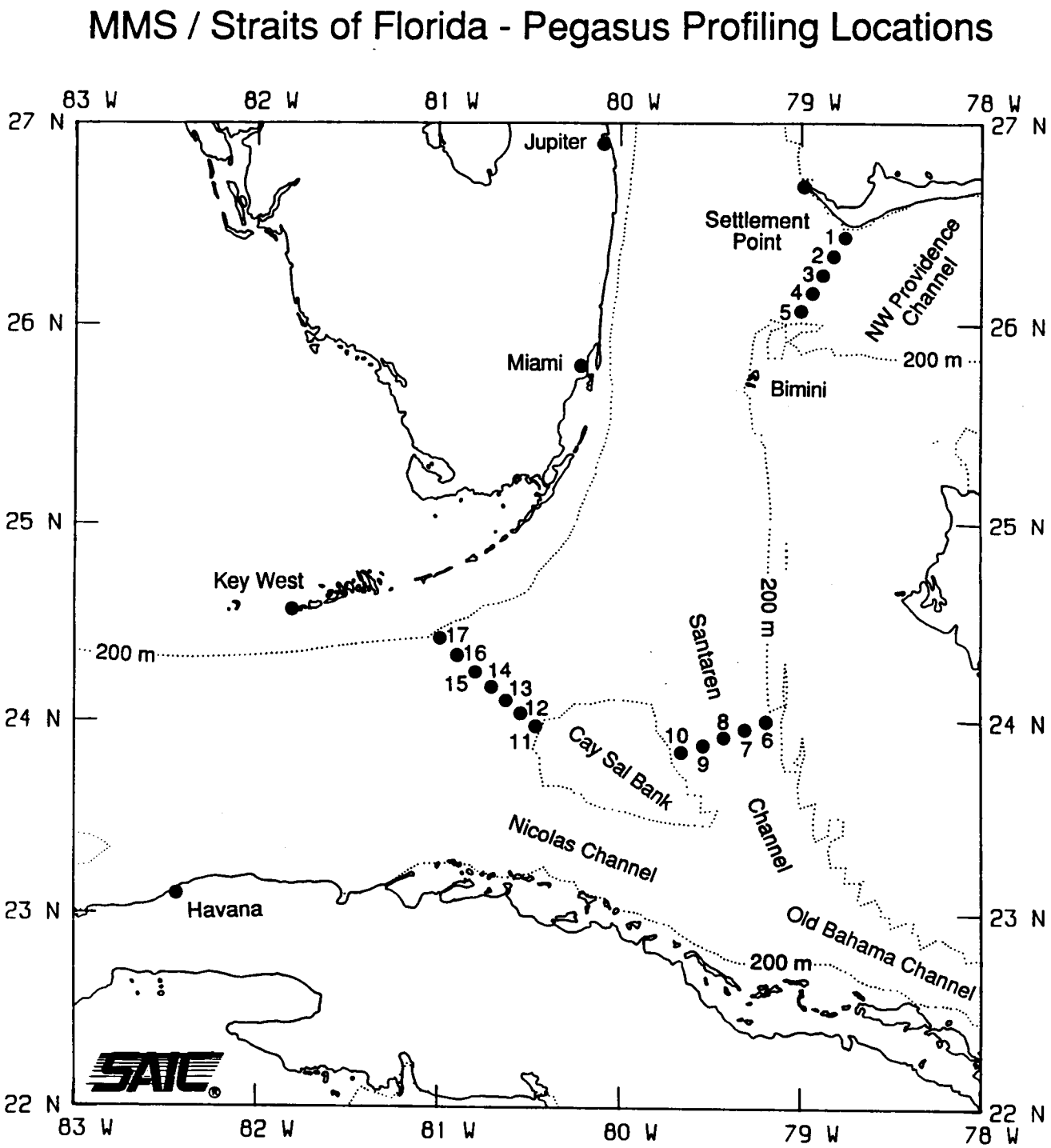


Figure 2.2-3 Map showing the location of PEGASUS profiling stations.

Table 2.2-2 Nominal station location for PEGASUS profiling.

Station	Latitude	Longitude	Location Relative To Baseline
X1	26°26.3′N	78°45.3′W	right
X2	26°21.3′N	78°48.5′W	right
X3	26°16.4′N	78°51.4′W	right
X4	26°11.3′N	78°54.3′W	right
X5	26°06.5′N	78°57.1′W	right
X6	24°03.3′N	79°16.9′W	right
X7	24°01.1′N	79°22.5′W	right
X8	23°58.9′N	79°28.8′W	left
X9	23°57.2′N	79°34.1′W	right
X10	23°55.7′N	79°39.9′W	right
X11	24°03.2′N	80°29.7′W	right
X12	24°06.8′N	80°34.7′W	right
X13	24°09.9′N	80°39.0′W	right
X14	24°14.2′N	80°44.4′W	right
X15	24°16.6′N	80°48.9′W	right
X16	24°20.4′N	80°53.5′W	left
X17	24°25.2′N	80°58.3′W	right

because of the conditions actually found during the cruise. An example of a typical station distribution is shown in Figure 2.2-4.

2.2.6 Ancillary Data

2.2.6.1 Satellite Imagery

SAIC obtained daily AVHRR/HRPT imagery of the study area from the University of Miami for those periods when meaningful surface thermal gradients could be expected to occur. These were to be used in conjunction with other program data sets to help resolve and illustrate key processes affecting current, hydrographic and transport fields. Imagery plays a valuable role since it is one of the only data sets that provide essentially synoptic, area-wide coverage of a variable that reflects diagnostic aspects of the regional circulation and transport processes.

2.2.6.2 Meteorological Data

Of primary direct use in the process synthesis is wind speed and direction and hence estimates of wind stress on the water surface. Winds in the study area can be important to local dynamics in this laterally bounded channel, which rotates counterclockwise by 90° through the center of the study area. As a result of this direction change, a uniform wind field changes its orientation relative to the channel between the southern and northern SoF. The potential impact of this change in geometry is not known. Primary sources of meteorological data are shown in Figure 2.2-5.

2.2.6.3 Water Levels

Water level data provides potentially useful information in support of future modeling. In addition, recent work in this area has shown that water level gradients are fairly well correlated with transport. Water levels were measured across many of the primary and secondary channels. These may help resolve and describe key dynamic processes occurring in the study area.

Some of the water level observations were obtained from NOAA as part of their routine observational program. These were supplemented by water level observation made by this program at the offshore ends of mooring Transects B and C. Locations of key water level stations are shown in Figure 2.2-5.

2.3 Field Program Summary

2.3.1 Subsurface Currents

Subsurface current/temperature time series were provided by three different instruments:

- RDI, Acoustic Doppler Current Profiler (ADCP)
- Aanderaa RCM (4/5/7/8)
- General Oceanics (GO) NWCM/Mark II (Vector Averaging)

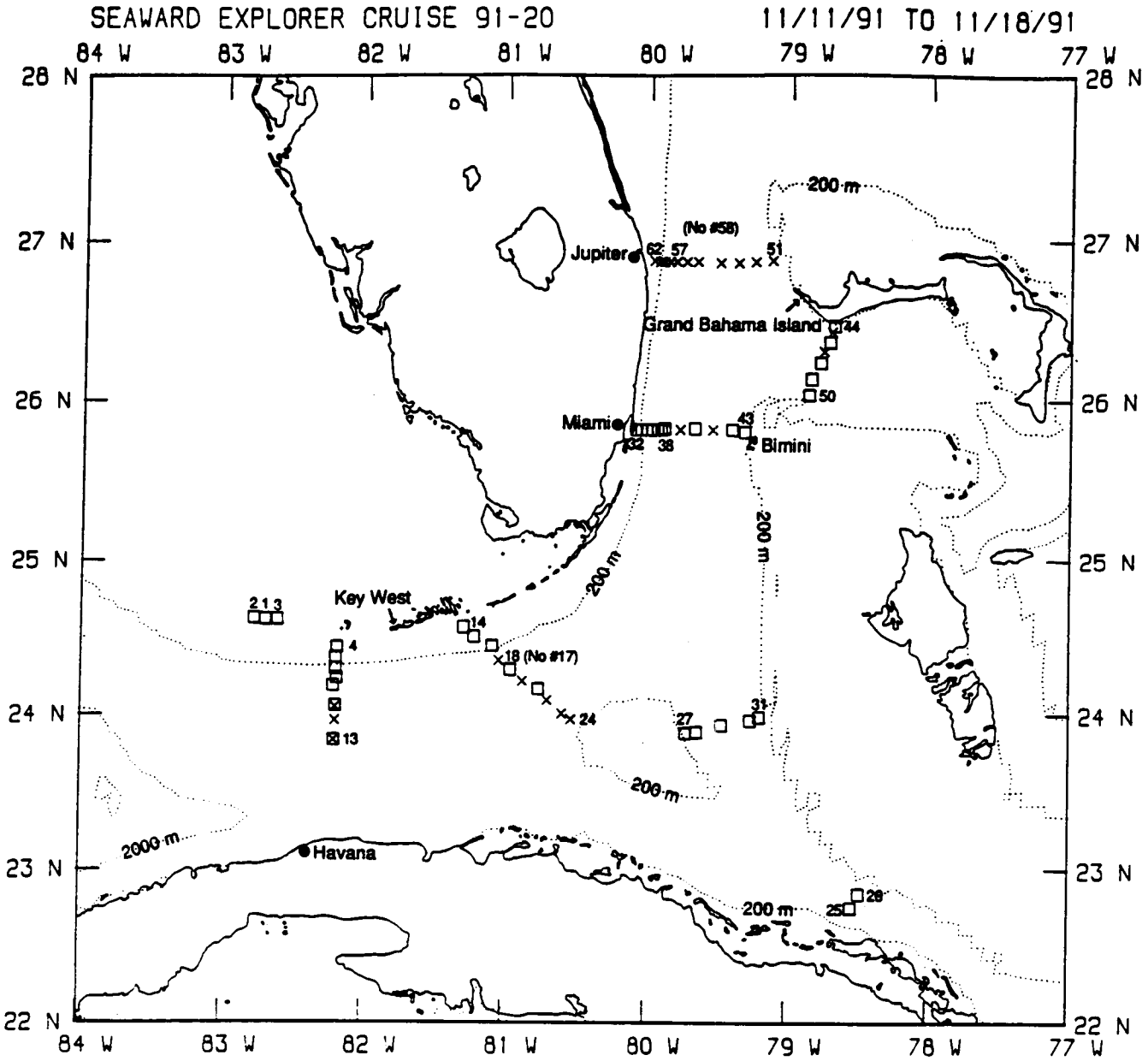


Figure 2.2-4 Map showing typical hydrographic station spacing and locations.

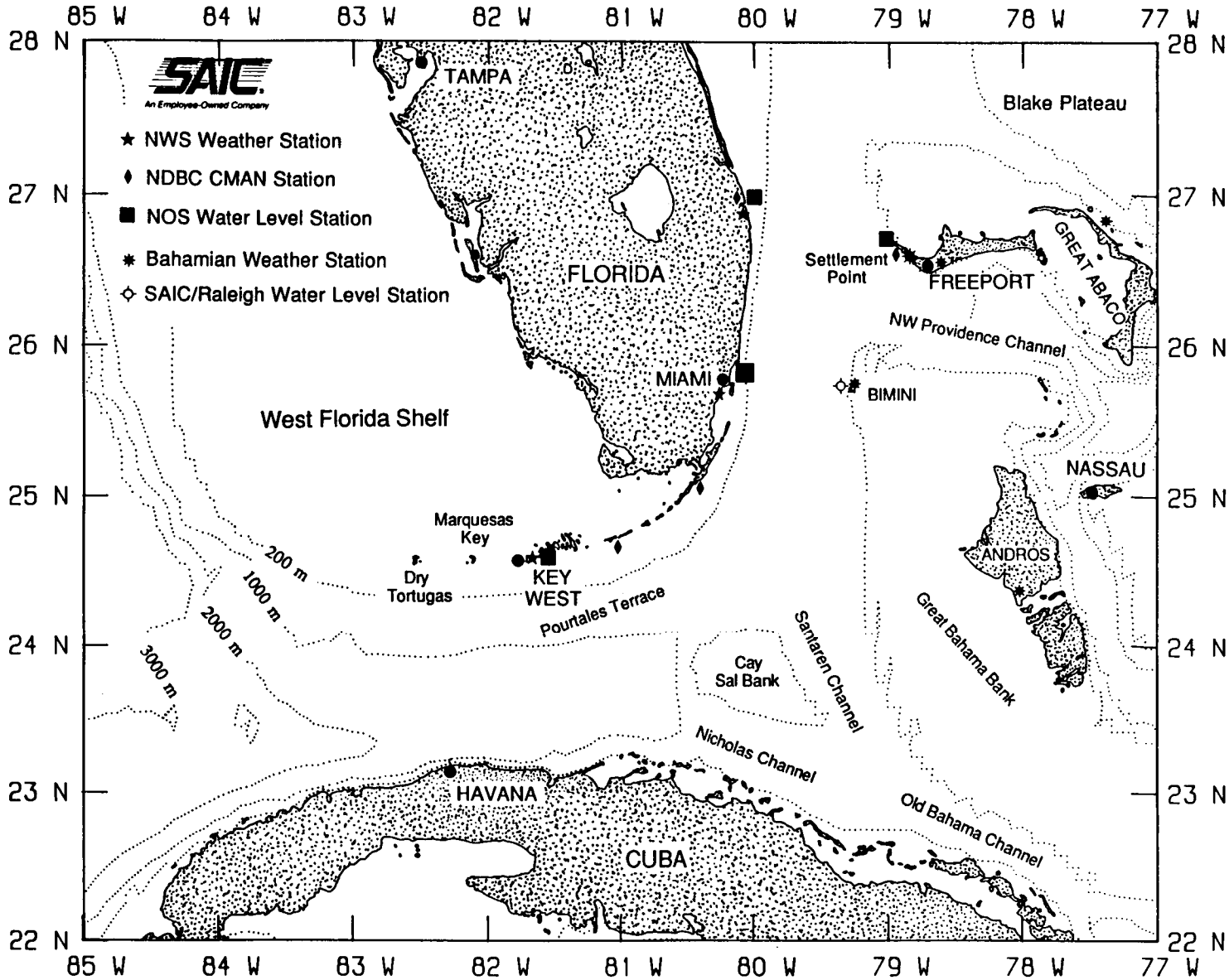


Figure 2.2-5 Map showing the location of NOAA meteorological and water level measurement sets.

The equipment was either provided by the government (GFE) or was taken from the SAIC instrument pool. Regardless of source, all equipment was maintained and calibrated according to the same procedures.

During the course of the program, equipment was on occasion moved from one position to another in response to maintenance and cruise schedule requirements. However, those locations where Aanderaas were initially deployed generally had that same type of instrument throughout the program. A similar pattern occurred for the GO current meters. The Acoustic Doppler Current Profiler (ADCP) was deployed on Mooring B3 during the first 6 months and B4 during the last three months. During months 7, 8 and 9, the ADCP was sent to the manufacturer to repair a defective tape recording unit. This resulted in replacement of the tape drive with EPROM memory units.

Figure 2.3-1 provides a timeline for "good" data for each measurement position. Table 2.3-1 shows the kind of instrument used to make each set of measurements. Since moorings were maintained on a quarterly basis, it was possible to alter the specific instrument every three months.

2.3.2 PEGASUS Profiling

During the four PEGASUS cruises, Transects B, E and F were documented a variable number of times. The general measurement dates and number of times measurements over the transect were completed for that period are shown in Table 2.3-2. These are then summed to provide an indication of the total number of transport estimates obtained. It should be reiterated that during one measurement period, successive transport estimates are probably not independent since the correlation time scale is expected to be greater than the time between sets of observations. However, since some change could occur, successive observations during the same cruise are not perfectly correlated. It is expected that conditions during successive cruises should not be interdependent and hence should provide independent estimates of transport. Clearly, the hope is that by spreading observations over different seasons, it may be possible to document transports that are substantially different.

2.3.3. Lagrangian Drifter

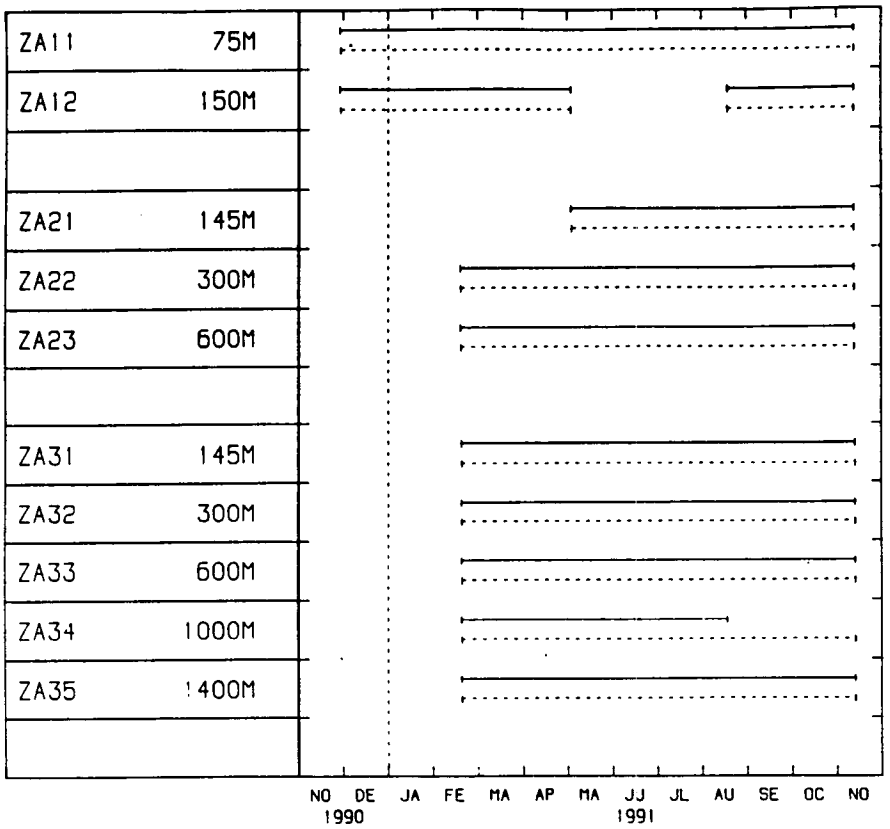
The key information (ID, deployment date and time, and deployment location) are shown in Table 2.3-3 for each group of drifters released during each mooring/hydrography cruise. Information on the trajectories is provided in subsequent sections of this report.

Note that adverse weather caused Cruise 1 (Nov/Dec, 1990, mooring deployment cruise) to be shortened so that no drifters were released. To adjust for this, six drifters were released on Cruise 2 (Feb. 1991).

2.3.4 Hydrography

CTD and XBT profiles were measured on all mooring transects. The number of profiles by kind on each transect is shown in Tables 2.3-4 for each cruise.

(a)



(b)

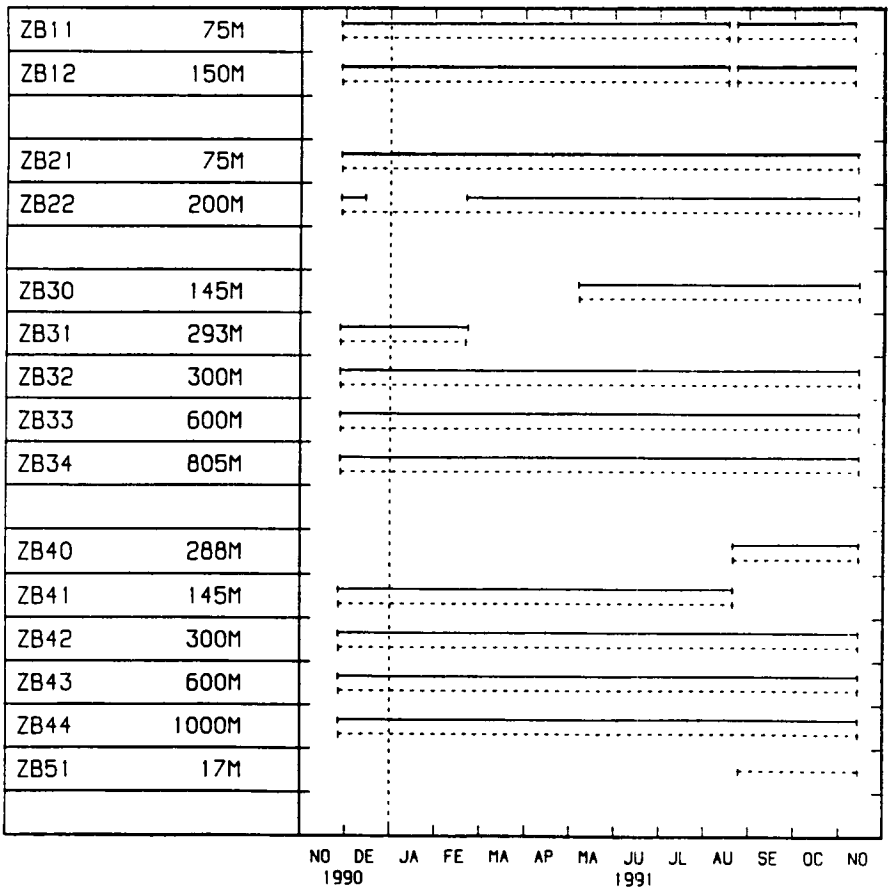
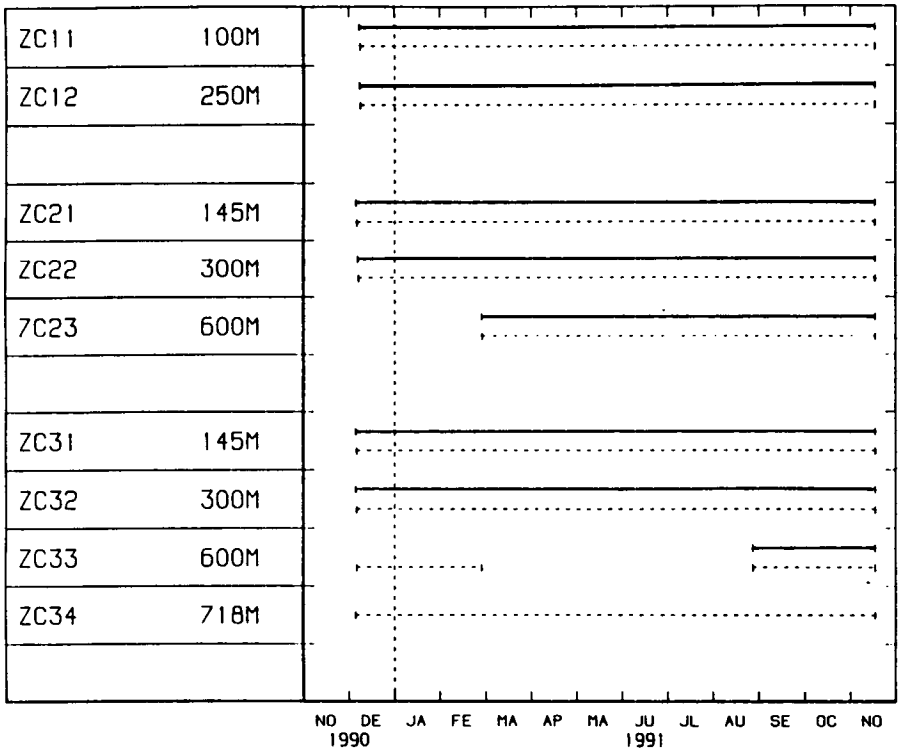


Figure 2.3-1(a,b) Timeline for subsurface observations. (a) Transect A, (b) Transect B.

(c)



(d)

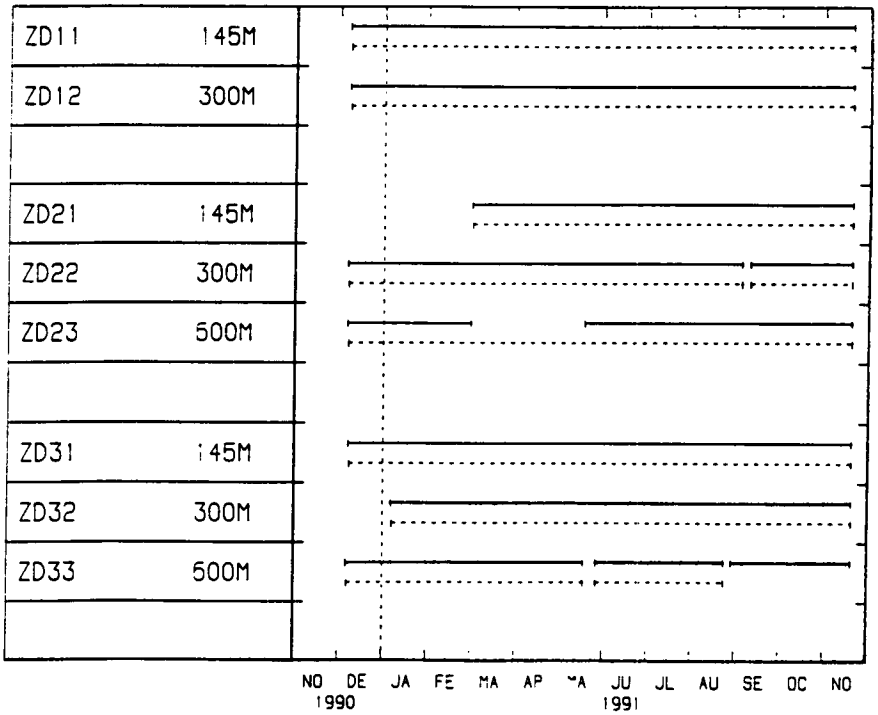
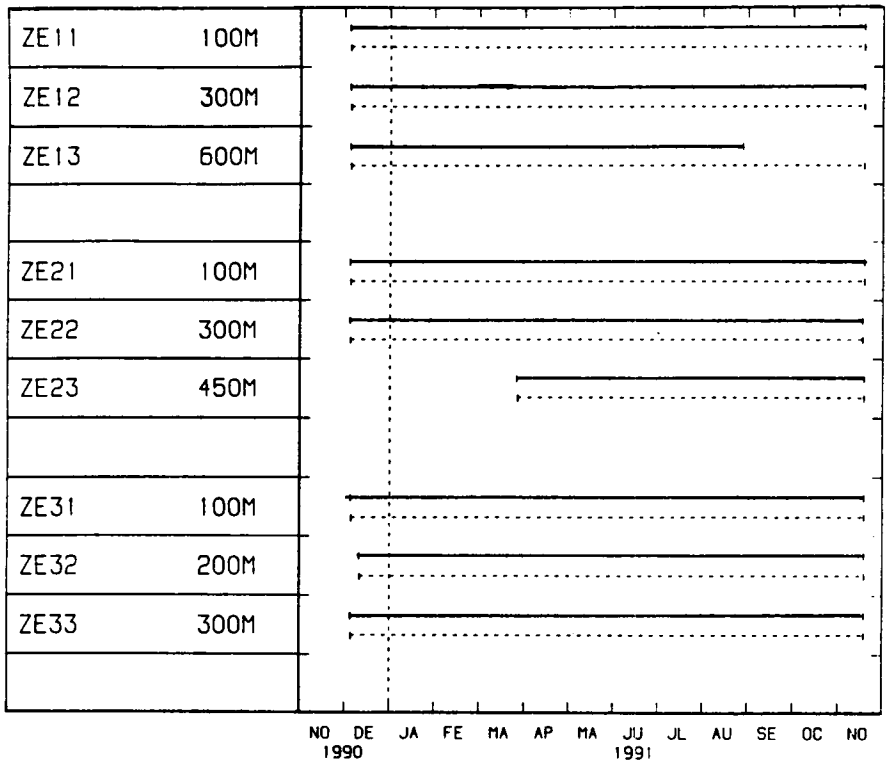


Figure 2.3-1(c,d) Timeline for subsurface observations. (c) Transect C, (d) Transect D.

(e)



(f)

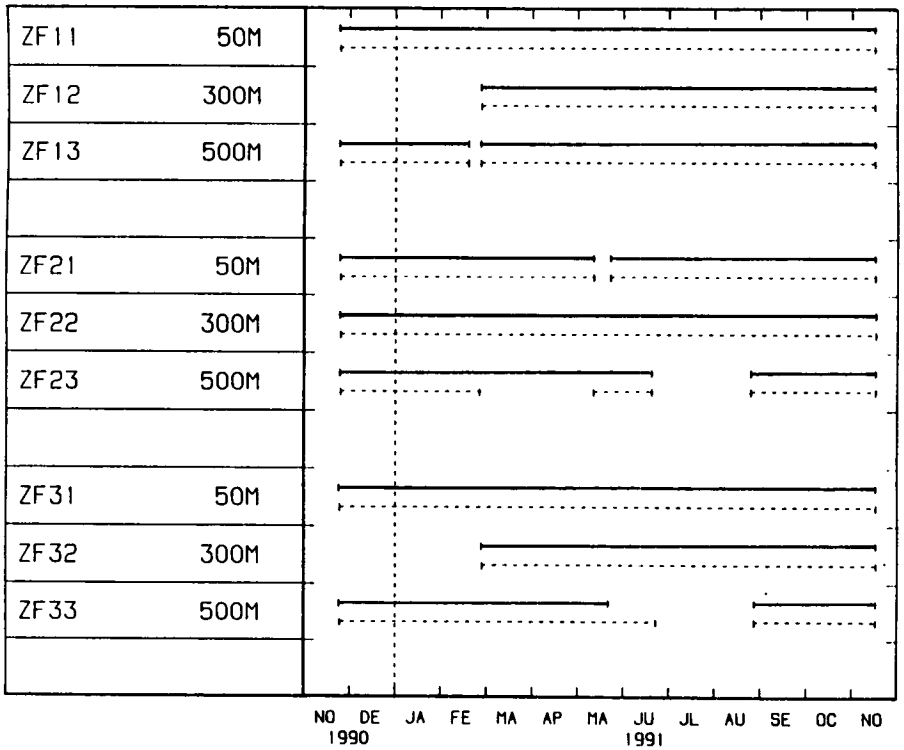
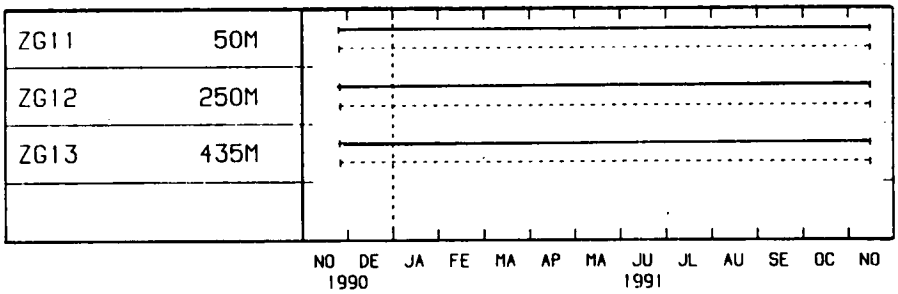


Figure 2.3-1(e,f) Timeline for subsurface observations. (e) Transect D, (f) Transect F.

(g)



(h)

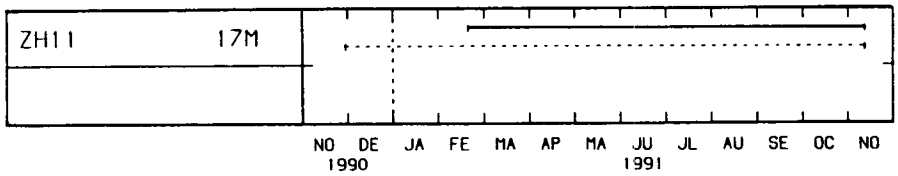


Figure 2.3-1(g,h) Timeline for subsurface observations. (g) Transect G, (h) Transect H.

Table 2.3-1 Compilation of location and types of subsurface instruments used.

MOORING	DEPTH	LATITUDE/ LONGITUDE	INSTRUMENT TYPE AND DEPTH			
			INITIAL DEPLOYMENT	FIRST ROTATION	SECOND ROTATION	FINAL DEPLOYMENT
A1	245	24°17.7'N 82°12.2'W	AA 6538* (75m) AA 6922 (150m)	AA 7262 (75m) AA 7239 (150m)	AA 7238 (75m) AA 6539 (150m)	AA 6538 (75m) AA 5676 (150m)
A2	820	24°03.2'N 82°09.7'W		GO 281* (145m) GO 311 (300m) GO 173 (600m)	GO 332 (145m) GO 264 (300m) GO 173 (600m)	GO 281 (145m) GO 276 (300m) GO 173 (600m)
A3	1500	23°49.7'N 82°11.8'W		GO 283 (145m) GO 271 (300m) GO 191 (600m) AA 7403 (1000m) AA 7404 (1400m)	GO 283 (145m) GO 271 (300m) GO 191 (600m) AA 7403 (1000m) AA 7404 (1400m)	GO 283 (145m) GO 271 (300m) GO 204 (600m) AA 7403 (1000m) AA 7404 (1400m)
B0	153	24°28.3'N 81°22.6'W	RD 382 (142m)			
B1	200	24°27.1'N 81°07.9'W	AA 7239 (75m) AA 7262 (150m)	AA 6539 (75m) AA 7238 (150m)	AA 5465 (75m) AA 5676 (150m)	AA 7594 (75m) AA 5465 (150m)
B2	320	24°18.1'N 80°57.6'W	AA 7583 (75m) AA 6536 (200m)	AA 6922 (75m) AA 6538 (200m)	AA 7239 (75m) AA 7262 (200m)	AA 7262 (75m) AA 7238 (200m)
B3	850	24°10.5'N 80°47.6'W	RD 322 (293m) GO 284 (300m) GO 192 (600m) AA 7528 (805m)	RD 322* (273m) GO 284 (280m) GO 192 (580m) AA 7528 (785m)	GO 322 (125m) GO 311 (280m) GO 192 (580m) AA 6922 (785m)	GO 328 (125m) GO 269 (280m) GO 191 (580m) AA 7528 (785m)
B4	1080	24°00.0'N 80°35.1'W	GO 288 (145m) GO 333 (300m) GO 156 (600m) AA 7364 (1000m) AA 1330 (1078m)	GO 379 (145m) GO 333 (300m) GO 156 (600m) AA 7582 (1000m)	GO 333 (145m) GO 284 (300m) GO 156 (600m) AA 7582 (1000m)	RD 322 (288m) GO 332 (300m) GO 192 (600m) AA 7582 (1000m)
B5	18	23°58.0'N 80°26.8'W			GO 055 (17m)	AA 567 (17m)

Table 2.3-1 Compilation of location and types of subsurface instruments used. (Cont.)

MOORING	DEPTH	LATITUDE/ LONGITUDE	INSTRUMENT TYPE AND DEPTH			
			INITIAL DEPLOYMENT	FIRST ROTATION	SECOND ROTATION	FINAL DEPLOYMENT
C1	320	25°48.3'N 79°51.8'W	GO 256 (100m) GO 330 (250m)	GO 290 (100m) GO 190 (250m)	GO 256 (100m) GO 330 (250m)	GO 256 (100m) GO 380 (250m)
C2	765	25°48.5'N 79°38.7'W	GO 289 (145m) GO 378 (300m) GO 185 (600m)	GO 256 (145m) GO 330 (300m) GO 272 (600m)	GO 290 (145m) GO 272 (300m) GO 275 (600m)	GO 289 (145m) GO 297 (300m) GO 198 (600m)
C3	720	25°48.3'N 79°23.8'W	GO 290 (145m) GO 339 (300m) GO 190 (600m) AA 1329 (718m)	GO 289 (145m) GO 378 (300m) GO 185 (600m) AA 1329 (719m)	GO 289 (145m) GO 378 (300m) GO 127 (600m) AA 1329(719m)	GO 290 (145m) GO 275 (300m) GO 272 (600m) AA 1329 (719m)
D1	350	26°49.5'N 79°48.2'W	GO 380 (145m) GO 198 (300m)	GO 380 (145m) GO 198 (300m)	GO 380 (145m) GO 181 (300m)	GO 322 (145m) GO 181 (300m)
D2	770	26°51.0'N 79°29.8'W	GO 328 (145m) GO 200 (300m) GO 075 (600m)	GO 328 (145m) GO 200 (300m) GO 075 (600m)	GO 331 (145m) GO 200 (300m) GO 075 (600m)	GO 331 (145m) GO 344 (300m) GO 195 (600m)
D3	630	26°51.1'N 79°14.0'W	GO 331 (145m) GO 204 (300m) GO 099 (600m)	GO 331 (145m) GO 204 (300m) GO 181 (600m)	GO 344 (145m) GO 195 (300m) GO 153 (600m)	GO 280 (145m) GO 200 (300m) GO 185 (600m)
E1	775	26°20.8'N 78°42.6'W	GO 280 (100m) GO 276 (300m) GO 181 (600m)	GO 293 (100m) GO 266 (300m) GO 339 (600m)	GO 291 (100m) GO 339 (300m) GO 222 (600m)	GO 293 (100m) GO 268 (300m) GO 190 (600m)
E2	510	26°13.9'N 78°46.2'W	GO 291 (100m) GO 344 (300m) GO 264 (450m)	GO 291 (100m) GO 344 (300m) GO 222 (450m)	GO 280 (100m) GO 266 (300m) GO 190 (450m)	GO 298 (100m) GO 339 (300m) GO 222 (450m)
E3	395	26°07.2'N 78°49.9'w	GO 293 (100m) GO 266 (200m) GO 222 (300m)	GO 280 (100m) GO 276 (200m) AA 7364 (304m)	GO 293 (100m) GO 268 (200m) AA 7364 (304m)	GO 291 (100m) GO 266 (200m) AA 6536 (304m)

Table 2.3-1 Compilation of location and types of subsurface instruments used. (Cont.)

MOORING	DEPTH	LATITUDE/ LONGITUDE	INSTRUMENT TYPE AND DEPTH			
			INITIAL DEPLOYMENT	FIRST ROTATION	SECOND ROTATION	FINAL DEPLOYMENT
F1	550	23°51.8'N 79°36.9'W	GO 268 (50m) GO 269 (300m) AA 5465 (500m)	GO 298 (50m) GO 297 (300m) AA 6536 (500m)	GO 299 (50m) GO 274 (300m) AA 6537 (500m)	GO 288 (50m) GO 333 (300m) AA 6537 (500m)
F2	560	23°55.0'N 79°26.3'W	GO 299 (50m) GO 272(300m) AA 5676 (500m)	GO 274 (50m) GO 275 (300m) AA 7402 (500m)	GO 288 (50m) GO 335 (300m) AA 6536 (500m)	GO 379 (50m) GO 099 (300m) AA 7583 (500m)
F3	575	23°57.0'N 79°14.5'W	GO 274 (50m) GO 275 (300m) AA 7402 (500m)	GO 299 (50m) GO 268 (300m) AA 6537 (500m)	GO 298 (50m) GO 297 (300m) AA 7402 (500m)	GO 299 (50m) GO 274 (300m) AA 7239 (500m)
G1	495	22°44.5'N 78°31.8'W	GO 298 (50m) GO 297 (250m) AA 6537 (435m)	GO 335 (50m) GO 288 (250m) AA 7583 (435m)	GO 379 (50m) GO 099 (250m) AA 7583 (435m)	GO 284 (50m) GO 311 (250m) GO 156 (435m)
H1	26	26°36.4'N 82°41.8'W	AA 7594 (17m)	GO 269 (16m)	GO 269 (16m) AA 7594 (16m)	GO 264 (16m)

* Instrument manufacturer and serial number
AA = Aanderaa
GO = General Oceanics
RD = RDI, ADCP

Table 2.3-2 PEGASUS Profiling data return by Cruise.

Cruise No./ Date	PROFILES/TRANSECTS			
	Transect E	Transect F	Transect B	Total
CRUISE 1 (Nov. 19-29, 1990)	10/2	5/1	14/2.5	29/5.5
CRUISE 2 (Feb 23 - March 2, 1991)	10/2	21/4	24/3.5	55/9.5
CRUISE 3 (May 28 - June 2, 1991)	____	20/4	13/3.5	33/7.5
CRUISE 4 (Sept. 6-12; Sept. 15, 1991)	20/4	28/4	27/4	75/12
TOTAL	40/8	74/13	78/13.5	192/34.5

Table 2.3-3a ARGOS drifter deployments during the first mooring rotation cruise.

Drifter No.	Deployment Location	Date (GMT) Deployed	Time (GMT) Deployed
12955 (near A3)	23°50.29′N 82°12.11′W	02/17/91	2118
12956 (near A2)	24°03.03′N 82°10.08′W	02/18/91	0404
12958 (near A1)	24°18.01′N 82°12.68′W	02/18/91	0820
12957 (inshore of A1)	24°25.02′N 82°11.43′W	02/18/91	0926
12959 (near H1)	24°37.01′N 82°41.72′W	02/18/91	1927
12960 (near G1)	22°46.56′N 78°33.03′W	02/23/91	2028

Note: All drifters were Technocean ministar drifters drogued at 15 meters.

Table 2.3-3b ARGOS drifter deployments during the second mooring rotation cruise.

Drifter No.	Deployment Location	Date (GMT) Deployed	Time (GMT) Deployed
12961 (Near A3)	23°50.45'N 82°11.33'W	05/04/91	1639
12962 (upstream of B4)	23°35.82'N 80°48.42'W	05/09/91	0436
12963 (Nicholas Channel)	23°14.83'N 79°42.92'W	05/09/91	1325

Note: All drifters were Technocean ministar drifters with the bottom of the drogue at 7.5 meters, and the drogue center at 6.25 meters.

Table 2.3-3c ARGOS drifter deployments during the third mooring rotation cruise.

Drifter No.	Deployment Location	Date (GMT) Deployed	Time (GMT) Deployed
12964 (near A3)	23°50.20'N 82°11.51'W	08/18/91	2207
12965 (upstream of B4)	23°35.72'N 80°48.39'W	08/23/91	0347
12966 (Nicholas Channel)	23°14.72'N 79°42.55'W	08/23/91	1035

Note: All drifters were Technocean ministar drifters with the bottom of the drogue at 7.5 meters, and the drogue center at 6.25 meters.

Table 2.3-3d ARGOS drifter deployments during the mooring recovery (final) cruise.

Drifter No.	Deployment Location	Date (GMT) Deployed	Time (GMT) Deployed
12967 (upstream of B4)	23°35.70'N 80°48.40'W	11/14/91	0249
12968 (Nicholas Channel)	23°14.74'N 79°42.63'W	11/14/91	1033
12969 (NW Providence Channel)	26°10.00'N 78°36.00'W	11/18/91	0330

Note: All drifters were Technocean ministar drifters with the bottom of the drogue at 7.5 meters, and the drogue center at 6.25 meters.

Table 2.3-4. Summary listing of hydorgraphic profiles by transect, cruise and type.

Transect	Cruise 1		Cruise 2		Cruise 3		Cruise 4		Cruise 5	
	Station Nos.	CTD/ XBT	Station Nos.	CTD/ XBT	Station Nos.	CTD/ XBT	Station Nos.	CTD/ XBT	Station Nos.	CTD/ XBT
A	-	-	1-9	1/8	1-9	7/12	4-13	7/3	4-14	7/3
B	9-18	7/3	13-24	9/3	13-16 18-24	7/4	14-19 21-25	8/3	14-16 18-24	5/5
C	27-30 43-50	8/4	57-68	8/4	32-34 36-44	8/4	33-44	10/2	32-43	10/2
D	31-42	0/12	36-56	1/20	52-63	0/12	52-62	0/11	51-57 59-62	0/11
E	22-26	1/4	31-35	5/0	45-51	5/2	45-51	5/2	44-50	5/2
F	1-7	5/2	26-30	5/0	27-31	5/0	28-32	1/4	27-31	5/0
G	8	1/0	25	1/0	25-26	2/0	26-27	1/1	25-26	2/0
H	19-21	3/0	10-12	0/3	10-12	0/3	1-3	3/0	1-3	3/0
Total	50	22/28	68	30/38	61	34/27	61	35/26	60	37/23

2.3.5 Ancillary Data

2.3.5.1 Satellite Imagery

Imagery was only of use to the study when reasonable sea surface temperature (SST) gradients (>1°C) could be expected in the study area. As proposed, this occurred only during the cool months of approximately November through April.

To implement the proposed atmospheric corrections, it is necessary to use information from Channels 4 and 5, which was provided only by NOAA-11 during the period of interest. This satellite passed over the study area twice a day--one daylight and one night pass. A total of 486 High Resolution Picture Transmission (HRPT) images with nominal 1.1 km pixel resolution were received and processed. This total is greater than expected for twice a day coverage over the indicated time period; however, at various times more than one pass was needed to create a single image for the entire study area. Of the 486 images, 254 were identified as providing possibly useful coverage. Cloud cover over all or a significant part of the study area was the major reason that an image was not used.

2.3.5.2 Meteorological Data

Meteorological variables were obtained from the following locations:

CMAN STATIONS

- SPGF1 - Settlement Point, Bahama Islands
- LKWF1 - Lakeworth, FL
- MLRF1 - Molasses Reef, FL
- SMKF1 - Sombrero Key, FL

NWS STATIONS

- W. Palm B. - West Palm Beach, FL
- Miami
- Key West

At the time of this report the complete year-long time series of data requested from NOAA are not yet available. The time lines for the records received are shown in Figure 2.3-2.

2.3.5.3 Water level Data

Water levels were obtained for the locations listed below and shown in Figure 2.2-5. As with the meteorological data, complete records are not yet available from NOAA/NOS. The duration of records received are as indicated in Figure 2.3-3.

- STLMT PT - Settlement Point, Bahama Islands
- LK WORTH - Lake Worth, FL
- HAULOVER - Haulover Pier (Miami), FL
- KEY WEST - Key West, FL

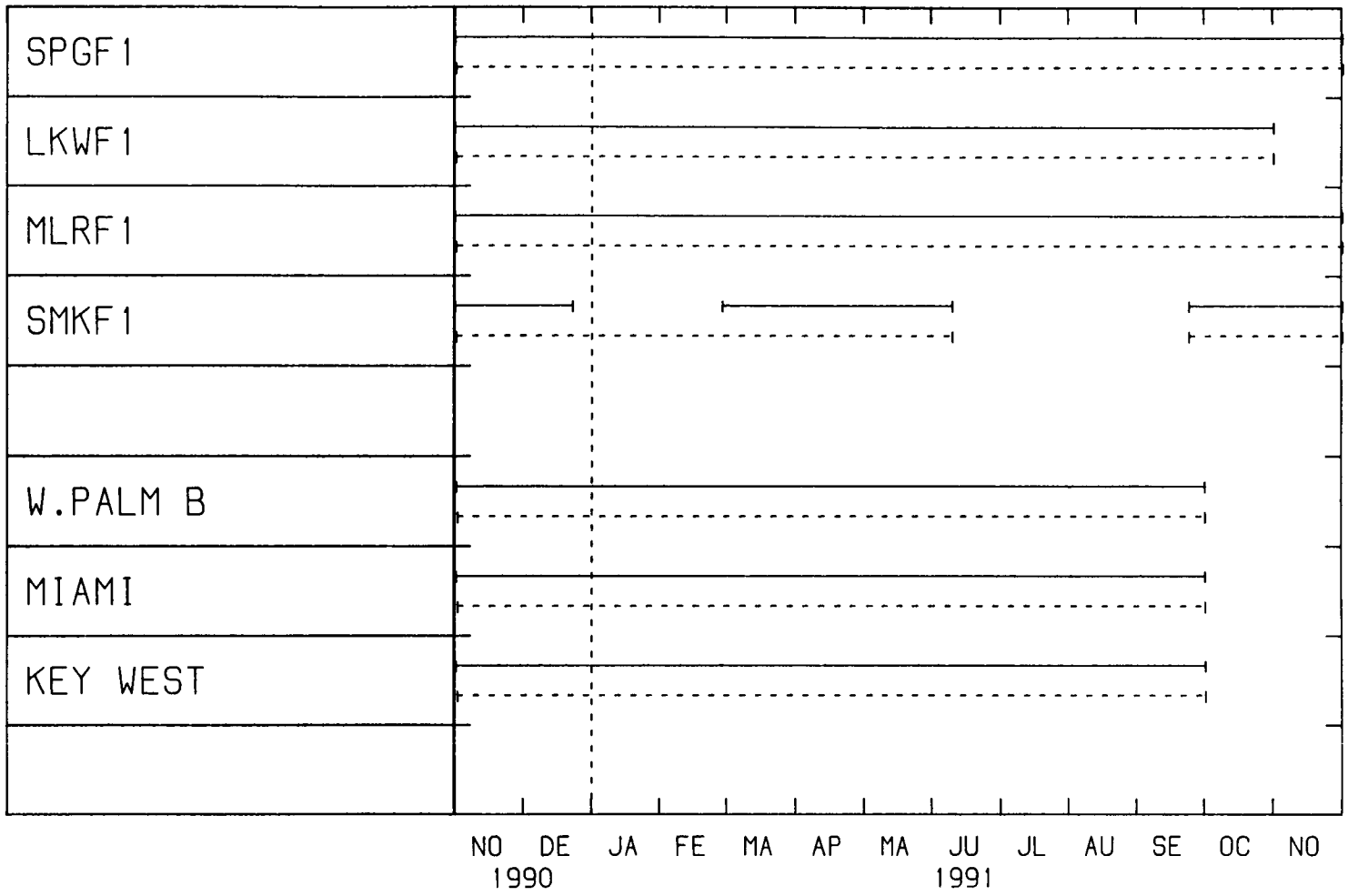


Figure 2.3-2 Timelines for meteorological data received to date.

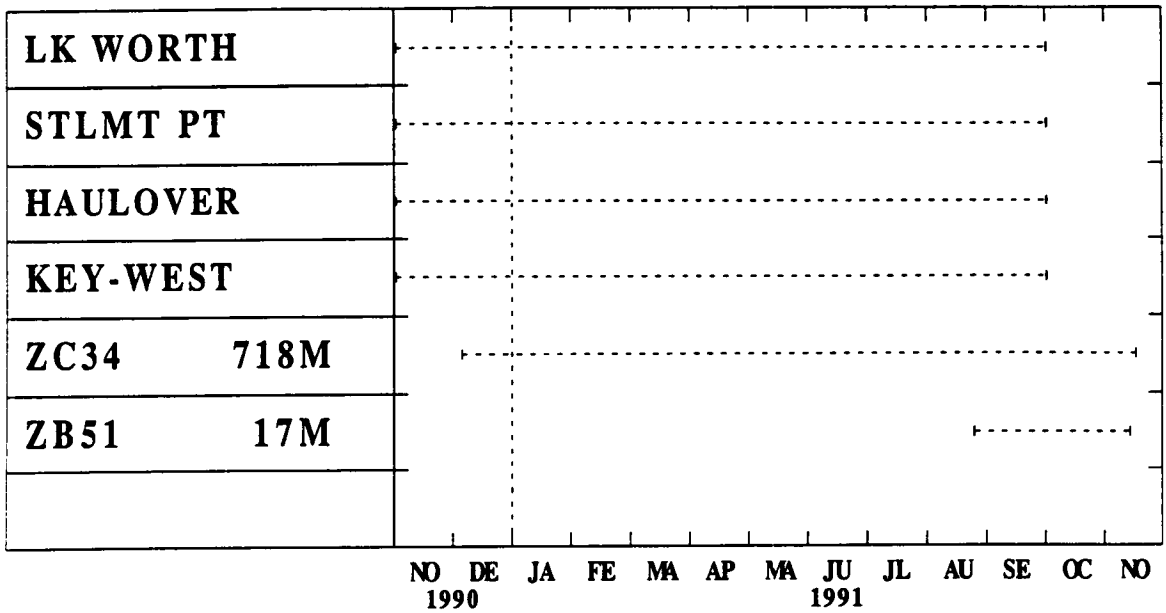


Figure 2.3-3 Timelines for water level data received or measured to date.

III. CURRENT VELOCITY DATA

3.1 Introduction

This chapter describes the following:

- instrumentation used (Section 3.2)
- data processing procedures (Section 3.3), and
- details of measurement locations

for the various methods by which water velocities were measured.

3.2 Instrumentation

3.2.1 Current Meters

3.2.1.1 Aanderaa Recording Current Meter (RCM)

Aanderaa Model RCM-5 current meters, all equipped with temperature and some with conductivity sensors, were used to provide some of the subsurface in-situ data. These instruments record speed by counting the number of turns of the rotor over the period of sampling. Direction is registered only at the time when data are recorded on the 1/4" reel-to-reel magnetic tape. The RCM-5 is mounted in a gimbled-vane assembly to permit up to 25 degrees of mooring inclination, and it is capable of detecting speeds up to 250 cm/sec. Instrument specifications are given in Table 3.2-1. The RCM-5 can store up to six months of data at the recommended 30-minute sampling rate.

These instruments were used at the mid- to lower levels of the deeper moorings, and/or at the upper level of the U.S. shelf/slope moorings along Transects A and B. It is noted that at all locations the instrument was deep enough so that it would not be subjected to data biasing from wave action. These instruments are fairly easy to maintain, and data are read from tape to a PC with an Aanderaa Model 2650 Tape Reader.

3.2.1.2 General Oceanics (GO), Nisken Winged Current Meter (NWCM)

Two versions of the General Oceanics NWCM, the MkI and MkII, were used. They are nearly identical in external appearance, except that the MkII has the added capabilities, besides providing vector average velocity and temperature, of being able to measure conductivity and pressure if appropriate sensors are added. The current meter itself is a solid state recording instrument with no external moving parts. Specifications for the Mark II are given in Table 3.2-2. The meter is attached with a swivel on a mooring standoff and hangs vertically in the absence of current. In the presence of current, the instrument is tilted downstream (Figure 3.2-1). The angle of tilt varies with the speed of the current, i.e. the greater the current, the greater the angle of tilt. The housing contains a tilt sensor (a force balanced inclinometer) for speed, a three-axis flux gate compass for direction and a thermistor for temperature.

The instrument is fitted with a wing-like structure which stabilizes and orients it in the direction of current flow. Three different wing styles are available for the following ranges: zero to 70 cm/sec, zero to 225 cm/sec and zero to 300

Table 3.2-1 Specifications of the Aanderaa RCM-4 and RCM-5 current meter.

SPECIFICATIONS:

MEASURING SYSTEM:
Self balancing bridge with sequential measuring of six channels and recording on magnetic tape. A ten bit binary word is used for each channel.
Measuring Speed: 4 seconds each channel. The channels are:

1. REFERENCE:
This is a fixed reading that acts as a control on the performance of the RCM, and also as an identification of individual instruments.

2. TEMPERATURE:
Sensor Type: Thermistor (Fenwel GB32JM19)
Wide Range: -0.34°C to 32.17°C.
Accuracy: ±0.15°C
Resolution: 0.1% of range selected.
63% Response Time: 12 seconds

3. CONDUCTIVITY:
(Optional)
Sensor Type: Inductive cell.
Range: 0 to 77 mmho/cm., (standard)
Resolution: 0.1% of range.

4. PRESSURE:
(Optional)
Sensor Type: Bourdon tube driving a potentiometer.
Range: 0-100 PSI, 0-200 PSI, 0-500 PSI, 0-1000 PSI, 0-3000 PSI, and 0-8000 PSI.
Accuracy: ±1% of range.
Resolution: 0.1% of range.
Calibration: Lowest calibrated pressure 14.24 PSI.

5. CURRENT DIRECTION:
Sensor Type: Magnetic compass with needle clamped on to potentiometer ring.
Resolution: 0.35°
Accuracy: ± 7.5° speed within 2.5 to 5 cm/sec., or 100 to 200 cm/sec. ± 5° speed within 5 to 100 cm/sec.
Maximum Compass Tilt: 12° from horizontal.

6. CURRENT SPEED:
Principle: Rotor with magnetic coupling through instrument case. The number of rotations during the period between 2 samplings is counted by an electronic counter. This counter has a pre-circuit with a choice between ten dividing factors, suited for sampling intervals from 0.5 to 180 minutes. Standard is 4 rev/count.
Range: 2.5 to 250 cm/sec.
Accuracy: ± 1 cm/sec. or ± 2% of the actual speed, whichever is greater.
Starting Velocity: 2.0 cm/sec.

CLOCK:
Type: Quartz Clock 2574.
Accuracy: Better than ± 2 sec/day within 0°C to 20°C.
Sampling Intervals: 0.5, 2, 5, 10, 15, 20, 30, 60 and 180 minutes, selected by interval selecting switch.

RECORDING SYSTEM:
Type: Reel-to-reel 1/4 inch magnetic tape.
Coding: 10 bit binary words (short and long pulses) in serial form.
Storage Capacity: 10,000 samplings using 600 feet of magnetic tape on 3 inch reels.

POWER:
Battery: 9 volts, non magnetic
Size: 63 x 50 x 80 mm.
Capacity: Sufficient for 10,000 samplings.

MOORING:
Spindle designed for 15 mm. maximum diameter wire rope. Gimbal mounting permits 25° deviation between spindle and instrument Drag Force of RCM (typical values):
2.5 kg. at 105 cm/sec.
5 kg. at 155 cm/sec
10 kg. at 195 cm/sec
20 kg. at 250 cm/sec.

DEPTH CAPABILITY

	RCM4	RCM5
	2000m	6000m

NET WEIGHT:

Recording Unit,		
in air	13.7kg	15.8kg
in water	9.2kg	11.0kg
Vane Assembly,		
in air	12.9kg	13.4kg
in water	8.1kg	8.5kg

DIMENSIONS:

Recording Unit:		
height	510mm	535mm
diameter	128mm	
Overall length	1370mm	
Overall height	750mm	
Vane Size	370mm x 1000mm	

GROSS WEIGHT:

Recording Unit	19.1kg	21.0kg
Vane Assembly	14.6kg	15.2kg

Table 3.2-2 Specifications for the General Oceanics NWCM, MkII.

Specifications

	Sensor type	Range	Accuracy	Resolution
Speed	Force-balance tilt sensor	0-300 cm/sec.	1 cm/sec.	1 cm/sec.
Direction	Three-axis flux gate compass	0-360 degrees	± 2 degrees	1 degree
Temperature	Aged linear thermistor	-5°C to +45°C	.25°C	1/64 C
Conductivity	Inductive toroid	0-75 mS/cm.	2.5 mS/cm.	1 mS/cm.
Pressure	Strain gauge	0-6000 meters	.5% of depth	.1% of depth

Time Reference: Solid-state crystal controlled oscillator: ±.1 sec/day accuracy

Measuring System: During the measuring period, signals from the sensors are digitized and then placed in the 6011 MK II memory together with the time code and the instrument serial number. The information is then shifted serially during the record period into the tape head drive circuitry.

Attachment Method: Clamp-on, motion-compensating standoff.

Sampling Interval: 10-position switch selects from 1 to 512 readings per hour.

Burst Sampling: 1, 2, 4, 8, 16, 32, readings per burst at intervals of 1, 2, 4, 8 seconds.

Data Record: 20,000 readings on Phillips-style type I cassette; 40,000 readings on Phillips-style type II cassette.

Data Translation: Model 6000 MK II Interface Unit.

Battery: Lithium Cells (2).

Battery Life: 12 months.

Activation: Turn-on switch on the outside of the pressure housing.

Operational Depth: 6000 meters (19,600 ft).

Weight in Air: 9 kg (20 lb).

Pressure Case Size: Overall length 51.4 cm (20.25 in.); Overall diameter 10.5 cm (4.125 in.).

Pressure Seal: Single O-ring, tool-free opening and sealing using General Oceanics standard plastic cord sealing system.

Exposed Material: Plastic and hard-coat anodized dichromate sealed aluminum.

WING CHARACTERISTICS

Low Speed: 0 to 70 cm/sec.
Standard: 0 to 225 cm/sec.
High Speed: 0 to 300 cm/sec.

Wings may be changed to obtain optimum results in any application. A low speed wing has more surface area than a high speed wing and is more responsive. Conversely, the smaller surface area of a high speed wing gives it a greater range.

MODEL DESIGNATION

6011 MK II

Standard: Current speed and direction. To determine the model number when ordering, add the following suffixes:

T — temperature
P — pressure
C — conductivity

i.e., a 6011 MK IITPC would have all available options.

Covered Under One or More of the Following U.S. and Foreign Patents.

3,644,811 3,182,743 3,155,174 3,242,740 3,339,417 3,372,585 3,412,496 3,425,664 3,490,012 3,499,987 3,537,062 3,688,433 3,729,656 3,793,889 3,815,422 3,836,120 3,955,412 3,971,251 3,937,070 3,970,156 3,986,636 4,026,146 4,037,477 4,091,666 4,091,676 232,922, 238,422, 248,463, 248,464, 248,465, 248,466, 248,467, 612,462

VECTOR AVERAGING

2, 4, 8, 16, or 32 samples can be vector averaged and recorded on tape, as one data point.

Vector averaging of burst samples conserves tape space, resulting in long term deployments with accurate data in wave zones.

SPECIFICATION, MODEL 6000 MK II INTERFACE UNIT

Dimensions: 18" W x 13" D x 5" H

Weight: 15 lbs.

Inputs: (1) Cassette tape (2) Test cable

Output: Digital serial bit stream

Optional: 6000 MK IIC with visual display and analog voltage output.

SPECIFICATION, MODEL 6900 COMPUTER

Based on Motorola 68000 16-bit microprocessor.

Operating Memory: 512 kbytes semiconductor

Disk Memory: 10 Mbyte

Call or write General Oceanics to place your order today. For further information, contact C.E. Casagrande or G. Williams. Sample units available to qualified buyers on a loan basis for testing and trial approval. Complete data processing services are available for a nominal fee from General Oceanics.

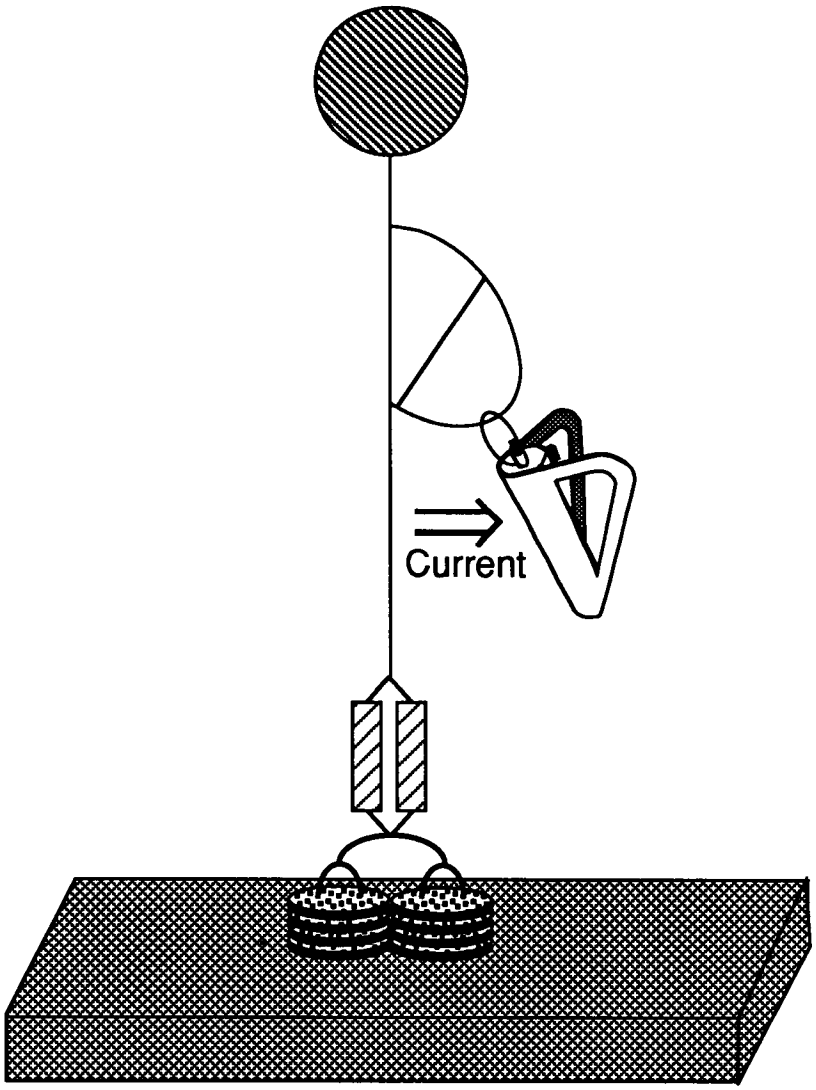


Figure 3.2-1 Depiction of the appearance and performance of a GO/NWCM.

cm/sec. The standard (zero to 225 cm/sec) wing is appropriate for most all depths, though the high speed (zero to 300 cm/sec) wing will be considered for the upper instrument on moorings expected to experience the high-speed near surface core of the Gulf Stream. In addition, as many of the GFE Mk2 instruments had pressure sensors, they were placed at the upper levels of the moorings, along with ten provided by SAIC.

During the deployment period, signals from the sensors are digitized and placed in a 64-bit parallel-in/serial-out shift register together with an associated time code and instrument serial number. The information is then shifted serially and recorded in serial form on a Phillip style magnetic tape cassette. The sampling rate is user selected, and burst sampling and vector averaging options help suppress observational noise. For this program, the Mk2 instrument would be set for vector averaging at 30 minute intervals. The actual averaging would be made over 32 subsamples collected at 2 second intervals over 64 seconds every half hour.

The cassette data are read and input directly to a computer where software calculates current velocity directly from tilt by converting tilt angle to current speed, using an empirically determined calibration curve. The three vector components of the earth's magnetic field provided by the flux-gate compass are combined in an appropriate equation to produce magnetic headings. The results are transferred to the main SAIC computer for further processing and analysis.

Some of the advantages of this instrument over more conventional mechanical instruments include the following:

- The amount of mooring tilt does not affect the instrument speed and direction sensing capabilities, and no data corrections are needed for excessive inclination of the mooring, should it occur. In particular, because of this characteristic it is planned that these instruments will be deployed at or near the tops of most moorings.

- The instrument is easily serviced at sea.

- Calibration of current measurements basically consists of a compass check since the housing dimensions and buoyant weight remain constant.

- Mooring line segmentation is not required and there are no strength requirements other than to withstand the water pressure. The instrument's operational depth is 6000 m.

3.2.1.3 RD Instruments, Acoustic Doppler Current Profiler (ADCP).

An RD Instruments, self-contained Acoustic Doppler Current Profiler Model RD-SC0150 with a 20 degree beam angle was used. This model unit is conservatively rated to collect data over a range of 250 meters but has been routinely observed to collect useable data over 350 to 400 meters (Johns, 1987). A beam angle of 20 degrees is preferred over the 30 degree standard as it permits the collection of data closer to the surface interface and permits deeper deployment of the unit, thereby reducing the impact of strong currents on the moorings and the

subsequent tilt of the profiler. For this study, data were collected over 50 bins with bin lengths of eight meters every 30 minutes. For each 30 minute sampling, 200 pings were averaged, with one ping approximately every nine seconds. Data are stored on a 60 Mbyte cartridge. Instrument specifications and a schematic are presented in Table 3.2-3 .

3.2.2 ARGOS Drifter - Technocean, Inc.

At the beginning of this program, discussions took place between this program's technical staff and a representative of the World Ocean Circulation Experiment (WOCE) Lagrangian Drifter Working Group. The objective was to use a drifter for this study which satisfied WOCE specifications. Several alternatives were identified and the Technocean "Ministar" drifter was selected.

A schematic of this drifter is shown in Figure 3.2-2. The primary drag element is a large cruciform type of structure, which is quite large, being approximately 3.3m across the diagonal. This drag element is made of ripstop nylon held in form by a series of support members, which extend out from the center of the unit. The size, geometry and relative rigidity of the structure provides a drag ratio of the order 40 between the primary drag unit and any parasitic drag from other portions of the overall drifter. For the model used, the bottom of the drag element was originally 15 meters below the water surface. This was modified after the second cruise to reduce the likelihood of grounding in shallow water. On subsequent drifters the bottom of the primary drag element was at a depth of approximately 7m. A light weight was suspended below the entire drag element to help assure that the line remained relatively vertical and that shears did not tend to "string the unit out".

The primary drag unit and bottom weight was supported by two subsurface floats. The lower float was selected so the combined buoyancy of the drag element and this float was only slightly negatively buoyant. The upper float, which contains the ARGOS transmitter, was sized so the combined net negative buoyancy of the items below and the weight of the upper float would cause the upper float to "ride low in the water". Use of this two float system helped uncouple the primary drag element from surface wave motion.

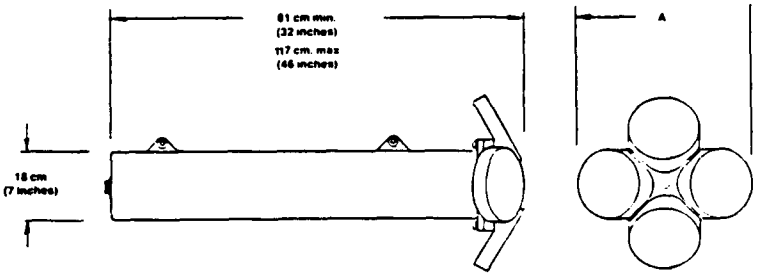
3.2.3 Direct Reading Profiling Current Meter (DRCM)

The Neil Brown Direct Reading Current Meter (DRCM) includes a cabled underwater unit and a microprocessor based deck unit. As configured for this program, these can accurately measure current velocity, temperature, conductivity, pressure and tilt. The multicomponent tilt measurement is important when the instrument is suspended from a cable, as in this program, so compensation can be made when converting measured velocity to horizontal velocity. The deck unit and underwater unit are connected by a two-conductor cable in which power is sent down the cable and an audio signal (containing the sensed information) is superimposed on the power on the uplink.

The DRCM velocity sensor, which utilizes acoustic shift techniques to sense orthogonal speed components, is capable of extremely accurate resolution. The sensed currents are corrected for sound speed variations using the sensed temperature and salinity. The recorded velocity data is vector averaged in the microprocessor unit. As selected, data and/or average vector data are converted

Table 3.2-3 Specifications and schematic for the RDI, ADCP.

RD-SC OUTLINE DRAWINGS



MODEL #	"A" DIMENSION
RD-SC/DR0075	76.2 cm (30.0 inches)
→ RD-SC/DR0150	45.7 cm (18.0 inches)
RD-SC/DR0300	40.6 cm (16.0 inches)
RD-SC/DR0600	33.0 cm (13.0 inches)
RD-SC/DR1200	21.6 cm (8.5 inches)

SPECIFICATION

ACOUSTIC CHARACTERISTICS:

Acoustic Frequency:

Model #	Acoustic Frequency
RD-SC/DR0075	75 kHz
→ RD-SC/DR0150	150 kHz
RD-SC/DR0300	300 kHz
RD-SC/DR0600	600 kHz
RD-SC/DR1200	1200 kHz

***Acoustic Beams:** 4 beam JANUS, oriented 30 degrees off vertical in 90 degree azimuth increments. (Optional beam configurations are available).

CURRENT MEASUREMENT:

Range:

Model #	"L" Units	"H" Units
RD-SC/DR0075	350 meters	700 Meters
→ RD-SC/DR0150	250 meters	400 Meters
RD-SC/DR0300	120 meters	250 Meters
RD-SC/DR0600	60 meters	100 Meters
RD-SC/DR1200	30 meters	50 Meters

Velocity Range: ± 10 meters/sec

****Number of Depth Cells:** Up to 128

****Depth Cell Length:** 1 to 32 meters

Long-term Accuracy: ± 0.2% ± 0.5 cm/sec

*****Short-term Accuracy:**

	Short-term error (cm/sec) at Depth Cell Lengths of: 1m	2m	4m	8m	16m	32m
RD-SC/DR0075	240	120	60	30	15	8
→ RD-SC/DR0150	90	45	22	11	6	3
RD-SC/DR0300	30	15	8	4	2	1
RD-SC/DR0600	10	5	3	2	–	–
RD-SC/DR1200	4	2	1	–	–	–

Direction Accuracy: ± 2 degrees (For ± 30 degrees tilt)

****Measurement Interval:** 1 to 64K pings

ECHO LEVEL MEASUREMENT:

Acoustic backscattering profiling range and cells are the same as for current measurement. Short-term accuracy is ± 3 db.

DATA RECORDING:

Type: Magnetic Cassette or Cartridge Tape

Capacity: Cassette = 1.5 Mbytes
Cartridge = 40 Mbytes

POWER:

Power Consumption: 2 watt-second energy during measurement interval, for "L" units. "H" units require 150 watts.

Internal Batteries: Lithium or optional Alkaline single or double pack

External DC Power: +5.5 to 15VDC & +12.5 to 40VDC external power may be used instead of batteries. Optional 115VAC, 50-60Hz input power is available for RD-DR models.

ELECTRICAL INTERFACE:

Data Interface Type: RS422 serial @ .3 to 19.2k baud. Optional RS423 is available.

Communications Protocol: ASCII based control commands. Leader/trailer bounded block of 8 bit bytes for current profile data.

****Output Data:** North, East & Vertical current velocity components for 128 cells. Echo Level for 128 cells. Data Validity status for each cell. Time. Water Temperature. X and Y Tilt. BIT Status. BIT Diagnostics and other data.

Input Data: Time. Standby/Measurement Mode Selection. # Depth Cells. Depth Cell Length. Ping Rate. Measurement Interval. BIT Request, and other controls.

MAINTAINABILITY:

GO/NO GO Test: Automatic end-to-end built in test (BIT) evaluates instrument operational status. BIT is performed at power turn-on, at the end of each measurement interval, and upon receipt of a BIT Request command. GO/NO GO BIT status is identified in data output and on a visual indicator.

Diagnostics Test: Automatic diagnostics tests are performed by BIT, localizing fault to plug-in module. BIT diagnostics are displayed internally and provided as output data.

PHYSICAL CONFIGURATIONS:

General: Single unit, 116.8 cm (46 inches) long, 15.2 cm (6 inches) ID pressure vessel with a transducer on one end of vessel and an I/O connector on other end. Transducer size is dependent upon the acoustic frequency. (See Outline Drawing above.) Optional pressure vessel lengths are available dependent upon battery capacity and other configuration options. An optional 90° transducer configuration is available.

Weight: In air: 38.6 kgm (85 lbs)
In water: 8.6 kgm (19 lbs)

Operating Pressure: 2000 PSI. Optional higher pressure units are available.

NOTES:

*May use any 4 or any 3 of the 4 beams for operation

**User programmable through data interface

***Short term accuracy is the statistical uncertainty in the velocity measurement for a one second measurement interval at the maximum ping rate. For longer measurement intervals the short-term error will be reduced proportional to the square root of the measurement interval (i.e. for 100 second measurement interval short term error is reduced by a factor of 10)

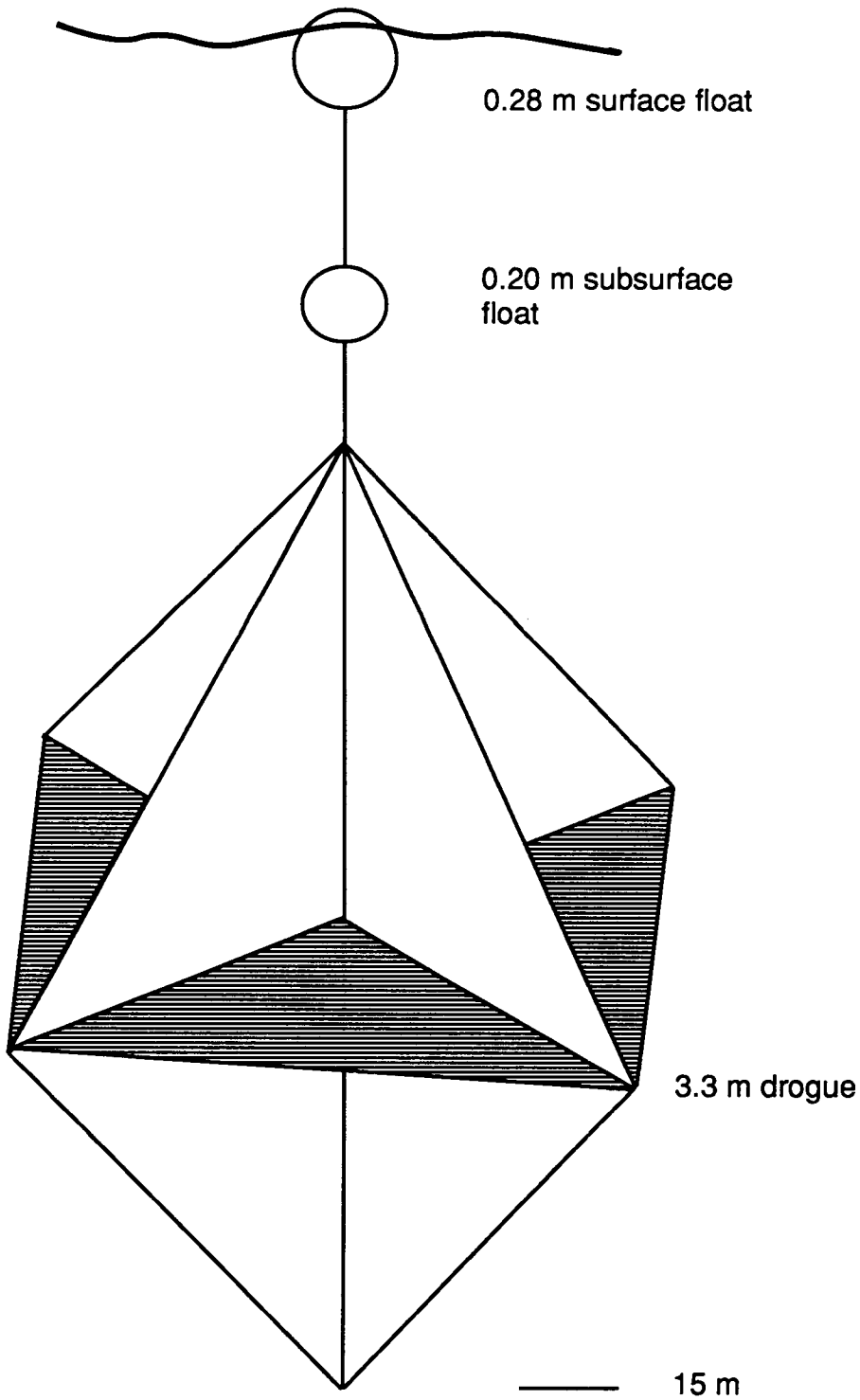


Figure 3.2-2 Schematic drawing of the Technocean ARGOS drifter.

to ASCII characters and transmitted out the RS232 connector to the user-provided recording device, which for this program was a portable computer.

A drawing of the underwater housing for the DRCM is shown in Figure 3.2-3.

3.2.4 PEGASUS Profiling Methodology

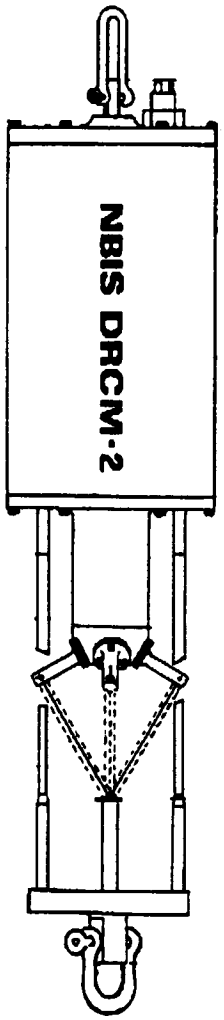
As an overview, PEGASUS technology involves tracking the location of a body by knowing at specific times its depth below the surface and its location relative to two known positions, i.e.,end points of a baseline. These data are converted to estimates of velocity as a function of depth.

In practice, use of PEGASUS involves the following: In the area where a velocity profile is desired, two transponders are placed on the bottom at known (surveyed) locations. The baseline between the two bottom units is generally short and, for high speed current regimes, oriented in the expected current direction. The PEGASUS fish, the underwater unit, contains an acoustic transmitter and receiver as well as sensors for temperature and pressure. To make the observations from which velocity profiles can be reconstructed, the fish is released at the surface. As it descends, a signal is sent to both bottom-mounted transponders. When this signal is received, a return signal is sent to the fish, which records the total acoustic travel time of the signal going to and returning from each bottom unit. Simultaneously, both temperature and pressure are also recorded. After the instrument reaches the bottom, a weight is released to change the buoyancy to slightly positive and an upcast is made. With one round trip to the bottom, two profiles can be reconstructed. The fall velocity of the fish produces one estimate of location approximately every 3 m in the vertical.

Knowing pressure, depth is estimated. The acoustic travel times to both bottom-mounted transponders provides the basis for computing the horizontal position of the fish. Temperature and pressure data can be used for accurate estimates of sound speed as a function of depth, which can be used to convert each total acoustic travel time to a distance. Knowing the time of each position estimate provides the basis for converting the differences in successive positions to horizontal velocity at the depth of the fish.

An error in velocity estimates can result from inaccuracy in determining the orientation or length of the baseline. Thus, it is important to get good determinations of the bottom transponder positions. For this study, Global Positioning System (GPS) was often available for normal operation, so that the vessel location could be estimated quite accurately. This is important because the bottom position of the transponders is determined by measuring the slant-line range from the vessel to the bottom unit from a series of positions around the transponder site. These data are solved simultaneously to produce the best estimate of the true bottom location of the transponder. Any inaccuracy in the estimated position of the vessel during this survey can translate to an unknown potential error in the bottom position estimate. Typically, such an error translates into a systematic offset between the surface estimates in the cross-channel velocity between the beginning and the end of the drop because of the predominant along-channel nature of the currents. This offset can usually be detected from a review of repeated observations and removed by adjusting the baseline length used in computations (Leaman and Vertes, 1983).

Cable to Surface



Direct Reading Current Meter - Mk II (DRCM-2)

Figure 3.2-3 Schematic of the NBIS, Direct Reading Current Meter.

3.3 Data Processing Procedures

3.3.1 General Time Series Analyses

Many of the instruments produce data in the form of a time series with sampling intervals ranging from 10 to 60 minutes. Twelve months of time series data is to be expected from each instrument/measurement site. In addition to current meter data, wind data will be received from relevant NDBC, CMAN platforms through the National Climatic Data Center in Asheville, N.C. and the National Oceanographic Data Center in Washington, D.C., respectively. Water level stations are maintained at open coastal sites by the National Ocean Survey (NOS) Sea and Lake Levels Branch. These data were obtained from NOS in Rockville, MD.

General QA procedures applied to time series data are as follows:

Checks are made for missing records or repeated records. If a record is missing, a blank record with the appropriate time is inserted into the data set. This is rarely a problem with current meter records, but is often a problem for NOS tidal height observations and NDBC buoy observations. Stop times are computed from start times, time interval and number of points and compared with the data log and time of the last record. Small gaps of one or two points due to data out of range or drop outs are normally filled by linear interpolation. If appropriate, larger gaps can be filled by more elaborate procedures involving spectral approximations. These latter techniques are not usually performed during data validation.

The filling of data gaps and removal of outliers is performed with a versatile user-friendly SAIC-developed program (BINFIX) which allows interactive searching and editing of spurious data points and the filling of gaps. The program makes extensive use of interactive graphics and allows linear interpolation over small gaps of one or two points or cubic splines under tension with nodes controlled by the analyst for interpolation of slightly larger gaps.

A schematic representation of the various steps involved in processing both Aanderaa and GO current meters is shown in Figure 3.3-1 and 3.3-2 respectively.

3.3.2 ARGOS Drifters

As part of preparation for a cruise, each drifter to be released was turned on and an end-to-end quality control check made by retrieving transmitted temperature and locations while the drifter was at a fixed and known location. When completed, each drifter was turned off until a day prior to release. At that time, it was again turned on and another performance check made. On release of a properly functioning drifter, the time and location were noted, and this information was given to those involved in data retrieval. All drifters worked properly for all or a substantial portion of the tracking period.

During tracking, all data were retrieved daily. Generally at the end of each week a cumulative plot of position information was made on a map showing local bathymetry. Prior to this, all positions and temperature values were evaluated for duplication and realism, in speed primarily, and by using the ARGOS data quality code. Apparent outliers were evaluated and, if determined to be inaccurate, discarded. By this means, only positions in which there was confidence were entered into the Lagrangian data base and used in subsequent

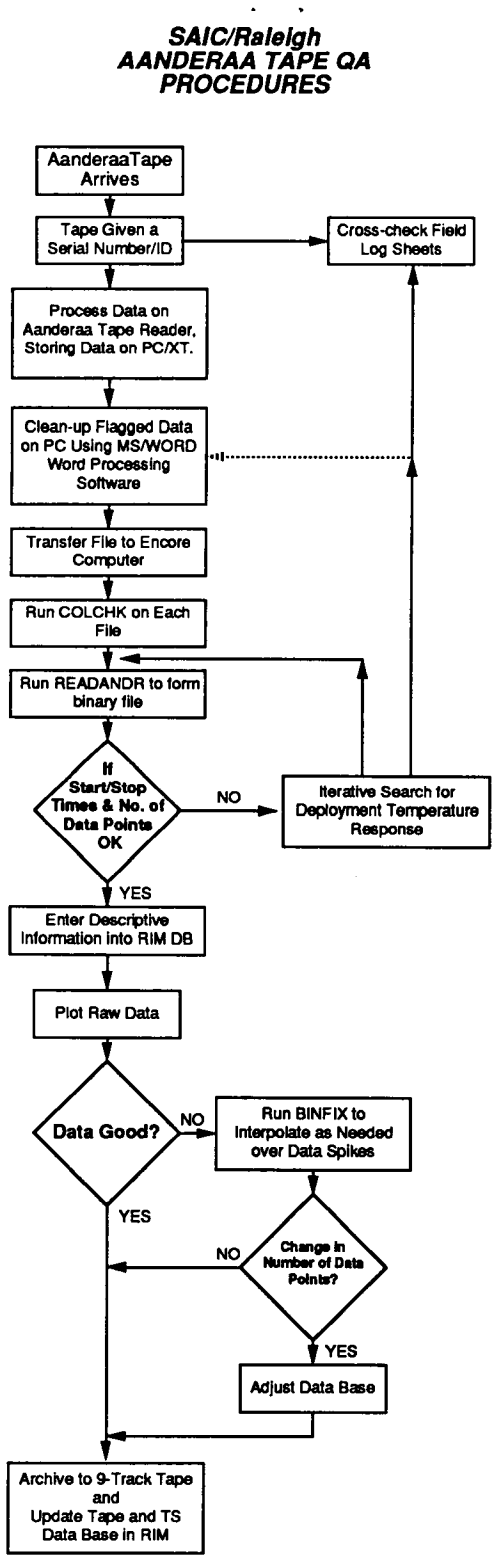


Figure 3.3-1 Schematic showing the processing sequence for data from Aanderaa RCMs and WLR.

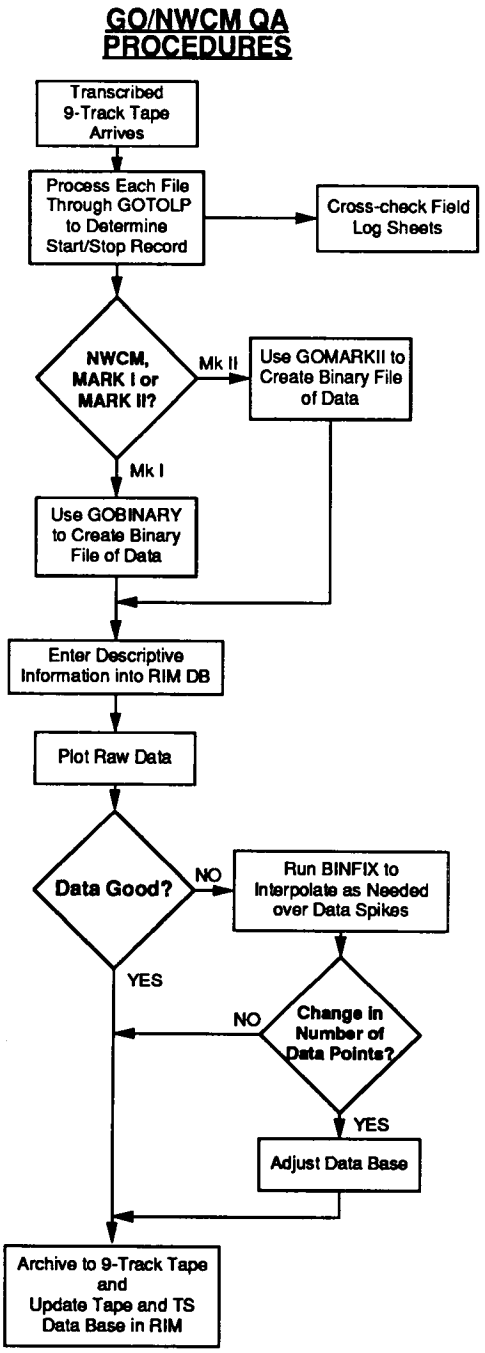


Figure 3.3-2 Schematic showing the processing sequence for data from the GO/NWCM, MkII.

program phases. All raw data is retained if there is a need to reevaluate trajectories. The quality controlled but raw trajectories are based on locations determined at irregular times. For a more useful presentation, N-S and E-W positions can separately be smoothed using a spline under tension. The resulting smoothed data is resampled at regular, user-determined intervals and the component positions recombined to provide a smoothed trajectory with position indicated at a constant time increment. Those same position data can then be used to compute velocity over the time increment selected.

An example of data products that can be created to show drifter-derived circulation and velocity patterns is shown in Figure 3.3-3(a,b,c).

3.3.3 PEGASUS Profiles

While a profile is being measured, raw data are recorded on the PEGASUS fish every 8 or 16 seconds as 16-bit binary words for pressure, temperature, and an acoustic travel time (PEGASUS-transponder round-trip) for each of the two bottom transponders. Once PEGASUS is back on board the vessel, these data are transferred from its internal RAM to a 3 1/2" disk file on an HP 9816 mini-computer.

To process a drop, pressure data are scanned to determine the first and last points for the down and up portions of the drop. A low-order polynomial is fitted to pressure over each portion to edit out any bad pressure values, and pressure counts are converted to scientific units (decibars). A similar procedure is carried out with temperature.

Finally, the count values (equivalent to seconds if divided by 10,000) for round-trip travel time in each of the two travel-time channels are edited. This is done for each channel by scanning through the data in segments, plotting them on the CRT, doing low-order fits to the data segment, and determining if any points are significantly (e.g. >two standard deviations) off the curve, in which case they are replaced by values determined by the fitted curve. The data (calibrated temperature/pressure and the two travel times) from the above procedures are output to separate HP 9816 files for the up and down portions. These data are input to a second program, which determines the spatial positions of the profiler in a transponder-based coordinate system by applying harmonic sound speeds computed using PEGASUS temperature and (if available) other (e.g. CTD salinity) data to convert travel time to ranges from each transponder. This, together with pressure, gives spatial position. The horizontal positions are then fitted to a running (usually 7-point) least-squares-fit straight line, whose slope is the horizontal velocity at the depth of the center point in the fit. The horizontal velocity components in the transponder-based coordinate system (parallel and perpendicular to the baseline) are rotated to geographic (east, north) components. Finally, the temperature, pressure and horizontal velocity data are interpolated to equally spaced (every 10 m) depths.

3.3.4 Surface Currents

The basic data received at the end of a cruise was a series of ship positions at known times and a corresponding vector averaged current measured by the DRCM during the same time. By knowing the ship motion and hence velocity, it can be vectorially subtracted from the DRCM-measured velocity to estimate the local near surface currents. Prior to the study an estimate was made of the measurement

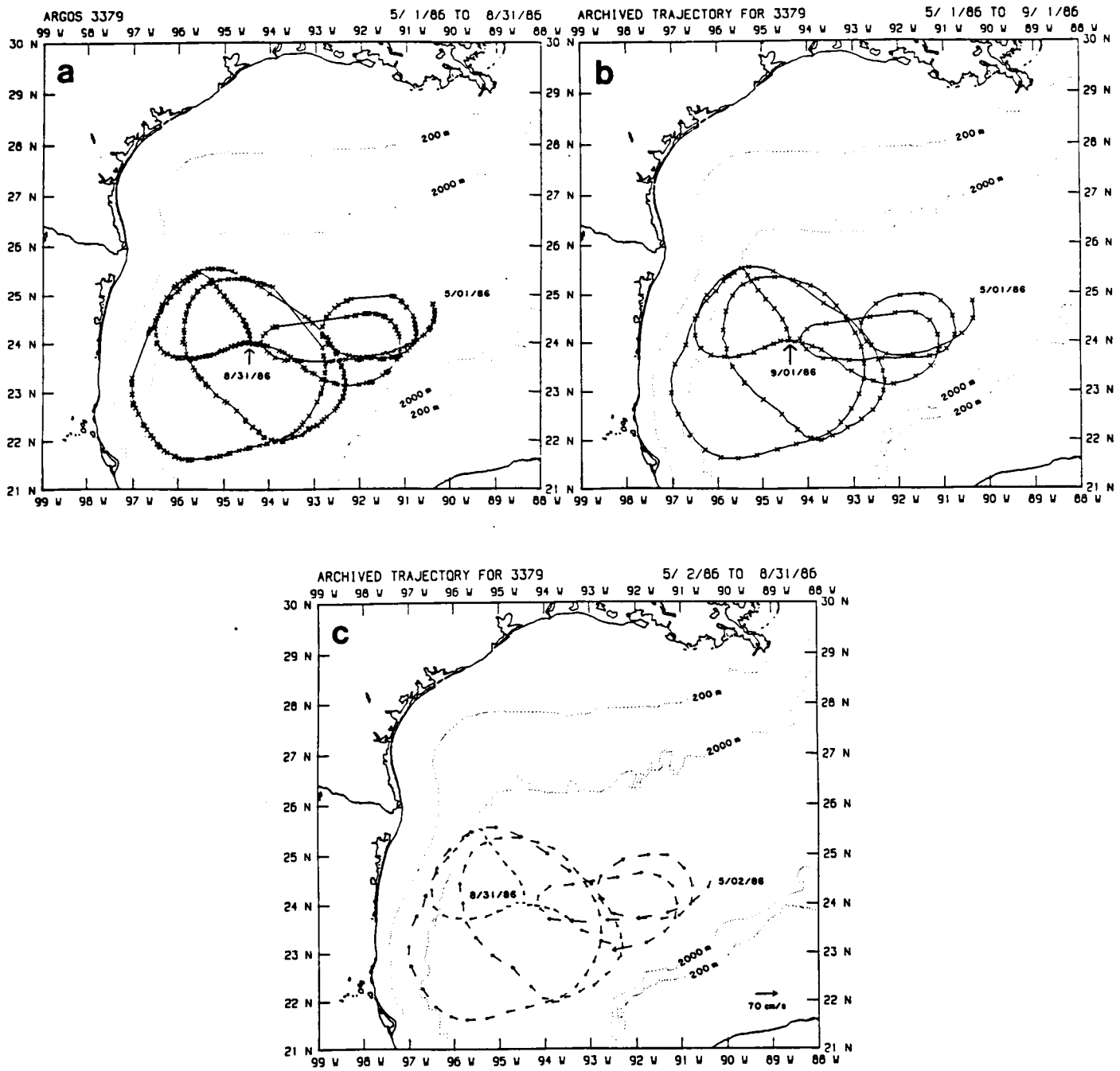


Figure 3.3-3 Illustration of data presentation for (a) raw but QA'ed data, (b) spline smoothed trajectories with crosses every 24 hours, (c) scaled vectors which graphically present the mean daily velocity of the drifter.

duration required to achieve a desired absolute or relative accuracy. The results of this are shown graphically in Figure 3.3-4.

Processing of the data was more "hands on" since durations and speeds changed with location and time. The general processing sequence described above is iteratively applied to successive estimates of ship motion and measured currents. For these data a realism and consistency check was made for each estimate.

3.4 Measurement Locations and Data Return Summary

3.4.1 Subsurface Currents

The approximate mooring locations were presented previously in Figure 2.2-1. Specific locations and depth for each three-month deployment period are given in Table 2.3-1. The data return timeline for the concatenated records for the complete year is shown in Figure 2.3-1. A tabular representation of data return is given in Table 3.4-1.

3.4.2 ARGOS Drifters

The deployment locations and dates are shown in Tables 2.3-3. Trajectories and velocities of the various drifters while in the study area are given in Figures 3.4-1 through 4.

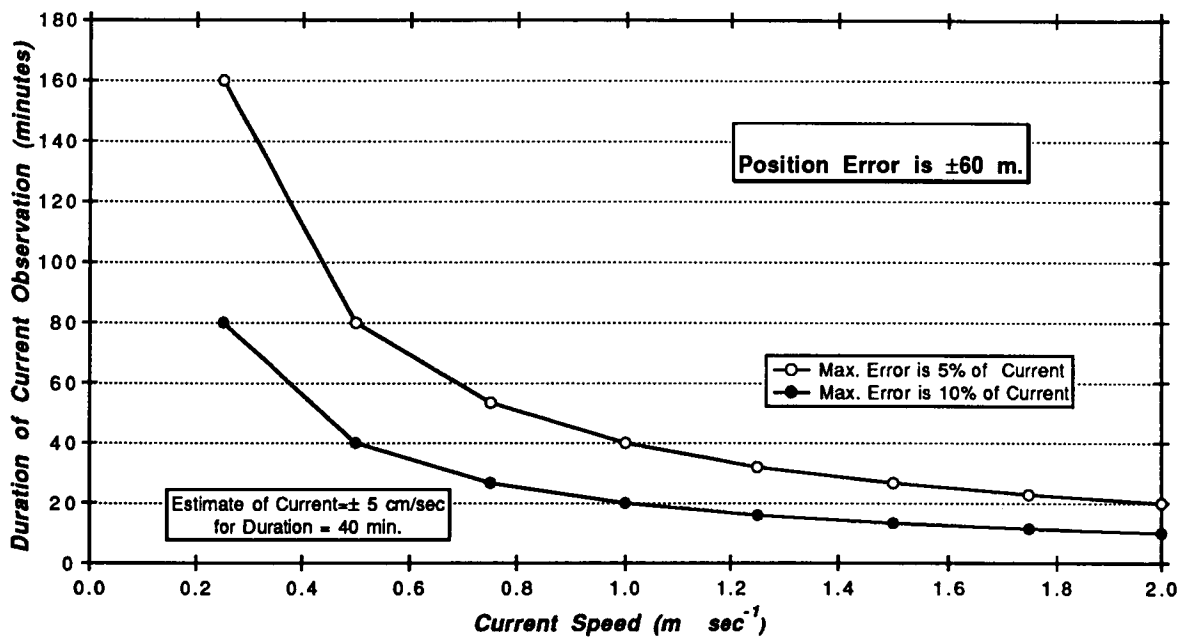
3.4.3 PEGASUS

The location of various PEGASUS profile stations is shown by transect in Table 2.2-2. Table 3.4-2(a-d) presents the dates and times for profiling at each station for each of the four PEGASUS cruises.

3.5 Calibration of Subsurface Temperature

Temperature sensors on the Aanderaa and General Oceanics current meters were calibrated following completion of the measurement program. Data for all General Oceanics current meters are shown in Table 3.5-1. For each instrument (serial number) the sensed temperature (recorded temperature) is compared with the actual or true temperature. The temperature defect is the difference between the actual or true temperature and the recorded temperature. The manufacturer's specifications indicated a value of the defect term of +- 0.25°C. In the mean all instruments meet this. Each individual defect meets these specifications within the normal operating range of approximately 0-30°C. Typically, the temperature sensors in the Mk II provided consistently more accurate temperature estimates.

On an Aanderaa current meter, each temperature sensor is calibrated individually and the resulting calibration curve is used to convert the recorded (binary) temperature sensor output to an actual temperature. There is no standard calibration from which a defect can be computed. SAIC had the temperature sensors on all Aanderaa current meters recalibrated and a new calibration curve was estimated for use in data reduction.



$$T = \frac{200(L)}{(\text{Error})S_T}$$

T = Duration of Measurement

L = Position Error

Error = Maximum Error in Speed Estimate(%)

S_T = True Current Speed

(All units are meters and min.)

Figure 3.3-4 Method for estimating surface current averaging period.

Table 3.4-1 Overall Data Return for subsurface instruments shown in Figure 2.3-1. When velocity (V) and temperature (T) operated for differing durations, each are presented separately.

SUBSURFACE CURRENT/TEMPERATURE DATA RETURN			
INSTRUMENT ID	INSTRUMENT DEPTH	TOTAL DURATION (DAYS)	PERCENT DATA RETURN
MOORING A (water depth = 245m)			
A11	75	349	100%
A12	150	241	69%
MOORING A2 (820m)			
A21*	145	193	72%
A22	300	268	100%
A23	600	268	100%
MOORING A3 (1500m)			
A31*	145	268	100%
A32	300	268	100%
A33	600	268	100%
A34	1000	180 -V	67%
		268 -T	100%
A35	1400	268	100%
MOORING B1 (200m)			
B11	75	342	99%
B12	150	342	99%
MOORING B2 (320m)			
B21	75	351	100%
B22	200	282 -V	81%
		351 -T	100%
MOORING B3 (850m)			
B30	145	191	100%
B31*(ADCP)s	293	86	50%
B32	300	352	100%
B33	600	352	100%
B34	805	352	100%
MOORING B4 (1080m)			
B40*(ADCP)	288	85	100%
B41*	145	268	100%
B42	300	353	100%
B43	600	353	100%
B44	1000	353	100%

Table 3.4-1 Overall Data Return for subsurface instruments shown in Figure 2.3-1. (Cont.)

SUBSURFACE CURRENT/TEMPERATURE DATA RETURN			
INSTRUMENT ID	INSTRUMENT DEPTH	TOTAL DURATION (DAYS)	PERCENT DATA RETURN
	MOORING B5 (17m)		
B51	17 (waterlevel)		23%
	MOORING C1 (320m)		
C11*	100	344	100%
C12	250	344	100%
	MOORING C2 (765m)		
C21*	145	346	100%
C22	300	346	100%
C23	600	346	100%
	MOORING C3 (720m)		
C31*	145	347	100%
C32	300	347	100%
C33	600	82	24%
		165	48%
C34	720 (waterlevel)	347	100%
	MOORING D1 (350m)		
D11	145	347	100%
D12	300	347	100%
	MOORING D2 (770m)		
D21	145	263	76%
D22	300	341	98%
D23	600	268	77%
		347	100%
	MOORING D3 (630m)		
D31*	145	347	100%
D32	300	316	91%
D33	600	334	96%
	MOORING E1 (775M)		
E11	100	349	100%
E12	300	349	100%
E13	600	267	76%

Table 3.4-1 Overall Data Return for subsurface instruments shown in Figure 2.3-1. (Cont.)

SUBSURFACE CURRENT/TEMPERATURE DATA RETURN			
INSTRUMENT D	INSTRUMENT DEPTH	TOTAL DURATION (DAYS)	PERCENT DATA RETURN
MOORING E2 (510m)			
E21*	100	349	100%
E22	300	349	100%
E23	450	349	100%
MOORING E3 (395m)			
E31*	100	348	100%
E32	200	348	100%
E33	300	348	100%
MOORING F1 (550m)			
F11	50	357	100%
F12	300	264	74%
F13*	500	350	98%
MOORING F2 (560m)			
F21	50	345	97%
F22	300	357	100%
F23	500	213 -T	60%
		289 -V	81%
MOORING F3 (575m)			
F31	50	357	100%
F32	300	264	74%
F33	500	291 -T	82%
		259 -V	73%
MOORING G1 (495m)			
G11	50	355	100%
G12	250	355	100%
G13	435	355	100%
MOORING H1 (26m)			
H11*	17	266 -V	76%
		348 -T/P	100%

* These instruments had a pressure sensor. All instruments measured velocity and temperature.

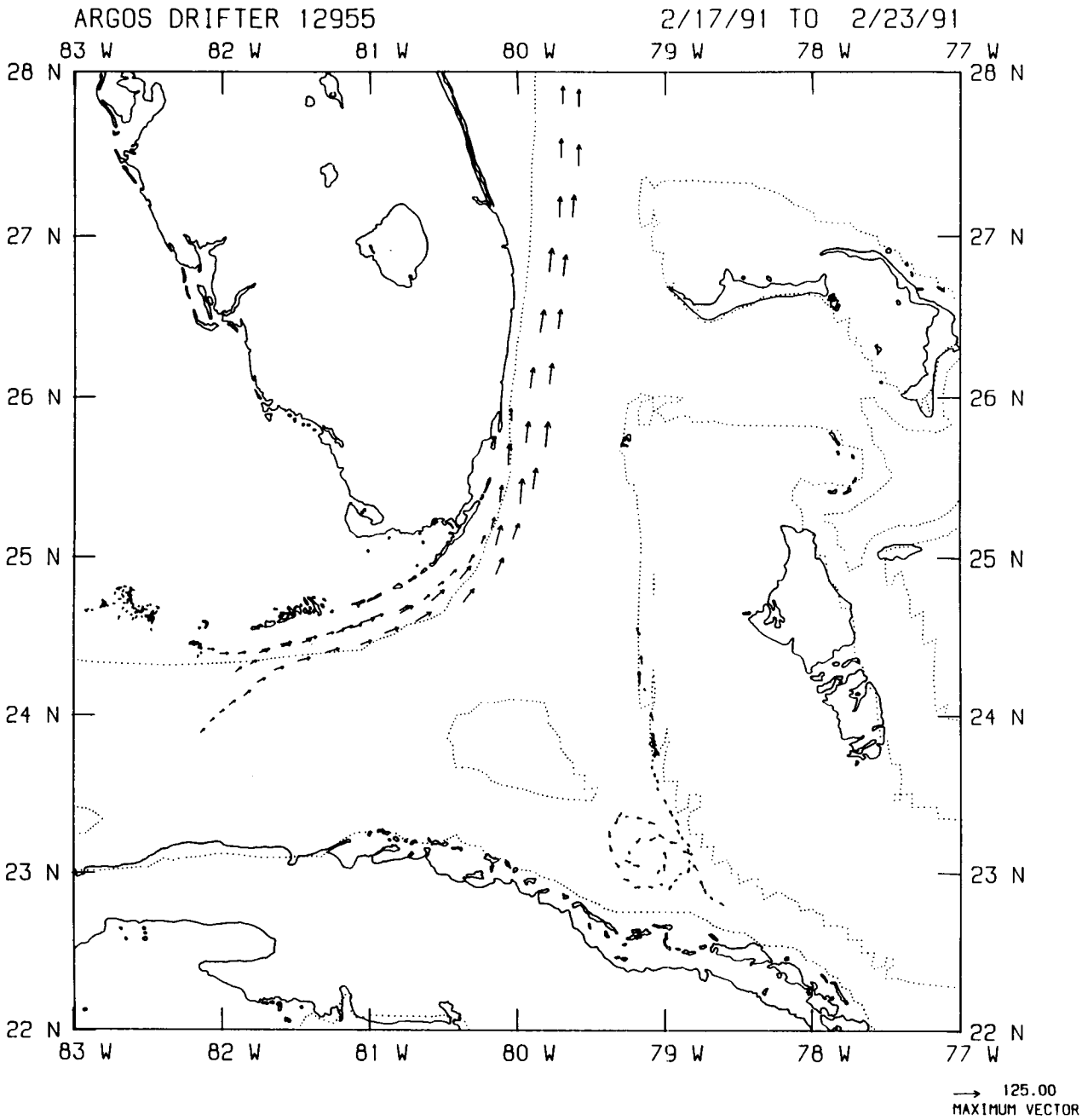


Figure 3.4-1 Trajectories of ARGOS drifters released during mooring Cruise No. 2.

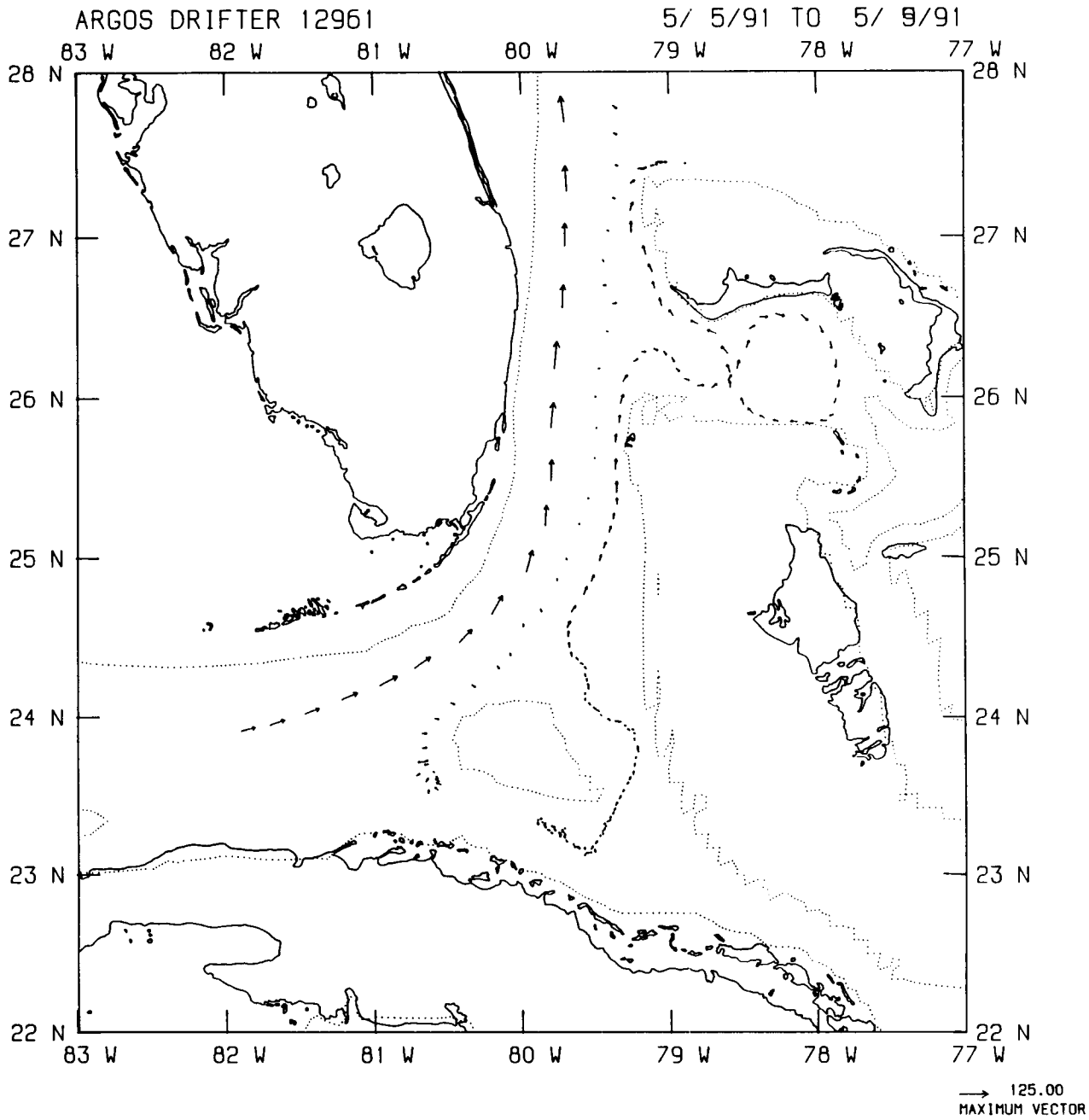


Figure 3.4-2 Trajectories of ARGOS drifters released during mooring Cruise No. 3.

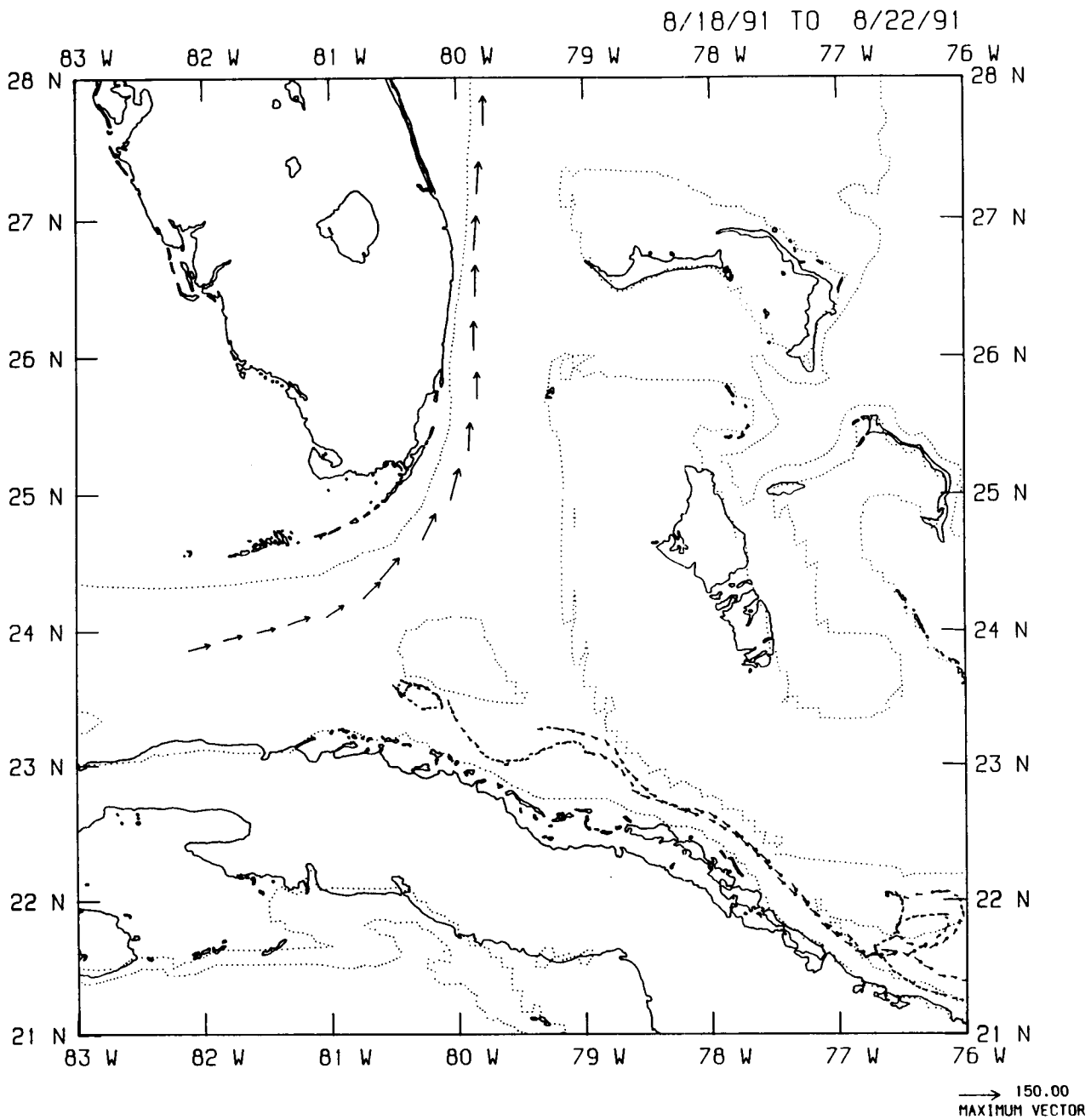


Figure 3.4-3 Trajectories of ARGOS drifters released during mooring Cruise 4.

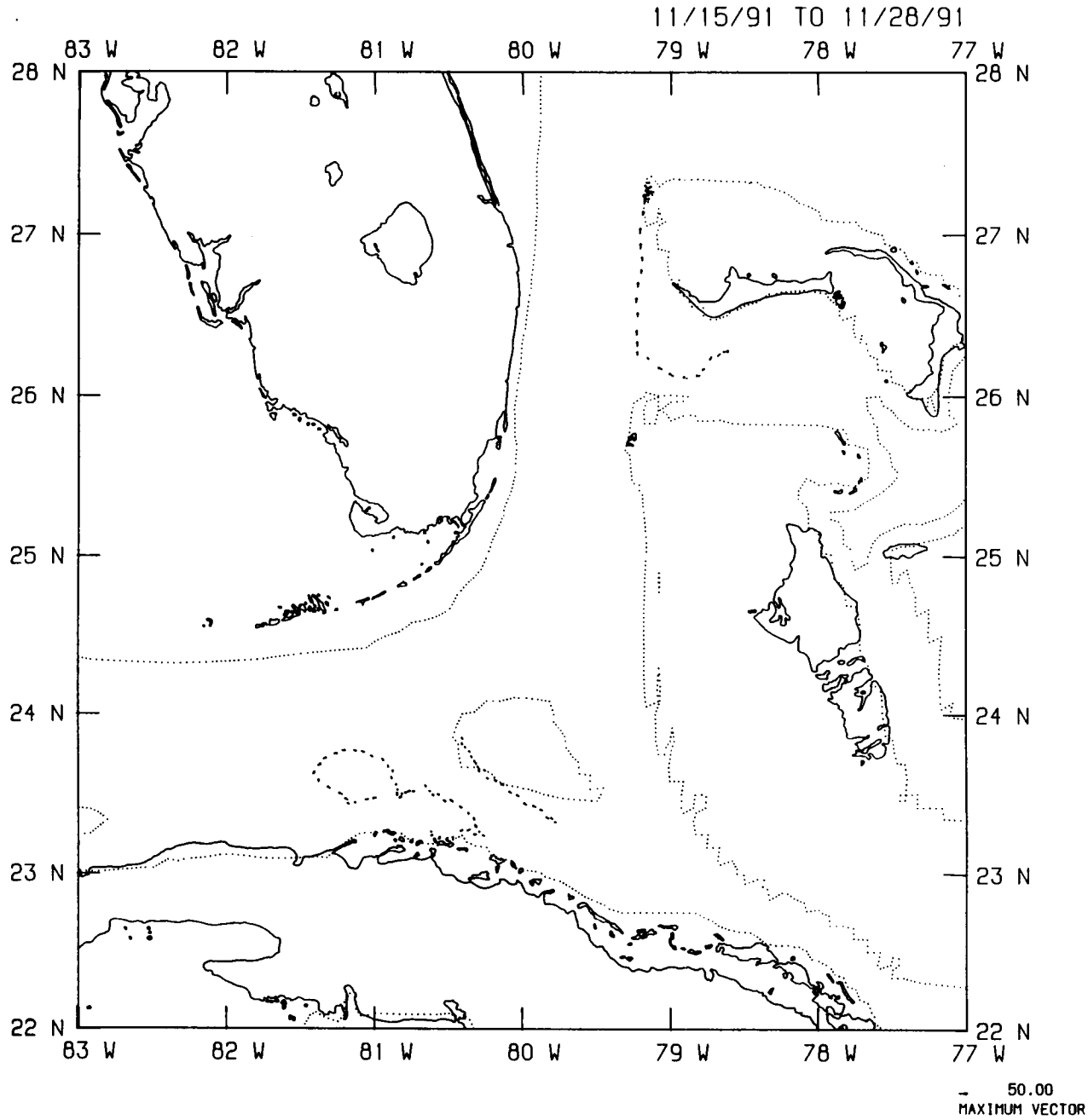


Figure 3.4-4 Trajectories of ARGOS drifters released during mooring Cruise 5 - the final cruise.

Table 3.4-2(a). Listing of profiles by station and time for the first PEGASUS cruise.

PEGASUS Cruise I: Nov. 19 - 29, 1990			
Date	Time (GMT)	Station ID	Drop No.
11/22/90	0630	X1	816
	0853	X2	817
	1239	X1	818
	1502	X2	819
	1701	X3	820
	2040	X4	821
	2320	X3	822
11/23/90	0259	X4	823
	0450	X5	824
	1057	X5	825
11/24/90	1640	X6	826
	2046	X7	827
	2357	X8	828
11/25/90	0245	X9	829
	0544	X10	830
	1509	X11	831
	1849	X12	832
	2237	X13	833
11/26/90	0218	X14	834
	0531	X15	835
	0827	X16	836
	1239	X15	837
	1521	X14	838
	1908	X13	839
	2305	X12	840
11/27/90	1201	X11	841
	1450	X12	842
	1636	X12	843
	2011	X13	844

Table 3.4-2(b) Listing of profiles by station and time for the second PEGASUS cruise.

PEGASUS Cruise II - Feb. 23 - Mar. 2, 1991			
Date	Time (GMT)	Station ID	Drop No.
2/24/91	0310	X1	870
	0525	X2	871
	0925	X1	872
	1137	X2	873
	1401	X3	874
	1529	X4	875
	1650	X5	876
	2031	X3	877
	2204	X4	878
	2327	X5	879
2/25/91	1713	X6	880
	1927	X7	881
	2317	X6	882
	2358	X6	883
2/26/91	0139	X7	884
	0527	X6	885
	0743	X7	886
	1146	X6	887
	1400	X7	888
	1549	X8	889
	1726	X9	890
	1904	X10	891
	2150	X8	892
	2333	X9	893
2/27/91	0200	X10	894
	0427	X8	895
	0603	X9	896
	0739	X10	897
	1026	X8	898
	1205	X9	899
	1402	X10	900
	2135	X11	901

PEGASUS Cruise II - Feb. 23 - Mar. 2, 1991			
Date	Time (GMT)	Station ID	Drop No.
2/28/91	0018	X12	902
	0241	X13	903
	0506	X14	904
	0748	X15	905
	0955	X16	906
	1051	X16	907
	1347	X17	908
	1511	X16	909
	1728	X15	910
	1906	X14	911
	2139	X13	912
	2349	X12	913
3/01/91	0210	X11	914
	0430	X12	915
	0708	X13	916
	1003	X14	917
	1239	X15	918
	1444	X16	919
	1643	X15	920
	1826	X14	921
	2131	X13	922
3/02/91	0004	X12	923
	0250	X11	924

Table 3.4-2(c) Listing of profiles by station and time for the second PEGASUS cruise.

PEGASUS Cruise III: May 28 - Jun 2, 1991			
Date	Time (GMT)	Station ID	Drop No.
5/30/91	0312	X6	925
	0511	X7	926
	0929	X6	927
	1113	X7	928
	1537	X6	929
	1733	X7	930
	2108	X6	931
	2300	X7	932
5/31/91	0046	X8	933
	0221	X9	934
	0357	X10	935
	0700	X8	936
	0835	X9	937
	1029	X10	938
	1252	X8	939
	1424	X9	940
	1600	X10	941
	1815	X8	942
	1954	X9	943
	2136	X10	944
6/01/91	0701	X11	945
	0928	X12	946
	1155	X13	947
	1419	X14	948
	1632	X15	949
	1829	X16	950
	2006	X17	951
	2118	X16	952
	2236	X15	953
6/02/91	0007	X14	954
	0208	X13	955
	0358	X12	956
	0617	X11	957

Table 3.4-2(d) Listing of profiles by station and time for the fourth PEGASUS cruise.

PEGASUS Cruise IV:Sept. 6-12 & 15-21, 1991			
Date	Time (GMT)	Station ID	Drop No.
9/07/91	0832	X1	984
	1038	X2	985
	1445	X1	986
	1649	X2	987
	2059	X1	988
	2302	X2	989
9/08/91	0300	X1	990
	0522	X2	991
	0722	X3	992
	0919	X4	993
	1102	X5	994
	1332	X3	995
	1529	X4	996
	1722	X5	997
	1942	X3	998
	2152	X4	999
	2325	X5	1000
9/09/91	0153	X3	1001
	0355	X4	1002
	0537	X5	1003
9/10/91	0047	X6	1004
	0344	X7	1005
	0851	X6	1006
	1149	X7	1007
	1456	X6	1008
	1800	X7	1009
	2115	X6	1010
09/11/91	0013	X7	1011
09/16/91	1420	X17	1012
	1530	X16	1013
	1657	X15	1014
	1826	X14	1015
	2026	X13	1016
	2219	X12	1017

Cruise IV:Sept. 6-12, 1991; Sept. 15-21, 1991			
Date	Time (GMT)	Station ID	Drop No.
09/17/91	0029	X11	1018
	0236	X12	1019
	0535	X13	1020
	0830	X14	1021
	1047	X15	1022
	1251	X16	1023
	1430	X17	1024
	2200	X17	1025
	2309	X16	1026
09/18/91	0021	X15	1027
	0151	X14	1028
	0353	X13	1029
	0557	X12	1030
	0814	X11	1031
	1500	X10	1032
	1646	X9	1033
	1832	X8	1034
	2113	X10	1035
	2258	X9	1036
09/19/91	0042	X8	1037
	0325	X10	1038
	0510	X9	1039
	0653	X8	1040
	0938	X10	1041
	1124	X9	1042
	1308	X8	1043
	1447	X7	1044
	1653	X6	1045
	2059	X7	1046
	2304	X6	1047
09/20/91	0313	X7	1048
	0532	X6	1049
	0924	X7	1050
	1130	X6	1051
	2045	X11	1052
	2250	X12	1053
09/21/91	0107	X13	1054
	0332	X14	1055
	0548	X15	1056
	0756	X16	1057
	0937	X17	1058

Table 3.5-1 Table showing the difference between recorded temperature and actual temperature for the indicated instruments (serial numbers) at the noted actual temperatures. The difference between actual and recorded temperatures is called the defect.

GO Instr. Serial Number	Temperature Defect (ΔT in °C)										Defect Mean	Defect St.Dev
	-8°C	-5°C	0°C	10°C	20°C	25°C	30°C	40°C	50°C	56°C		
Mk I												
75	0.00	0.00	-0.12	-0.12	0.12	-0.06	-0.12	-0.12	-0.25	-0.12	-0.079	0.100
99	0.00	0.00	-0.12	-0.06	0.13	0.00	0.00	0.00	-0.12	0.00	-0.017	0.072
153	0.00	0.12	0.00	0.06	0.25	0.12	0.06	0.06	-0.06	0.06	0.067	0.085
156	0.00	0.13	-0.02	0.00	0.05	-0.03	-0.02	-0.06	0.06	0.11	0.022	0.063
173	0.00	0.00	-0.06	0.00	0.25	0.06	0.06	0.06	-0.06	0.00	0.031	0.089
181	-0.19	0.25	0.00	-0.19	-0.25	0.19	0.00	-0.25	0.12	0.06	-0.026	0.185
185	-0.25	0.12	0.06	0.25	-0.19	-0.25	-0.19	-0.06	0.00	0.19	-0.032	0.185
190	0.00	0.12	0.00	-0.06	0.06	-0.12	-0.19	-0.31	0.19	0.25	-0.006	0.172
191	-0.25	-0.06	-0.12	-0.06	0.19	0.00	0.00	0.12	0.06	0.19	0.007	0.139
192	0.00	0.00	-0.06	0.00	0.19	0.06	0.00	0.00	-0.12	0.00	0.007	0.080
195	0.00	-0.02	-0.03	0.00	0.06	0.02	0.02	0.02	0.17	0.20	0.044	0.079
198	0.00	0.00	-0.06	0.00	0.25	0.12	0.12	0.12	0.06	0.19	0.080	0.097
200	0.00	0.00	-0.12	-0.06	0.19	0.00	0.00	0.00	-0.12	0.00	-0.011	0.086
204	0.00	0.00	-0.06	0.06	0.25	0.12	0.06	0.00	-0.12	-0.12	0.019	0.112
222	0.00	0.00	0.00	0.19	-0.19	-0.25	-0.25	-0.12	-0.12	0.06	-0.068	0.143
Mk II												
256		-0.08	-0.05	0.05	0.14	0.11	0.11	0.12	0.27		0.096	0.111
264		0.11	0.09	0.11	0.17	0.14	0.12	0.14	0.28		0.166	0.060
266		0.09	0.09	0.11	0.17	0.14	0.12	0.11	0.25		0.154	0.053
268		0.06	0.06	0.09	0.16	0.12	0.11	0.11	0.23		0.134	0.056
269		0.08	0.06	0.09	0.16	0.11	0.09	0.11	0.25		0.136	0.061
271		0.11	0.09	0.11	0.17	0.12	0.11	0.11	0.25		0.153	0.052
272		0.02	0.02	0.11	0.17	0.14	0.12	0.11	0.23		0.131	0.071
274		0.09	0.08	0.11	0.16	0.12	0.11	0.11	0.25		0.147	0.054
275		0.02	0.02	0.09	0.16	0.11	0.11	0.11	0.23		0.121	0.069
276		0.05	0.05	0.08	0.16	0.11	0.11	0.11	0.25		0.131	0.065
280		0.03	0.03	0.06	0.12	0.09	0.08	0.09	0.23		0.104	0.064
281		0.05	0.05	0.06	0.12	0.09	0.08	0.08	0.23		0.109	0.059
283		0.08	0.06	0.08	0.14	0.09	0.08	0.08	0.23		0.120	0.056
284		0.05	0.05	0.08	0.14	0.11	0.09	0.11	0.25		0.126	0.064
288		0.02	0.02	0.09	0.16	0.11	0.09	0.09	0.20		0.111	0.062
289		0.02	0.02	0.08	0.14	0.11	0.09	0.08	0.20		0.106	0.060
290		0.08	0.06	0.08	0.14	0.11	0.09	0.09	0.25		0.129	0.060
291		0.07	0.06	0.08	0.14	0.11	0.09	0.11	0.25		0.130	0.061
293		0.02	0.02	0.11	0.17	0.12	0.11	0.11	0.23		0.127	0.070
297		0.11	0.09	0.11	0.17	0.12	0.11	0.12	0.27		0.157	0.058
298		0.10	0.08	0.11	0.17	0.12	0.11	0.11	0.27		0.153	0.061
299		0.05	0.05	0.06	0.12	0.08	0.08	0.08	0.22		0.106	0.056
311		0.02	0.02	0.11	0.16	0.11	0.11	0.11	0.23		0.124	0.069
322		0.16	0.13	0.16	0.22	0.17	0.16	0.16	0.30		0.209	0.054
328		0.09	0.08	0.11	0.17	0.12	0.11	0.11	0.27		0.151	0.062
330		0.02	0.02	0.09	0.16	0.12	0.11	0.11	0.23		0.123	0.069
331		-0.19	-0.11	0.02	0.11	0.08	0.05	0.03	0.16		0.021	0.115
332		-0.12	-0.14	-0.08	0.00	-0.02	-0.02	0.02	0.19		-0.024	0.103
333		0.10	0.09	0.12	0.19	0.16	0.14	0.16	0.31		0.181	0.070
335		0.11	0.09	0.11	0.17	0.12	0.11	0.11	0.27		0.156	0.059
339		-0.17	-0.09	0.05	0.19	0.17	0.17	0.18	0.31		0.116	0.160
344		0.02	0.02	0.12	0.19	0.12	0.12	0.12	0.23		0.134	0.073
378		0.11	0.09	0.12	0.19	0.14	0.12	0.12	0.28		0.167	0.061
379		0.11	0.09	0.12	0.19	0.14	0.14	0.14	0.28		0.173	0.060
380		0.06	0.06	0.09	0.16	0.11	0.11	0.61	0.25		0.207	0.184
Temp. Mean	-0.046	0.044	0.015	0.062	0.136	0.080	0.064	0.075	0.166	0.071	0.067	
St.Dev	0.096	0.079	0.071	0.079	0.101	0.091	0.089	0.124	0.144	0.115		

IV. CONDUCTIVITY AND TEMPERATURE DATA

4.1 Instrumentation

CTD casts were made using SAIC's Neil Brown Mark IIIB CTD fish with a 1600 m depth capability and a Model 1150 Data Terminal. Its sensor specifications are presented in Table 4.1-1. This system is controlled by microcomputer and software, which records data on a magnetic medium. It also permits real-time display of temperature and salinity versus depth on the CRT screen, the printing of plots of these displays on the built-in printer, and a real-time digital display of temperature, conductivity and pressure on the front panel of the Model 1150 Data Terminal. This system has been in use since 1983. Back-up data logging capabilities are on a TECHTRAN digital cassette recorder. A system schematic is shown in Figure 4.1-1.

A Sippican MK-9 digital XBT system equipped with an LM-3A hand held launcher and 100 feet of cable was interfaced to a micro computer(see Figure 4.1-2). Data was stored on data cartridges or floppy disks. These data can then be plotted or listed as desired. The specifications of the MK-9 system are presented in Table 4.1-2. Sippican T-10 (200 m), T-7 (760 m), and T-5 (1830 m) XBT probes were used depending on water depth.

4.2 Data Processing

Conductivity, temperature, and depth measurements made by the Neil Brown Mark IIIB CTD were calibrated in several ways. The near bottom and near surface Niskin bottles were fitted with NBS trackable reversing thermometers (two protected and one unprotected). After a five minute soak, these bottles were tripped. This provided primary temperature calibration. Water samples collected in mixed layers provided primary salinity calibration. A laboratory grade conductive salinometer was used for this determination. Periodically, during each cruise, duplicate salinity samples were collected for a calibration intercomparison with another laboratory. The depth sensors were checked by a comparison to wire out and the depth calculated from the unprotected and protected reversing thermometer readings. The final CTD data were then corrected for any constant, depth, or time-dependent errors. SAIC's Neil Brown Mark IIIB was recently recalibrated at the Northwest Regional Calibration Center in Bellevue, Washington.

XBT

The Sippican MK-9 XBT digitizer system is equipped with a 1AB Test Canister, built in electronics, and computer software to check out proper calibration and operation of the data acquisition system. In addition, it actually allows a system check each time a new XBT probe is loaded. As an additional check, comparisons were made with CTD casts.

SAIC/Raleigh has developed a systematic procedure for the processing of CTD and XBT profiles based on the careful control of each step in the processing procedure. The following list summarizes the processing steps for CTD/XBT profile data respectively:

Table 4.1-1 Specifications of sensors on the NBIS Mark III B, CTD.

	Conductivity Mark IIIB	Temperature Mark IIIB	Pressure Mark IIIB
Accuracy: (mmho/cm °C %FS)	±0.005	±0.005	±0.1
Resolution: (mmho/cm °C %FS)	0.001	0.0005	0.0015
Response Time: (msec at 1m/sec drop rate)	40	30	1
Range: (mmho/cm °C db)	1-65	-3 to+32	0-1600

Table 4.1-2 General specifications of the Mark 9 digital system and XBTs used.

ITEM	TEMPERATURE	PRESSURE-DEPTH
Range	-2.2 to 35.6°C	0-2000m
Accuracy	± 0.15°C	± 2% or ±5m whichever is greater
Resolution	± 0.01°C	N/A

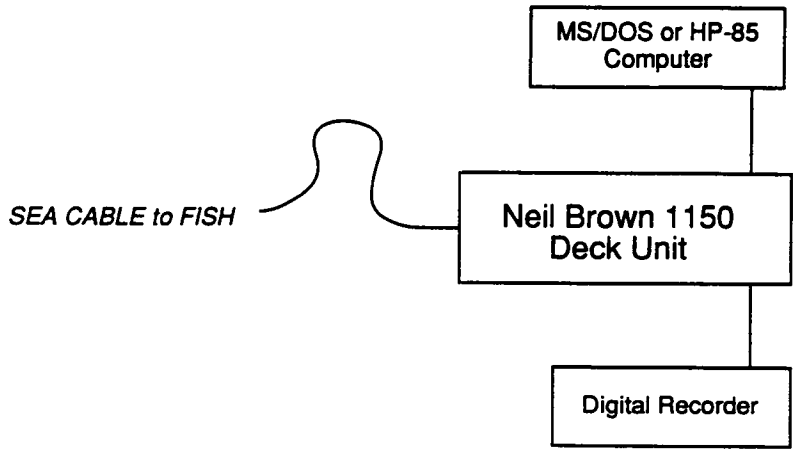


Figure 4.1-1 Schematic of data flow in the NBIS, MkIII, CTD.

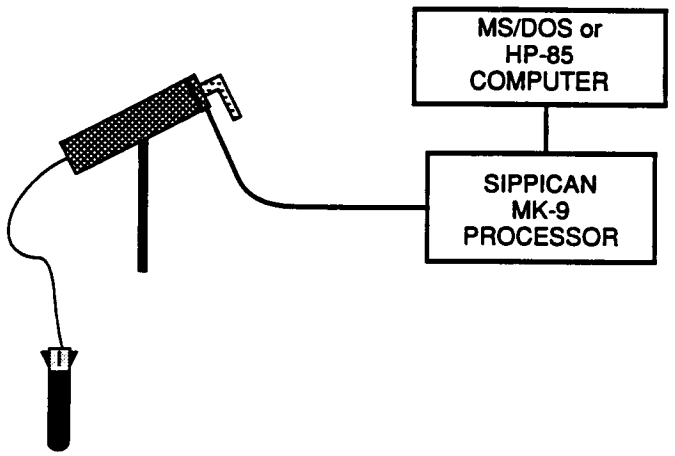


Figure 4.1-2 Schematic of data flow in the Sippican Mk9 digital XBT system.

- 3½" or 5¼" floppy data diskettes containing CTD data are logged into the SAIC Physical Oceanography Data Base and the cruise is assigned a unique cruise ID. Next, the data are read into binary disk files on the ENCORE 32/67. These files are created by storing the data scans as ASCII characters in a sequential file using the system file utility program. During sequential file creation, checks are made on the input parameters (temperature, conductivity and depth) for large spikes, data gaps and number of data scans for each individual cast (CTDSTR).

- Cast header information required for NODC data files is stored in the individual cast file header record and is thus always associated with the proper cast. This information is then stored in the SAIC Hydrographic Data Base with a specific ID that links the header file with the sequential data file created previously (HYDBM).

- The programs HYDLAG, DELATC and EVNMTR make any necessary time lags in the temperature data, insure monotonically increasing depths and establish a 1-meter increment between samples, respectively. However, the final increment between sample depths is variable and can easily be changed to accommodate specific requests for different sampling intervals.

- Vertical profiles of temperature and conductivity are plotted and checked for spikes or obviously questionable data. The bad data scans are removed or the entire cast is discarded depending on the number of bad data points (BLMCST).

- From this corrected data set, both vertical (HYVCON) and horizontal (RJWCONT) contour maps are produced for individual sections and the entire cruise, respectively. These maps are checked visually against the profiles as a quality control measure.

- Other data products (geostrophic velocity, integrated transports, dynamic heights) are produced as required for further analysis.

These procedures are summarized in a flow chart (Figure 4.2-1).

4.3 Data Summary

4.3.1 Cruise 1 - November 20 - December 7, 1990

The locations and type of hydrographic observations during Cruise 1 (initial cruise) are shown in Figure 4.3-1 where "Xs" indicate XBT profiles and squares indicate CTD profiles. The specific dates, locations and water depths are given in Table 4.3-1.

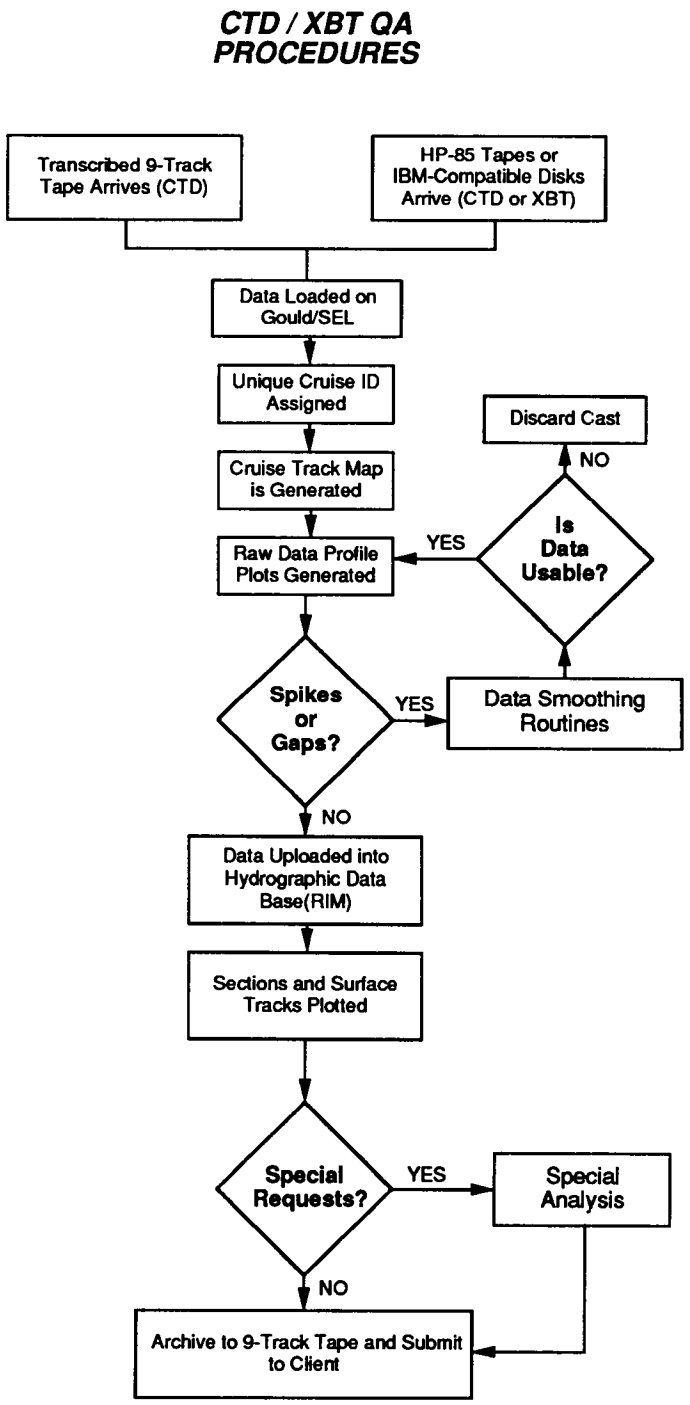


Figure 4.2-1 Flow diagram illustrating the processing sequence for XBT and CTD data.

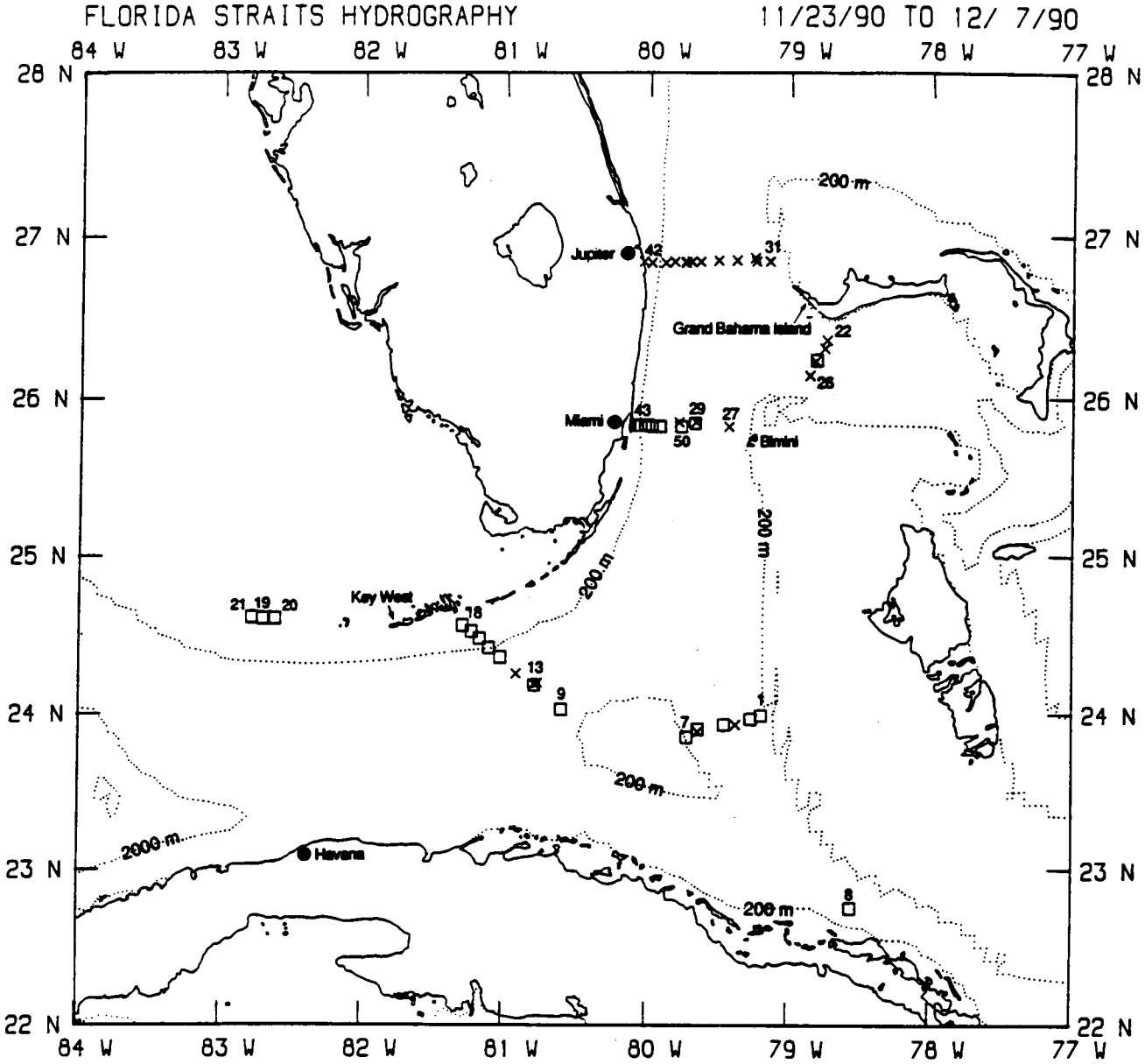


Figure 4.3-1 Hydrographic station locations - Cruise 1.

Table 4.3-1 Listing of dates, locations, water depths and types of casts during Cruise 1, the mooring deployment cruise.

Cruise No. 1 Nov. 23 - Dec. 7, 1990				
Station No.	Type of Cast	Latitude (N)	Longitude (W)	Water Depth (m)
1	C	23° 59.5'	79° 11.5'	480
2	C	23° 58.3'	79° 16.0'	585
3	X	23° 56.1'	79° 22.0'	566
4	C	23° 56.0'	79° 26.8'	575
5	X	23° 53.5'	79° 38.1'	566
6	C	23° 54.3'	79° 38.2'	562
7	C	23° 51.2'	79° 43.0'	360
8	C	22° 45.4'	78° 33.4'	500
9	C	24° 02.0'	80° 35.4'	1080
10	C	24° 11.3'	80° 47.3'	850
11	X	24° 11.6'	80° 47.0'	850
12	X	24° 12.2'	80° 45.7'	829
13	X	24° 15.7'	80° 54.7'	455
14	C	24° 21.6'	81° 01.8'	260
15	C	24° 25.2'	81° 06.4'	185
16	C	24° 28.9'	81° 10.4'	190
17	C	24° 31.2'	81° 13.6'	135
18	C	24° 33.7'	81° 17.5'	26
19	C	24° 36.3'	82° 42.3'	27
20	C	24° 36.2'	82° 37.2'	23
21	C	24° 36.6'	82° 47.2'	26
22	X	26° 21.8'	78° 44.0'	769
23	X	26° 18.6'	78° 45.0'	582
24	C	26° 14.3'	78° 48.2'	490
25	X	26° 13.8'	78° 48.7'	458
26	X	26° 08.6'	78° 51.2'	376

Cruise No. 1 (cont'd) Nov. 23 - Dec. 7, 1990				
Station No.	Type of Cast	Latitude (N)	Longitude (W)	Water Depth (m)
27	X	25° 49.6'	79° 25.4'	680
28	C	25° 50.7'	79° 39.8'	765
29	X	25° 51.3'	79° 39.7'	720
30	X	26° 52.4'	79° 14.7'	606
31	X	26° 51.1'	79° 08.5'	456
32	X	26° 51.1'	79° 14.6'	566
33	X	26° 51.4'	79° 22.6'	658
34	X	26° 51.4'	79° 30.6'	736
35	X	26° 50.8'	79° 38.1'	726
36	X	26° 50.8'	79° 44.5'	570
37	X	26° 50.9'	79° 42.1'	239
38	X	26° 50.7'	79° 44.3'	436
39	X	26° 50.8'	79° 49.2'	348
40	X	26° 50.5'	79° 53.0'	265
41	X	26° 50.5'	79° 58.9'	144
42	X	26° 50.9'	80° 02.1'	33
43	C	25° 49.9'	80° 04.7'	55
44	C	25° 50.0'	80° 03.1'	215
45	C	25° 49.8'	80° 01.5'	245
46	C	25° 49.8'	79° 59.9'	270
47	C	25° 49.7'	79° 58.3'	275
48	C	25° 49.5'	79° 55.2'	285
49	C	25° 49.5'	79° 45.8'	800
50	X	25° 51.2'	79° 46.6'	786
	C=CTD X=XBT			

4.3.2 Cruise 2 - February 15 - March 1, 1991

The locations and type of hydrographic observations during Cruise 2 are shown in Figure 4.3-2. The specific dates, locations and water depths are given in Table 4.3-2.

4.3.3 Cruise 3 - May 1-18, 1991

The locations and type of hydrographic observations during Cruise 3 are shown in Figure 4.3-3. The specific dates, locations and water depths are given in Table 4.3-3.

4.3.4 Cruise 4 - August 16-29, 1991

The locations and type of hydrographic observations during Cruise 4 are shown in Figure 4.3-4. The specific dates, locations and water depths are given in Table 4.3-4.

4.3.5 Cruise 5 - November 10-19, 1991

The locations and type of hydrographic observations during Cruise 5 (final cruise) are shown in Figure 2.1-2. The specific dates, times locations and water depths are given in Table 4.3-5.

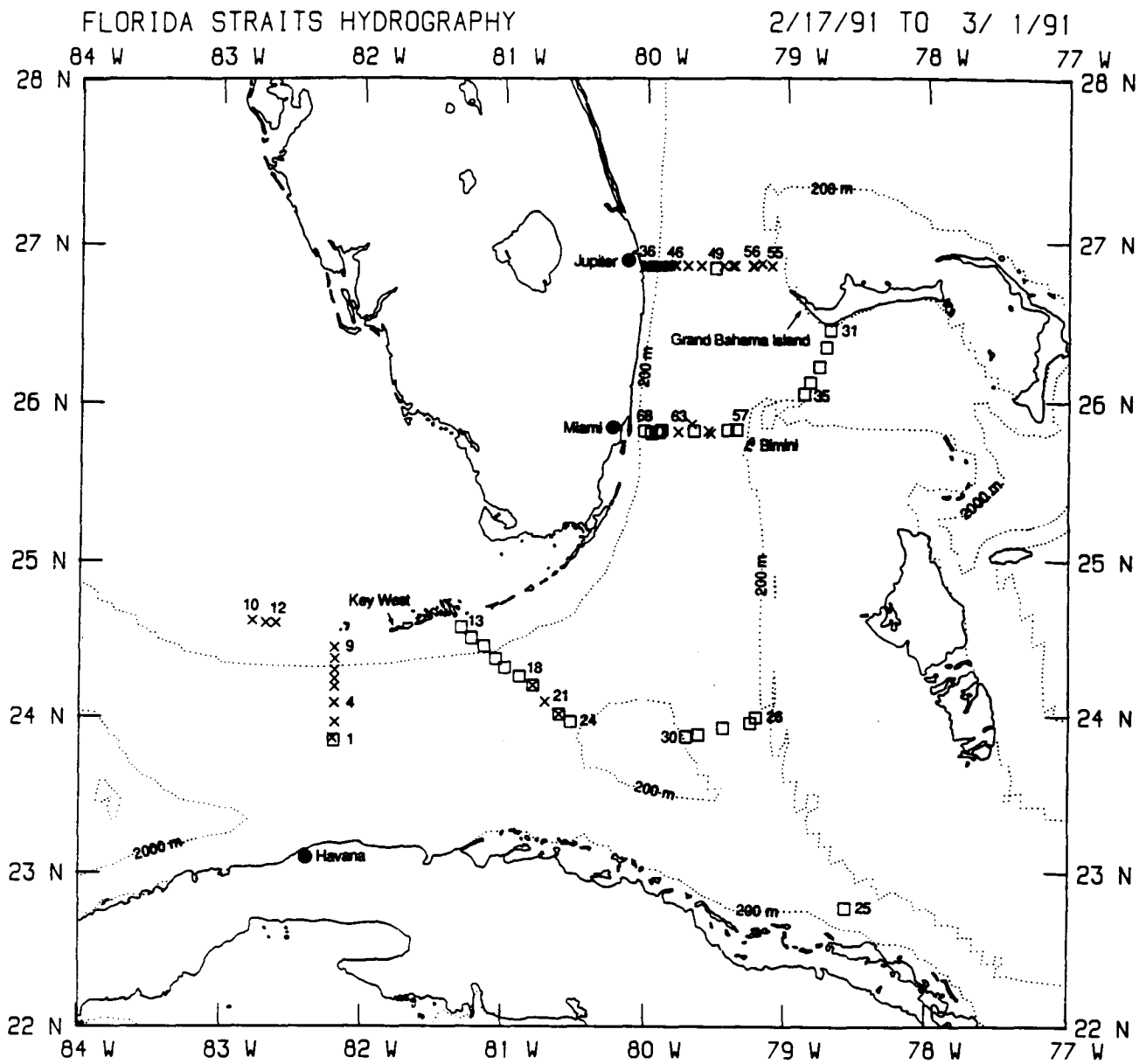


Figure 4.3-2 Hydrographic station locations - Cruise 2.

Table 4.3-2. Listing of dates, locations, water depths and types of casts for Cruise 2, the first mooring rotation cruise.

Cruise No 2 Feb. 17 - March 1, 1991				
Station No.	Type of Cast	Latitude (N)	Longitude (W)	Water Depth (m)
1	C	23° 50.7'	82° 12.2'	1500
2	X	23° 51.6'	82° 12.3'	1490
3	X	23° 57.9'	82° 11.6'	994
4	X	24° 05.2'	82° 11.6'	785
5	X	24° 11.6'	82° 11.6'	606
6	X	24° 14.8'	82° 11.7'	518
7	X	24° 18.0'	82° 11.6'	236
8	X	24° 22.6'	82° 11.5'	134
9	X	24° 26.9'	82° 11.4'	15
10	X	24° 37.1'	82° 46.9'	25
11	X	24° 36.0'	82° 41.0'	28
12	X	24° 36.1'	82° 36.6'	22
13	C	24° 34.2'	81° 17.5'	13
14	C	24° 30.3'	81° 13.0'	167
15	C	24° 27.5'	81° 07.8'	190
16	C	24° 22.7'	81° 02.8'	210
17	C	24° 18.9'	80° 59.4'	289
18	C	24° 15.5'	80° 52.8'	480
19	C	24° 11.9'	80° 47.1'	820
20	X	24° 12.2'	80° 47.1'	830
21	X	24° 05.9'	80° 41.8'	970
22	C	24° 01.0'	80° 35.8'	1075
23	X	24° 01.0'	80° 35.8'	1069
24	C	23° 58.0'	80° 31.4'	845
25	C	22° 46.5'	78° 34.3'	490
26	C	23° 59.5'	79° 12.3'	510
27	C	23° 57.5'	79° 15.1'	585
28	C	23° 55.6'	79° 26.6'	583
29	C	23° 53.1'	79° 37.2'	575
30	C	23° 52.3'	79° 42.6'	390
31	C	26° 27.2'	78° 41.2'	533
32	C	26° 20.6'	78° 43.3'	765
33	C	26° 13.2'	78° 46.1'	502
34	C	26° 07.2'	78° 50.0'	373
35	C	26° 03.1'	78° 52.1'	265

Cruise No 2 (cont'd) Feb. 17 - March 1, 1991				
Station No.	Type of Cast	Latitude (N)	Longitude (W)	Water Depth (m)
36	X	26° 51.1'	80° 01.4'	23
37	X	26° 51.2'	80° 00.3'	26
38	X	26° 51.3'	79° 59.2'	33
39	X	26° 51.4'	79° 57.5'	122
40	X	26° 51.4'	79° 56.4'	179
41	X	26° 51.5'	79° 55.2'	235
42	X	26° 51.4'	79° 54.1'	212
43	X	26° 51.4'	79° 52.4'	254
44	X	26° 51.4'	79° 51.3'	278
45	X	26° 51.4'	79° 50.2'	317
46	X	26° 51.4'	79° 47.6'	375
47	X	26° 51.3'	79° 42.4'	471
48	X	26° 51.2'	79° 36.5'	644
49	C	26° 50.5'	79° 30.2'	775
50	X	26° 51.5'	79° 26.8'	658
51	X	26° 51.2'	79° 23.3'	640
52	X	26° 51.2'	79° 22.3'	644
53	X	26° 51.5'	79° 14.3'	570
54	X	26° 52.3'	79° 10.4'	514
55	X	26° 51.4'	79° 06.1'	311
56	X	26° 51.3'	79° 14.2'	572
57	C	25° 49.4'	79° 21.1'	600
58	C	25° 49.5'	79° 25.1'	717
59	X	25° 48.4'	79° 32.3'	786
60	X	25° 49.1'	79° 33.5'	758
61	C	25° 49.2'	79° 39.6'	755
62	X	25° 51.5'	79° 40.3'	724
63	X	25° 48.6'	79° 46.1'	724
64	C	25° 49.3'	79° 53.4'	305
65	C	25° 48.6'	79° 54.4'	300
66	C	25° 48.5'	79° 55.5'	310
67	C	25° 48.4'	79° 58.0'	290
68	C	25° 49.1'	80° 01.0'	225
	C=CTD			
	X=XBT			

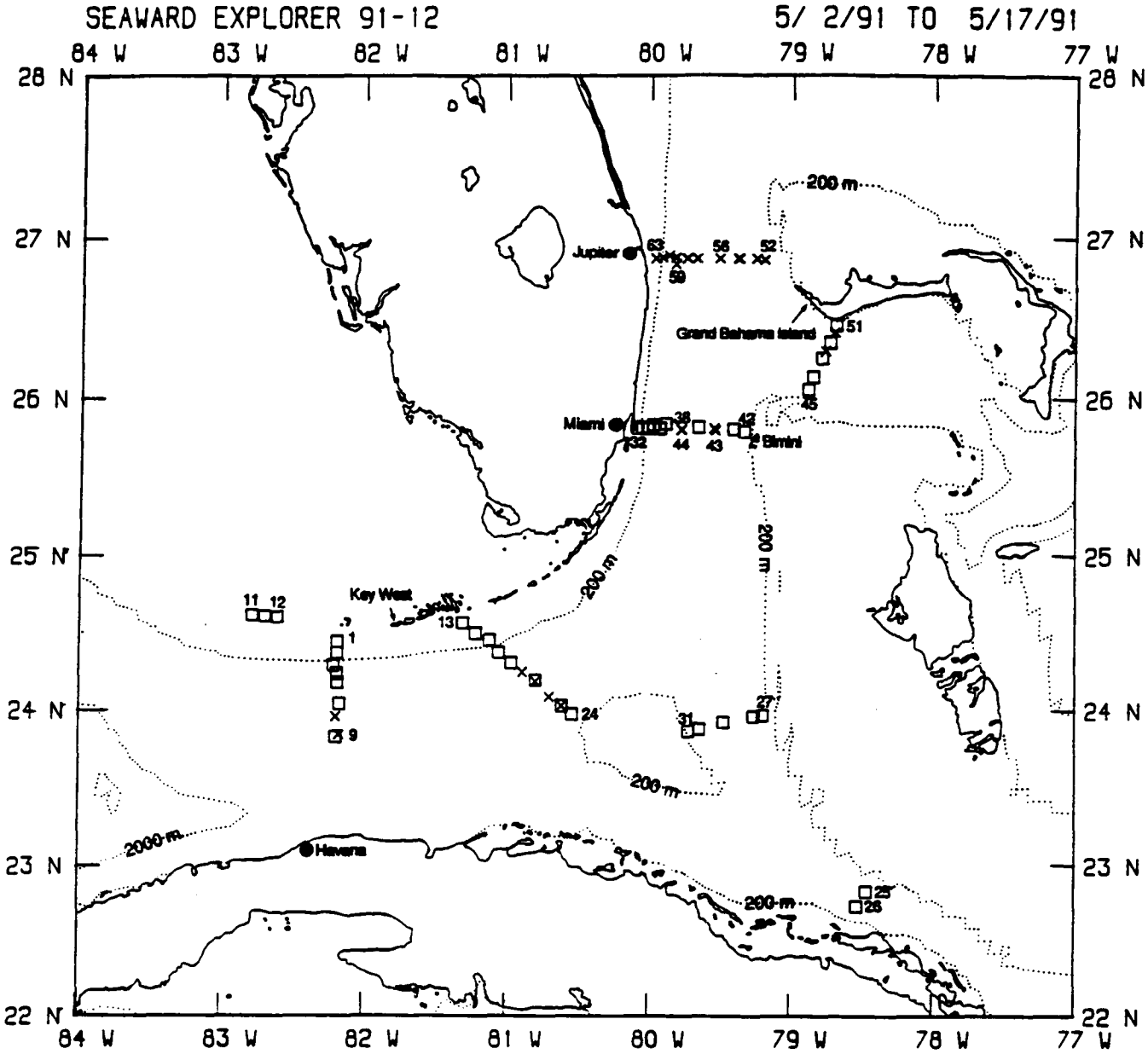


Figure 4.3-3 Hydrographic station locations - Cruise 3.

Table 4.3-3. Listing of dates, locations, water depths and types of casts for Cruise 3, the second mooring rotation cruise.

Cruise 3 May 2 - 17, 1991				
Station No.	Type of Cast	Latitude (N)	Longitude (W)	Water Depth (m)
1	C	24° 26.8'	82° 11.3'	38
2	C	24° 22.5'	82° 11.3'	145
3	C	24° 17.5'	82° 12.4'	244
4	C	24° 14.7'	82° 11.2'	520
5	C	24° 11.2'	82° 11.2'	630
6	C	24° 02.8'	82° 10.1'	840
7	X	23° 57.9'	82° 11.7'	971
8	C	23° 50.0'	82° 11.7'	1500
9	X	23° 50.9'	82° 10.2'	1495
10	C	24° 36.4'	82° 42.1'	26
11	C	24° 37.0'	82° 47.1'	25
12	C	24° 36.2'	82° 36.5'	17
13	C	24° 34.1'	81° 17.8'	13
14	C	24° 30.2'	81° 12.5'	183
15	C	24° 27.6'	81° 07.1'	195
16	C	24° 22.7'	81° 02.9'	220
18	X	24° 15.2'	80° 53.1'	536
19	X	24° 11.5'	80° 47.0'	835
20	C	24° 11.8'	80° 47.3'	835
21	X	24° 05.5'	80° 41.5'	983
22	C	24° 01.7'	80° 35.8'	1060
23	X	24° 01.9'	80° 36.1'	1061
24	C	23° 58.8'	80° 31.6'	850
25	C	22° 49.9'	78° 28.1'	422
26	C	22° 44.1'	78° 31.9'	510
27	C	23° 58.4'	79° 11.4'	570
28	C	23° 58.1'	79° 15.3'	590
29	C	23° 55.9'	79° 27.8'	580
30	C	23° 53.2'	79° 38.0'	560
31	C	23° 52.3'	79° 43.0'	390
32	C	25° 49.0'	80° 05.0'	34

Cruise 3 (cont'd) May 2 - 17, 1991				
Station No.	Type of Cast	Latitude (N)	Longitude (W)	Water Depth (m)
33	C	25° 49.4'	80° 03.2'	225
34	C	25° 49.1'	80° 00.6'	278
36	C	25° 49.2'	79° 55.6'	318
37	C	25° 50.7'	79° 53.1'	330
38	X	25° 48.7'	79° 46.1'	820
39	C	25° 49.5'	79° 39.3'	765
40	X	25° 48.4'	79° 32.0'	824
41	C	25° 48.6'	79° 23.9'	721
42	C	25° 47.9'	79° 19.8'	572
43	X	25° 49.1'	79° 32.5'	803
44	X	25° 48.8'	79° 46.3'	838
45	C	26° 03.3'	78° 52.7'	217
46	C	26° 08.0'	78° 50.7'	389
47	C	26° 14.9'	78° 47.1'	510
48	X	26° 17.7'	78° 45.3'	576
49	C	26° 20.6'	78° 43.4'	777
50	X	26° 24.5'	78° 41.8'	778
51	C	26° 27.4'	78° 41.1'	425
52	X	26° 51.9'	79° 11.4'	530
53	X	26° 52.1'	79° 14.7'	612
54	X	26° 52.3'	79° 22.4'	654
55	X	26° 52.2'	79° 30.3'	750
56	X	26° 52.2'	79° 22.6'	660
57	X	26° 52.3'	79° 39.8'	582
58	X	26° 52.2'	79° 44.3'	452
59	X	26° 50.0'	79° 49.1'	350
60	X	26° 52.5'	79° 49.1'	339
61	X	26° 53.3'	79° 52.3'	265
62	X	26° 52.8'	79° 55.2'	191
63	X	26° 52.3'	79° 58.0'	118
	C=CTD X=XBT			

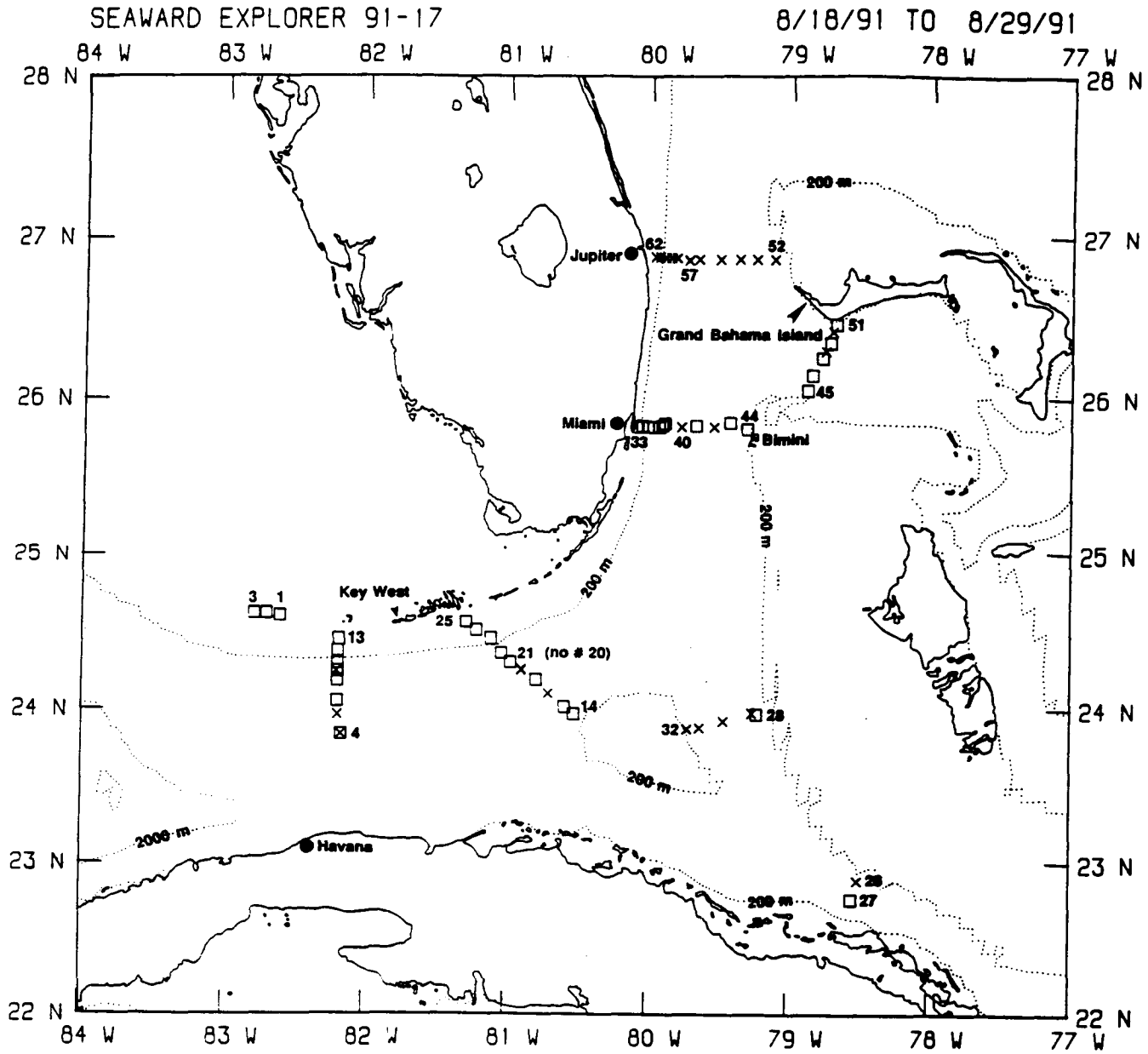


Figure 4.3-4 Hydrographic station locations - Cruise 4.

Table 4.3-4. Listing of dates, locations, water depths and types of casts for Cruise 4, the third mooring rotation cruise.

Cruise 4 August 18 - 29, 1991				
Station No.	Type of Cast	Latitude (N)	Longitude (W)	Water Depth (m)
1	C	24° 36.0'	82° 36.2'	22
2	C	24° 36.9'	82° 41.9'	25
3	C	24° 37.0'	82° 47.1'	22
4	C	23° 50.4'	82° 10.0'	1500
5	X	23° 50.3'	82° 10.3'	1490
6	X	23° 57.8'	82° 11.6'	994
7	C	24° 03.1'	82° 11.7'	840
8	C	24° 11.1'	82° 11.5'	650
9	C	24° 14.7'	82° 11.7'	560
10	X	24° 14.5'	82° 11.8'	540
11	C	24° 17.9'	82° 11.7'	245
12	C	24° 22.5'	82° 11.6'	150
13	C	24° 26.9'	82° 11.3'	23
14	C	23° 58.5'	80° 31.4'	840
15	C	24° 01.1'	80° 35.0'	1080
16	X	24° 06.2'	80° 41.7'	986
17	C	24° 11.7'	80° 46.9'	840
18	X	24° 15.0'	80° 53.3'	549
19	X	24° 15.3'	80° 53.6'	462
21	C	24° 18.3'	80° 58.1'	305
22	C	24° 21.6'	81° 02.0'	225
23	C	24° 27.4'	81° 06.2'	195
24	C	24° 30.3'	81° 12.9'	180
25	C	24° 33.7'	81° 17.0'	38
26	X	22° 53.3'	78° 29.9'	472
27	C	22° 45.8'	78° 32.7'	495
28	C	23° 58.3'	79° 13.4'	525
29	X	23° 58.9'	79° 15.4'	580
30	X	23° 55.7'	79° 27.6'	566
31	X	23° 53.2'	79° 37.8'	550
32	X	23° 52.6'	79° 42.7'	396

Cruise 4 (cont'd) August 18 - 29, 1991				
Station No.	Type of Cast	Latitude (N)	Longitude (W)	Water Depth (m)
33	C	25° 49.2'	80° 04.9'	45
34	C	25° 49.4'	80° 03.3'	215
35	C	25° 49.2'	80° 00.8'	270
36	C	25° 49.0'	79° 58.4'	295
37	C	25° 49.1'	79° 55.9'	315
38	C	25° 49.3'	79° 54.7'	305
39	C	25° 50.2'	79° 53.4'	315
40	X	25° 49.0'	79° 46.5'	836
41	C	25° 49.5'	79° 40.2'	765
42	X	25° 49.1'	79° 32.5'	805
43	C	25° 50.6'	79° 25.4'	720
44	C	25° 48.4'	79° 18.2'	275
45	C	26° 03.0'	78° 52.6'	215
46	C	26° 08.5'	78° 50.6'	385
47	C	26° 15.1'	78° 46.7'	505
48	X	26° 17.6'	78° 45.1'	593
49	C	26° 20.6'	78° 43.3'	780
50	X	26° 25.1'	78° 42.2'	758
51	C	26° 27.8'	78° 40.9'	290
52	X	26° 51.7'	79° 07.4'	406
53	X	26° 51.6'	79° 14.7'	628
54	X	26° 51.7'	79° 22.2'	658
55	X	26° 51.7'	79° 30.3'	736
56	X	26° 51.7'	79° 39.4'	586
57	X	26° 51.5'	79° 44.0'	442
58	X	26° 52.0'	79° 49.0'	338
59	X	26° 52.4'	79° 51.6'	278
60	X	26° 52.3'	79° 53.9'	228
61	X	26° 52.5'	79° 56.2'	172
62	X	26° 52.6'	79° 58.5'	93
	C=CTD X=XBT			

Table 4.3-5 Listing of dates, locations, water depths and types of cast for Cruise 5, the mooring recovery cruise.

Cruise 5
November 11 - 18, 1991

Station No.	Type of Cast	Latitude (N)	Longitude (W)	Water Depth (m)
1	C	24° 36.9'	82° 41.9'	24
2	C	24° 37.4'	82° 46.8'	25
3	C	24° 37.1'	82° 36.8'	23
4	C	24° 26.6'	82° 11.2'	68
5	C	24° 22.5'	82° 11.7'	161
6	C	24° 18.2'	82° 11.7'	245
7	C	24° 14.6'	82° 11.0'	560
8	C	24° 11.6'	82° 12.5'	650
9	C	24° 03.7'	82° 11.7'	840
10	X	24° 03.2'	82° 11.6'	840
11	X	23° 57.8'	82° 11.6'	1020
12	X	23° 50.5'	82° 11.8'	1510
13	C	23° 50.4'	82° 11.8'	1500
14	C	24° 33.9'	81° 17.0'	38
15	C	24° 30.5'	81° 12.9'	170
16	C	24° 27.1'	81° 05.0'	195
18	X	24° 21.4'	81° 01.9'	250
19	C	24° 17.8'	80° 57.1'	335
20	X	24° 13.2'	80° 51.7'	810
21	C	24° 10.1'	80° 45.4'	855
22	X	24° 05.7'	80° 41.4'	990
23	X	24° 00.5'	80° 35.1'	1080
24	X	23° 58.2'	80° 31.3'	800
25	C	22° 45.3'	78° 32.3'	510
26	C	22° 50.7'	78° 28.9'	427
27	C	23° 53.1'	79° 43.1'	396
28	C	23° 53.3'	79° 38.2'	533
29	C	23° 56.0'	79° 27.5'	575
30	C	23° 58.1'	79° 15.2'	604
31	C	23° 59.2'	79° 11.5'	475

Cruise 5 (cont'd)
November 11 - 18, 1991

Station No.	Type of Cast	Latitude (N)	Longitude (W)	Water Depth (m)
32	C	25° 49.2'	80° 04.9'	50
33	C	25° 49.1'	80° 03.0'	225
34	C	25° 49.1'	80° 00.8'	265
35	C	25° 49.0'	79° 58.3'	300
36	C	25° 49.1'	79° 55.9'	300
37	C	25° 49.1'	79° 54.5'	311
38	C	25° 49.6'	79° 53.0'	325
39	X	25° 48.9'	79° 46.3'	841
40	C	25° 49.7'	79° 40.0'	760
41	X	25° 49.1'	79° 32.5'	800
42	C	25° 49.0'	79° 24.1'	710
43	C	25° 48.2'	79° 18.7'	350
44	C	26° 28.2'	78° 41.2'	508
45	X	26° 25.7'	78° 42.3'	780
46	C	26° 21.9'	78° 43.3'	774
47	X	26° 18.5'	78° 45.5'	570
48	C	26° 14.3'	78° 46.8'	508
49	C	26° 08.3'	78° 50.9'	388
50	C	26° 02.2'	78° 51.7'	200
51	X	26° 52.5'	79° 07.9'	400
52	X	26° 52.0'	79° 14.7'	630
53	X	26° 51.8'	79° 22.4'	675
54	X	26° 51.6'	79° 30.0'	775
55	X	26° 52.2'	79° 39.7'	600
56	X	26° 52.1'	79° 44.4'	452
57	X	26° 52.2'	79° 48.9'	350
59	X	26° 52.1'	79° 51.8'	350
60	X	26° 52.4'	79° 54.2'	225
61	X	26° 52.3'	79° 56.1'	185
62	X	26° 52.6'	79° 58.6'	75
	C=CTD X=XBT			

V. METEOROLOGICAL DATA

5.1 Data Sources

Meteorological data to be used in this study was obtained from various units within NOAA. NDBC is responsible for CMAN stations, which provide data on wind velocity, air temperature and atmospheric pressure. Observations from weather stations, often from airports, is obtained from the NWS. These data may be close to the coast; however, they are generally not at the coast and hence are of lesser direct utility as compared to CMAN data. CMAN and NWS stations used in this study are identified in Section 2.3.5.2.

5.2 Data Processing

All meteorological data used in this study was obtained from NOAA. As such it has gone through their normal quality control procedures. All these data are also put through the entire time series quality control procedures that SAIC uses on any data prior to its being put in the program data base. A general description of these procedures is presented in Section 3.2. Generally, meteorological data received from the various NOAA sources has few problems other than possible data gaps.

5.3 Data Summary

Time line of meteorological data presently available is shown in Figure 2.3-2. Note that complete data records for the entire field effort are not available at this time. The key variable of interest for the present study is wind velocity (speed and direction), which is used when computing wind stress. Atmospheric pressure is needed primarily so that it can be removed from the subsurface pressure measurements, which are used as a measure of water level.

VI. WATER LEVEL DATA

6.1 Instrumentation and Data Sources

Much of the water level data for this program is obtained from NOAA/NOS. The specific sites have been presented previously in Section 2.3.5.3. In addition, as part of this program, SAIC deployed two bottom-mounted precision water level recorders. The version used was an Aanderaa, Model WLR7. The pressure sensor is based on a pressure-controlled, quartz crystal oscillator. For the unit having a range of 0-3000 psi, the water level resolution is 2cm based on a full-scale signal. The instrument has a real-time clock and is capable of collecting data at a 0.5 hr interval for 270 days. Data recorded is a 40-second average pressure. Data is recorded internally on a solid-state Data Storing Unit (DSU) and is retrieved using the Aanderaa Model 2995 DSU Reader, which outputs the data in a form compatible for input to a computer where normal time series processing techniques are applied.

Many of the subsurface current meters (generally at least one per mooring) also had a less sensitive pressure measuring capability. These observations were made to get a general idea about the response (draw down) of the mooring equipment as it was exposed to drag variations resulting from changing currents. These data are not appropriate for other uses, such as indications of changes in local water level.

6.2 Data Processing Procedure

Water level data received from NOAA/NOS has gone through an extensive quality review procedure prior to being released to the public. However, to maintain local quality assurance, time series processing procedures described in Section 3.2 are applied to all water level data regardless of source. Generally, water level data received from NOAA is of excellent quality.

Water levels measured as part of this program are transcribed as described in Section 6.1. Following this, standard time series processing techniques are applied. Because field, logistics and scientific personnel are collocated in Raleigh, NC where data processing takes place, any data concerns can be resolved locally and appropriate corrections or adjustments implemented. The data taken for the program was of excellent quality when available.

6.3 Data Summary

The water level sensor deployed at B4 at the beginning of the program was not retrieved during the first rotation cruise. This was the only instrument lost during the entire study. Since no backup was onboard, a replacement was not deployed at that time. During the second rotation cruise (at approximately six months) a water level sensor which had been borrowed was deployed but did not work properly. On the final rotation cruise, another Aanderaa WLR7 was deployed at B5 in shallow water on Cay Sal Bank very close to mooring B4. This instrument worked properly and provided good data for the final quarter. The Aanderaa WLR7 deployed at Mooring C3 near Bimini worked properly throughout the program. A timeline for both government provided and program water levels is shown in Figure 2.3-3. Data return from program water level observations is included in Table 3.4-1.

VII. SATELLITE IMAGERY

7.1 Overview

This chapter documents the acquisition and processing of advanced very high resolution radiometer (AVHRR) infrared imagery of sea surface temperature for the period from November 1, 1990 through April 30, 1991. All available AVHRR imagery from the NOAA-11 satellite was acquired and screened to reject images with a significant amount of cloud cover. Weekly composite images of the study area from 20.4°N to 30.6°N, 78°W to 87°W were prepared, and current meter data from December 1, 1990, through April 30, 1991 were overlaid on the images. Drifter tracks in weekly segments in the period from February 17 through April 6, 1991, were overlaid on the images, and the composite was photographed for inclusion in the data report.

7.2 Data Processing Procedures

This section provides an overview of AVHRR SST imagery, describes the imagery and drifter datasets used in the analysis, and outlines the analysis procedures.

7.2.1 SST Imagery Overview

Infrared imagery of the earth's surface is available from the NOAA Polar Orbiting satellites' AVHRR, which measures visible and infrared radiation in four or five bandwidths. Each satellite has a slightly different suite of instruments; however, the even numbered satellites (NOAA-6, -8, -10) generally measure radiation in four bandwidths (channels) and the odd numbered satellites (NOAA-7, -9, -11) and NOAA-12 measure in five bandwidths. Data transmission is always five channels. The fifth data transmission channel repeats the fourth bandwidth of radiometer data from a four channel radiometer. Two bandwidths (channels #4 and #5) of the five channel radiometer and one bandwidth (channel #4) of the four channel radiometer are generally used in determining sea surface temperature. These data are converted from radiance to temperature, corrected for water vapor in the atmosphere (but not for clouds) if two radiometer channels are available, remapped to a user selected map projection and displayed as color enhanced images. The use of two channels of data to determine SST (sea surface temperature) results in a more accurate temperature (McClain et al. 1983).

The highest spatial resolution of the AVHRR is nominally 1.1 km at nadir and temperature resolution is 1/8 degree Kelvin (10 bit scale). High resolution data are downlinked in real time if the satellite is in view of a ground station in the HRPT (High Resolution Picture Transmission) mode, or limited time periods are stored for later transmission as LAC (Local Area Coverage) data. Data are also averaged and stored in the satellite in a lower resolution GAC (Global Area Coverage) mode. The GAC data provide global coverage at a maximum resolution of four kilometers.

Each polar orbiting satellite passes over a portion of the U.S. east coast, including the study area (20.5°N to 30.6°N, 76°W to 87°W), twice daily. There are normally two polar orbiters operational (NOAA-10 and -11 during the time of this program) so two nighttime and two daytime views of some portion of the area are available daily. The AVHRR sensors also detect clouds so that clear sky images of the entire area are relatively rare. Successive views can be composited to alleviate the effects of cloud cover in some cases. Front

positions may be more difficult to distinguish in summer time as the sea surface becomes uniformly warm, thus only imagery from November through April was acquired. Technical details and data formats can be found in the NOAA Polar Orbiter Data Users Guide (NOAA 1991).

Each image used was a mercator projection of the study area. Remapping from satellite scan coordinates to 512x512 pixel earth coordinate mercator projection was done using bilinear interpolation in both space and intensity on a 12x12 interpolation grid. Data were converted from radiance to temperature and corrected for atmospheric water vapor using standard algorithms (McClain et al. 1983) for channels 4 and 5.

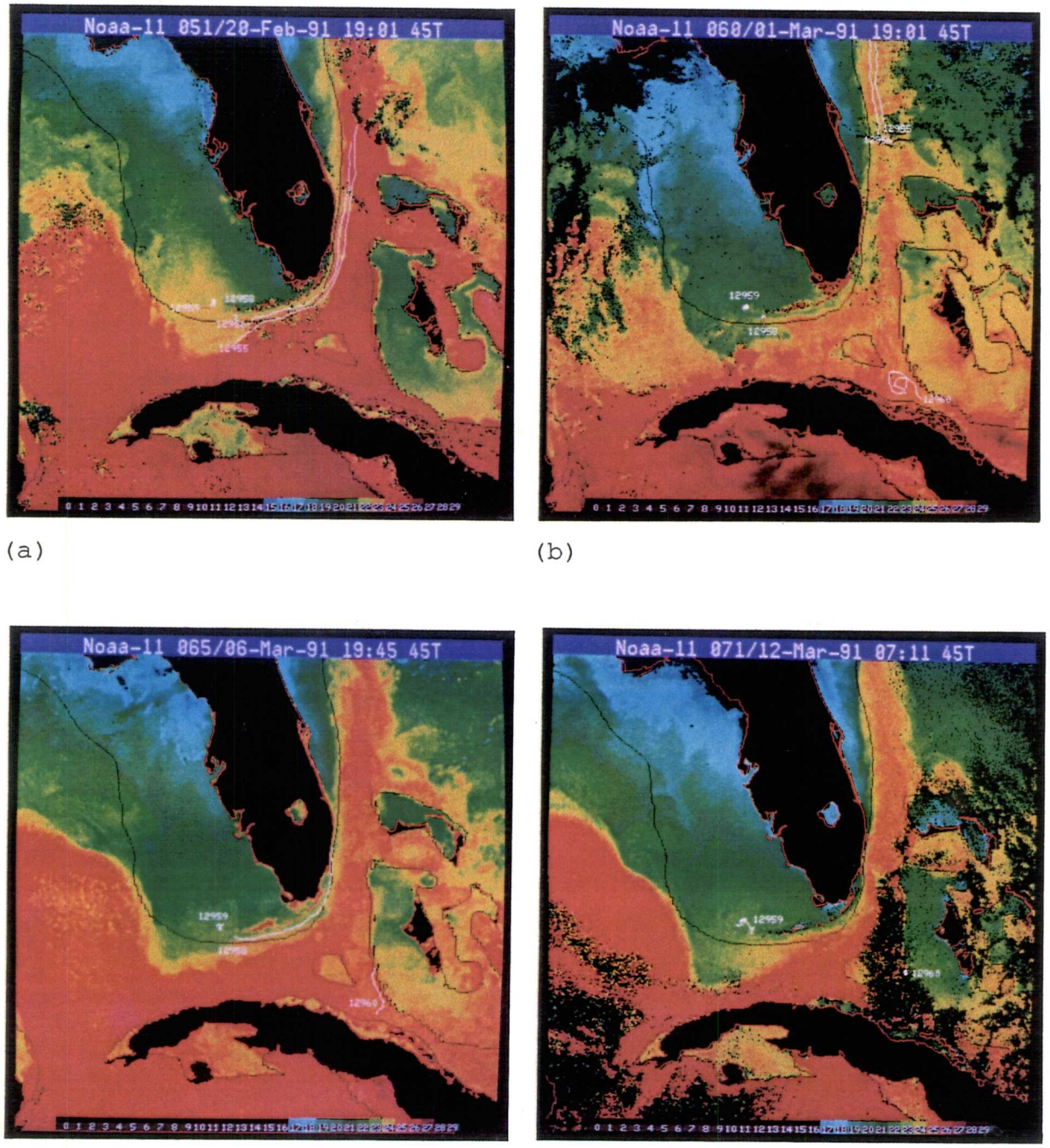
The image compositing routine involves a pixel by pixel comparison of two images with the warmer pixel being chosen for retention. This takes advantage of the facts that clouds are generally somewhat cooler than the sea surface at the study area latitude and they move. A secondary effect of the compositing process is to smear the edges of moving features such as eddies or the Gulf Stream. Images were selected such that a composite included either all AM or all PM passes and the time span between images was constant.

7.2.2 Imagery Database Summary

Data acquired for this project were 486 HRPT images for the period November 1, 1990, through April 30, 1991. Two hundred fifty four images were retained online for further evaluation. Sixty-nine images were chosen for use in the weekly composites.

Twenty-two weekly composites, each prepared for two or three images, provided a relatively cloud free view of the study area during the period when current meter data were available from most of the moorings. A total of 69 images were used in generating the composites. A subset of seven composites was also used in conjunction with the first deployment of lagrangian drifters as shown in Figures 7.2-1 and 7.2-2.

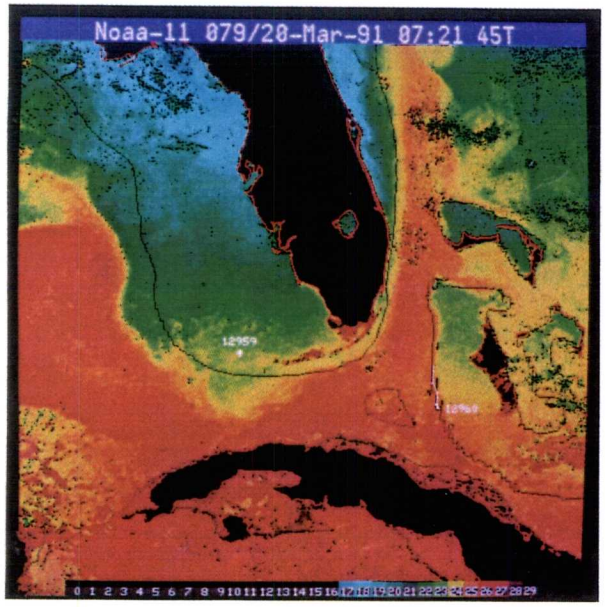
Two of the weekly composites (December 2-8, 1990, and January 13-19, 1991) had major portions of the Straits of Florida area covered by clouds such that none of the major oceanographic features were visible. A third composite (March 10-17, 1991) had substantial cloud cover in the Santaren and Old Bahama Channels. All of the remaining composites have some scattered clouds or areas of high moisture content, but these do not appear to obscure any major oceanographic features. Only 22 of the individual images were essentially cloud free over the water areas of interest.



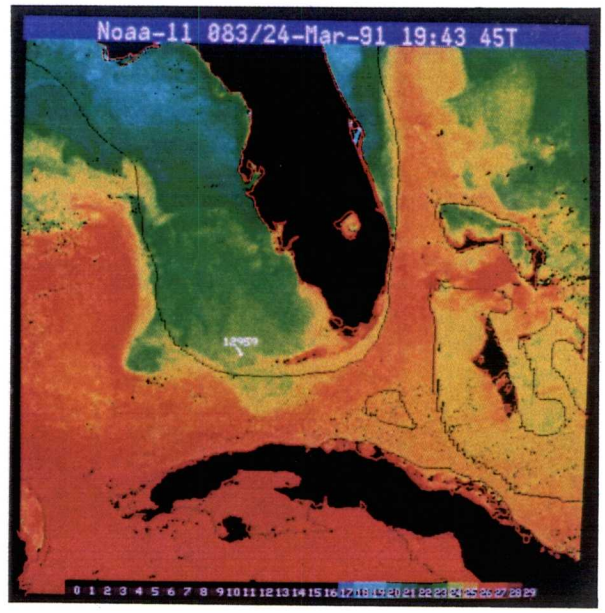
(a) (b)

(c) (d)

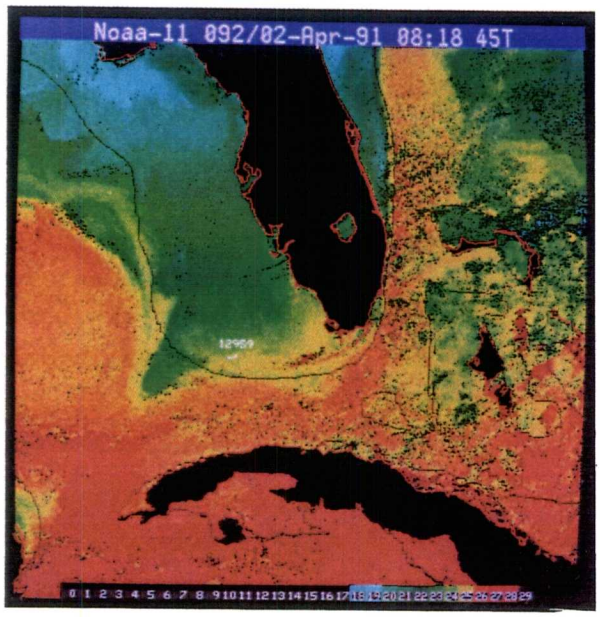
Figure 7.2-1. AVHRR weekly composite images with drifter segments overlaid. (a) February 17 - 23, 1991. (b) February 24 - March 2, 1991. (c) March 3 - 9, 1991. (d) March 10 - 16, 1991.



(a)



(b)



(c)

Figure 7.2-2. AVHRR weekly composite images with drifter segments overlaid. (a) March 17 - 23, 1991. (b) March 24 - 30, 1991. (c) March 31 - April 6, 1991.

VIII. SUMMARY

8.1 Summary

The present report is a description of observations taken and/or obtained for use as part of the Straits of Florida Physical Oceanographic Field Study. No discussion of analysis or scientific interpretation of the data is included. That will be presented in the Final Interpretive Report for the study.

The data acquisition phase of this study as described in this report has been quite successful. The general design appropriately supported the program objectives, and the proposed observations were completed in such a way as to provide a data base that will allow the program principals to develop the data and understandings expected from the study.

During five, seasonal cruises, a total of 21 moorings containing 63 in-situ instrument positions were successfully deployed, serviced and maintained. The resulting data return was excellent with only one instrument being lost. During the mooring/hydrographic cruises, 300 CTD/XBT stations were occupied and 15 ARGOS-tracked drifters were released. Meteorological data was obtained from seven coastal or near coastal locations (4-CMAN; 3-NWS) and water levels were obtained from four NOS stations. These latter data supplemented the observations at two sites made as part of this study. Approximately 486 satellite thermal (HRPT) images were obtained, processed and composited to provide area-wide documentation of sea surface temperature fields.

On four cruises, a total of 181 PEGASUS velocity profiles were made at 17 stations spanning three separate transects. These data are to provide accurate estimates of transport which can be used to help calibrate the scheme by which subsurface current data are used to compute total transport over a transect.

As a result of an Interagency Agreement with NOAA/Pacific Marine Environmental Lab (PMEL), estimates of transports across two key transects (82°W and 27°N) were provided. These are based on voltage measurements made on cables which extend across the entire section. The original northern cable was calibrated using PEGASUS profiles during STACS. The southern cable calibration was estimated from knowledge of other calibrations in the area. Near the beginning of the program, observations from the northern cable were no longer provided, and data from a new active cable was substituted. This was calibrated by examining overlapping periods when observations were made on both cables.

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