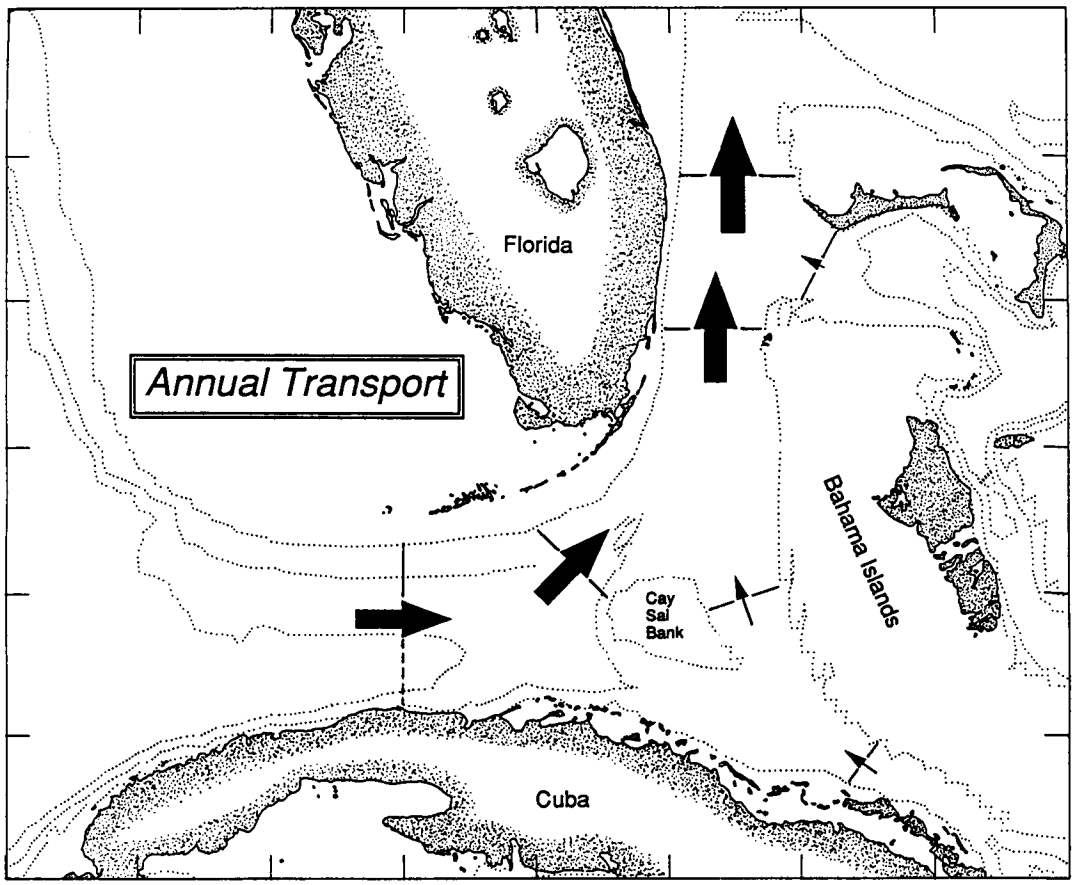
OCS Report
MMS 92-0024

Straits of Florida
Physical Oceanographic Field Study

Final Interpretive Report
Volume I: Executive Summary



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

OCS Report
MMS 92-0024

Straits of Florida Physical Oceanographic Field Study

Final Interpretive Report
Volume I: Executive Summary

Author:

Science Applications International Corporation

Prepared under MMS Contract
14-35-0001-30493
by
Science Applications International Corporation
Raleigh, North Carolina 27605

Program Manager: Evans Waddell, Ph.D.
Science Applications International Corporation
Raleigh, North Carolina 27605

Project Officer: Robert Miller, Ph.D.
Minerals Management Service
Atlantic OCS Regional Office

Published by:

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

Herndon
1992

DISCLAIMER

This report was prepared under contract between the Minerals Management Service (MMS) and Science Applications International Corporation (SAIC). This report has been technically reviewed by the MMS and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Service, nor does mention of trade names or commercial products constitute endorsement or recommendation for use. It is, however, exempt from review and compliance with MMS editorial standards.

REPORT AVAILABILITY

Extra copies of the report may be obtained from the Public Information Unit (Mail Stop OPS-3-4) at the following address:

U.S. Department of the Interior
Minerals Management Service
Atlantic Region (LE-4)
381 Elden Street
Suite 1109
Herndon, VA 22070-4817

Telephone Number: (504) 736-2519

CITATION

Science Applications International Corporation, 1992, Straits of Florida Physical Oceanographic Field Study, Final Interpretive Report. Volume I: Executive Summary. OCS Report/MMS 92-0024. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Regional Office, New Orleans, LA. 19 pp.

ABOUT THE COVER

The cover illustration suggests the relative scale of annual transport through the various channels in the general study area.

TABLE OF CONTENTS

Section	Page
List of Figures	ii
List of Tables	ii
Acknowledgements	iii
I. INTRODUCTION	1
1.1 Study Objectives	1
1.2 Scope of Study	1
1.3 Approach and Methodology	4
1.3.1 Study Area Description	4
1.3.2 Program Sampling Design	4
1.3.3 PEGASUS Profiling	6
1.3.4 Drifters	6
1.3.5 Hydrography	6
1.3.6 Ancillary Data	6
1.3.6.1 Satellite Imagery	6
1.3.6.2 Meteorological Observations	6
1.3.6.3 Water Level Observations	9
II. TECHNICAL DISCUSSION	11
2.1 Introduction	11
2.2 Current Patterns	11
2.3 Transport	12
2.4 Hydrography	17
2.5 Tides	17

LIST OF FIGURES

Figure No.	Caption	Page
1.1-1	Map of general study area	2
1.3-1	Locations of moorings deployed on the indicated sections (Transects A, B, C, D, E, F, G and H)	5
1.3-2	Locations of the 17 PEGASUS profiling stations on Transect E (Stations 1-5), Transect F (Stations 6-10) and Transect B (Stations 11-17)	7
1.3-3	Locations of typical hydrographic stations occupied during the five seasonal cruises. The squares indicated CTD stations and the "X" indicated XBT stations. Note that only a mid-channel station was sampled in OBC and stations only went halfway across Transect A	8
1.3-4	Map showing the locations meteorological and water level stations in the general study area	10
2.2-1	Vectors representing daily average drifter velocity. The unit released on Transect A moved rapidly along channel and quickly out of the SoF. The unit released SE of Cay Sal Bank, drifter slowly through Santeran Channel and eventually moved into and out of NW Providence Channel	13
2.3-1	Time series plots of transport based on current meters (solid lines) and cables (dashed lines) on the indicated transects for the period from December 1990 to November 1991	15
2.3-2	Transport time series estimated by sums or differences (solid lines) and cable-based or current-meter based estimates on the indicated transect. The bottom plot shows the complete estimate of transport on Transect A using both cable and sums and differences of transport in other channels	18

LIST OF TABLES

Table No.	Caption	Page
2.3-1	Transport Statistics and Correlations	16
2.5-1	Tidal Constituent Transports	19

Acknowledgements

The success of a complex undertaking such as the Straits of Florida Physical Oceanographic Field Study results from the diligent support of a number of skilled and dedicated individuals. Thanks are extended to those who went to sea aboard the **M/V Seaward Explorer** and the **R/V Calanus**. The excellence and continuity of data resulting from these field activities were the foundation of the program. Dr. Robert Miller (MMS/Atlantic Region) provided valuable program support and guidance which is much appreciated. An Interagency Agreement between MMS and NOAA provided for participation in the program of Dr. James Larsen, PMEL, and incorporation of transport estimates based on his cross-channel cable measurements. He also made us aware of additional Pegasus-based transport estimates at 27°N made by M. Bushnell (AOML) which provided program principal investigators with increased confidence in the computational scheme for estimating transport from current-meter time series.

I. INTRODUCTION

1.1 Study Objectives

The Minerals Management Service (MMS), through its Outer Continental Shelf (OCS) Environmental Studies Program funds contracted with Science Applications International Corporation (SAIC) to conduct the Physical Oceanographic Field Study of the Straits of Florida (SoF).

The specific objectives of this study were two-fold:

1) To acquire data sets which provide initial and boundary conditions for a numerical circulation model as well as information which 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 these objectives support, is development of a numerical circulation model which 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 (Figure 1.1-1). Effective and compatible modeling of the Loop Current and the Gulf Stream are 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 which 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).

1.2 Scope of the Study

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)

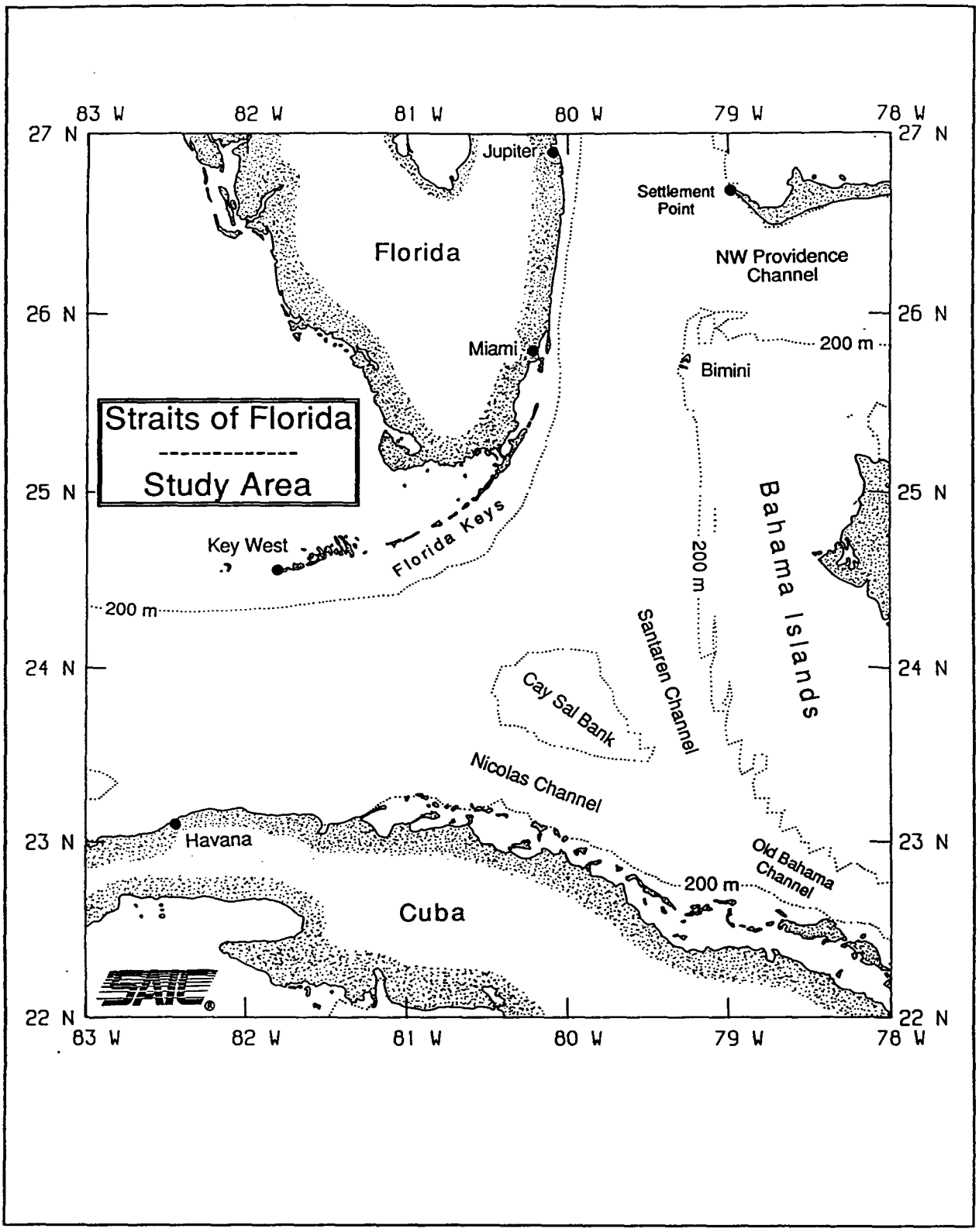


Figure 1.1-1 Map of the general study area.

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 were supplemented with transport computed using PEGASUS velocity profiles which were made on three key cross-channel transects.

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

One program deliverable which the reader is directed to is a Program Data Report which describes in detail data taken (when, where and what) data return and data processing procedures. These topics will be included in the present report only to the extent that is necessary to present program results in an appropriate framework.

1.3 Approach and Methodology

1.3.1 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 SoF. While in the Straits of Florida, this major western boundary current is called the Florida Current (FC). The study area (Figure 1.1-1) for the present program is the SoF and the primary oceanograhpic features to be documented are the FC 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 FC 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 - Nicholas Channel toward Cuba and Santaren Channel (SC) 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, which connects the SoF with the Caribbean Sea.

1.3.2 Program Sampling Design

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), SC (F) and OBC (G) as shown in Figure 1.3-1. 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 which was used to estimate transport through the main and lateral channels as well as providing information needed to document FC dynamics. 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 which 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.

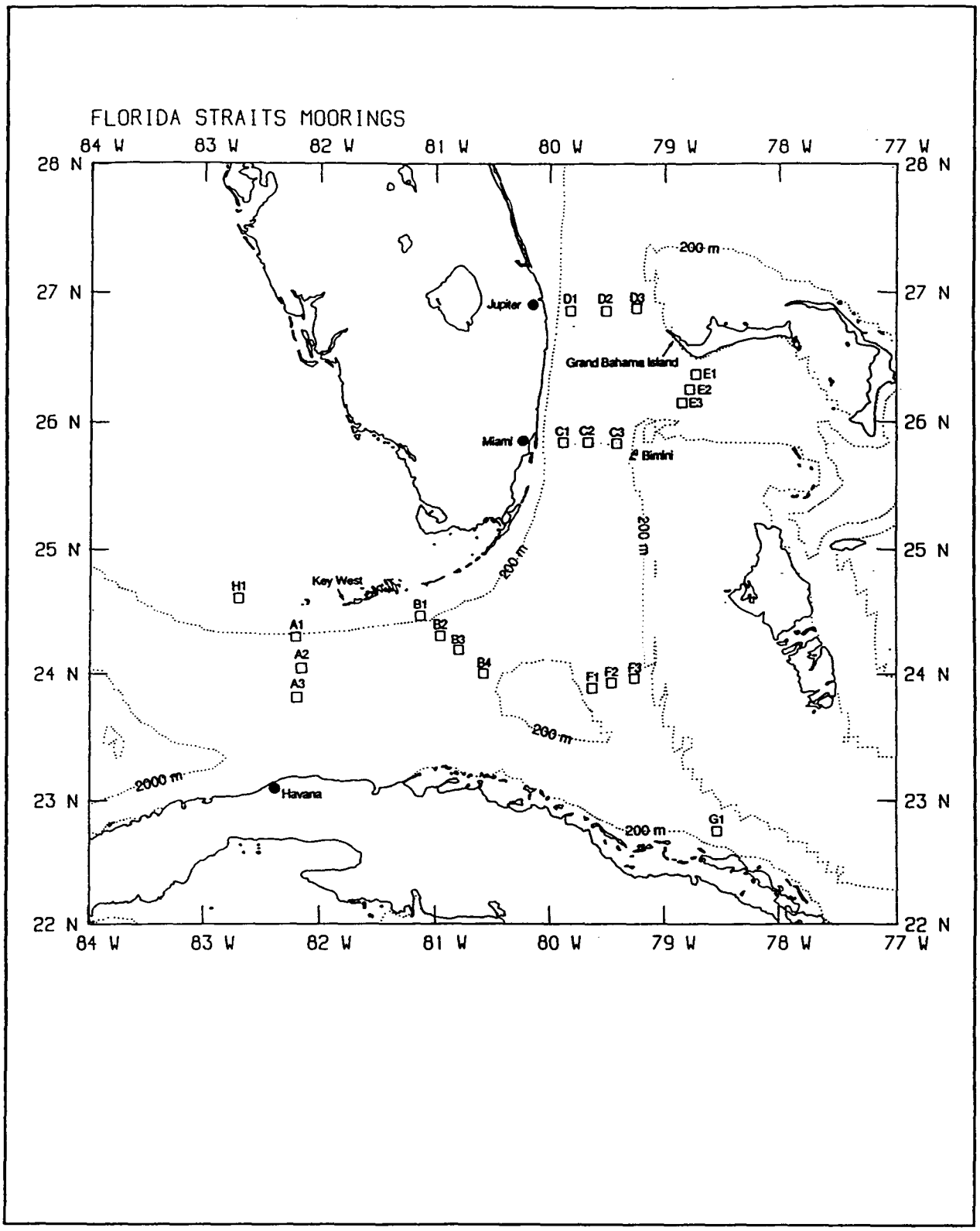


Figure 1.3-1 Locations of moorings deployed on the indicated sections (Transects A, B, C, D, E, F, G and H).

1.3.3 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 Climate Study (STACS) to provide sectional transport estimates. Via an Interagency Agreement with NOAA, the MMS arranged for Dr. J. Larsen (NOAA/PMEL) to provide these cable-based transport estimates as well as those for a cable between Key West and Havanna 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 1.3-2). With these and cable data from Transect D, transports computed from current meter time series through all key transects could be calibrated/evaluated.

1.3.4 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.

1.3.5 Hydrography

During each of the five quarterly mooring cruises, hydrographic profiles were measured along all of the mooring transects (Figure 1.3-3) shows a representative station location map. These profiles were obtained with either a CTD profiler or XBTs.

1.3.6 Ancillary Data

1.3.6.1 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 FC boundary at the surface can be located by looking for a marked temperature gradient between the FC 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.

1.3.6.2 Meteorological Observations

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 which

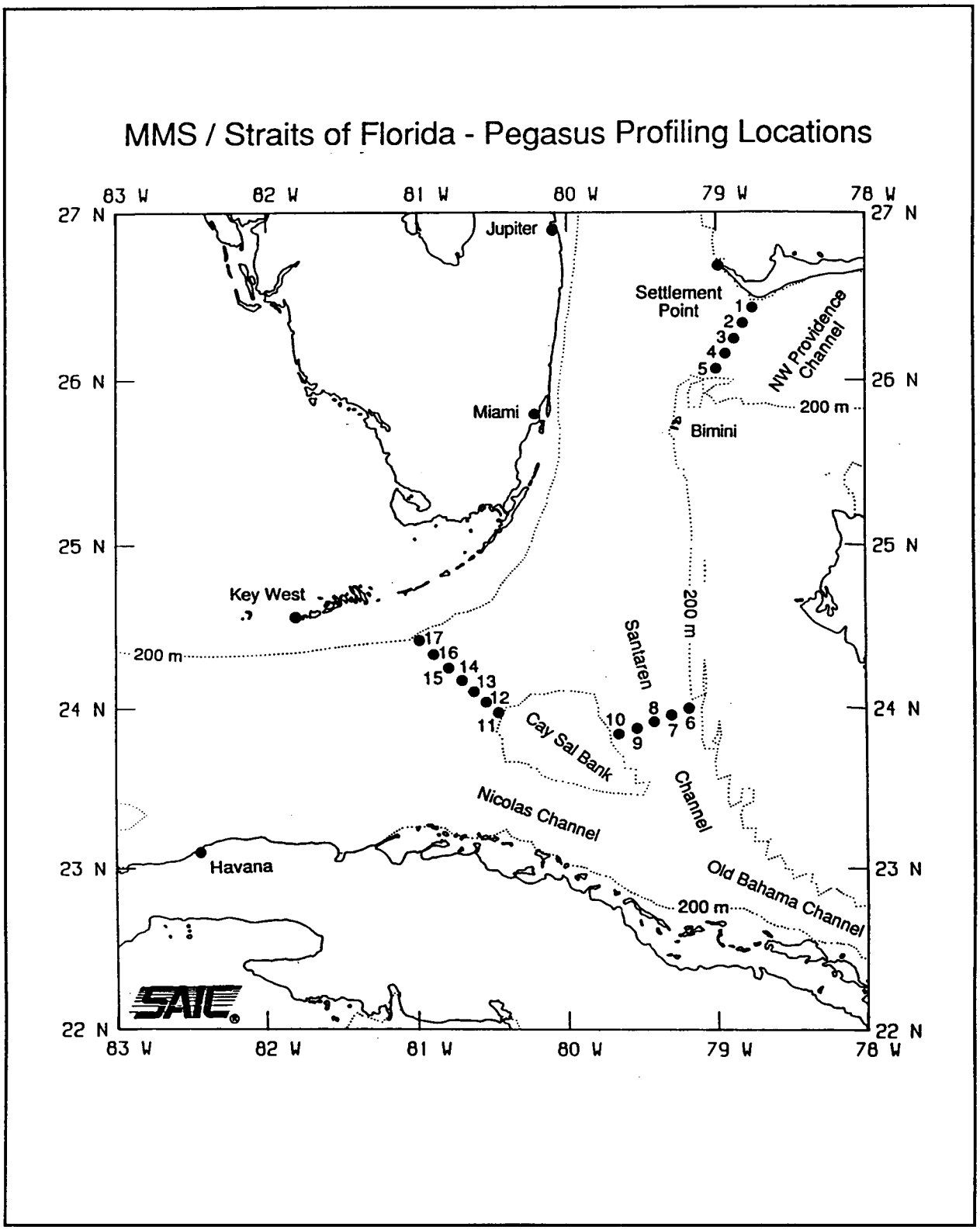


Figure 1.3-2 Locations of the 17 Pegasus profiling stations on Transect E (Stations 1-5), Transect F (Stations 6-10) and Transect B (Stations 11-17).

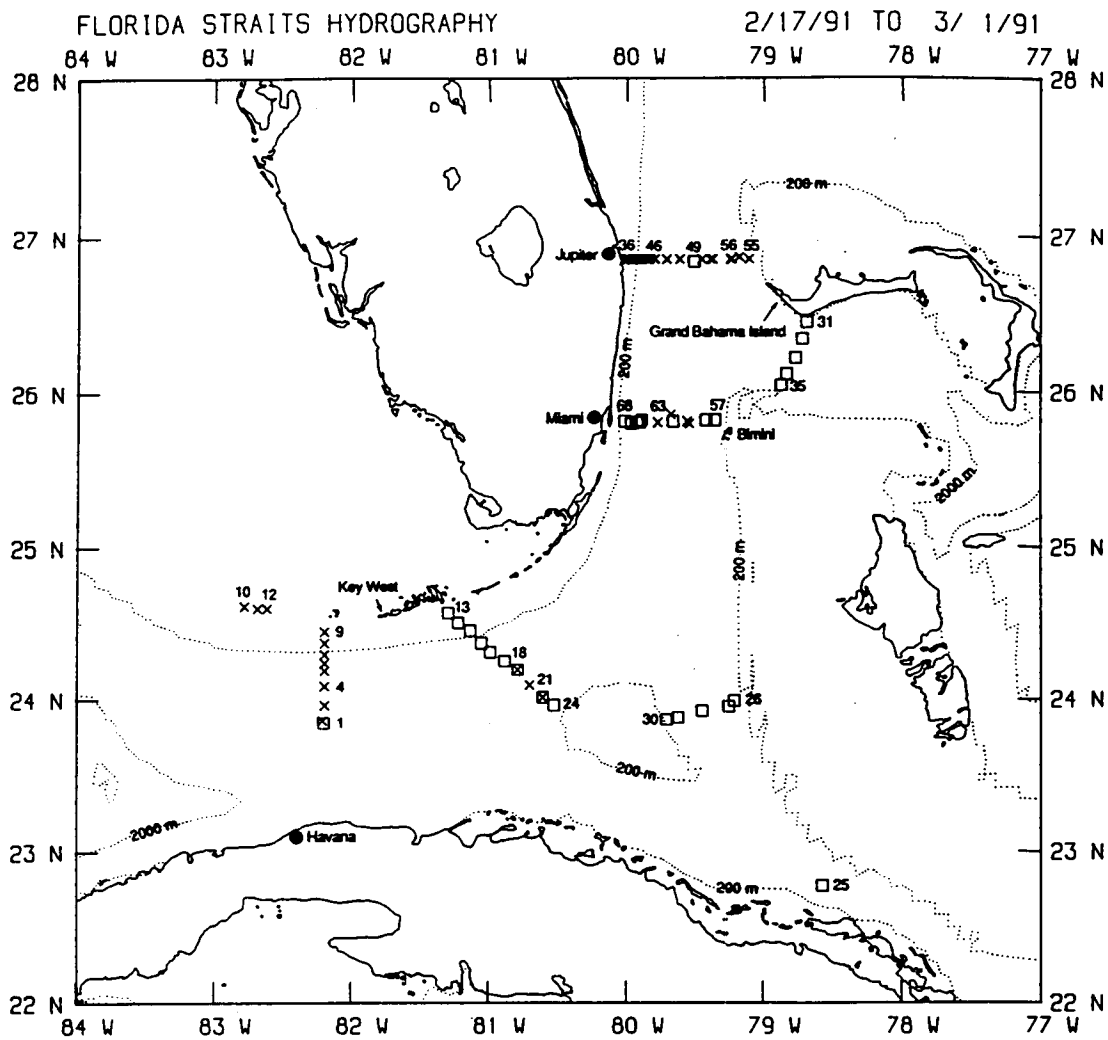


Figure 1.3-3 Locations of typical hydrographic stations occupied during the five seasonal cruises. The squares indicated CTD stations and the "X" indicated XBT stations. Note that only a mid-channel station was sampled in OBC and stations only went halfway across Transect A.

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 (Figure 1.3-4).

1.3.6.3 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 were located along the Florida Key and at one site in the Bahama Islands (Figure 1.3-4). These were supplemented with water level measurement at two sites as part of the present program. When the entire set of water level observations are grouped, water level gradients can be computed along or across many of the major channels (Transects B, C, D and E). Current meter based transport estimates were also made on all four of these channels with PEGASUS or cable calibration data being available for three transects (B, D and E).

Local winds (windstress on the water surface) have been identified as an important mechanism for causing variability in the nature and magnitude of currents and transport in the study area. Water levels often rise and fall in response to dynamic processes active in the SoF including tides. Thus it can be important to incorporate these data in an regional process characterization.

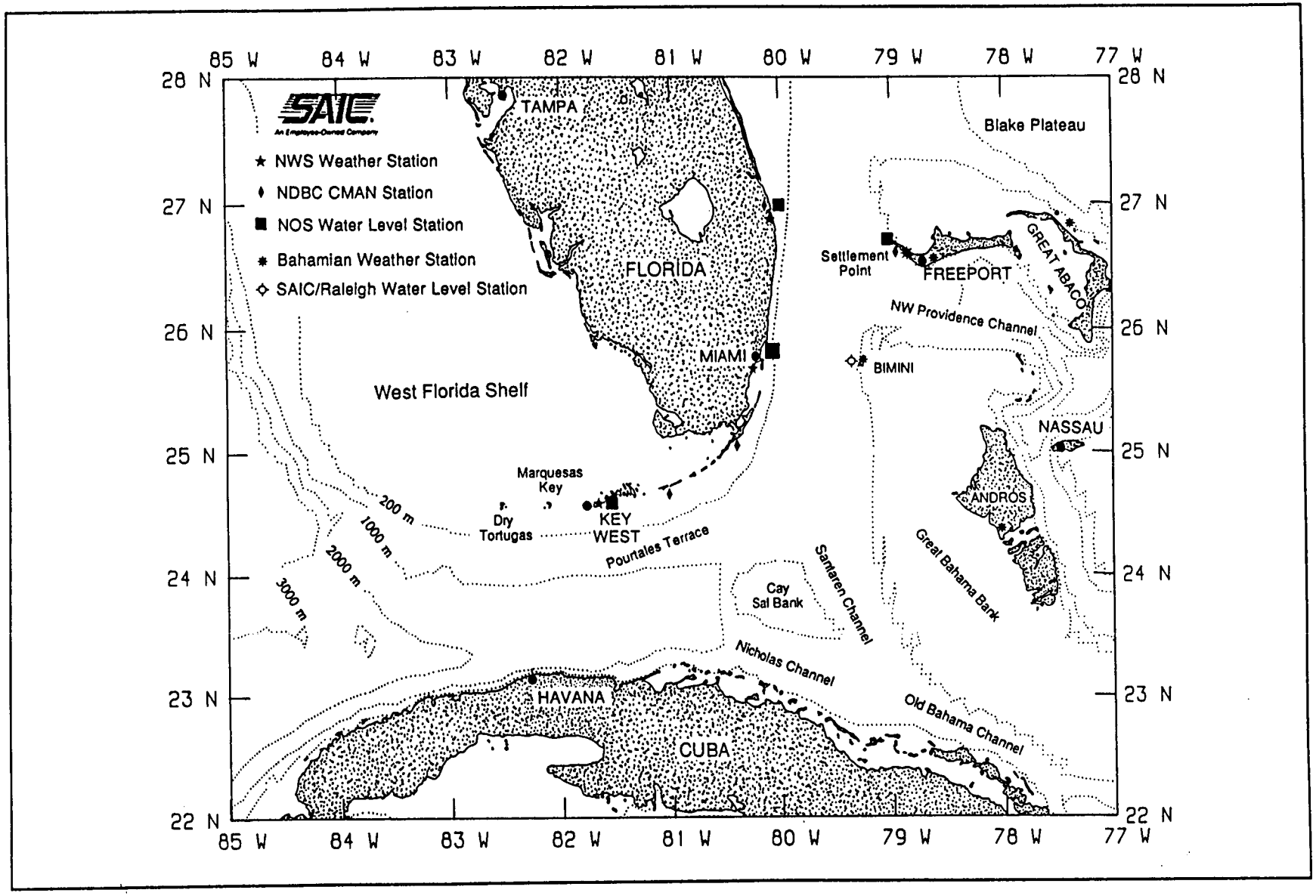


Figure 1.3-4 Map showing the locations of meteorological and water level stations in the general study area.

II. TECHNICAL DISCUSSION

2.1 Introduction

A comprehensive data base is available to a) support future numerical modeling activities in this key region connecting the Gulf of Mexico and the Atlantic Ocean, and b) provide an improved understanding of dynamic physical oceanographic process occurring in the study area.

The first (and primary objective) study objective of providing data to support modeling has been accomplished. It is the discussion of conditions in the area which is the major focus of this report. This discussion identifies and describes some of the major coherent patterns seen in this large data base. In particular, the focus has been on current patterns and transports as they vary in location and with time.

An effort has been made in this report to present the data in a concise manner. It should be realized however, that with time and reflection substantial additional insights can be developed from this excellent and comprehensive data base. It is the opinion of the project team that these data will provide oceanographers with a valuable resource well into the future.

In the discussion below different observations are joined to provide a more integrated appreciation of conditions in the study area.

2.2 Current Patterns

A combined analyses of satellite imagery, subsurface currents and hydrography helped identify an important pattern of the northern boundary of the FC and an associated circulation. Prior investigators have documented the presence of a fairly regularly occurring and persistent cold-dome off the southwestern corner of the west Florida shelf (Tortugas Gyre). While some evidence suggests it forms in conjunction with Loop Current boundary features, until now it was not clear what happened to it and where it went. In addition, we now have a better understanding of the larger impact which its migration can have on the larger scale circulation in the southern portion of the study area.

Results of this study show that the Tortugas Gyre is eventually advected to the east along the northern wall of the FC. In this movement, the dimension of the E-W oriented elliptical shape diminish. In the region of Transect B, this feature becomes what has been previously thought to be an independent feature called the Portales Gyre. In this eastward advection, a cyclonic rotation moves with the feature and establishes a mechanism for exchange of water between the outer shelf and upperslope.

These data do not provide evidence that this boundary feature "makes the turn" from the E-W channel to the N-S channel. Spectral analysis of velocity data indicates that the long period fluctuations in FC position seen in the south do not occur in the northern part of the FC.

The Tortugas Gyre tends to keep the main portion of the FC deflected to the south toward Cuba. As the gyre migrates eastward, the FC stays offshore. If this deflection is sufficiently large, the FC can become bifurcated by Cay Sal Bank

such that a substantial portion (as much as one half) of the FC flows counter clockwise around Cay Sal Bank (Nicolas Channel to Santaren Channel) and rejoins the main flow just south of Transect C.

Santaren Channel is also the conduit for the persistent (almost continuous) northward directed mid-depth currents in Old Bahama Channel (OBC). The temperature/salinity of the water comprising this mid-depth currents are different from those found in the Loop Current and the FC south and west of Transect B. They are more saline (up to 37 psu) and sometimes relatively warmer at this maximum salinity. This higher salinity water tends to move through Santaren Channel on the eastern side and at about 100-200m depth. This pattern may result in Santaren Channel water moving into NW Providence Channel on the south in conjunction with an often seen cyclonic (counter clockwise) circulation over Transect E in the channel entrance (Figure 2.2-1).

OBC surface and near surface currents alternately flow toward and away from FC. It is only below approximately 100-125m that currents are persistently directed northward toward the FC. Near surface currents measured in OBC are considerably stronger than previously suspected, reaching 2 kts (100 cm s^{-1}) and a 3 kt range (reversal) in approximately one day. These reversals are associated with strong tidal and inertial currents.

Currents in Santaren Channel show a definite maximum in mean currents on the eastern side centered about 250-300m in this 550m deep channel. Similarly mean currents in the entrance to the NW Providence Channel are a maximum at mid-depth such that flow is out (toward FC) on the north side and in (away from the FC) in the southern half of the channel.

Some of the structure of the currents in the main channel (Transects A, B, C and D) have been documented previously, especially in the northern portion of the study area. The relative difference in behavior of the FC between southern and northern sections is dependent in part on the change in the direction of regional wind fields relative to the channel orientation. In addition, the primary flow in the north seem more constrained by channel geometry such that large lateral shifts can not occur as they can in the region to the south.

2.3 Transport

Computation and estimation of transport in and through the study area was a major objective of the program design and a key component of the analysis effort. The high overall data return for subsurface currents (see the project Data Report) supported a transport computation scheme which has provided results are consistent with other independent estimates and historical data.

Previous studies of FC transport (STACS) have focused on water passing through a section at approximately 27°N. In addition, there was a calibrated cross channel cable which could provide historical and concurrent estimates of transport out of the study area. The availability of this data caused a major component of this study to be directed toward estimating transport through all the other sections which were instrumented with subsurface currents.

By using various sums and differences for instrumented transects, it is possible to estimate transport over sections which were not completely documented, e.g. Transect A. As an example, if transport over Transect B, F and G are known, then

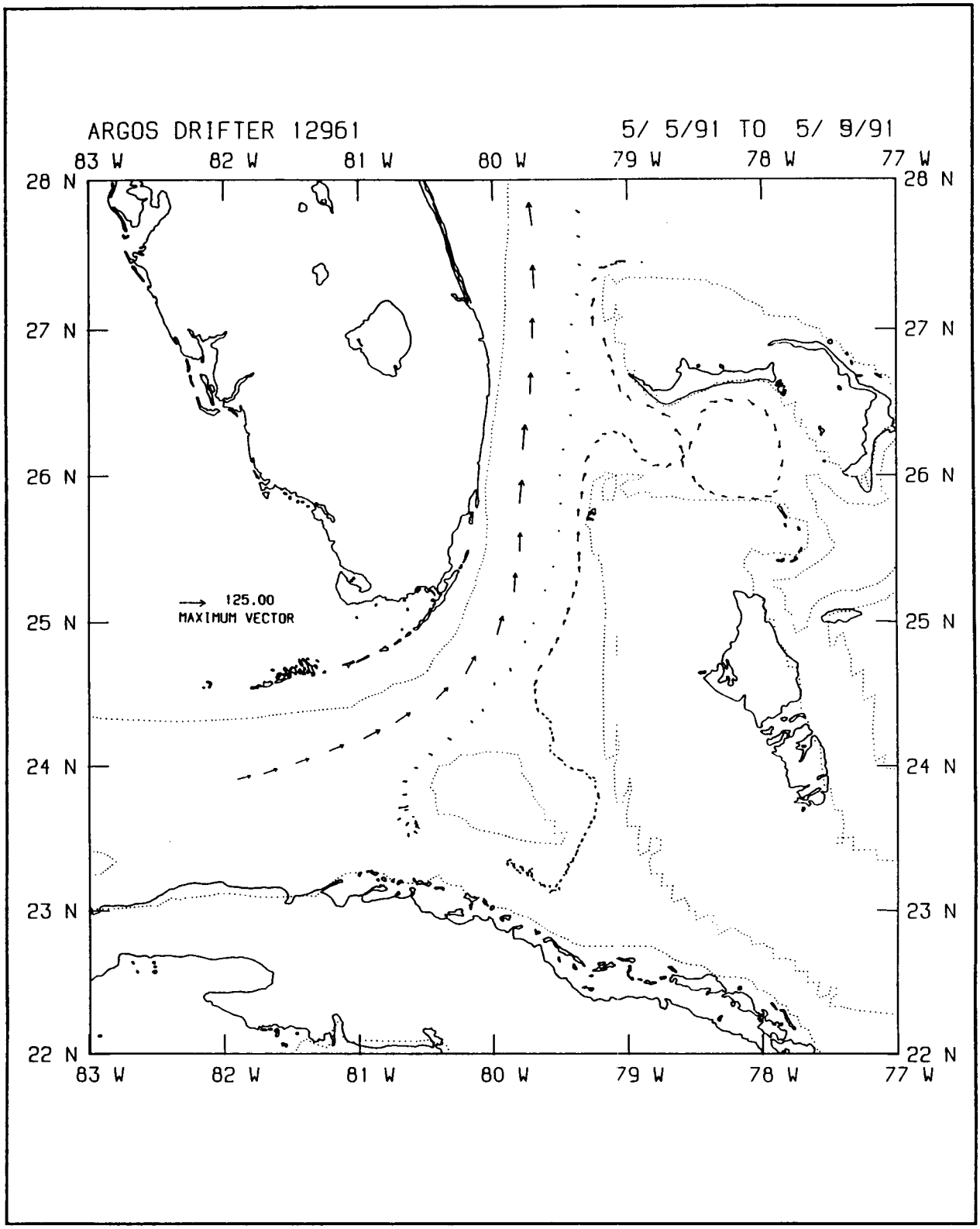


Figure 2.2-1 Vectors representing daily average drifter velocity. The unit released on Transect A moved rapidly along channel and quickly out of the SoF. The unit released SE of Cay Sal Bank, drifted slowly through Santeran Channel and eventually moved into and out of NW Providence Channel.

the transport over Transect A can be estimated by the sum of transports (B+F-G). Each of the component transports is based on local subsurface current-meter data. Similarly, the sum of (D-C) estimates transport over Transect E which can then be compared against the actual observations at E.

A summary of sums and differences and their correspondence to transects is shown below.

Transports at:		
	B + F - G	Corresponding to A
	B + F	Corresponding to C
	C - B	Corresponding to F
and	D - C	Corresponding to E

The time series of transports over the various transects is shown in Figure 2.3-1 in which transports are given in Sverdrups (1 Sverdrup (SV)=$1x10^6$ m^3 s^{-1}). The dashed lines represent transport as estimated by cables and the solid lines are estimates based on current-meter data. The statistics of these time series are given in Table 2.3-1. Also shown are the zero-lag correlation of some of these various transports. Note the strong agreement in all statistics between the cable-based estimate of transport over Transect A and that based on current meters. In addition, the estimated contributions of the main and lateral channels (input vs. output) balance quite closely at the study boundaries.

An important point is the lack of correlation between transport at Transect D as estimated by cable and current meters. The calibrated cable which has historically provided transport estimates ceased functioning so a new active cable was utilized. This new cable may not provide the same quality of data as the previous abandoned cable. During the study, comparison of the cable with transport estimates based on Pegasus data taken by NOAA, showed the cable missed some fairly large variations in transport which the current meter data detected.

The correlations also provide added support for the inverse correlation of currents and transport over Transects B and F. As mentioned in the previous section and discussed in the report volume, there is evidence that FC boundary features can deflect the main body of the FC sufficiently far south that a counterclockwise circulation is set-up around Cay Sal Bank which at times can be quite large (11.1 Sv). This is associated with reduced transport over Transect B (minimum of 10.3 Sv). The dominance of this pattern in flow through Transect F is further illustrated by the lack of significant correlation between flow through the OBC Transect G and Transect F.

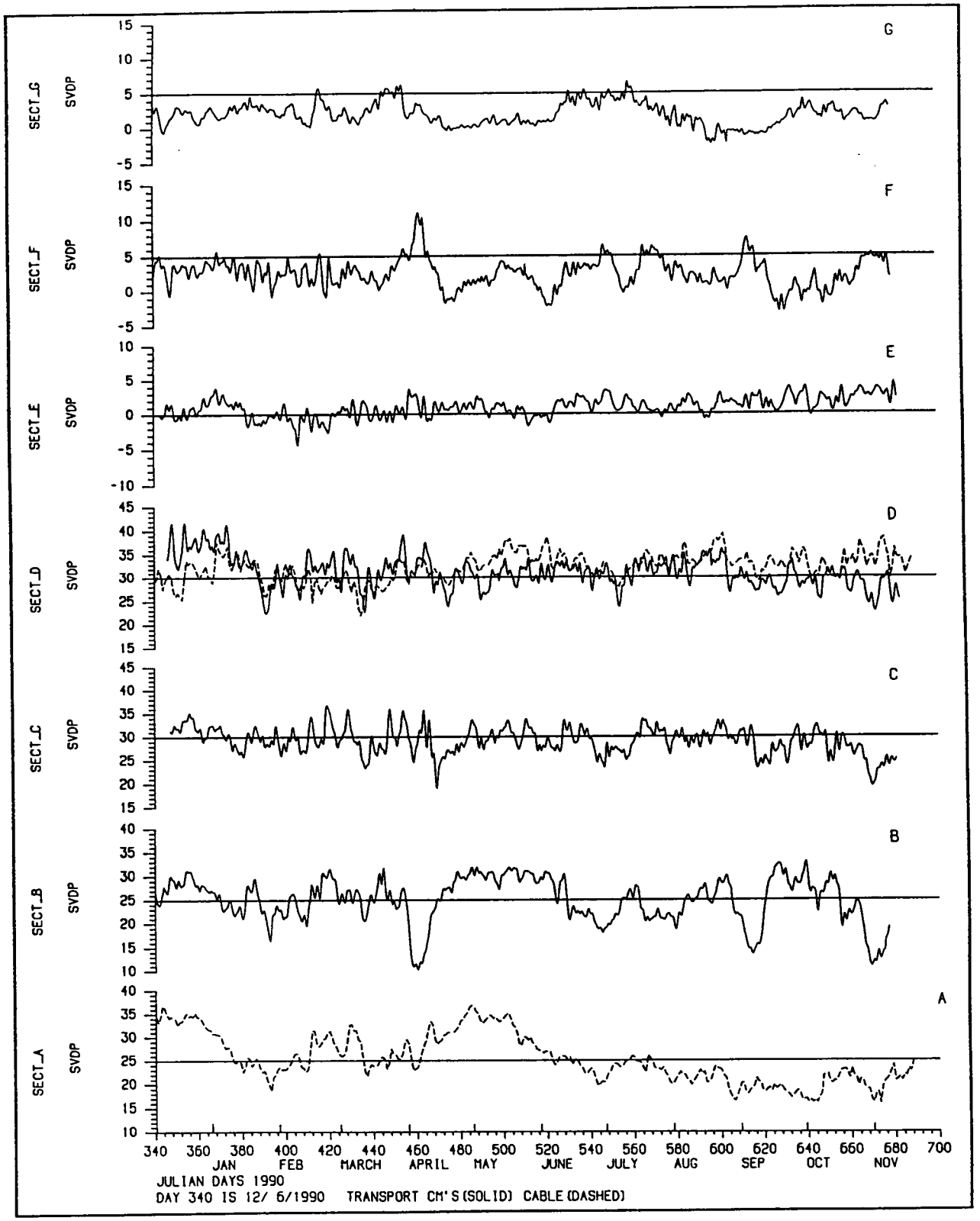


Figure 2.3-1 Time series plots of transport based on current meters (solid lines) and cables (dashed lines) on the indicated transects for the period from December 1990 to November 1991.

Table 2.3-1 Transport Statistics and Correlations

Transport (11 Months 12/13/90 - 11/81/91)				
	Mean	**Standard Deviation**	**Minimum**	**Maximum**
Line A (Cable)	25.2	5.16	15.9	36.8
B+F-G	25.3	4.27	13.6	34.5
B+F	27.3	3.93	15.3	36.2
Line B	24.8	4.87	10.26	33.0
Line C	29.1	2.88	19.1	36.8
Line F	2.4	2.14	-3.1	11.1
Line C-B	4.2	4.73	-6.1	21.6
Line D	31.1	3.49	22.3	41.8
Line D (Cable)	32.2	2.90	21.8	39.2
Line E	0.9	1.33	-4.5	3.9
Line D-C	2.0	3.10	-6.3	11.4
Line G	1.9	1.67	-2.4	6.6

CORRELATIONS

B versus C	0.34
B+F versus C	0.48
B versus F	-0.62
G versus F	0.21*
C versus F	0.10*
C-B versus F	0.70
C versus D	0.55
C versus E	-0.31
E versus D	0.00*
D-C versus E	0.28
B+F-G versus A (cable)	0.52
B+F versus A (cable)	0.58
D versus D (cable)	0.22

* Not significant at 99% level.

The important contributions of flow through ODC is shown by the magnitude and range of the transport. An average of almost 2 Sv flows into the FC system through this channel with a maximum of 6.6 Sv. This is sufficient that it may be necessary to account for it during modeling exercises. In addition, the unique temperature/salinity character of some of this OBC inflow adds to its importance as a tracer.

A comparison of transports estimated by sums and differences and those computed from local current measurements or from cables is shown in Figure 2.3-2. In particular, in the southern portion of the study area, the various methods of estimating transport agree quite well which would suggest that these are good records. For Transect A, the major difference between the cable and current-meter based estimates occurs during the latter three months of observations. Because this cable is not well calibrated this difference may point to some changes in the cable rather than the current meters. Certainly, on Transect D the transports from current meters reproduced better the large transport fluctuations detected by Pegasus technology.

Winds acting on the water surface are an important mechanism for causing variability of transport. The frequency bands in which the along channel component of wind energy is concentrated often shows a strong coherence (correlation) with transport. This is true in the northern and southern portions of the study area even though the channel orientation changes by 90°.

2.4 Hydrography

Comprehensive hydrographic data was taken during each of five cruises. These will be directly usable by any modeling effort to establish initial and intermediate mass fields. These data showed aspects of conditions in the main part of the FC which have been documented previously. It is data from the lateral channels which which provided new insight concerning water mass types and sources. In particular, the OBC is a source for high salinity water (37 psu) which enters the study area at mid-depth and moves through Santaren Channel (Transect F) on the eastern side and joins the main body of the FC just south of Transect C. There are some indications that this high salinity water may be drawn into the NW Providence Channel along the southern entrance.

2.5 Tides

Current meter/transport data indicate that a mixed (diurnal and semidiurnal) tide is common throughout the study area. On Transects B, D and F, the primary diurnal and semidiurnal constituents are similar contributors to section transport. On Transects C, E and G, the diurnal component substantially exceeds the transport contribution by the semidiurnal component. Note in Table 2.5-1 that the maximum total transport due to tides can be a substantial portion of the subtidal transport, e.g. about 20% over Transect B.

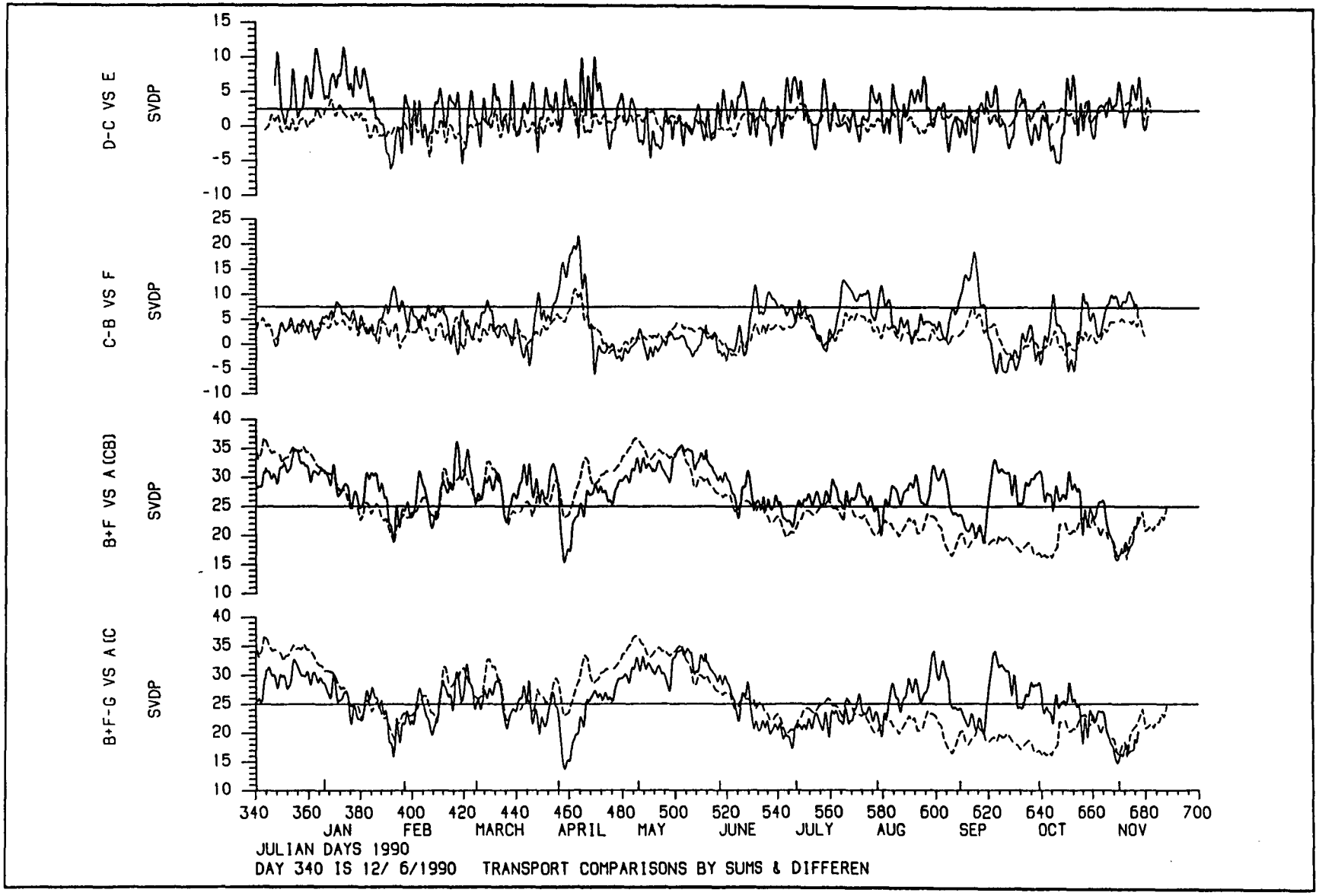


Figure 2.3-2 Transport time series estimated by sums or differences (solid lines) and cable-based or current-meter based estimates on the indicated transect. The bottom plot show the complete estimate of transport on Transect A using both cable and sums and differences of transport in other channels.

Table 2.5-1 Tidal Constituent Transports

Transect	Cross-Sectional Area (km^2)	Constituent Transports (Sv)		
		M_2	K_1	O_1
B	59	1.8	1.9	2.2
C	46	1.3	2.1	1.7
D	48	1.2	0.9	1.5
E	27	0.4	0.9	0.9
F	31	0.2	0.3	0.3
G	11	0.3	0.9	0.6