NOAA Technical Memorandum NOS OMA 50

TAMPA BAY
CURRENT PREDICTION QUALITY ASSURANCE MINIPROJECT

Rockville, Maryland
December 1989

noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

National Ocean Service

Office of Oceanography and Marine Assessment
National Ocean Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

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TAMPA BAY CURRENT PREDICTION QUALITY ASSURANCE MINIPROJECT

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and
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All the best!
Hank Frey

Rockville, Maryland
December 1989

United States Department of Commerce
Robert A. Mosbacher, Secretary

National Oceanic and Atmospheric Administration
John A. Knauss, Under Secretary

National Ocean Service
Virginia K. Tippie
Assistant Administrator

Introduction

In response to the U.S. Coast Guard's Marine Safety Office and the Tampa Bay Pilots for an evaluation of predictions in the NOAA Tidal Current Tables, a quality assurance (QA) miniproject was conducted. The QA miniproject was necessary because of presumed changes in the circulation resulting from the construction of the new Sunshine Skyway Bridge, and dredging and shoaling since 1963, when NOAA last made current measurements in the Bay.

NOAA's National Ocean Service (NOS) deployed two remote acoustic Doppler sensing (RADS) systems at four locations in the Bay from December 1988 through February 1989. Analysis of the new data confirmed that the circulation had changed, and that predictions should be updated.

Recommendations are made to improve information for the Bay, including the deployment of real-time current measurement systems for supplementing new predictions.

Summary of Collected Data

The QA miniproject consisted of deploying RADS systems at the reference station in Egmont Channel (Tampa Bay, T-REF), and at the secondary stations at the Sunshine Skyway Bridge (T-l), Manatee Channel (T-3), and Port Tampa (T-4) (Figure 1). The RADS is a high-technology system which, when mounted on the bottom, produces a profile of currents through the water column (Figure 2). The instruments can be placed closer to navigation channels, where the measurements are needed, than conventionally moored current meters.

The locations, water depths, and times of deployment and retrieval for the RADS are shown in Table 1. Extensive quality control procedures performed on the RADS system data, as well as post retrieval processing, showed that all data were of high quality. The depths chosen for the analysis of the RADS profile data correspond to the depths of the 1963 measurements from which the tables were produced.

The current data were analyzed to produce time series plots, vertical profile plots of horizontal currents, times and velocities of maximum flood current (MFC) and maximum ebb current (MEC), and times of slack before flood (SBF) and slack before ebb (SBE). The differences between new observations and NOAA Tidal Current Table predictions, based on data from a circulation survey in 1963, were tested against working standards for adequacy established for the QA miniproject (Figure 3).

Results

Statistical analysis of the differences between the NOAA Tidal Current Table parameters and those computed from the new measurements showed that the only presently published parameters that meet working standards are speeds of maximum flood currents at all stations, and speeds of maximum ebb currents at Manatee Channel. All other parameters did not meet the criteria of Figure 3. The statistics are based on approximately 30 days of data.

Statistics on the differences between the NOAA Tidal Current Table predictions and the 1988/89 RADS-measured currents, are presented as histograms in Figures 4 to 9, and in Tables 2 to 4, which give maximum and minimum observed differences, means, standard deviations, and limits within which 90 percent of the differences must fall.

The measured current speeds for the Sunshine Skyway Bridge location are less than the predicted current speeds (Table 3, and Figures 6 and 9). In the opinions of many local mariners currents at the Bridge are larger than predicted currents. This difference may result from the RADS having been deployed southwest of the crossing of the old bridge over the channel (Figure 1) due to bridge construction.

The predominant directions of the flood and ebb currents have changed since the 1963 survey, as given in Table 5.

New predictions for the Sunshine Skyway Bridge and Manatee Channel, based on the 1988/89 RADS data, provide improvement over the NOAA Table predictions. An indication of the improvement can be seen in the graphs of 24-hour time series of the new predictions and the RADS-measured currents, as seen in Figures 10 through 19, part B, and by comparing them with the 1963-based NOAA Table predictions in part A.

However, even for the new predictions, the slack times for all stations, and the times of maximum currents, except the time of maximum flood current at Manatee Channel, still do not meet working standards (Figures 20 through 25).

The vertical profiles of horizontal currents, for one-meter RADS range increments, or "bins," are given for Sunshine Skyway Bridge, and for Manatee Channel. The top three feet of the Sunshine Skyway Bridge profiles may not be representative of horizontal water currents because of acoustic reflections from the surface.

For the Sunshine Skyway Bridge (Figures 26 to 28), the vertical shear of horizontal currents reaches a maximum of about 0.3 knots at 5 feet of depth around the time of slack water, and significant shear persists for over an hour or more, particularly for the flood current. Vertical shear is usually small at the time of maximum current, particularly for the ebb current. The highest current speeds usually occur near the surface. Subsurface currents may be stronger than surface currents by a few tenths of knots near the times of slack water and also as the flood current accelerates to maximum speed.

At Manatee Channel (Figures 29 to 31), vertical shear of horizontal currents is generally more pronounced than at the Sunshine Skyway Bridge. The largest vertical shear is on the same order as at the Sunshine Skyway Bridge, but it occurs more frequently throughout the tidal cycle rather than primarily near the slack times. Subsurface currents may be larger than the surface current at Manatee Channel, particularly during the flood current.

Although the mean values of the differences between the RADS data and the new predictions are usually smaller than the differences with the NOAA Table predictions, the differences between the new data and new predictions indicate that even perfect predictions of the tidal currents will not provide adequate information for piloting. The causes of the variability include currents driven by the winds, density differences, and freshwater runoff. These components of the circulation cannot be forecast without a model and real-time current and wind data.

Recommendations

The following actions are recommended to provide improved knowledge of currents:

- Deploy a RADS system for a minimum of 12 months to develop a new reference station. This length period is required to separate the three largest diurnal harmonic constituents.
- Apply and validate a circulation model of Tampa Bay to produce a circulation and water level atlas for various meteorological scenarios. The model results would also be used to provide computer-form products.
- Determine the lateral variability of the currents around the Sunshine Skyway Bridge with a towed RADS.
- Deploy real-time current and wind-measuring systems at Sunshine Skyway Bridge and at Manatee Channel (Figures 32 to 33). For a prediction of the total current, real-time systems and a hydrodynamic model would be needed.

Acknowledgments

This QA miniproject was conducted at the request of the U.S. Coast Guard Marine Safety Office, Tampa, and the Tampa Bay Pilots.

Field support was provided by the U.S. Coast Guard Group in St. Petersburg. CWO Mark Allen was extremely helpful in coordinating Coast Guard support for the RADS deployments. The USCG Ship WHITE SUMAC, under the command of CWO John Sitton, provided outstanding vessel support for the project. Some of the RADS deployments/retrievals were more difficult and required more time than anticipated; CWO Sitton often worked late into the night planning the next day's operations. The officers and men of the WHITE SUMAC also provided and deployed two surface moorings for the RADS stations at Manatee Channel and Port Tampa, to simplify retrieval.

Captain Steve Day, of the Tampa Bay Pilots, provided valuable insight into navigation problems, and arranged interaction with the Tampa Bay Marine Advisory Council.

Diving services were provided by Dive-Tech Inc. of Largo, Florida, led by Mr. Victor Griswold. The Dive-Tech team provided valuable assistance during deployment and recovery operations.

The process of procuring field equipment, required on short notice, was greatly aided by Ms. Dorothy Newman of the OMA Management and Budget staff, and Ms. Sara Huber of the NOAA Purchasing Office.

This miniproject could not have been accomplished without the assistance of our colleagues in the Estuarine and Ocean Physics Branch, especially Geoffrey French, James Bruce, and Peter Stone. Most of the software used specifically for the QA analysis was written by Wayne Wilmot. Helpful discussions were held with Bruce Parker, Elmo Long, Alan Klavans, and Joseph Welch.

Table 1

STATION DEPLOYMENTS

Station	Latitude	Longitude	Deployed	Retrieved	Water Dep.(Ft)
Tampa Bay Reference T-REF	27° 36' 33.42"	82° 46' 06.54"	12/7/88	1/9/89	85
Sunshine Skyway Bridge T-2	27° 37' 06.94"	82° 39' 43.22"	12/7/88	1/9/89	33
Manatee Channel T-3	27° 39' 24.34"	82° 36' 14.07"	1/12/89	2/15/89	28
Port Tampa T-4	27° 51' 44.96"	82° 33' 20.52"	1/12/89	2/15/89	32

Table 2

TABLE OF DIFFERENCE STATISTICS

1988 OBSERVED - 1963 PREDICTED
TAMPA BAY ENTRANCE

Tidal Current Parameter	Minimum	Lower 90%	Std Dev	Mean	Upper 90%	Maximum
SBF Time (MINUTES)	-85.0	-85.0	35.9	-16.8	70.0	80.0
MFC Time (MINUTES)	-100.0	-92.0	36.8	-22.4	31.0	104.0
MFC Speed (CM/S)	-33.9	-33.8	15.7	-9.1	22.0	29.1
SBE Time (MINUTES)	-47.0	-47.0	38.5	16.7	95.0	99.0
MEC Time (MINUTES)	-71.0	-71.0	33.0	-15.9	39.0	76.0
MEC Speed (CM/S)	-28.8	-28.8	20.2	21.4	46.7	52.3

Table 3

TABLE OF DIFFERENCE STATISTICS

1988/89 OBSERVED - 1963 PREDICTED
SUNSHINE SKYWAY BRIDGE

Tidal Current Parameter	Minimum	Lower 90%	Std Dev	Mean	Upper 90%	Maximum
SBF Time (MINUTES)	-75.0	-72.5	37.9	-4.9	59.1	100.0
MFC Time (MINUTES)	-99.0	-67.4	40.4	-3.2	57.3	96.0
MFC Speed (CM/S)	-46.4	-29.3	15.9	-2.9	25.3	32.3
SBE Time (MINUTES)	-93.0	-61.9	43.4	9.5	89.3	97.0
MEC Time (MINUTES)	-84.0	-79.5	36.5	-24.3	48.4	86.0
MEC Speed (CM/S)	-25.6	-20.7	20.9	25.7	50.2	58.1

Table 4

TABLE OF DIFFERENCE STATISTICS

1988 OBSERVED - 1963 PREDICTED
MANATEE CHANNEL

Tidal Current Parameter	Minimum	Lower 90%	Std Dev	Mean	Upper 90%	Maximum
SBF Time (MINUTES)	24.0	24.0	26.2	87.1	117.0	118.0
MFC Time (MINUTES)	-73.0	-2.0	27.9	46.1	98.0	105.0
MFC Speed (CM/S)	-28.8	-27.5	11.3	-7.9	13.2	21.3
SBE Time (MINUTES)	-68.0	-50.0	34.9	17.7	79.0	96.0
MEC Time (MINUTES)	-18.0	-1.0	33.1	54.4	103.0	114.0
MEC Speed (CM/S)	-34.8	-30.3	16.6	-5.6	25.7	32.9

Table 5

PREDOMINANT CURRENT DIRECTIONS

	DIRECTION OF MAXIMUM FLOOD		DIRECTION OF MAXIMUM EBB	
Location	**NOAA Table**	**RADS Data**	**NOAA Table**	**RADS Data**
Tampa Bay	100°	100°	285°	280°
Sunshine Skyway Bridge	055°	060°	230°	235°
Manatee Channel	030°	030°	210°	210°
Port Tampa	030°	015°	215°	195°

Table 6

TABLE OF DIFFERENCE STATISTICS

1988/89 OBSERVED - 1988/89 PREDICTED
SUNSHINE SKYWAY BRIDGE

Tidal Current Parameter	Minimum	Lower 90%	Std Dev	Mean	Upper 90%	Maximum
SBF Time (MINUTES)	-40.0	-30.1	25.7	14.4	62.0	95.0
MFC Time (MINUTES)	109.0	85.6	41.3	0.18	76.1	117.0
MFC Speed (CM/S)	35.9	7.4	9.3	7.4	19.4	22.3
SBE Time (MINUTES)	30.0	25.5	24.6	11.4	66.0	72.0
MEC Time (MINUTES)	-82.0	-74.3	37.9	-3.0	77.7	82.0
MEC Speed (CM/S)	-17.9	-16.1	8.1	-2.3	7.9	10.8

Table 7

TABLE OF DIFFERENCE STATISTICS

1989 OBSERVED - 1989 PREDICTED
MANATEE CHANNEL

Tidal Current Parameter	Minimum	Lower 90%	Std Dev	Mean	Upper 90%	Maximum
SBF Time (MINUTES)	-31.0	-26.0	26.3	22.0	68.0	74.0
MFC Time (MINUTES)	-67.0	-34.0	30.7	8.5	66.0	97.0
MFC Speed (CM/S)	-16.9	-15.2	9.1	3.8	17.1	21.6
SBE Time (MINUTES)	-81.0	-63.0	24.3	5.8	52.0	69.0
MEC Time (MINUTES)	-54.0	-45.0	30.8	6.4	55.0	65.0
MEC Speed (CM/S)	-26.9	-15.0	8.8	-1.6	12.9	14.5

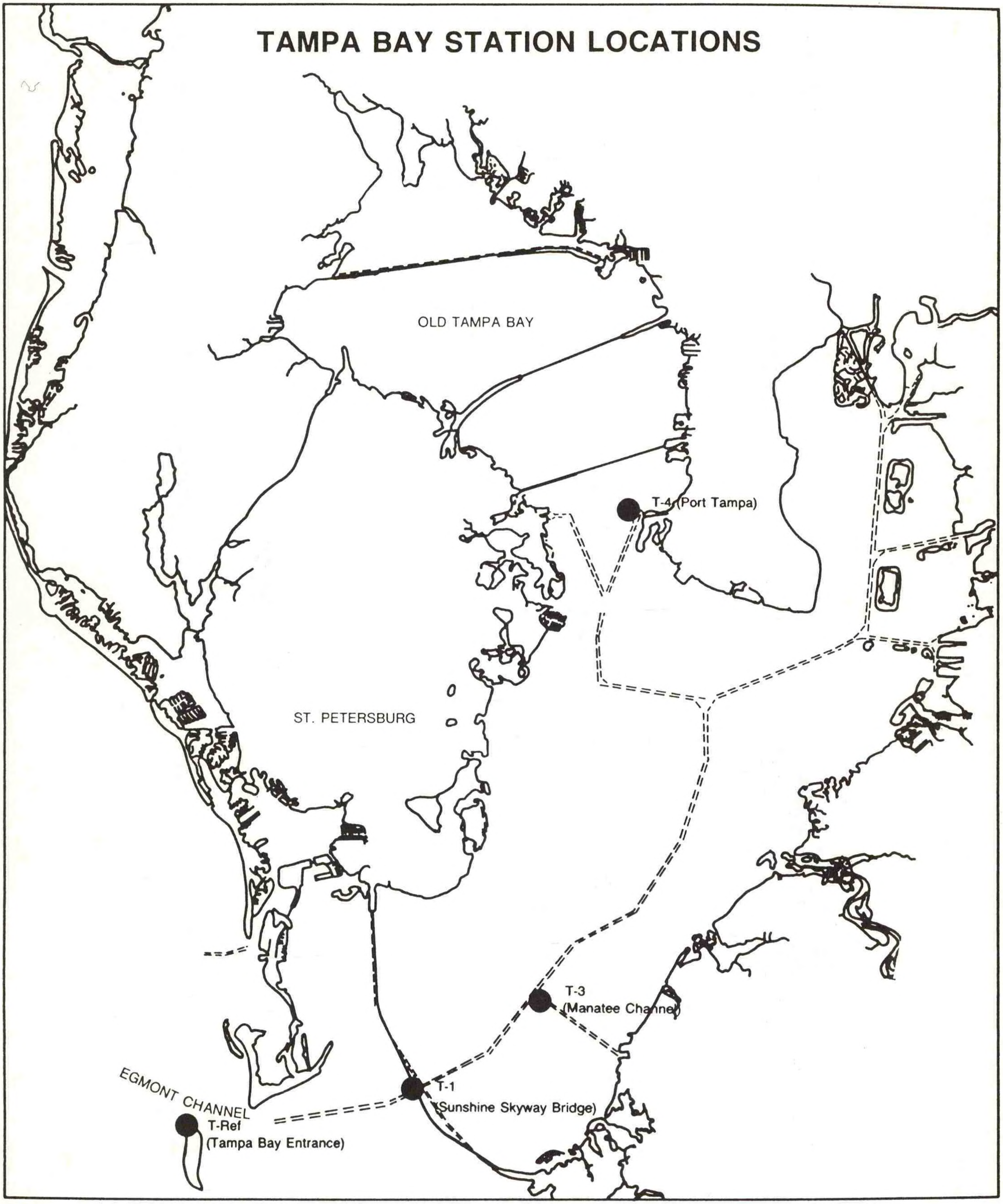

TAMPA BAY STATION LOCATIONS
OLD TAMPA BAY
T-4 (Port Tampa)
ST. PETERSBURG
T-3
(Manatee Channel)
EGMONT CHANNEL
T-1
(Sunshine Skyway Bridge)
T-Ref
(Tampa Bay Entrance)

Figure 1

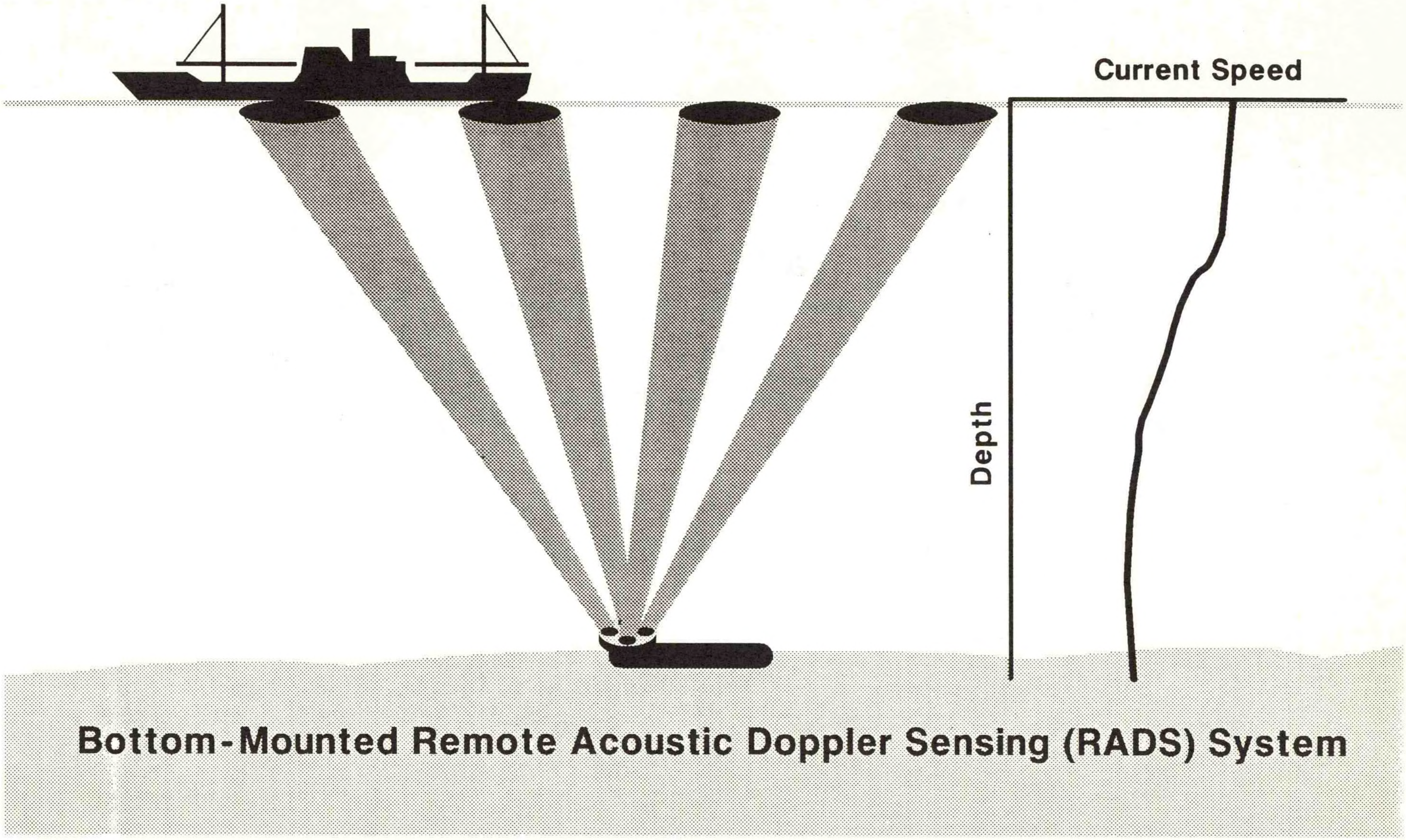

Current Speed
Depth
Bottom-Mounted Remote Acoustic Doppler Sensing (RADS) System

Figure 2

NOS Limits

NOAA Prediction for:	90% of Differences Between New Data and Predictions Within:		
	Min.	cm	cm / sec
Mean High Tide	15		
Mean High Tide		15	
Mean Low Tide	15		
Mean Low Tide		15	
Slack Before Flood	15		
Slack Before Ebb	15		
Maximum Flood Current	30		
Maximum Flood Current			32
Maximum Ebb Current	30		
Maximum Ebb Current			32

Figure 3

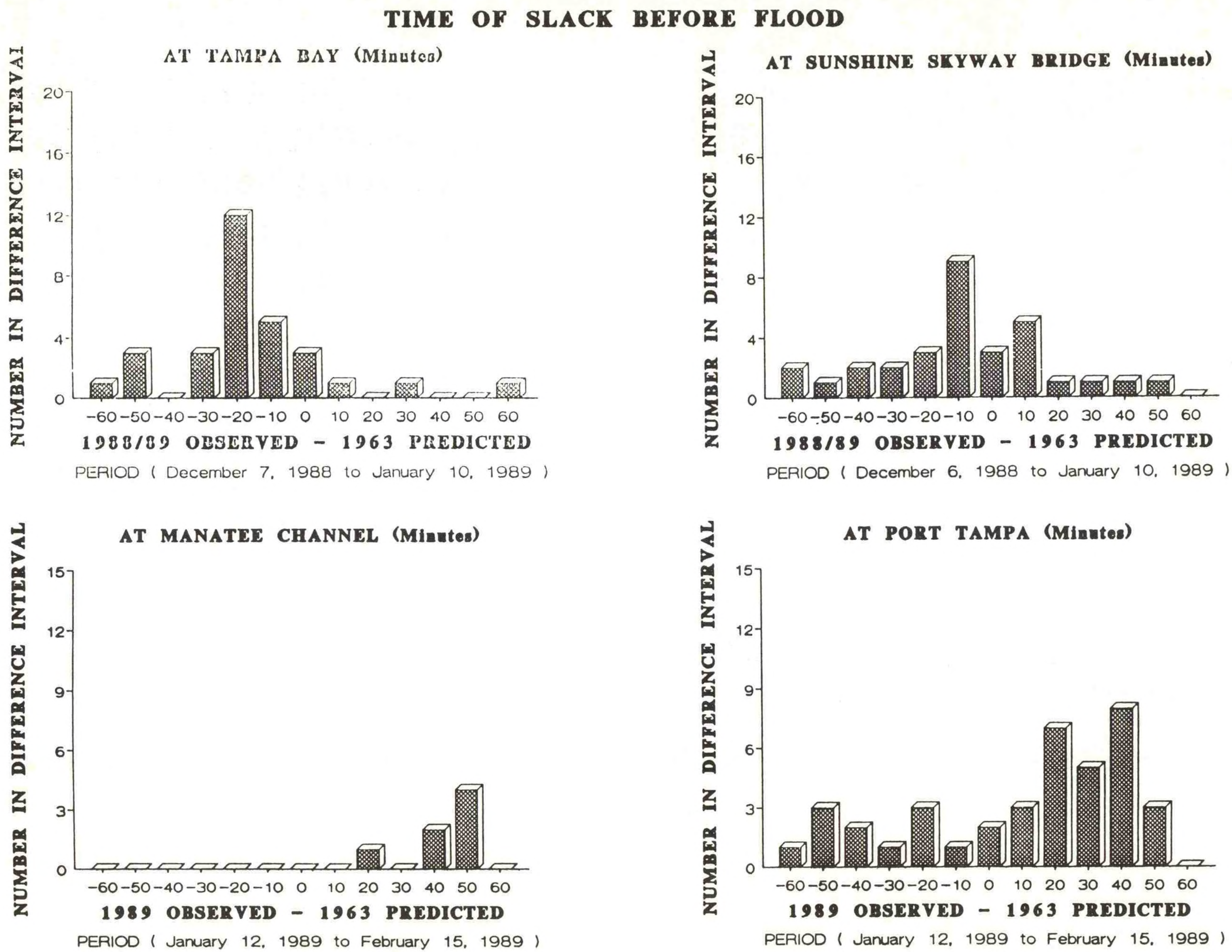

TIME OF SLACK BEFORE FLOOD
AT TAMPA BAY (Minutes)
NUMBER IN DIFFERENCE INTERVAL
20
16
12
8
4
0
-60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60
1988/89 OBSERVED - 1963 PREDICTED
PERIOD (December 7, 1988 to January 10, 1989)
AT SUNSHINE SKYWAY BRIDGE (Minutes)
NUMBER IN DIFFERENCE INTERVAL
20
16
12
8
4
0
-60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60
1988/89 OBSERVED - 1963 PREDICTED
PERIOD (December 6, 1988 to January 10, 1989)
AT MANATEE CHANNEL (Minutes)
NUMBER IN DIFFERENCE INTERVAL
15
12
9
6
3
0
-60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60
1989 OBSERVED - 1963 PREDICTED
PERIOD (January 12, 1989 to February 15, 1989)
AT PORT TAMPA (Minutes)
NUMBER IN DIFFERENCE INTERVAL
15
12
9
6
3
0
-60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60
1989 OBSERVED - 1963 PREDICTED
PERIOD (January 12, 1989 to February 15, 1989)

Figure 4

TIME OF MAXIMUM FLOOD CURRENT

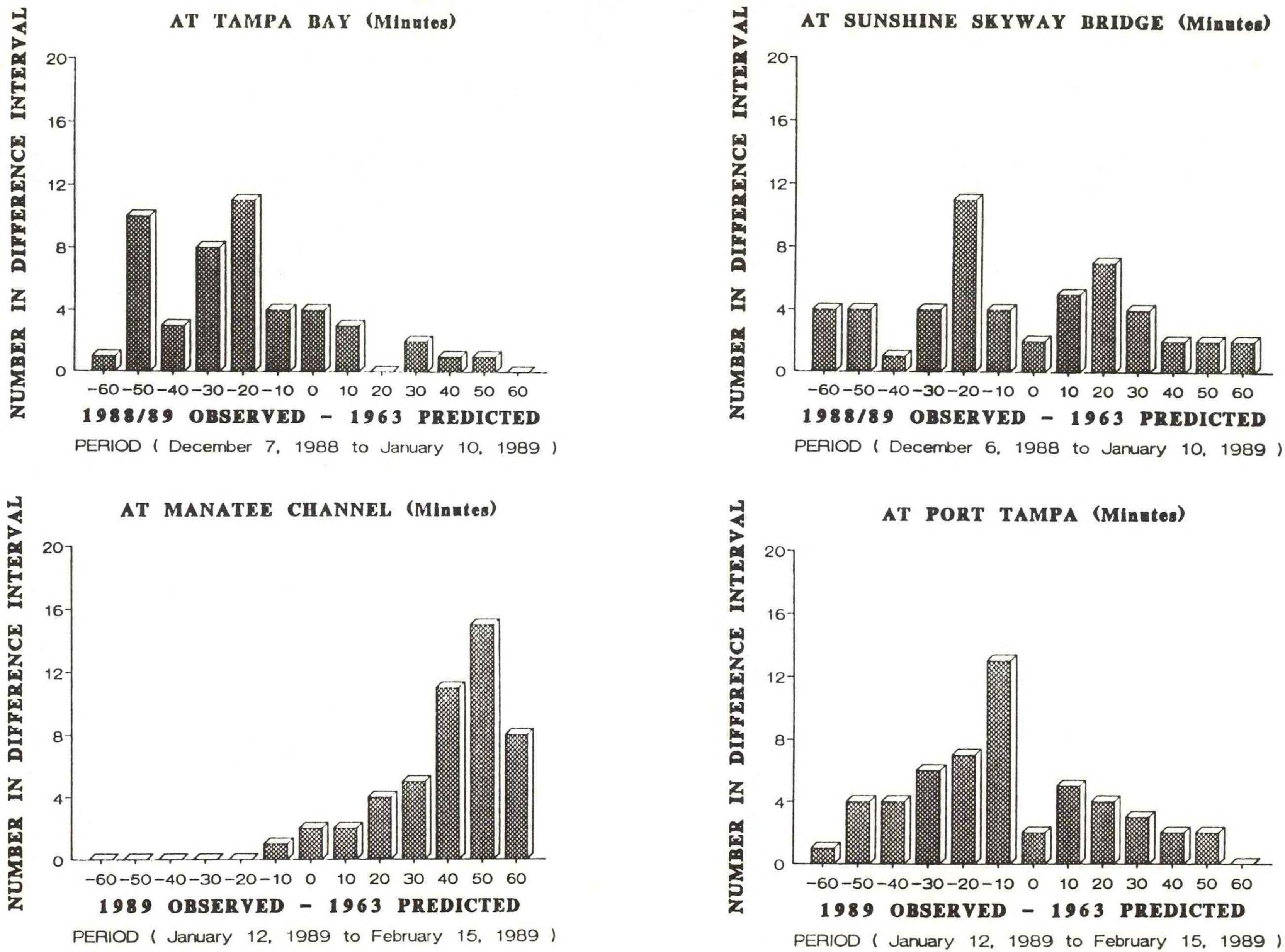


Figure 5

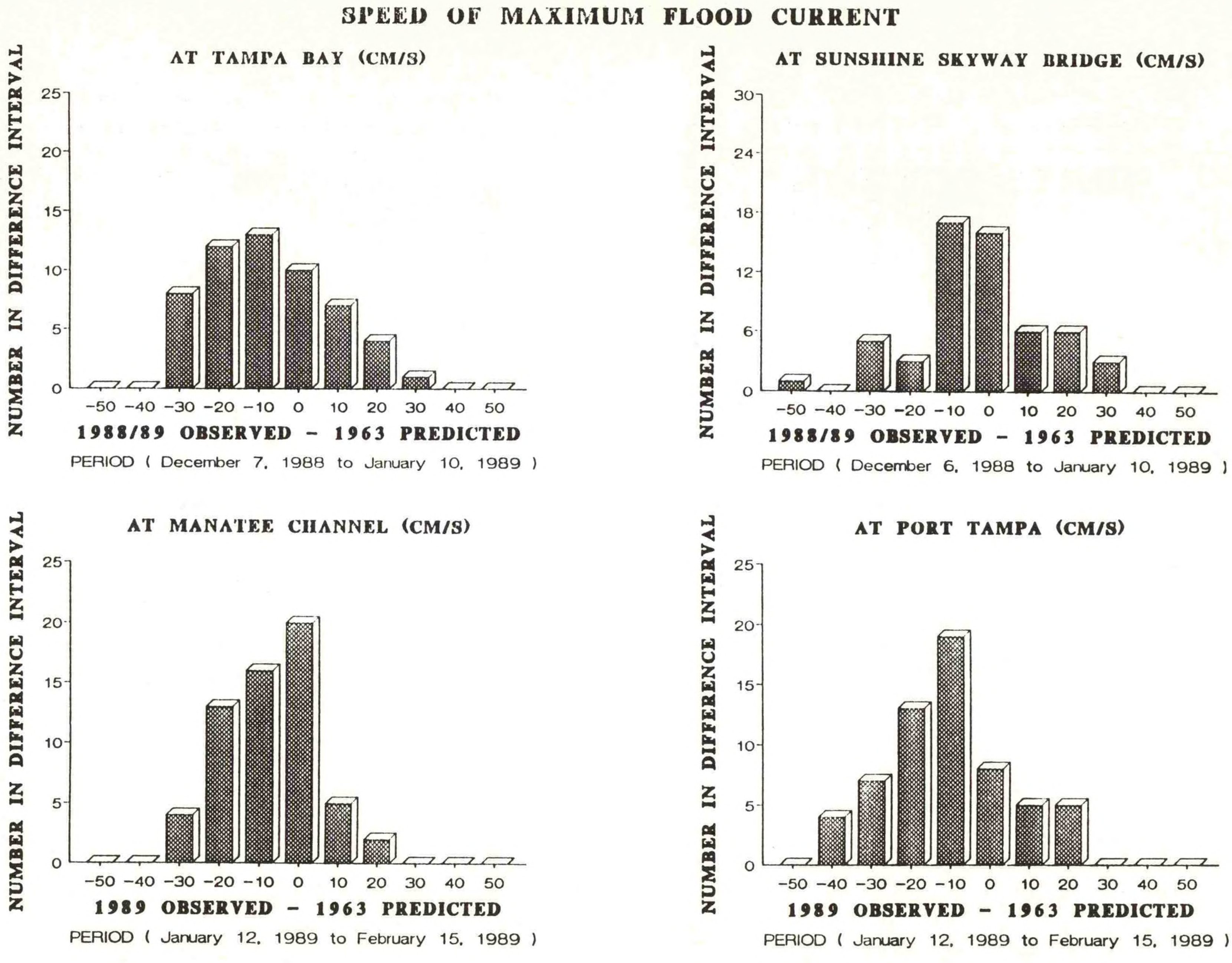

SPEED OF MAXIMUM FLOOD CURRENT
AT TAMPA BAY (CM/S)
NUMBER IN DIFFERENCE INTERVAL
0
5
10
15
20
25
-50 -40 -30 -20 -10 0 10 20 30 40 50
1988/89 OBSERVED - 1963 PREDICTED
PERIOD (December 7, 1988 to January 10, 1989)
AT SUNSHINE SKYWAY BRIDGE (CM/S)
NUMBER IN DIFFERENCE INTERVAL
0
6
12
18
24
30
-50 -40 -30 -20 -10 0 10 20 30 40 50
1988/89 OBSERVED - 1963 PREDICTED
PERIOD (December 6, 1988 to January 10, 1989)
AT MANATEE CHANNEL (CM/S)
NUMBER IN DIFFERENCE INTERVAL
0
5
10
15
20
25
-50 -40 -30 -20 -10 0 10 20 30 40 50
1989 OBSERVED - 1963 PREDICTED
PERIOD (January 12, 1989 to February 15, 1989)
AT PORT TAMPA (CM/S)
NUMBER IN DIFFERENCE INTERVAL
0
5
10
15
20
25
-50 -40 -30 -20 -10 0 10 20 30 40 50
1989 OBSERVED - 1963 PREDICTED
PERIOD (January 12, 1989 to February 15, 1989)

Figure 6

TIME OF SLACK BEFORE EBB

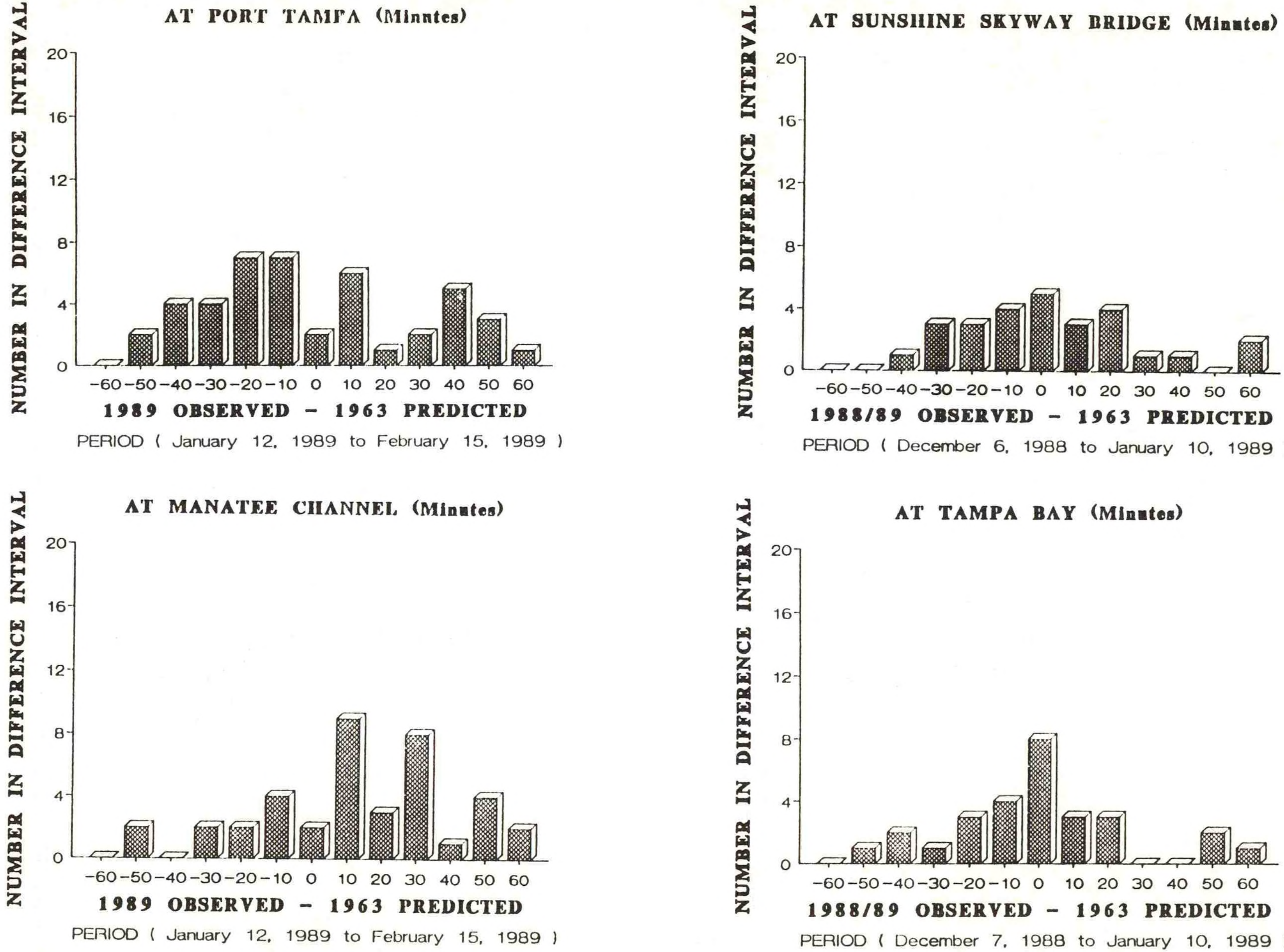


Figure 7

TIME OF MAXIMUM EBB CURRENT

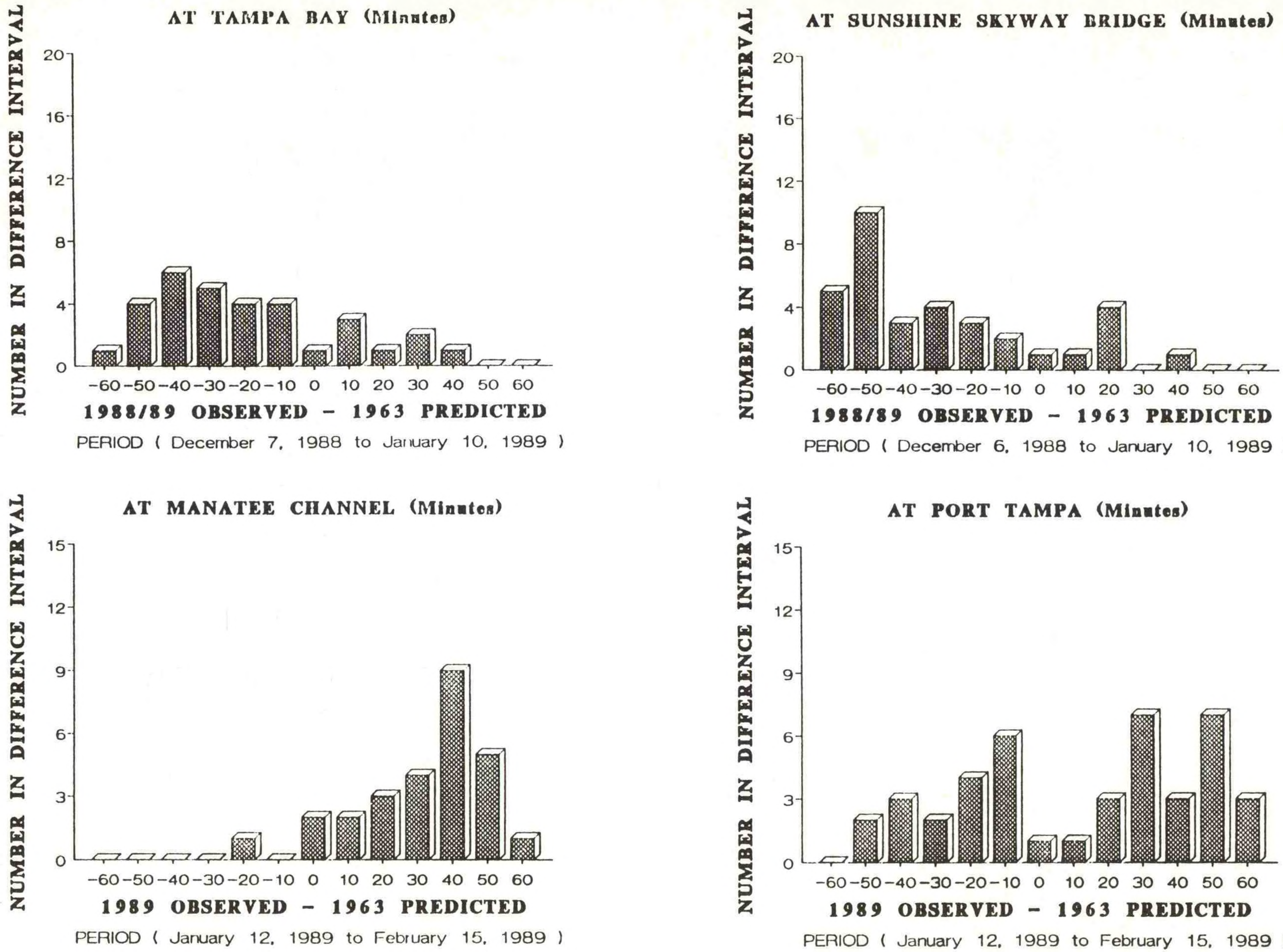


Figure 8

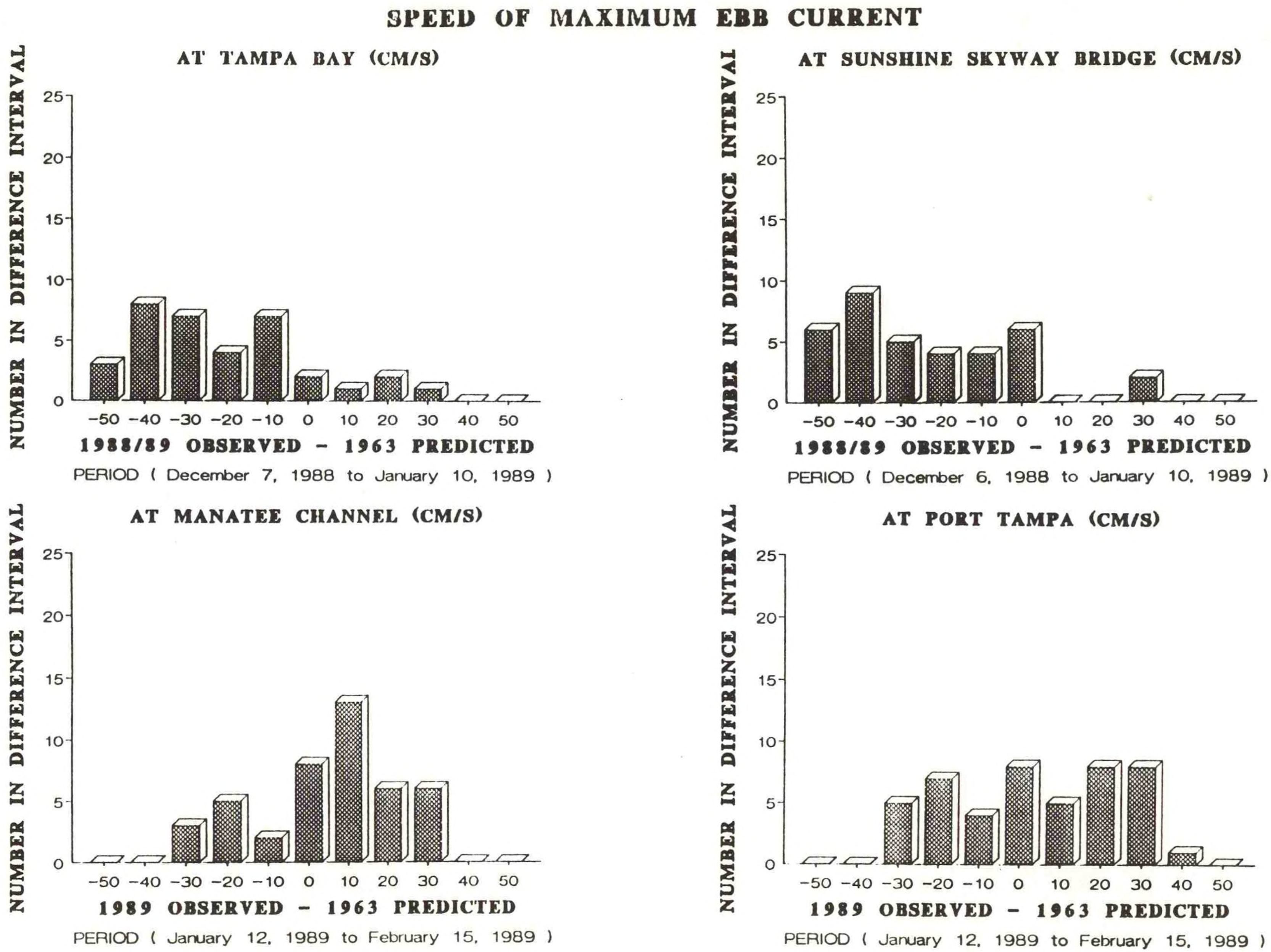
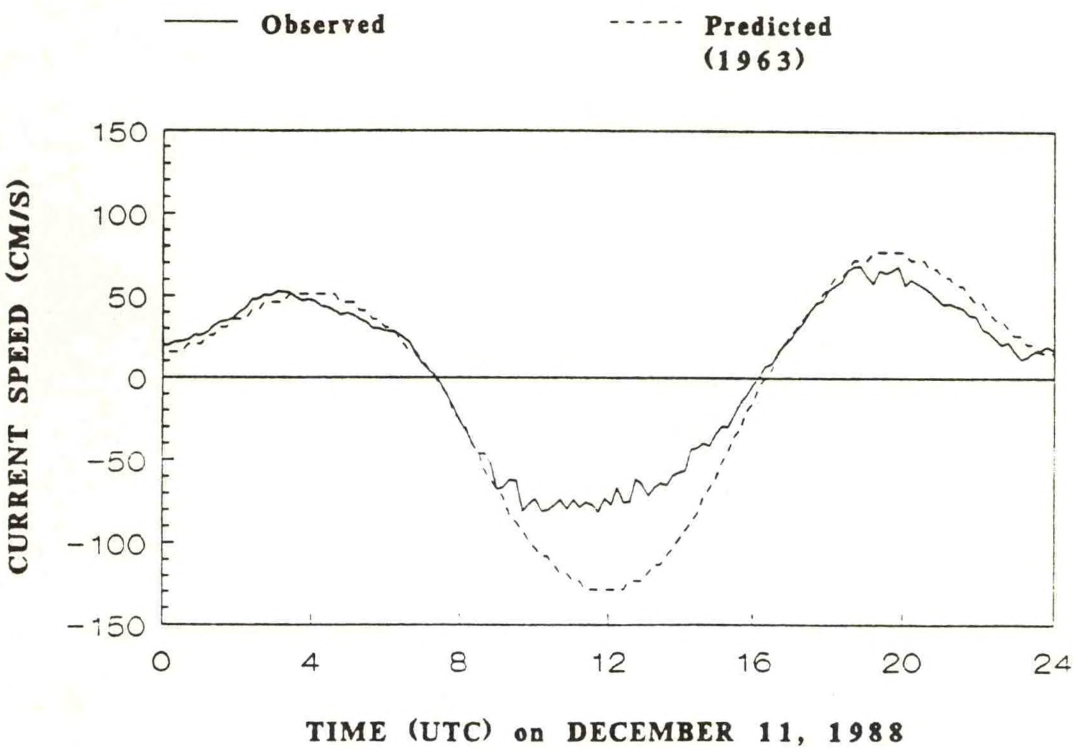

SPEED OF MAXIMUM EBB CURRENT
AT TAMPA BAY (CM/S)
NUMBER IN DIFFERENCE INTERVAL
25
20
15
10
5
0
-50 -40 -30 -20 -10 0 10 20 30 40 50
1988/89 OBSERVED - 1963 PREDICTED
PERIOD (December 7, 1988 to January 10, 1989)
AT SUNSHINE SKYWAY BRIDGE (CM/S)
NUMBER IN DIFFERENCE INTERVAL
25
20
15
10
5
0
-50 -40 -30 -20 -10 0 10 20 30 40 50
1988/89 OBSERVED - 1963 PREDICTED
PERIOD (December 6, 1988 to January 10, 1989)
AT MANATEE CHANNEL (CM/S)
NUMBER IN DIFFERENCE INTERVAL
25
20
15
10
5
0
-50 -40 -30 -20 -10 0 10 20 30 40 50
1989 OBSERVED - 1963 PREDICTED
PERIOD (January 12, 1989 to February 15, 1989)
AT PORT TAMPA (CM/S)
NUMBER IN DIFFERENCE INTERVAL
25
20
15
10
5
0
-50 -40 -30 -20 -10 0 10 20 30 40 50
1989 OBSERVED - 1963 PREDICTED
PERIOD (January 12, 1989 to February 15, 1989)

Figure 9

SUNSHINE SKYWAY BRIDGE



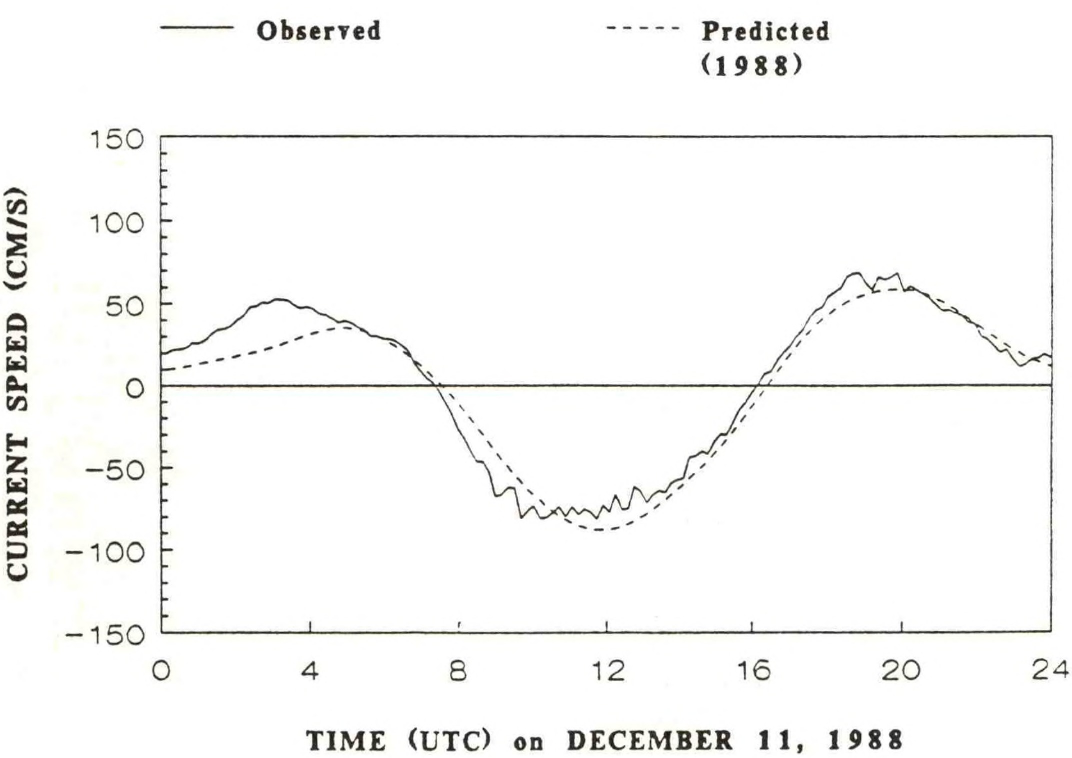
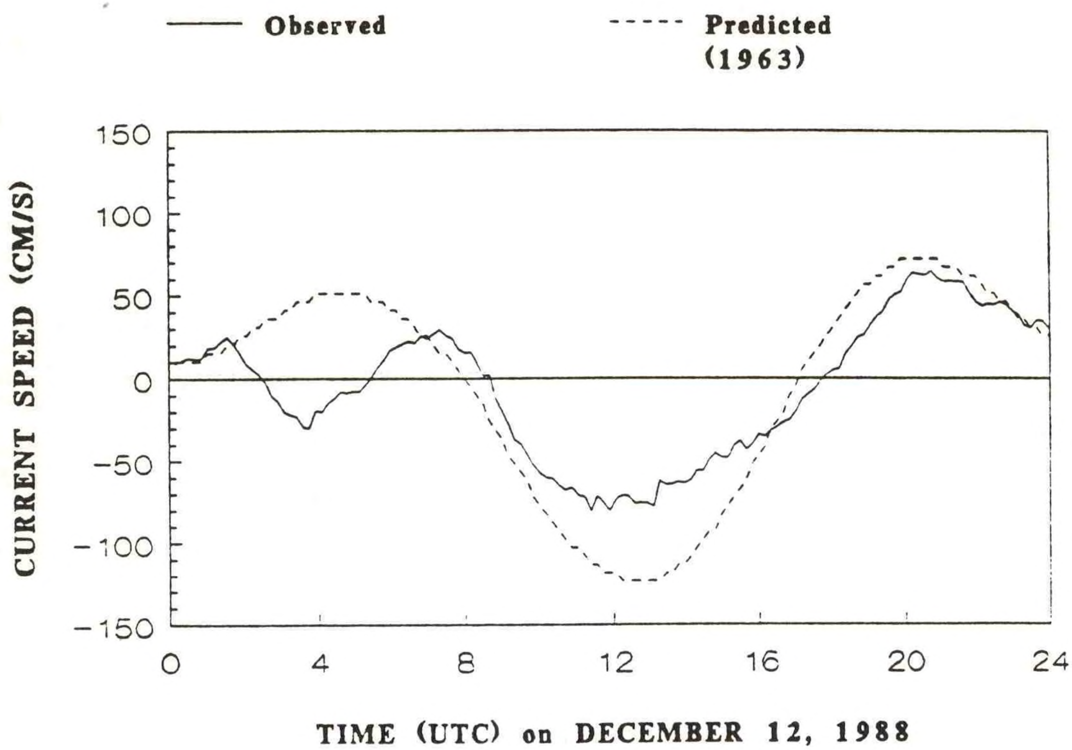


Figure 10

SUNSHINE SKYWAY BRIDGE



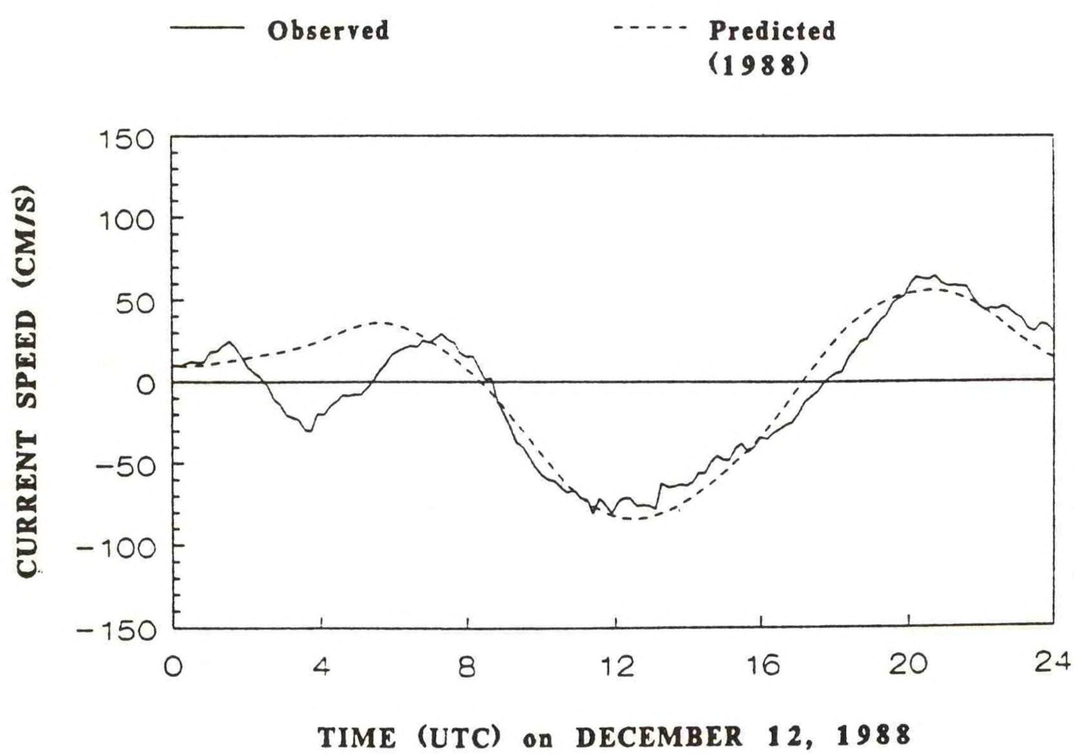
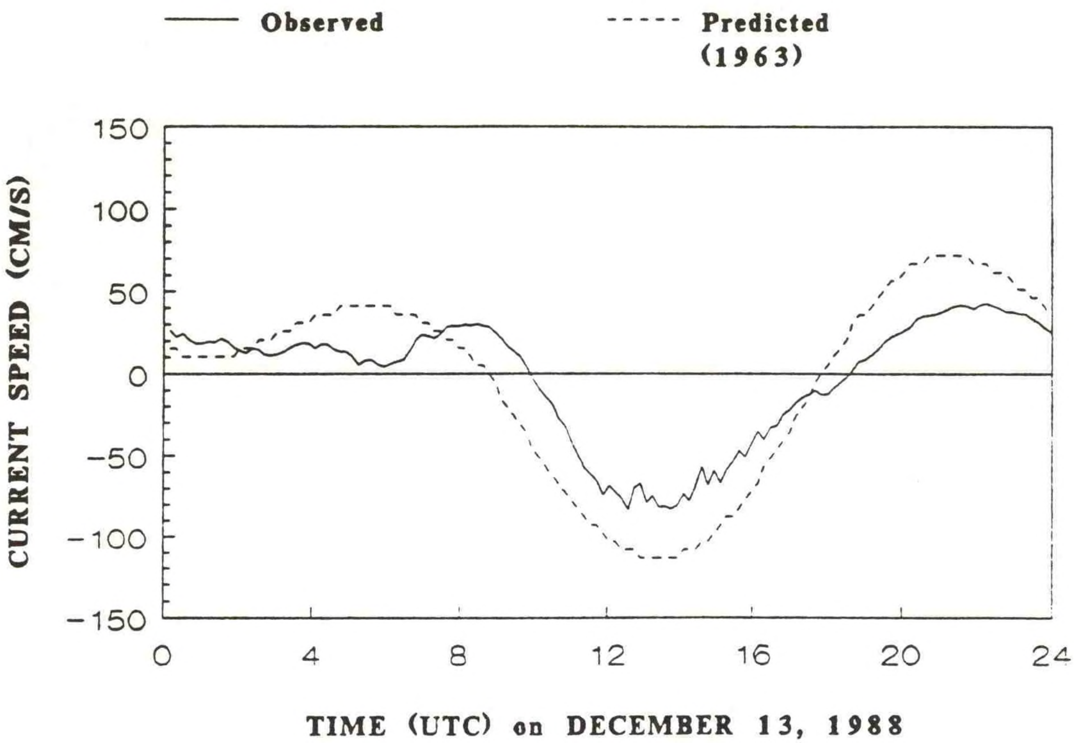


Figure 11

SUNSHINE SKYWAY BRIDGE



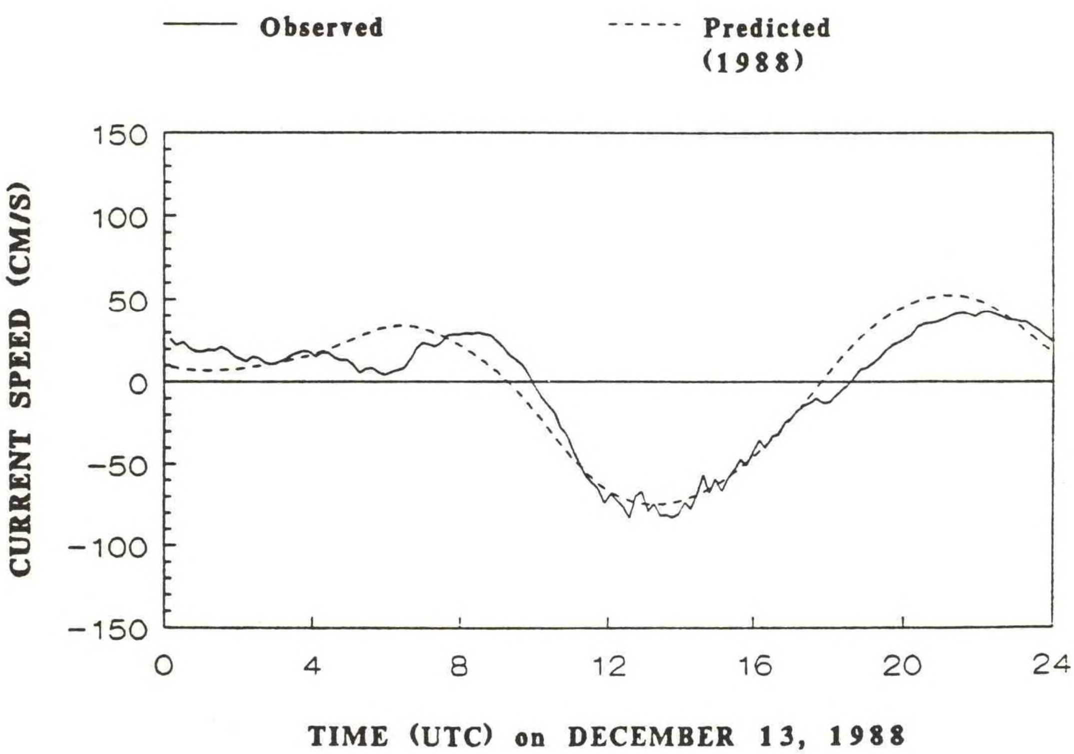


Figure 12

SUNSHINE SKYWAY BRIDGE

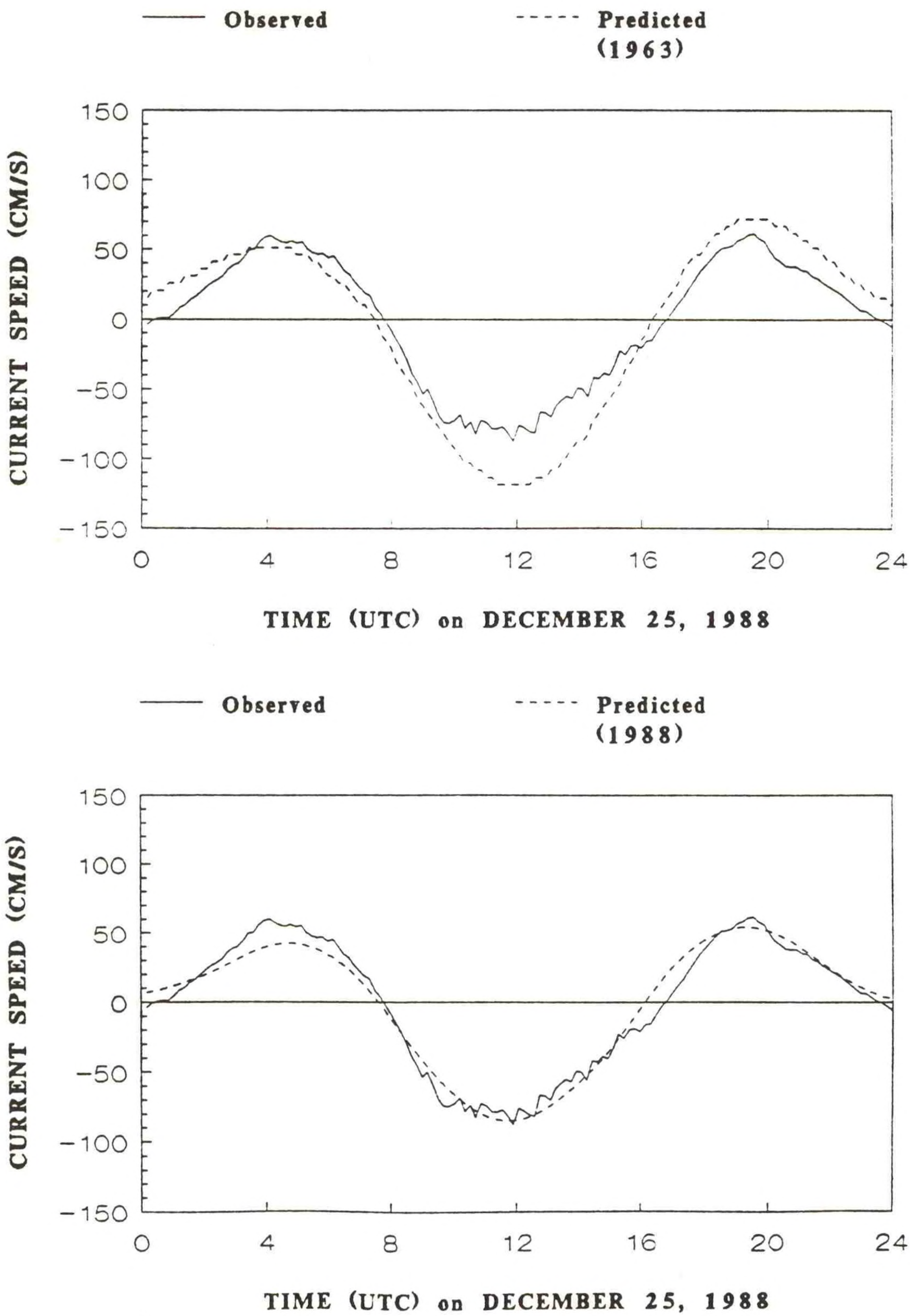
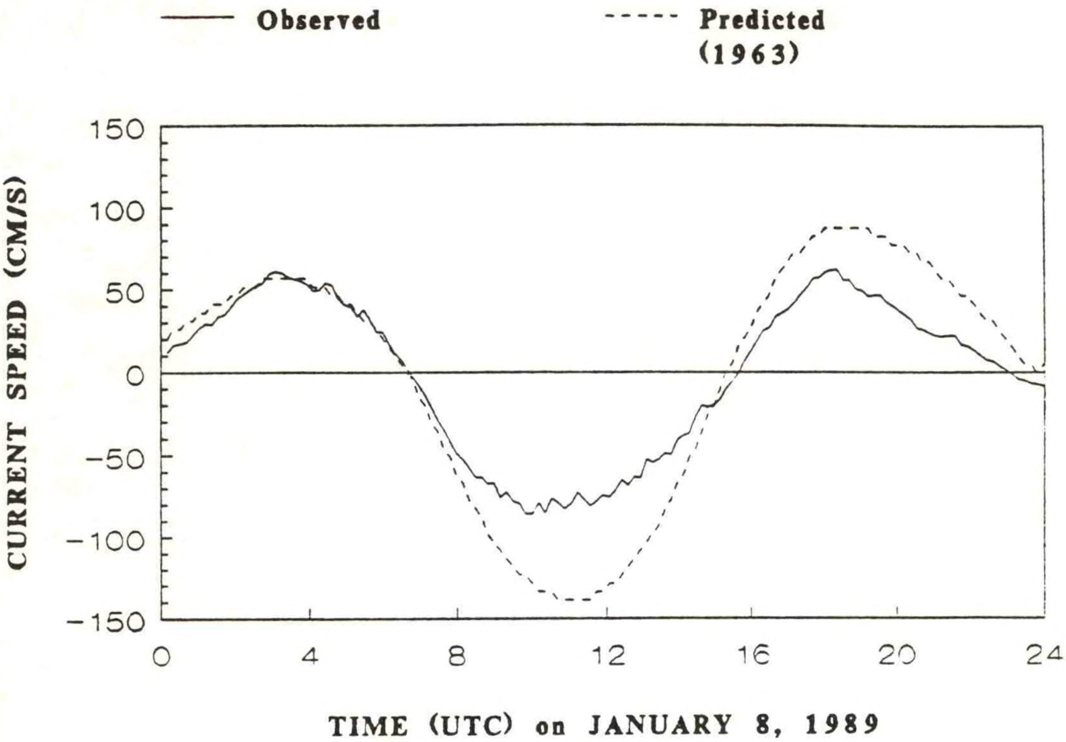


Figure 13

SUNSHINE SKYWAY BRIDGE



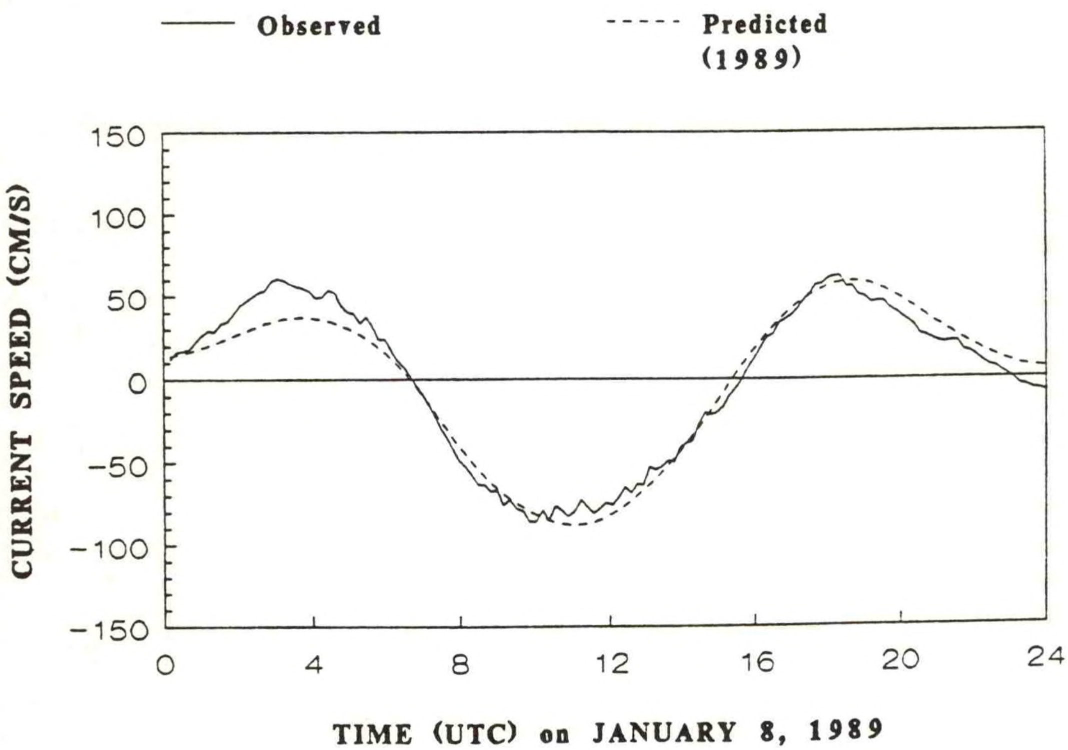
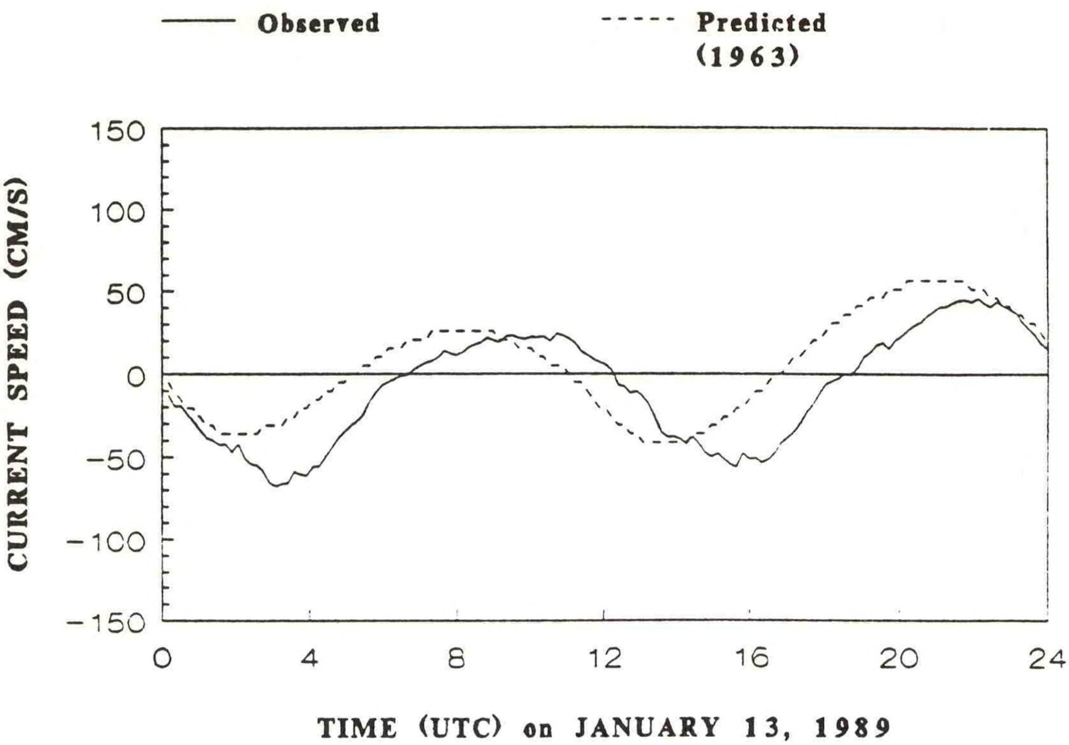


Figure 14

MANATEE CHANNEL



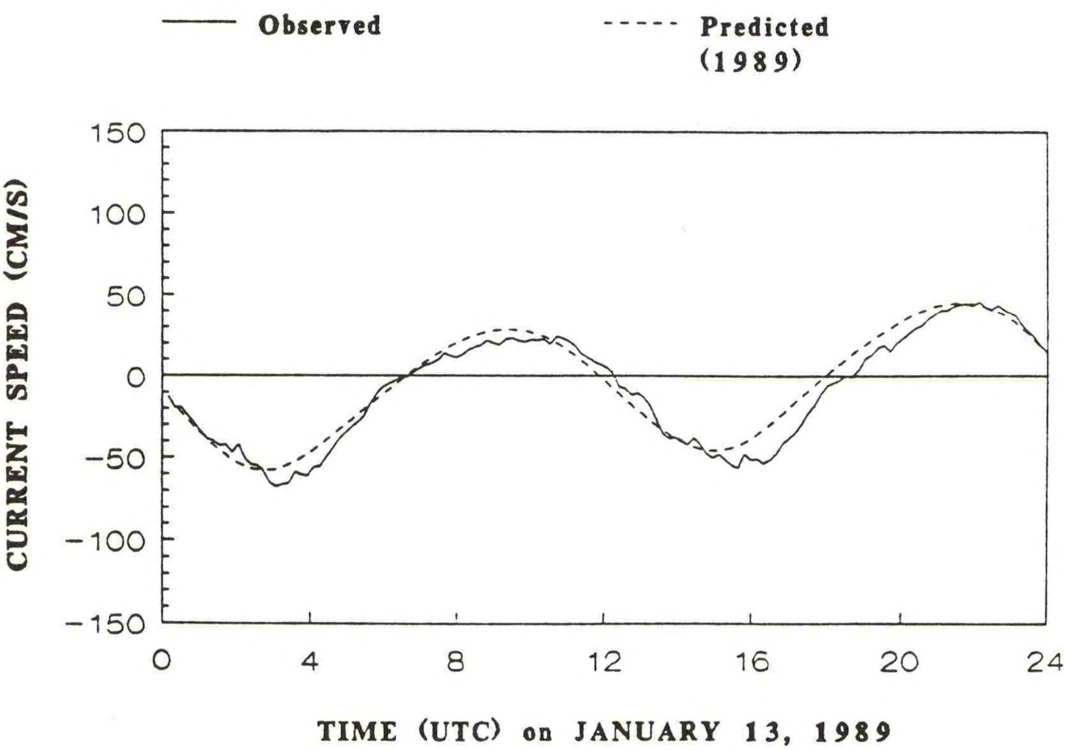


Figure 15

MANATEE CHANNEL

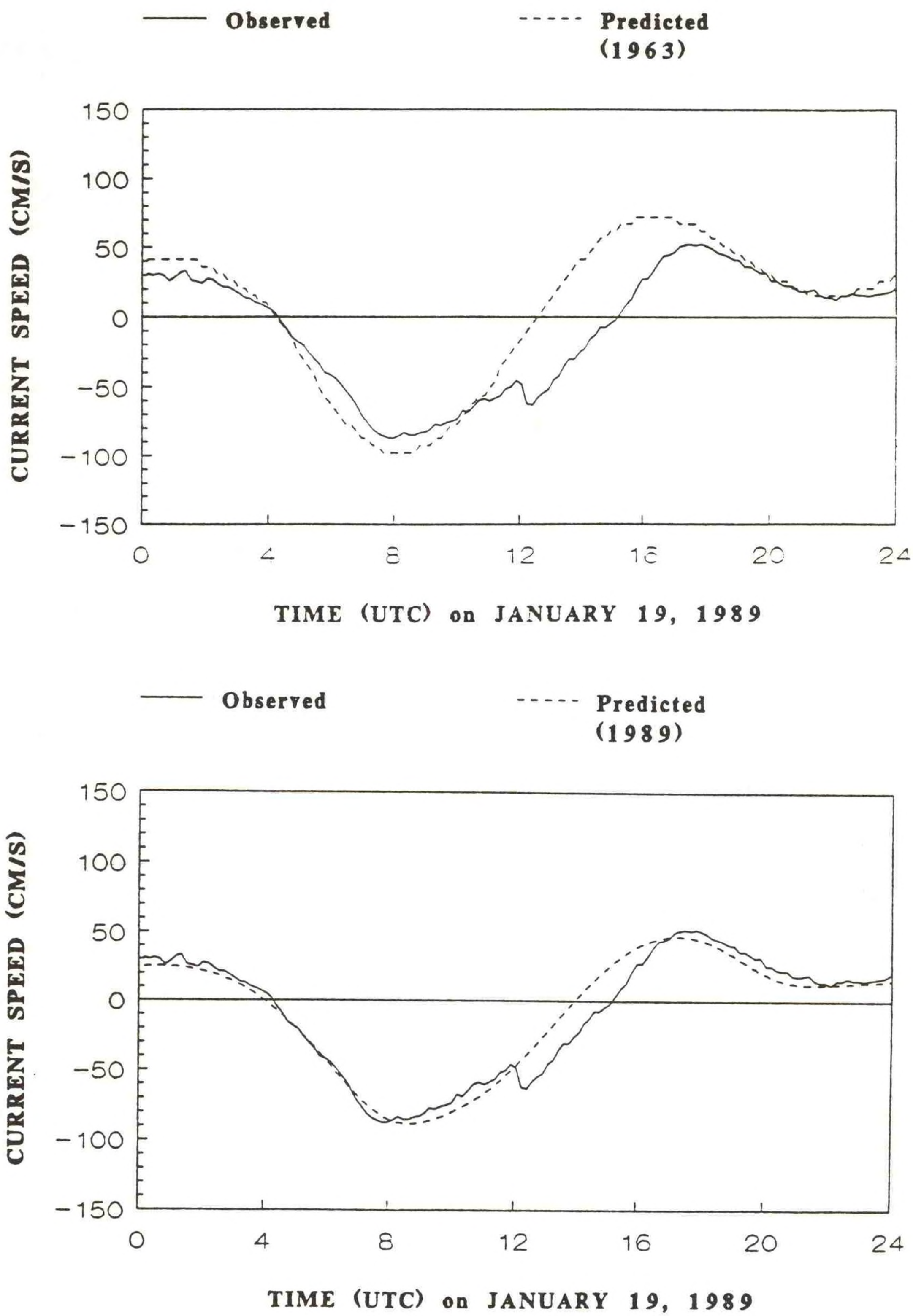
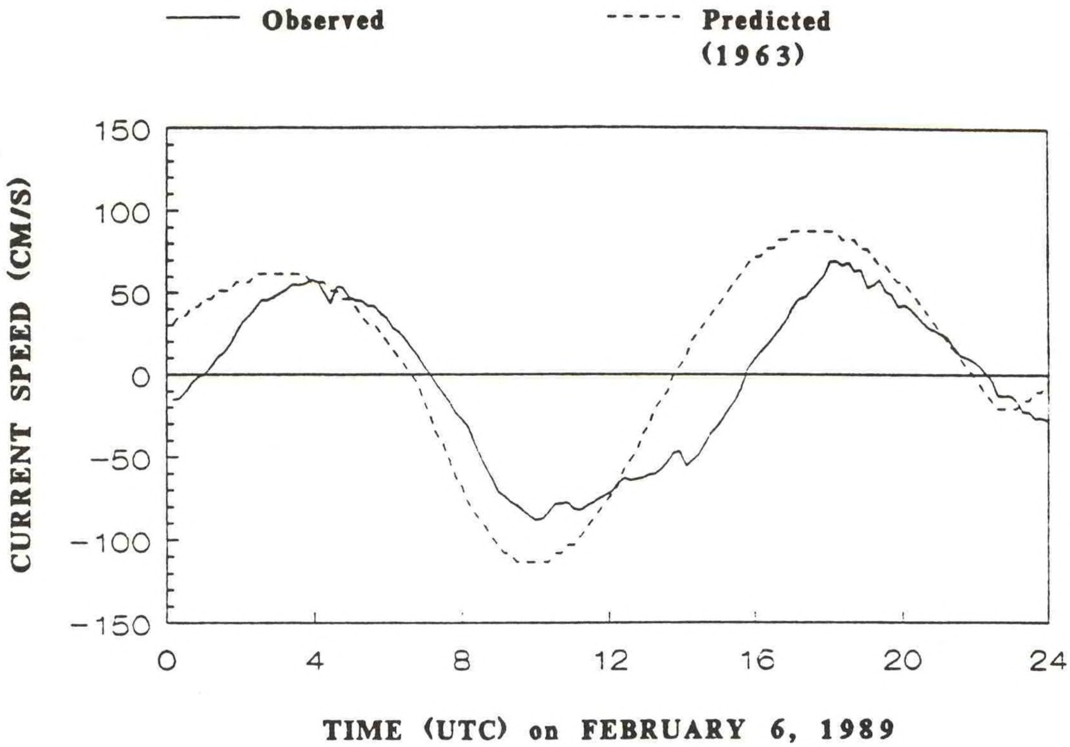


Figure 16

MANATEE CHANNEL



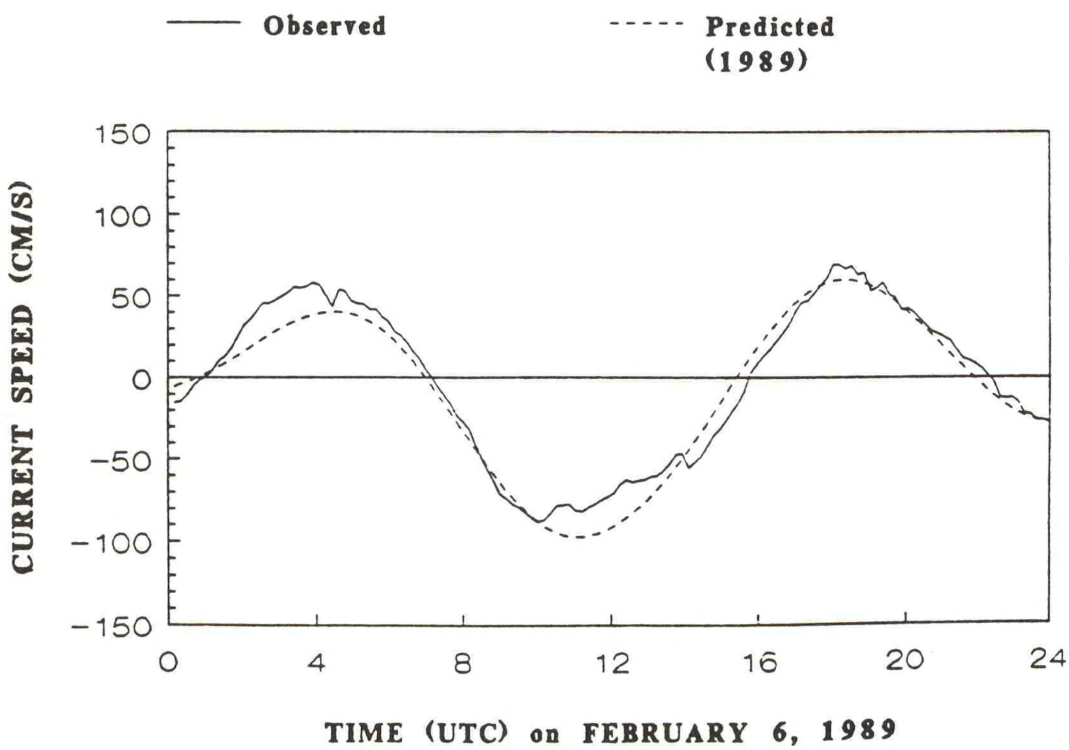


Figure 17

MANATEE CHANNEL

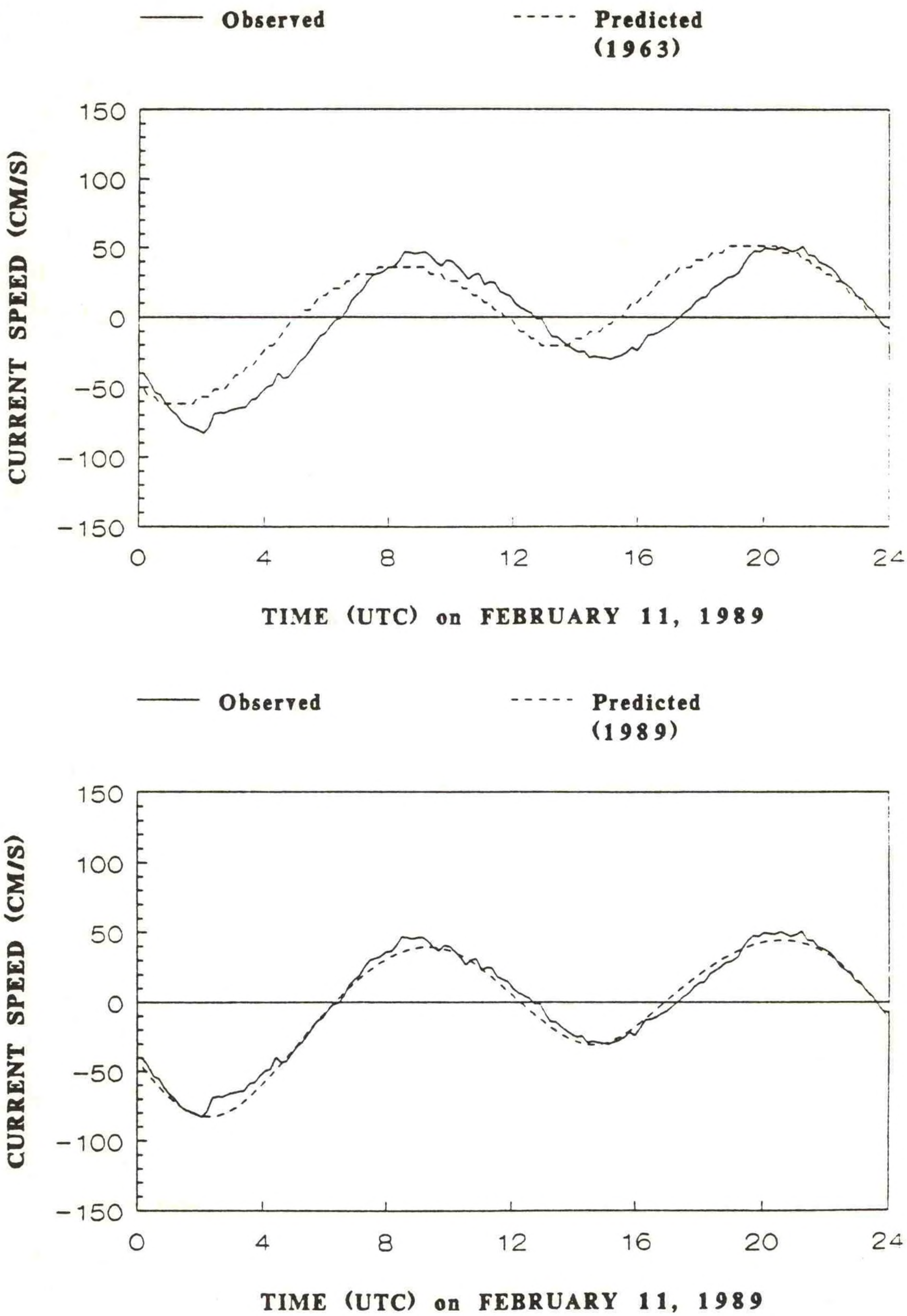


Figure 18

MANATEE CHANNEL

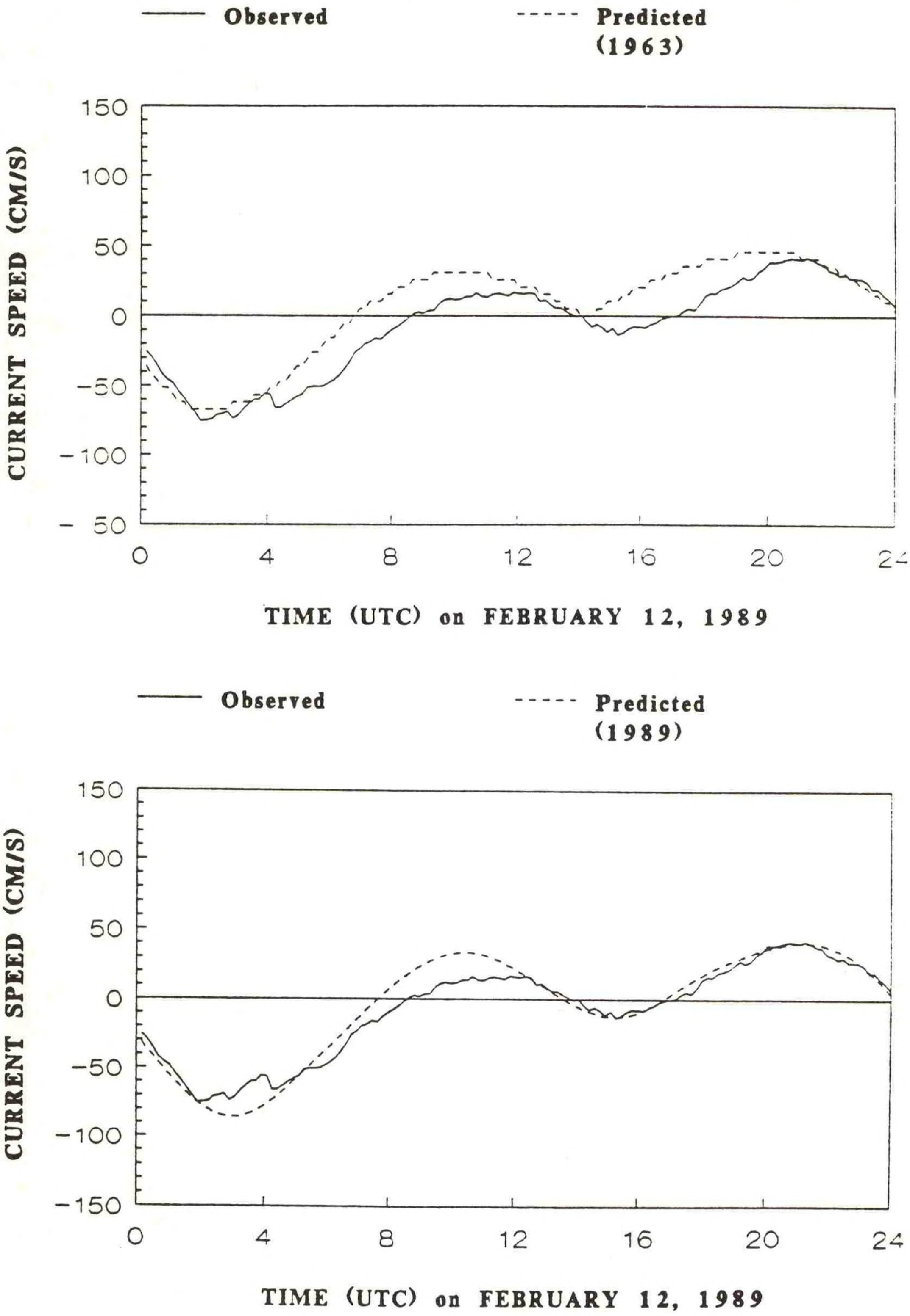
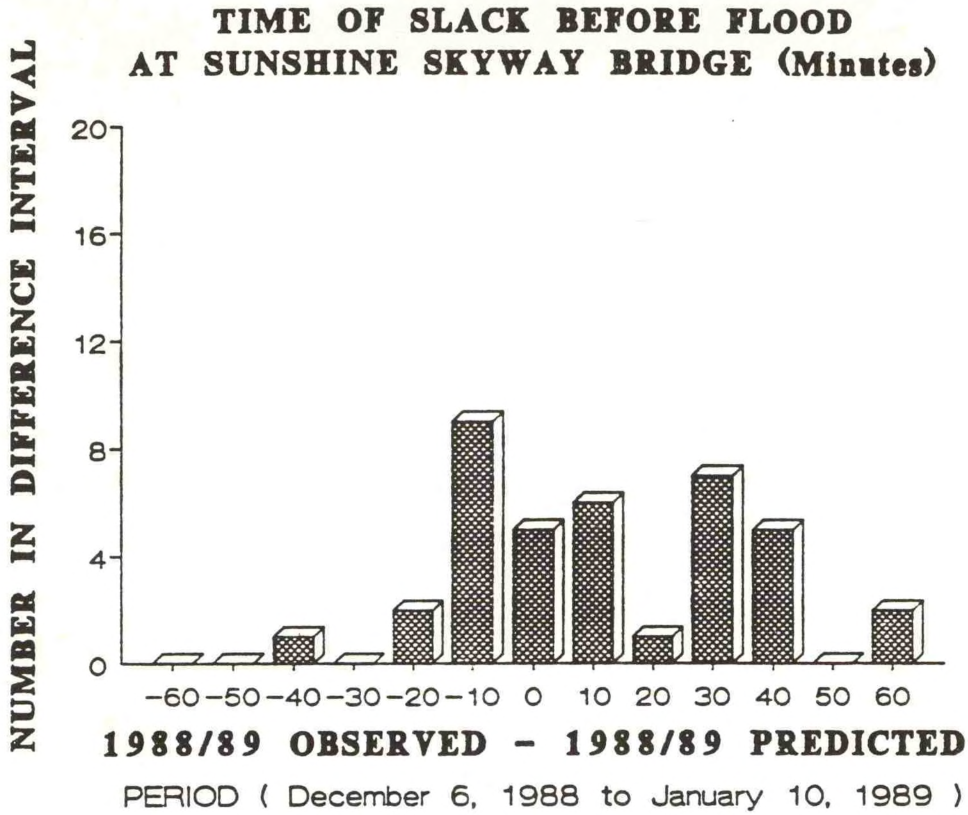


Figure 19


TIME OF SLACK BEFORE FLOOD
AT SUNSHINE SKYWAY BRIDGE (Minutes)
NUMBER IN DIFFERENCE INTERVAL
0
4
8
12
16
20
-60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60
1988/89 OBSERVED - 1988/89 PREDICTED
PERIOD (December 6, 1988 to January 10, 1989)

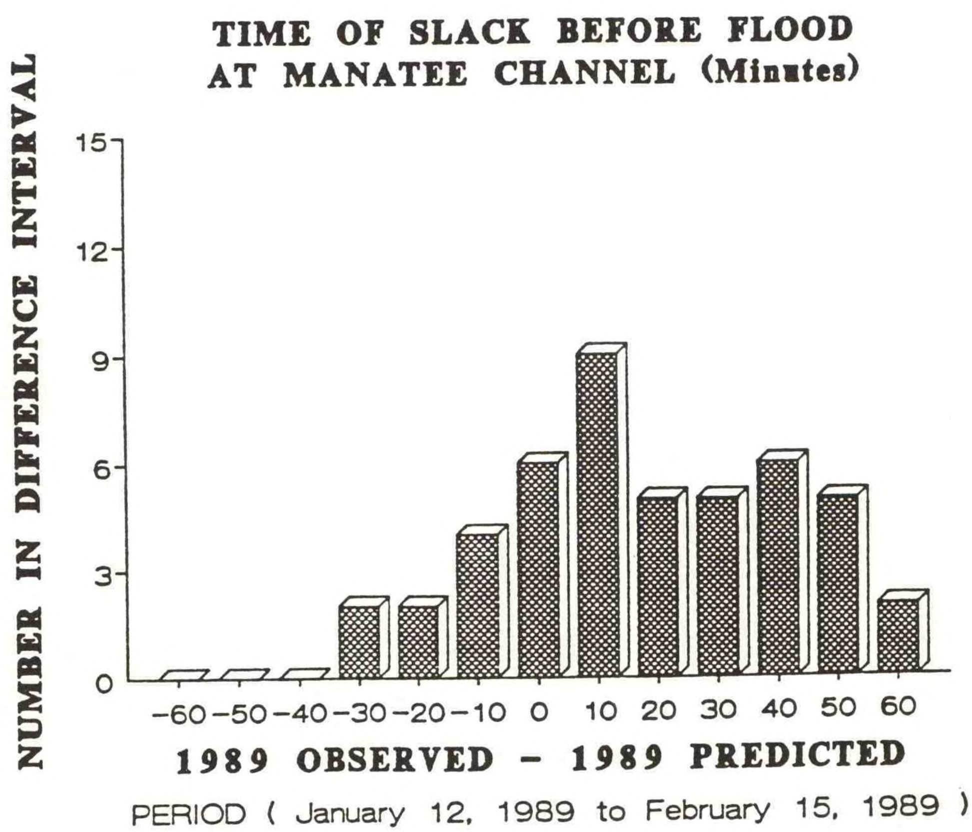
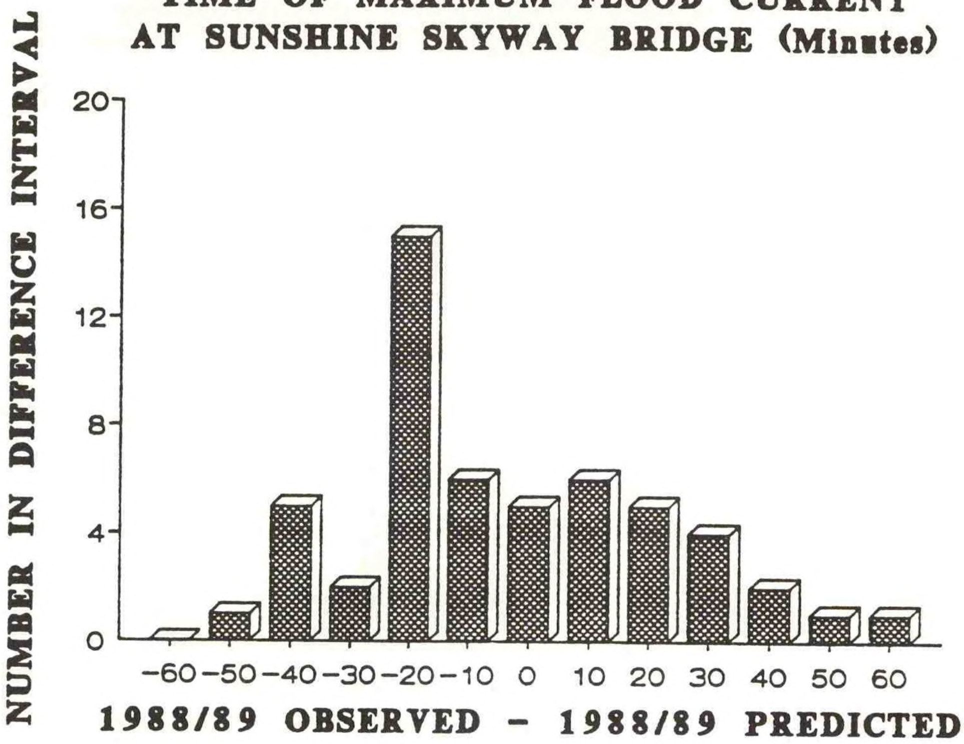

TIME OF SLACK BEFORE FLOOD
AT MANATEE CHANNEL (Minutes)
NUMBER IN DIFFERENCE INTERVAL
0
3
6
9
12
15
-60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60
1989 OBSERVED - 1989 PREDICTED
PERIOD (January 12, 1989 to February 15, 1989)

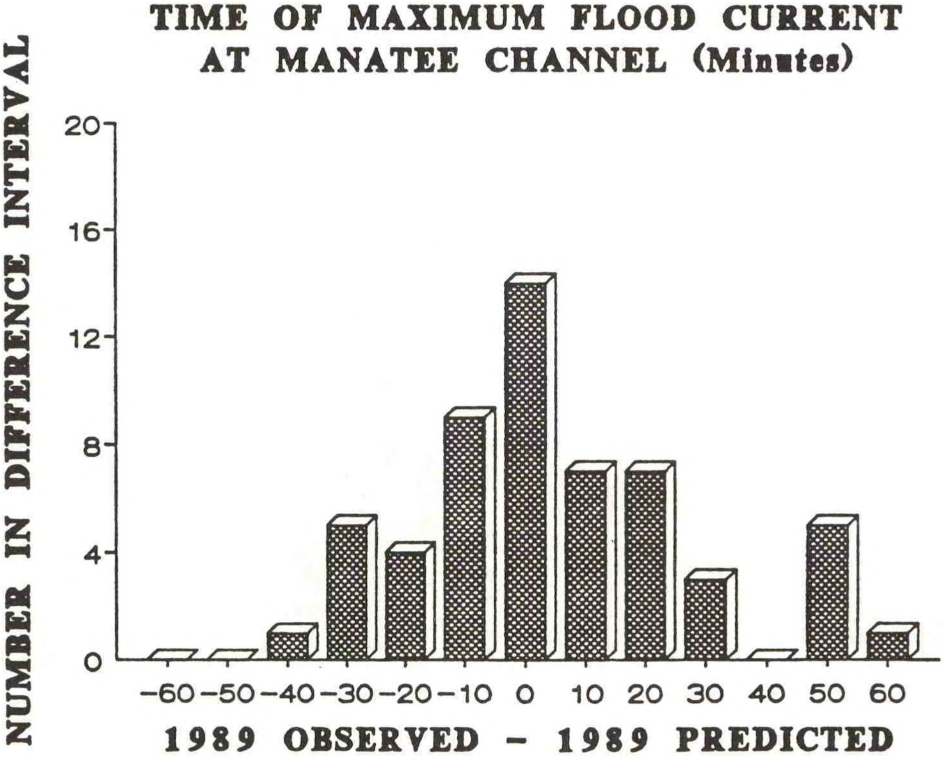
Figure 20

TIME OF MAXIMUM FLOOD CURRENT AT SUNSHINE SKYWAY BRIDGE (Minutes)



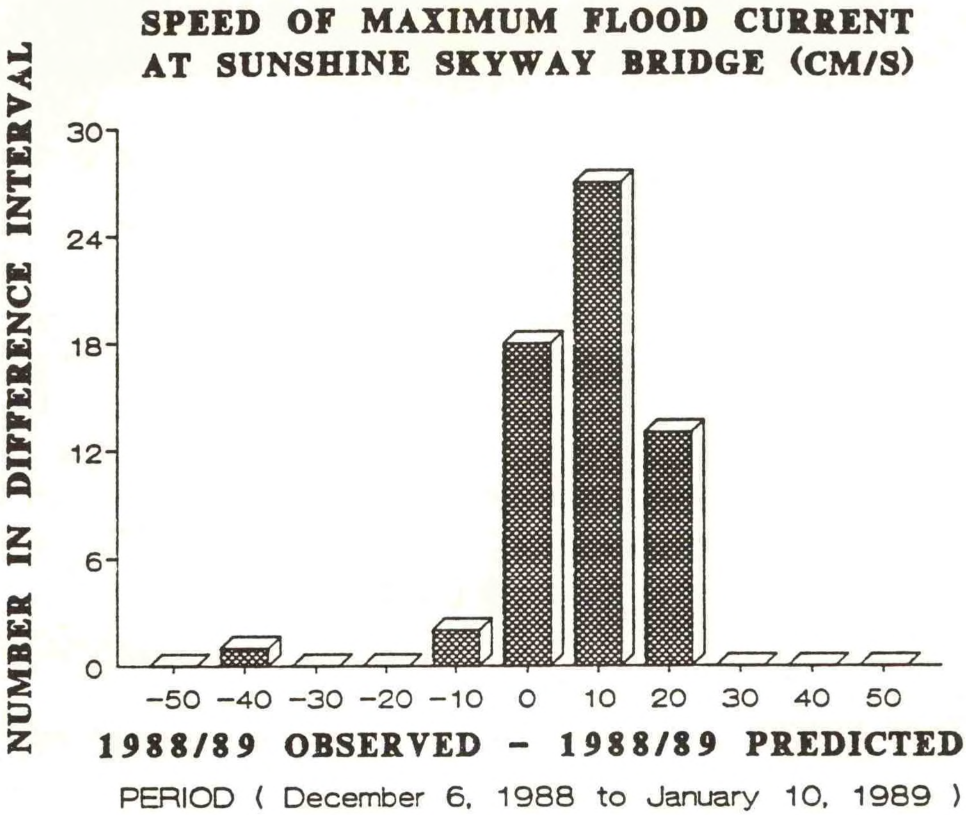
PERIOD (December 6, 1988 to January 10, 1989)

TIME OF MAXIMUM FLOOD CURRENT AT MANATEE CHANNEL (Minutes)



PERIOD (January 12, 1989 to February 15, 1989)

Figure 21


SPEED OF MAXIMUM FLOOD CURRENT
AT SUNSHINE SKYWAY BRIDGE (CM/S)
NUMBER IN DIFFERENCE INTERVAL
30
24
18
12
6
0
-50 -40 -30 -20 -10 0 10 20 30 40 50
1988/89 OBSERVED - 1988/89 PREDICTED
PERIOD (December 6, 1988 to January 10, 1989)

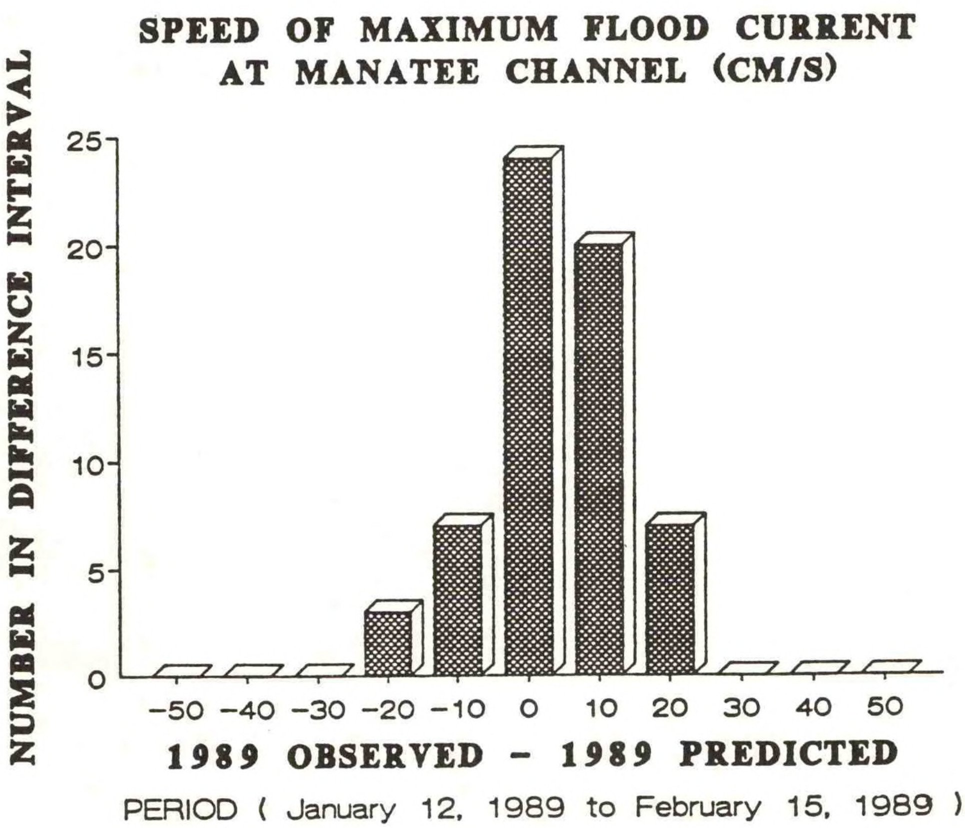
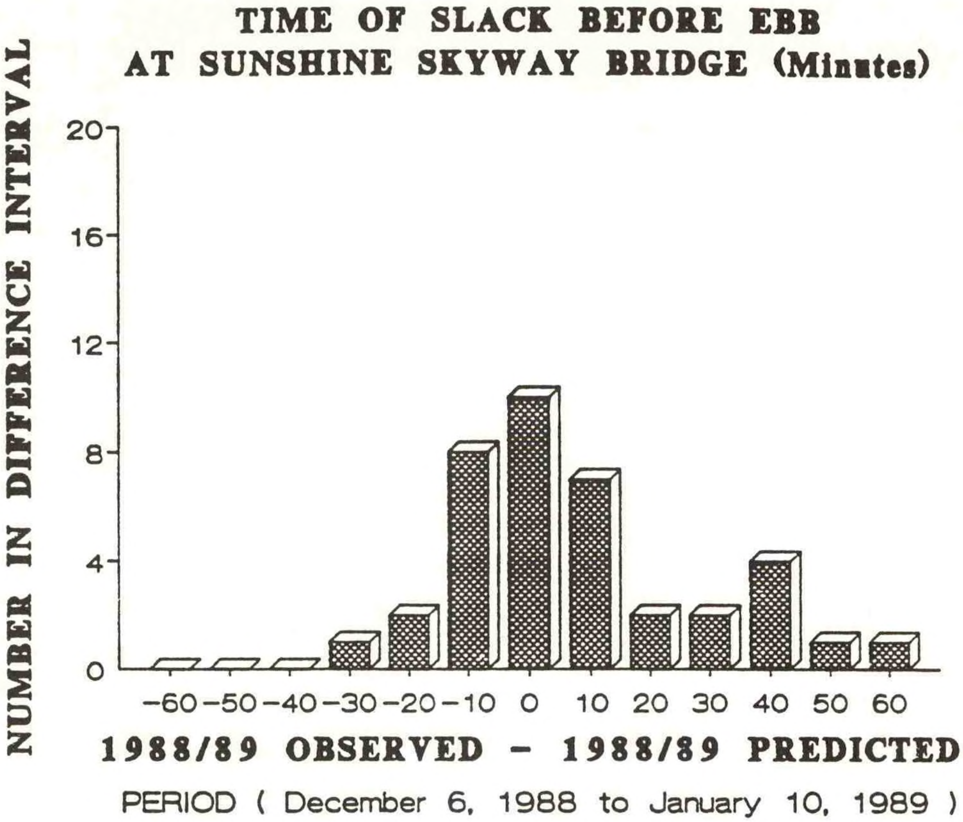

SPEED OF MAXIMUM FLOOD CURRENT
AT MANATEE CHANNEL (CM/S)
NUMBER IN DIFFERENCE INTERVAL
25
20
15
10
5
0
-50 -40 -30 -20 -10 0 10 20 30 40 50
1989 OBSERVED - 1989 PREDICTED
PERIOD (January 12, 1989 to February 15, 1989)

Figure 22


TIME OF SLACK BEFORE EBB
AT SUNSHINE SKYWAY BRIDGE (Minutes)
NUMBER IN DIFFERENCE INTERVAL
0
4
8
12
16
20
-60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60
1988/89 OBSERVED - 1988/89 PREDICTED
PERIOD (December 6, 1988 to January 10, 1989)

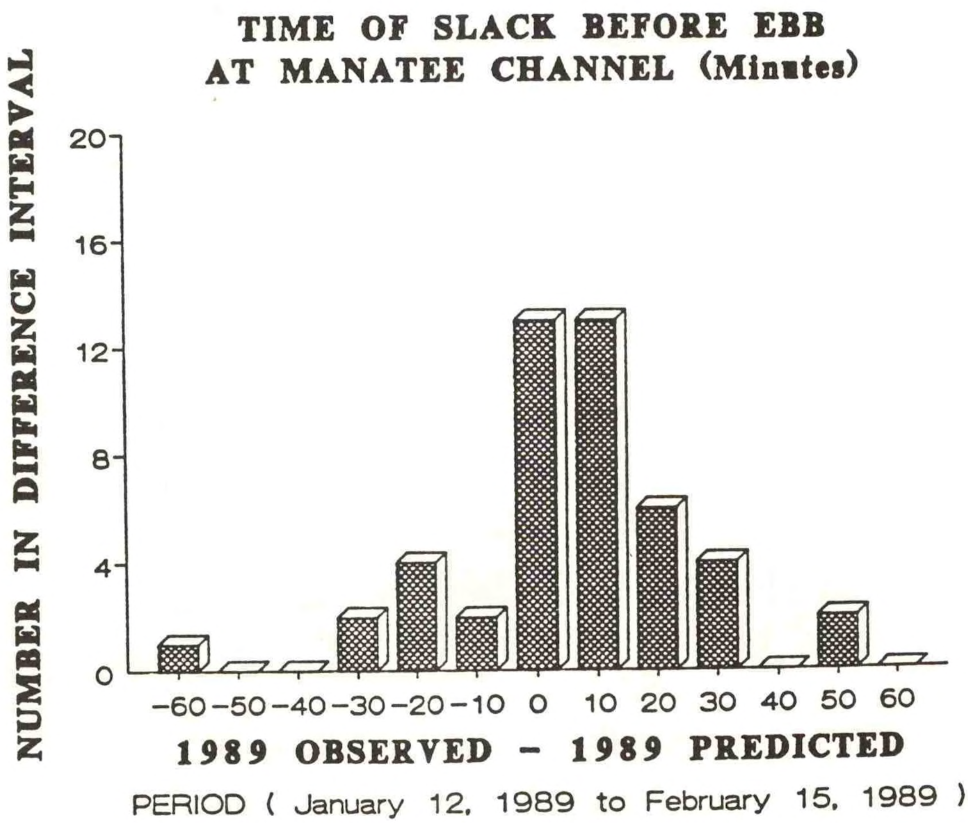
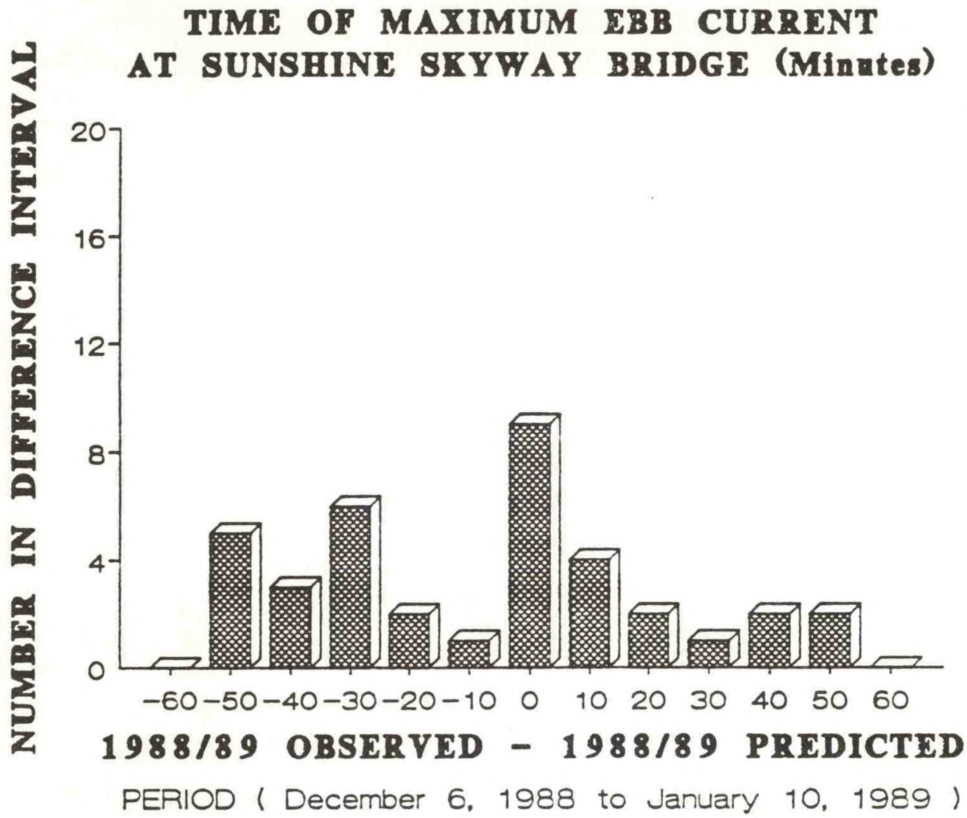

TIME OF SLACK BEFORE EBB
AT MANATEE CHANNEL (Minutes)
NUMBER IN DIFFERENCE INTERVAL
0
4
8
12
16
20
-60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60
1989 OBSERVED - 1989 PREDICTED
PERIOD (January 12, 1989 to February 15, 1989)

Figure 23


TIME OF MAXIMUM EBB CURRENT
AT SUNSHINE SKYWAY BRIDGE (Minutes)
NUMBER IN DIFFERENCE INTERVAL
0
4
8
12
16
20
-60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60
1988/89 OBSERVED - 1988/89 PREDICTED
PERIOD (December 6, 1988 to January 10, 1989)

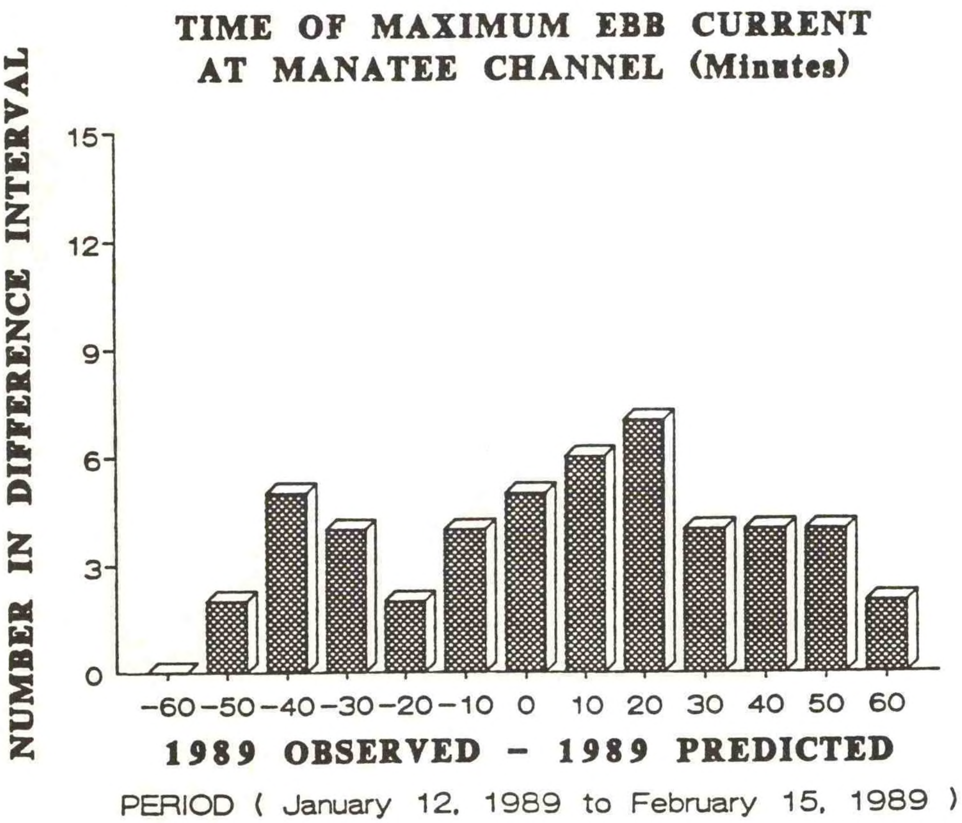
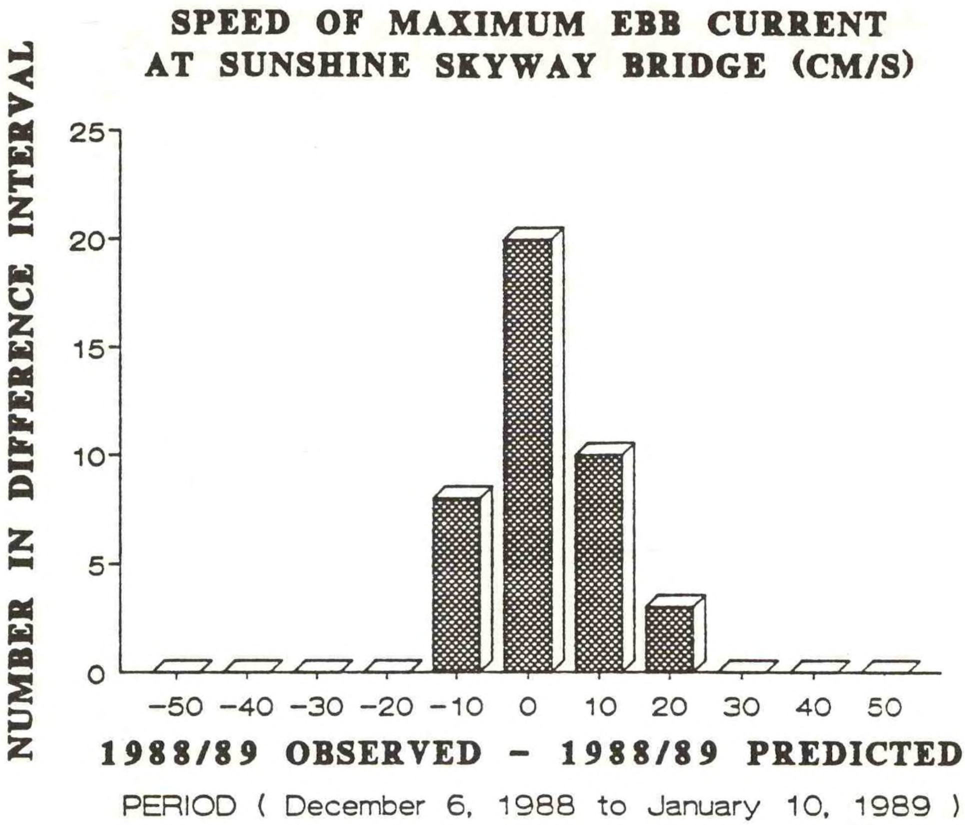

TIME OF MAXIMUM EBB CURRENT
AT MANATEE CHANNEL (Minutes)
NUMBER IN DIFFERENCE INTERVAL
0
3
6
9
12
15
-60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60
1989 OBSERVED - 1989 PREDICTED
PERIOD (January 12, 1989 to February 15, 1989)

Figure 24


SPEED OF MAXIMUM EBB CURRENT
AT SUNSHINE SKYWAY BRIDGE (CM/S)
NUMBER IN DIFFERENCE INTERVAL
25
20
15
10
5
0
-50 -40 -30 -20 -10 0 10 20 30 40 50
1988/89 OBSERVED - 1988/89 PREDICTED
PERIOD (December 6, 1988 to January 10, 1989)

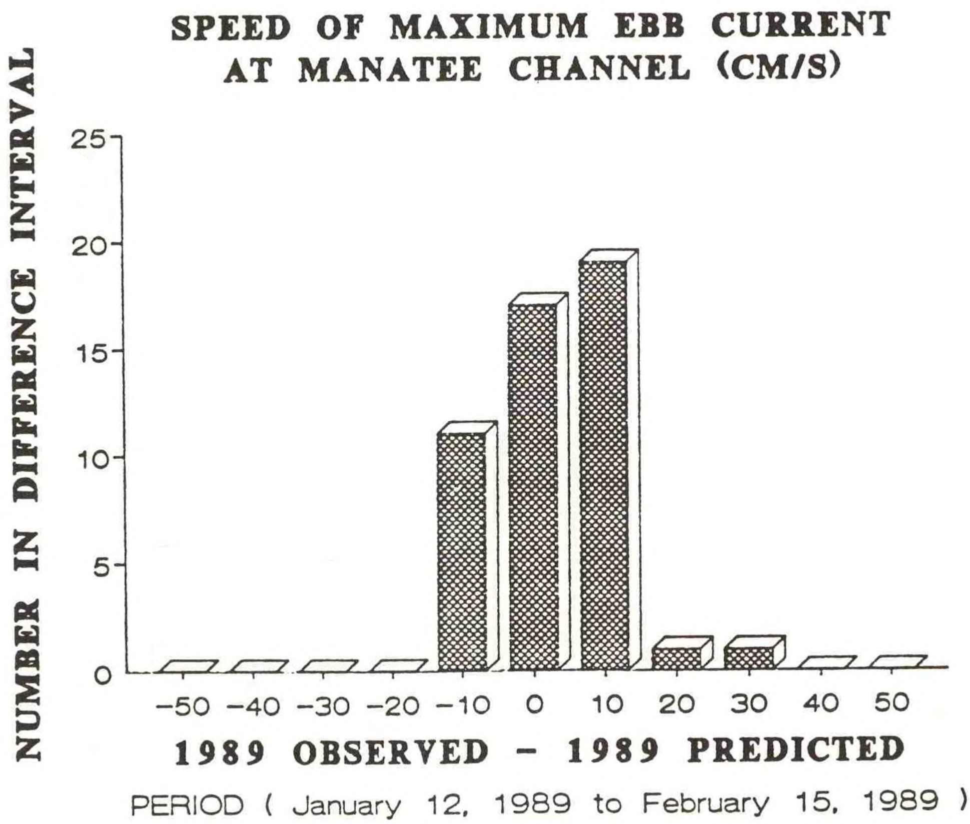

SPEED OF MAXIMUM EBB CURRENT
AT MANATEE CHANNEL (CM/S)
NUMBER IN DIFFERENCE INTERVAL
25
20
15
10
5
0
-50 -40 -30 -20 -10 0 10 20 30 40 50
1989 OBSERVED - 1989 PREDICTED
PERIOD (January 12, 1989 to February 15, 1989)

Figure 25

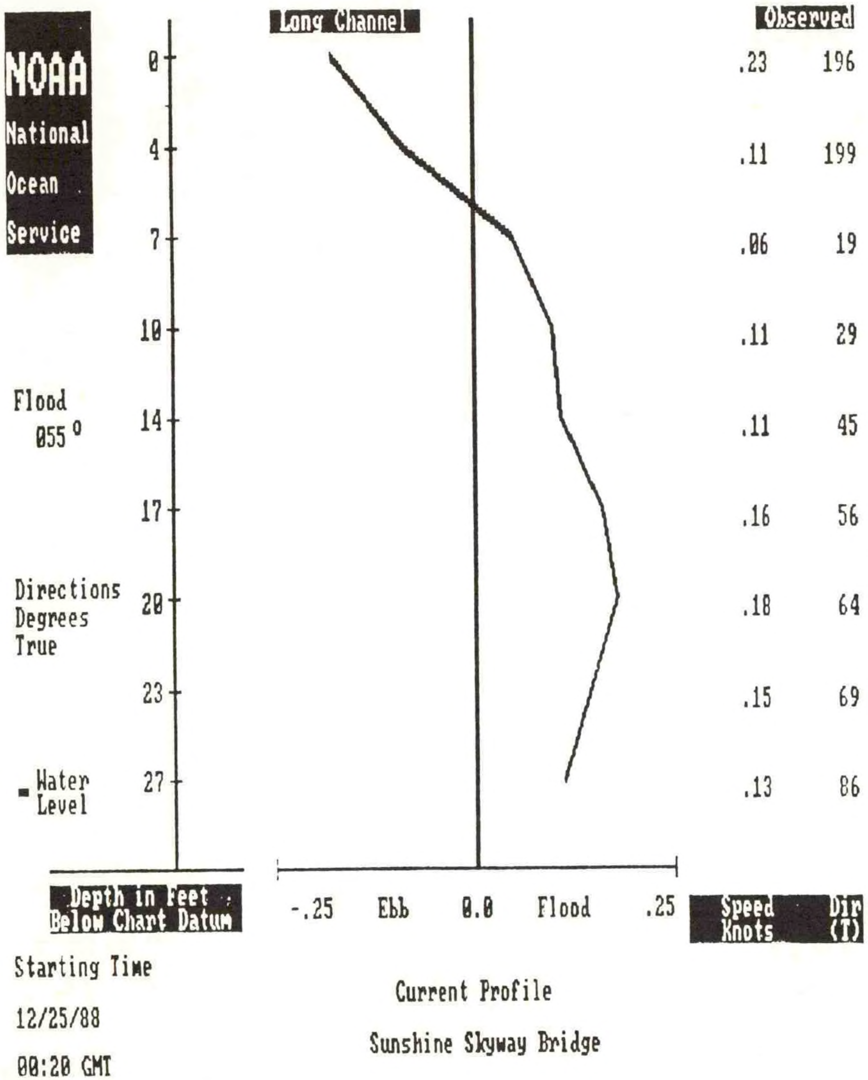


Figure 26a. 10 minutes after SBF

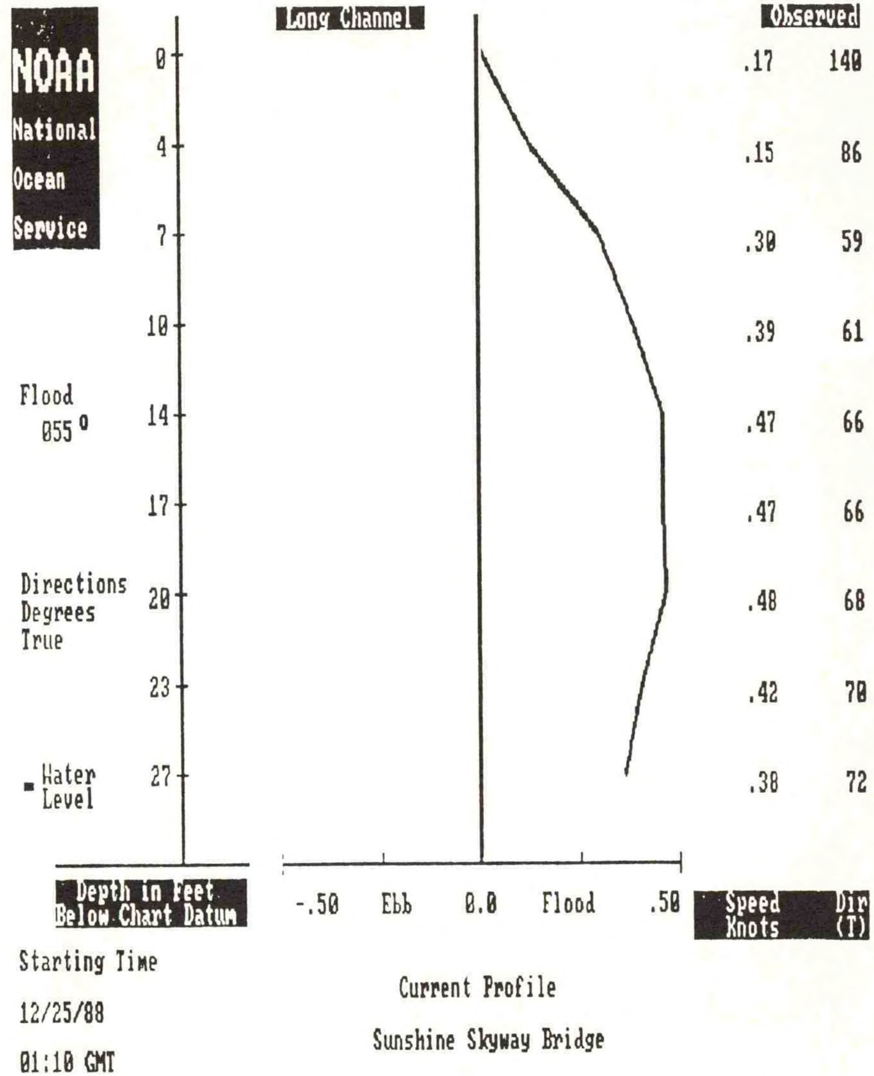


Figure 26b. 1 hour after SBF

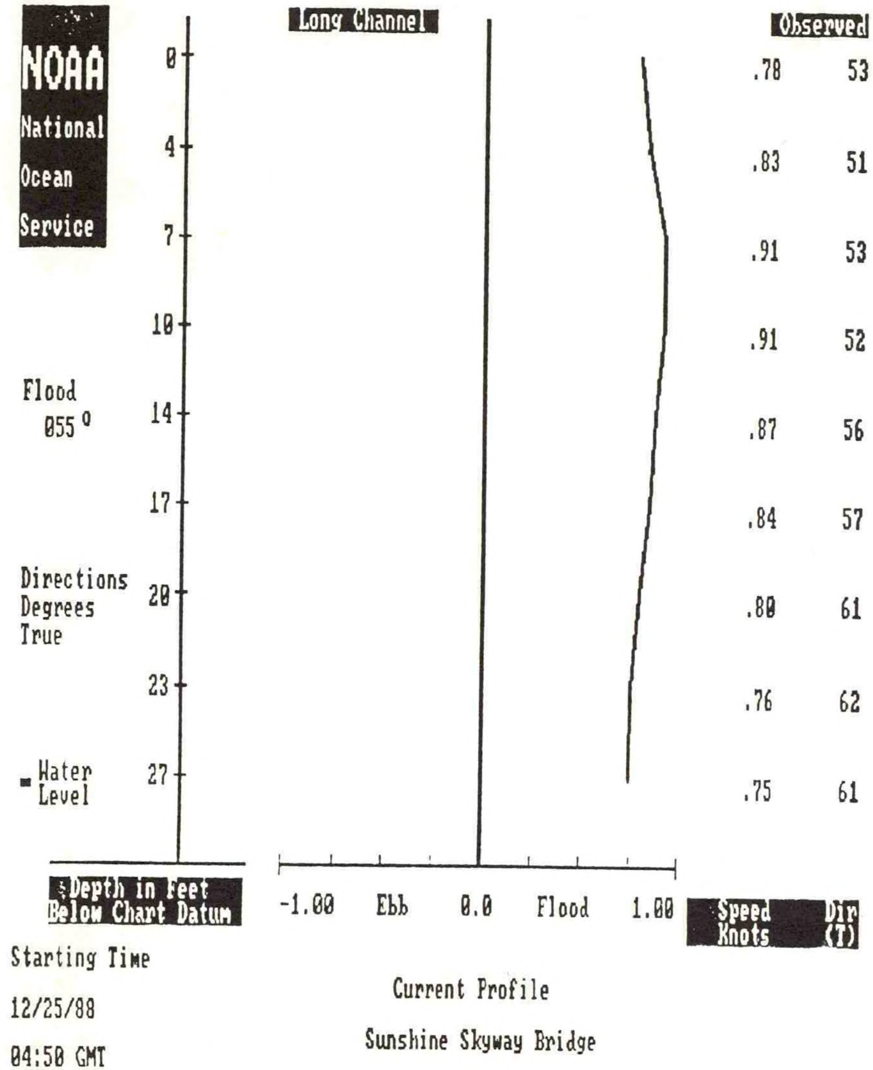


Figure 27a. MFC, 4 hours 40 minutes after SBF

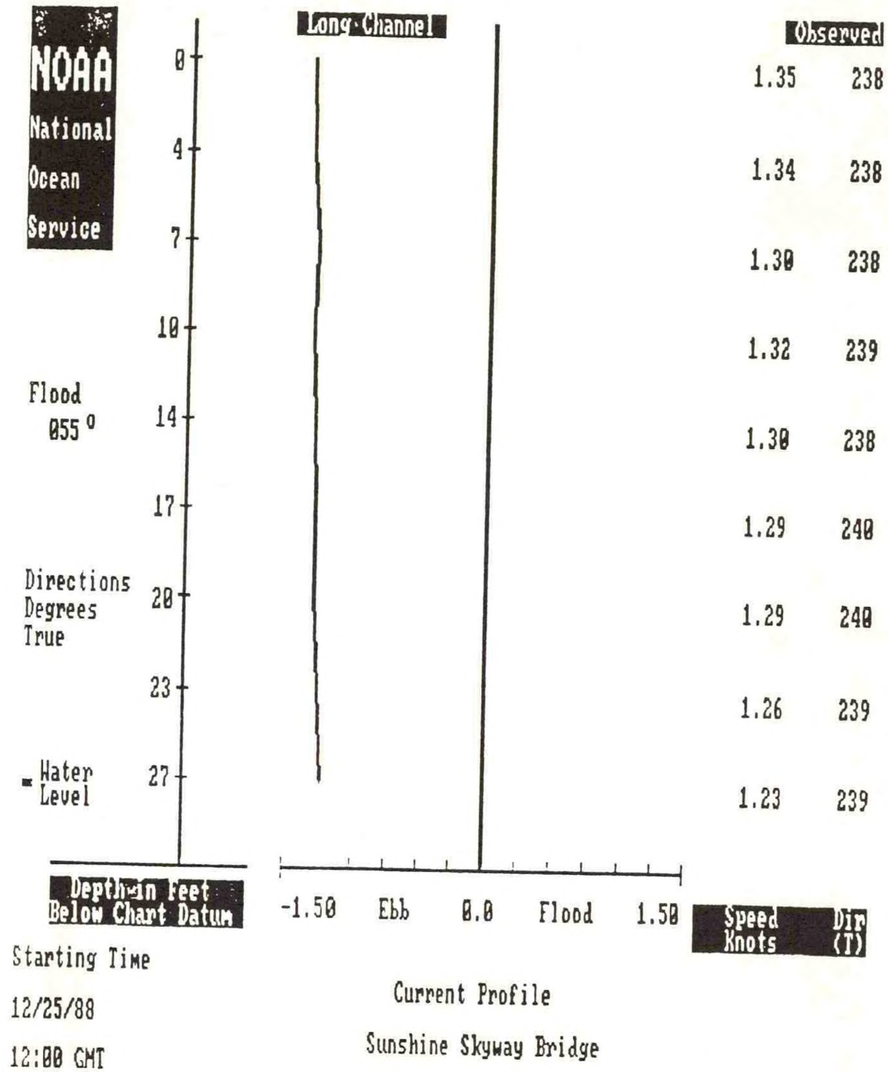


Figure 27b. MEC, 4 hours 50 minutes after SBE

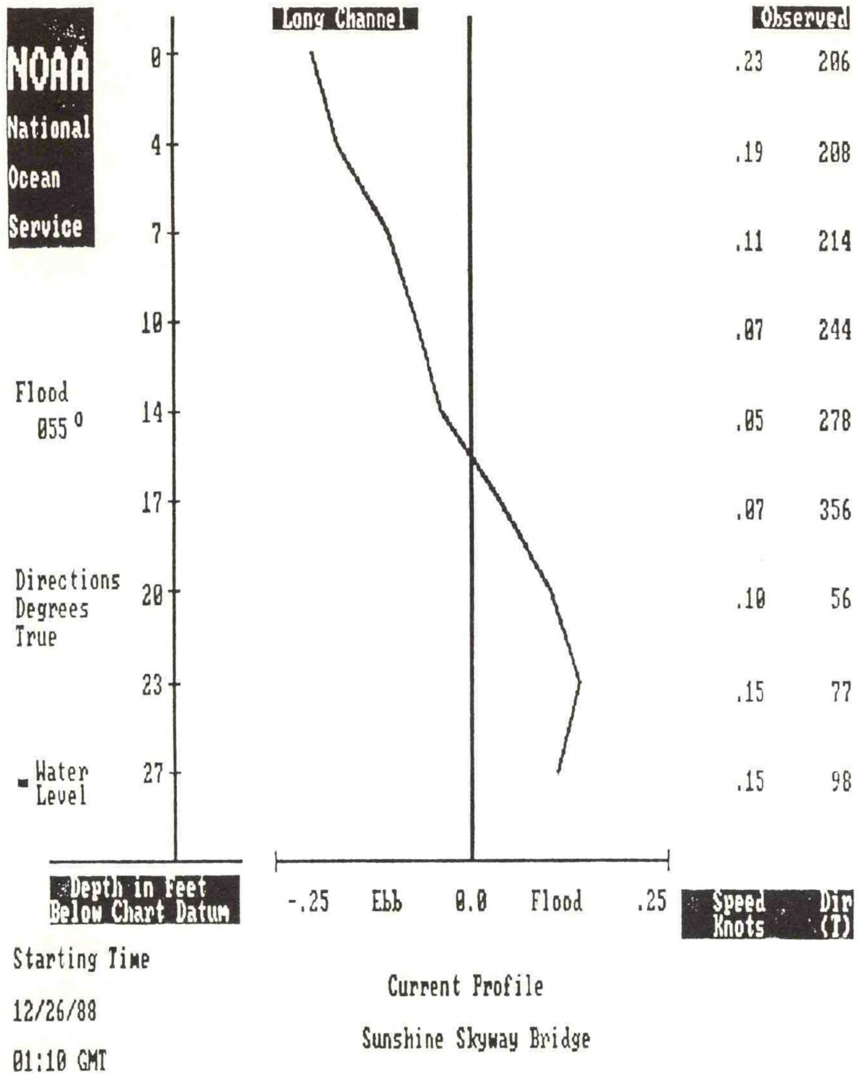


Figure 28a. 10 minutes after SBF

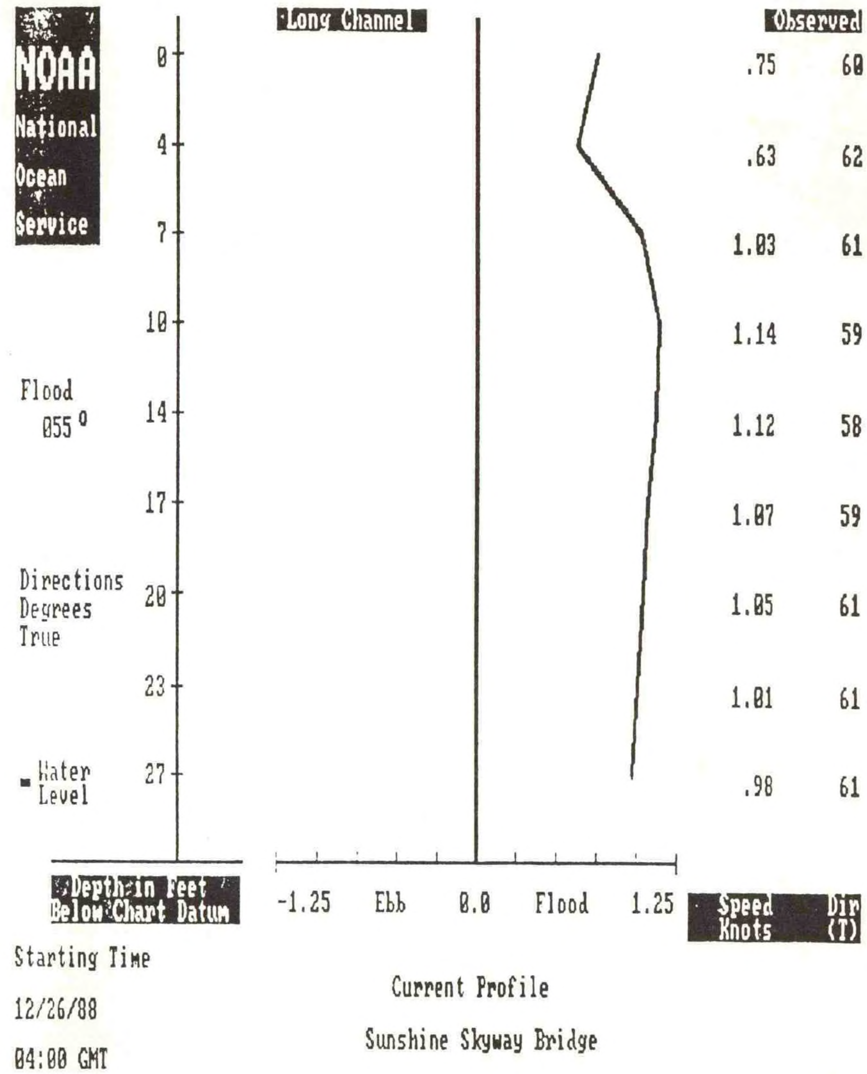


Figure 28b. MFC, 3 hours after SBF

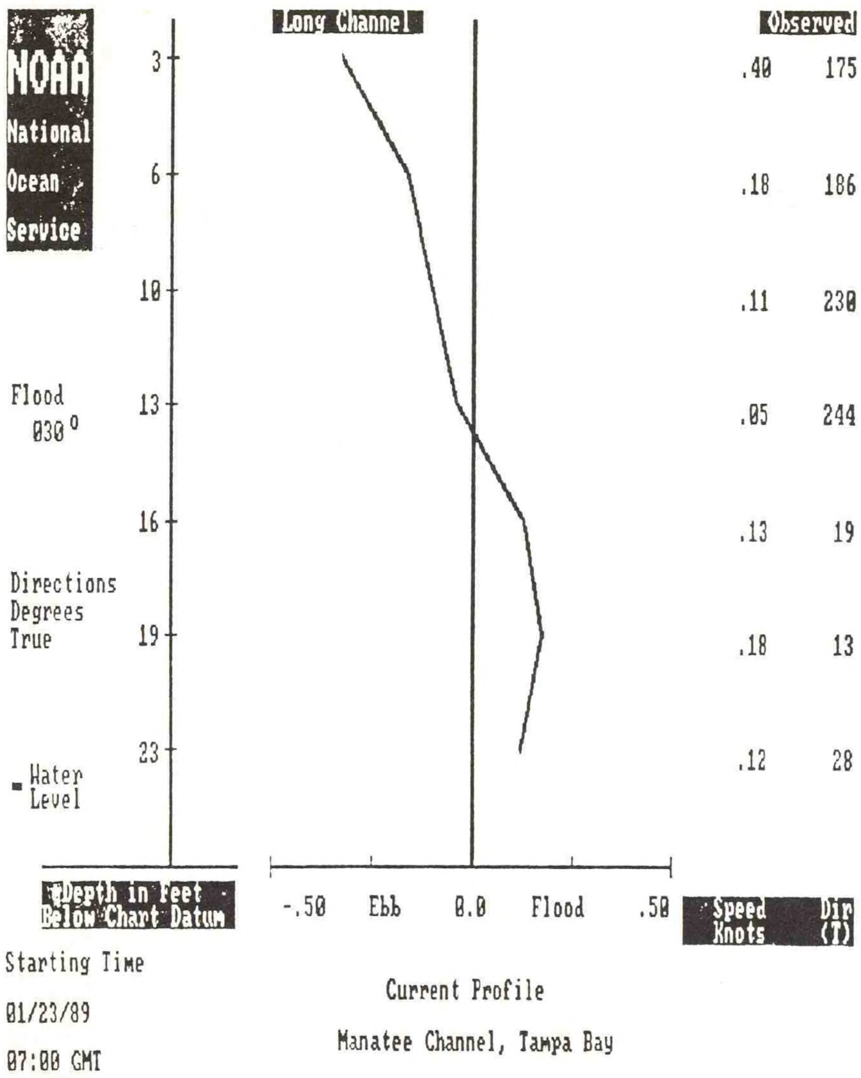


Figure 29a. SBE

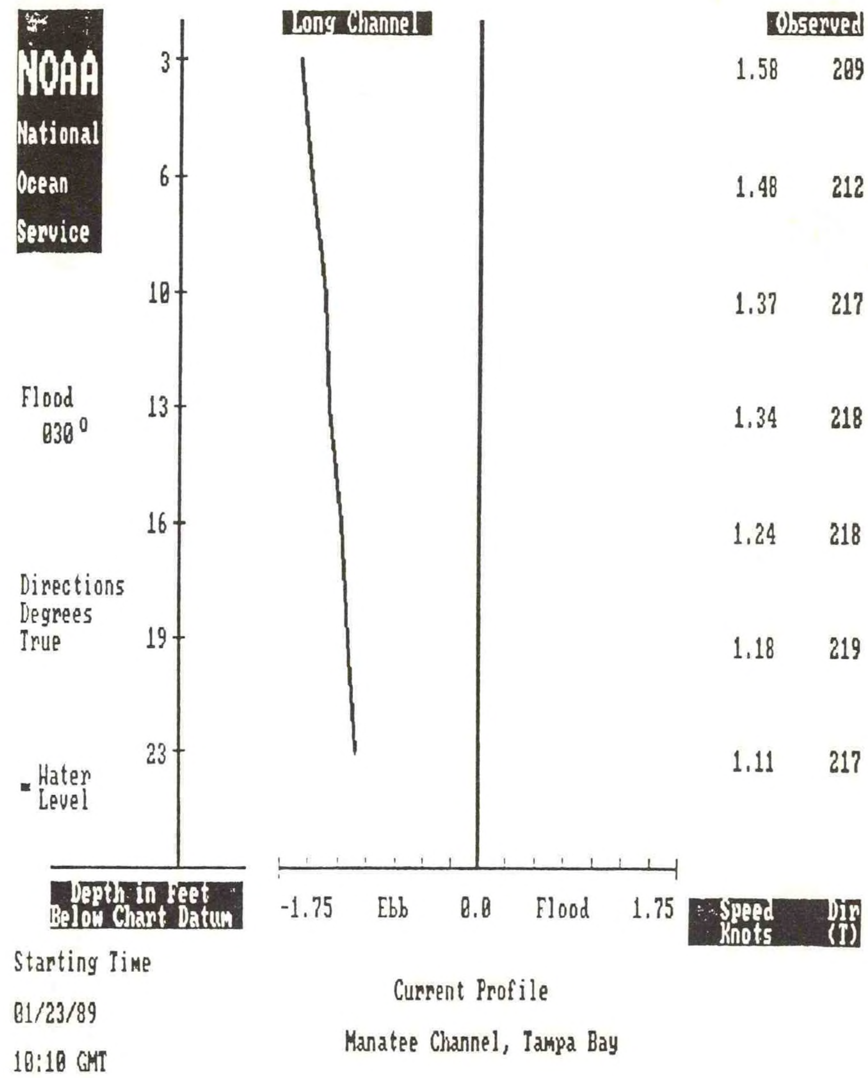


Figure 29b. 3 hours 10 minutes after SBE

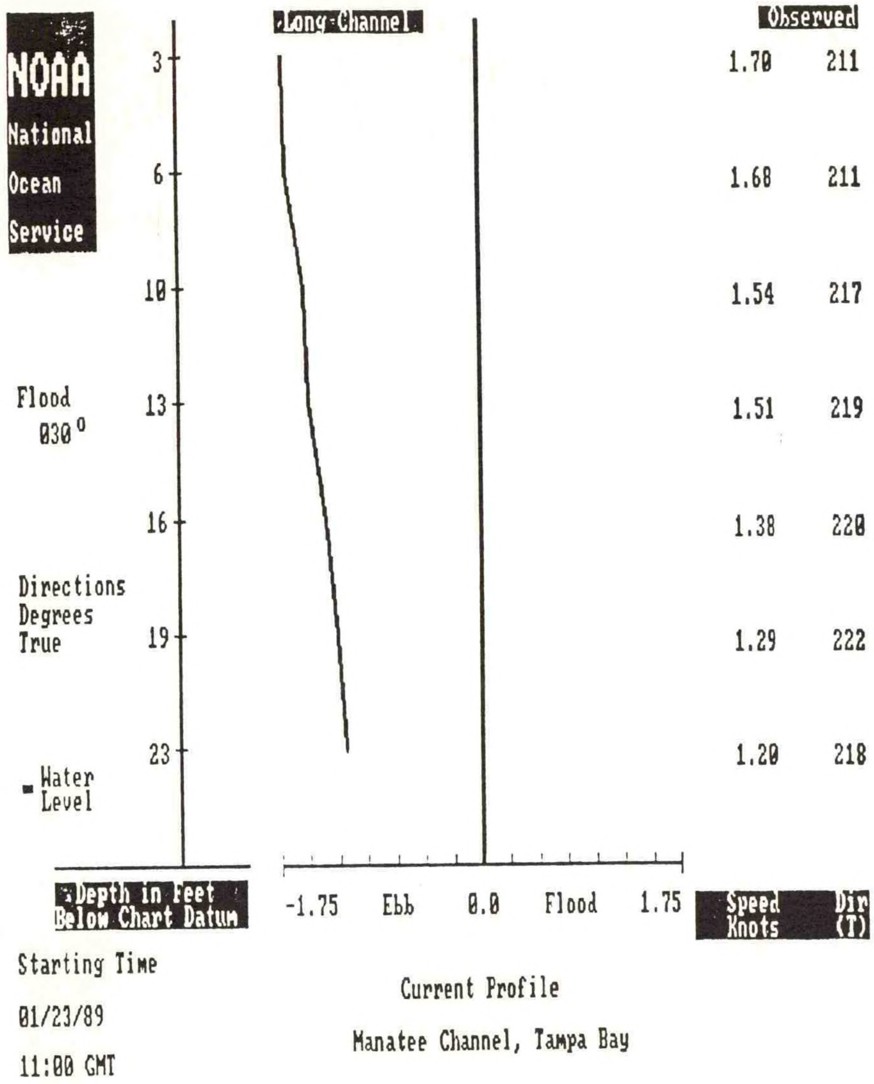


Figure 30a. MEC, 4 hours after SBE

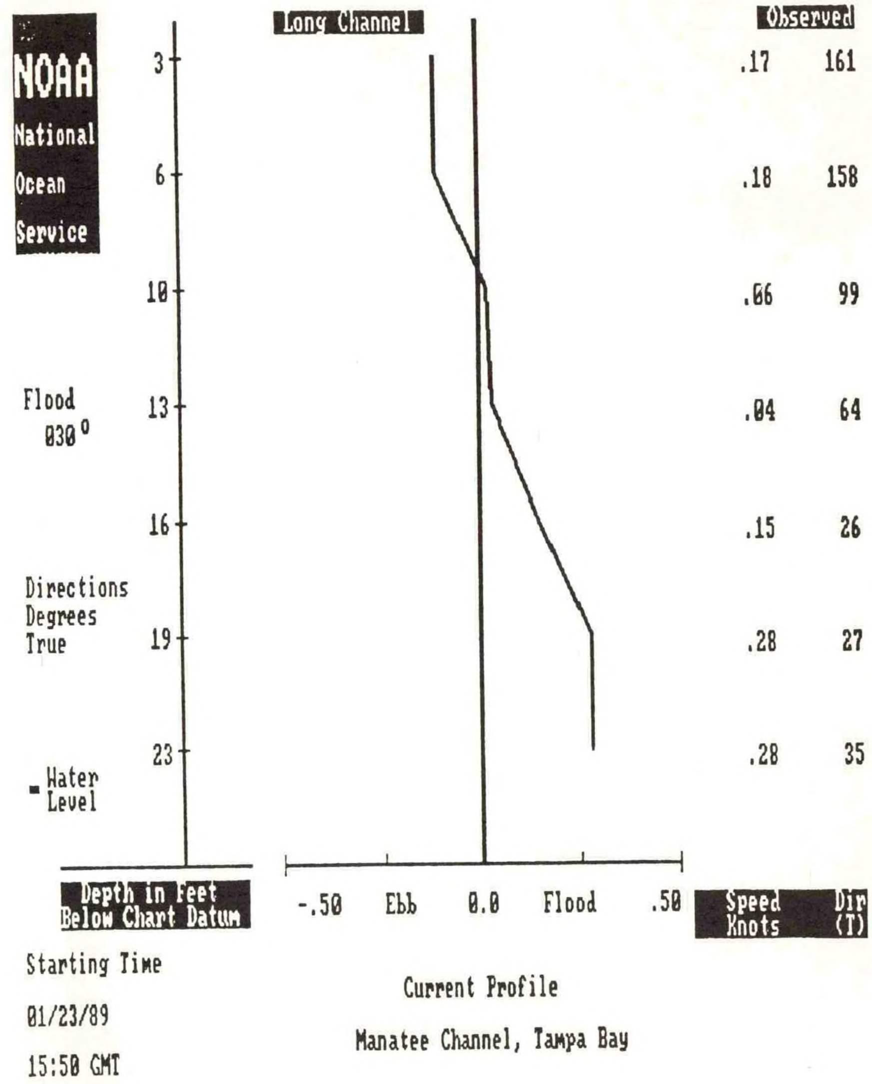


Figure 30b. SBF

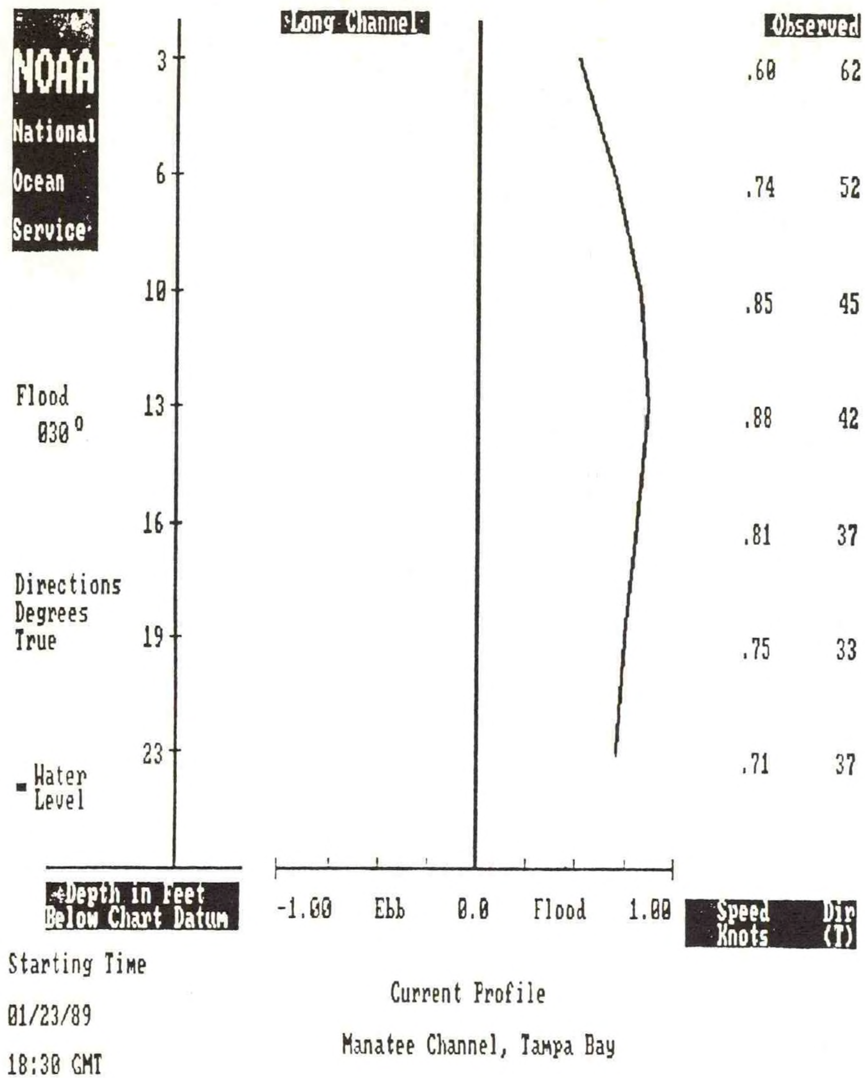


Figure 31a. MFC, 2 hours 40 minutes after SBF

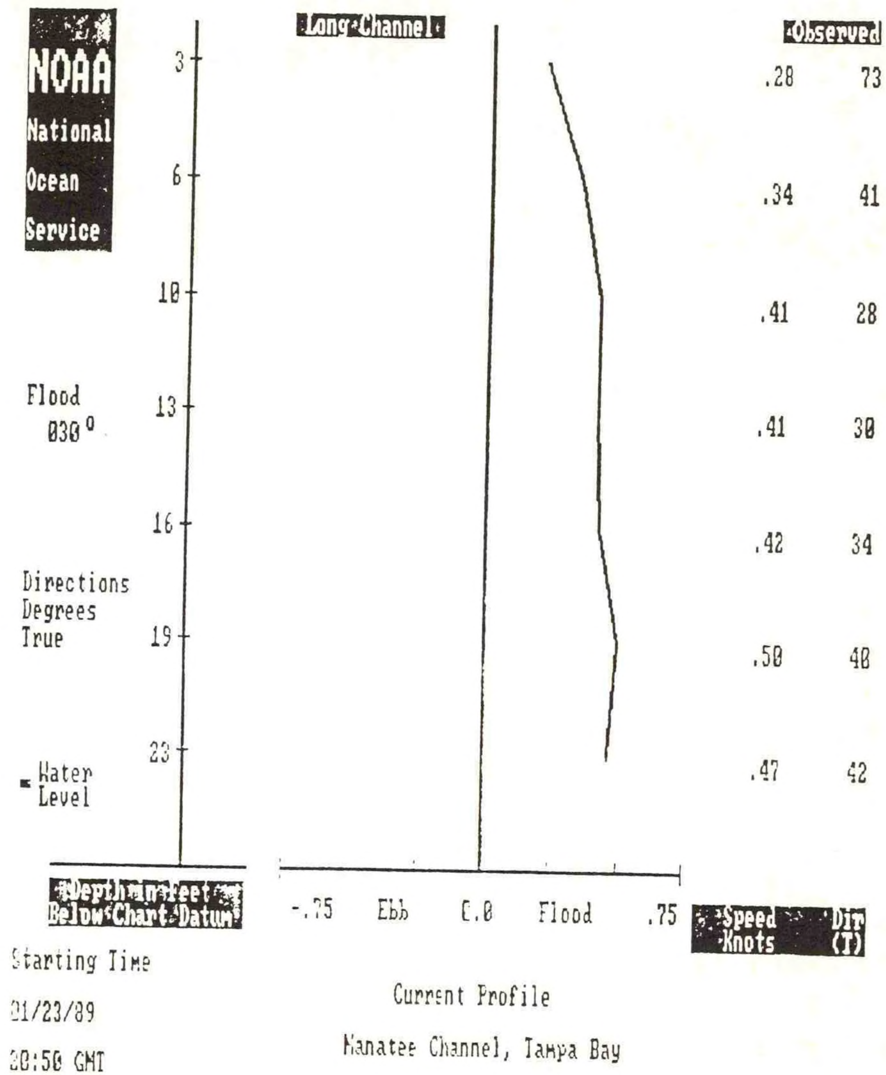


Figure 31b. 5 hours after SBF

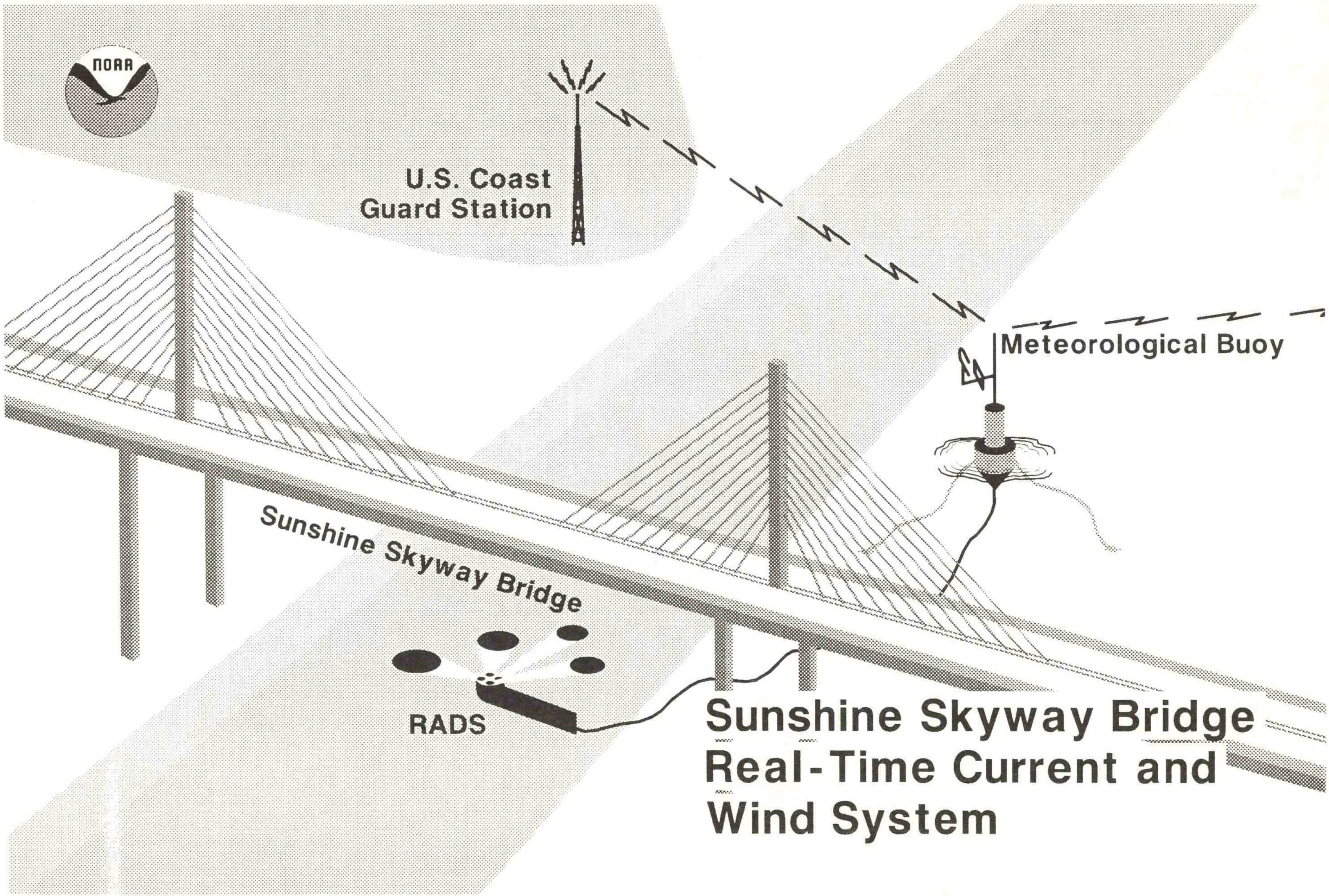
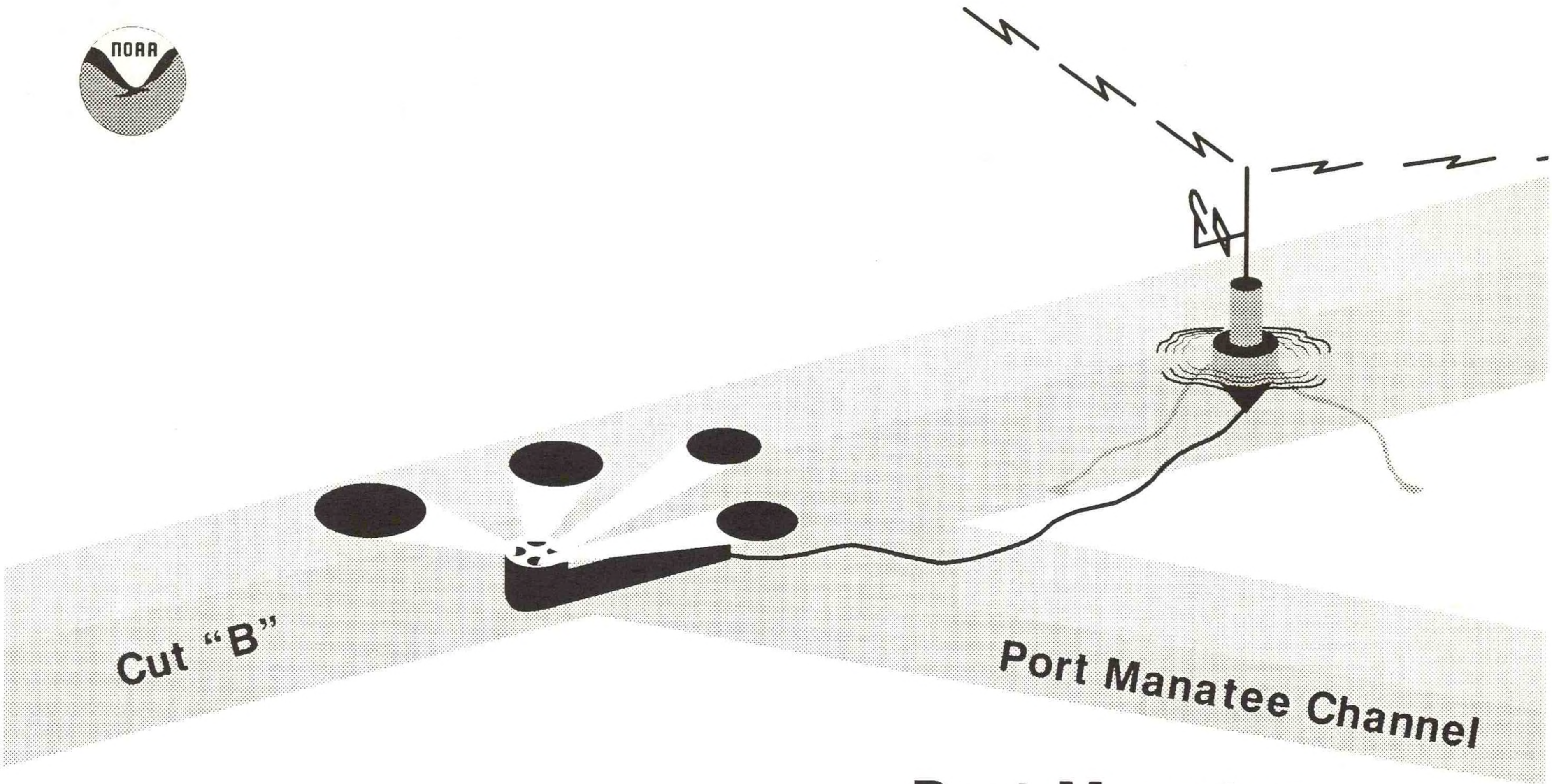

NOAA
U.S. Coast
Guard Station
Meteorological Buoy
Sunshine Skyway Bridge
RADS
Sunshine Skyway Bridge
Real-Time Current and
Wind System

Figure 32



Port Manatee Real-Time Current and Wind System

Figure 33