GC
57
.N6
no.60

NOAA Technical Memorandum NOS OMA 60

CORPUS CHRISTI BAY CURRENT PREDICTION QUALITY ASSURANCE MINIPROJECT

Rockville, Maryland
April 1991

noaa National Oceanic and Atmospheric Administration

National Ocean Service

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

The Office of Oceanography and Marine Assessment (OMA) provides decisionmakers with comprehensive, scientific information on characteristics of the oceans, coastal areas, and estuaries of the USA. The information ranges from strategic, rational assessments of coastal and estuarine environmental quality to real-time information for navigation or hazardous materials spill response. For example, OMA monitors the rise and fall of water levels at about 200 coastal locations of the USA (including the Great Lakes); predicts the times and heights of high and low tides; and provides information critical to national defense, safe navigation, marine boundary determination, environmental management, and coastal engineering. Currently, OMA is installing the Next Generation Water Level Measurement System that will replace by 1992 existing water level measurement and data processing technologies. Through its National Status and Trends Program, OMA uses uniform techniques to monitor toxic chemical contamination of bottom-feeding fish, mussels and oysters, and sediments at 200 locations throughout the USA. A related OMA program of directed research examines the relationships between contaminant exposure and indicators of biological responses in fish and shellfish.

OMA uses computer-based circulation models and innovative measurement technologies to develop new information products, including real-time circulation data, circulation forecasts under various meteorological conditions, and circulation data atlases. OMA provides critical scientific support to the U.S. Coast Guard during spills of oil or hazardous materials into marine or estuarine environments. This support includes spill trajectory predictions, chemical hazard analyses, and assessments of the sensitivity of marine and estuarine environments to spills. The program provides similar support to the U.S. Environmental Protection Agency's Superfund Program during emergency responses at, and for the cleanup of, abandoned hazardous waste sites in coastal areas. To fulfill the responsibilities of the Secretary of Commerce as a trustee for living marine resources, OMA conducts comprehensive assessments of damages to coastal and marine resources from discharges of oil and hazardous materials.

OMA collects, synthesizes, and distributes information on the use of the coastal and oceanic resources of the USA to identify compatibilities and conflicts and to determine research needs and priorities. It conducts comprehensive, strategic assessments of multiple resource uses in coastal, estuarine, and oceanic areas for decisionmaking by NOAA, other Federal agencies, state agencies, Congress, industry, and public interest groups. It publishes a series of thematic data atlases on major regions of the U.S. Exclusive Economic Zone and on selected characteristics of major U.S. estuaries. It also manages, for the U.S. Department of the Interior, a program of environmental assessments of the effects of oil and gas development on the Alaskan outer continental shelf.

OMA implements NOAA responsibilities under Title II of the Marine Protection, Research, and Sanctuaries Act of 1972; Section 6 of the National Ocean Pollution Planning Act of 1978; and other Federal laws. OMA has three major line organizations: The Physical Oceanography Division, the Ocean Assessments Division and the Ocean Systems Division.

GC
57
.N6
no. 60

NOAA Technical Memorandum NOS OMA 60

CORPUS CHRISTI BAY CURRENT PREDICTION QUALITY ASSURANCE MINIPROJECT

LIBRARY
NOV 2 3 1992
N.O.A.A.
U.S. Dept. of Commerce

Robert G. Williams
Thomas D. Bethem
Geoffrey W. French
Henry R. Frey

Rockville, Maryland
April 1991

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

A quality assurance (QA) miniproject was conducted to assess the adequacy of the published NOAA tidal current predictions in Port Aransas (Aransas Pass Channel), Texas. These are the only NOAA current predictions available to the Corpus Christi area, and are also the southernmost predictions for waters of the State of Texas. The QA miniproject was necessary because of presumed changes in the circulation since 1966, when the most recent NOS current measurements for the area were acquired. Port Aransas is a "table 2" station, which means that currents are predicted by using adjustment factors referred to Galveston Bay Entrance. The data on which the Galveston Bay Entrance reference station are based were acquired in 1936-37. A QA miniproject conducted in Galveston Bay in 1988 shows that the current predictions for the Houston Ship Channel/Galveston Bay region are significantly in error (Williams, R.G., H.R. Frey, and T.D. Bethem, 1990).

NOAA's National Ocean Service (NOS) deployed an acoustic Doppler current profiler (ADCP) system, formerly known as RADS, at Port Aransas from April to May 1990. Analysis of the new data confirms that the circulation has changed, and that predictions are inadequate. A second ADCP system was deployed at Port Ingleside in response to requests from local mariners for current information at the site of the new Navy Pier. The navigation aid to which this ADCP was moored was struck by a vessel two weeks into the deployment period, causing the instrument to tilt over on its side. Results from the short period of deployment prior to the collision are summarized. Subsequent to the collision, the data are suspect and are not included in this report.

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

Summary of Collected Data for the QA Miniproject

The current measurements were made with RD Instruments' 1200 kHz ADCP model RD-SC/DR 1200. The ADCP is a high-technology system which, when mounted on the bottom, produces a profile of currents through the water column in vertical segments or "bins" 1 meter in length (Figure 1). Because the bottom-mounted ADCP systems extend no more than 1.5 m above the bottom, they can be placed closer to the center of navigation channels than conventionally-moored current meters. An ADCP system was deployed at the location of the NOS table 2 station just inshore of buoy #9, Port Aransas (Figure 2) and Table 1.

The locations, water depths, and times of deployment and retrieval for the ADCPs are shown in Table 1. Extensive quality control procedures performed on the ADCP measurements show the data to be of high quality. The depth chosen for analysis is the standard depth used for predictions in the NOAA Tables, i.e., 15 feet (4.6 m).

The current data were analyzed to produce time series plots, summary statistics, 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). These times and velocities are collectively referred to as the "NOS Tidal Current Parameters". The differences between new observations and NOAA tidal current predictions provided in the published Tables were tested against working standards for adequacy established for the QA miniproject (Figure 3). There are no absolute standards for accuracy of predictions; these working standards were developed for QA miniprojects in consultation with mariners from all parts of the country and represent a goal to which NOS is striving.

Results

Statistical analysis of the differences between the published NOAA tidal current table parameters and those computed from the new ADCP measurements, based on over 40 days of data, shows that the presently published predictions do not meet working standards.

The results are presented as histograms in Figures 4 and 5, and in tabular form in Table 2. Table 2 provides maximum and minimum observed differences, means, standard deviations, and limits within which 90 percent of the differences must fall to be within working standards. The limits were determined empirically; it was not assumed that the differences are normally distributed.

The predominant direction of the flood current has changed since the time on which the tables are based. The present flood direction is 300 degrees, as can be seen from Figure 6, rather than 312 degrees, as given in the NOAA tables.

New predictions for Port Aransas, based on the 1990 ADCP data provide improvement over the NOAA table predictions. An indication of the improvement can be seen by comparing the graphs of 24-hour time series of ADCP-measured currents with the table predictions, and with the new predictions (Figures 7 through 20).

Statistics on the differences between the new observations and the new predictions are provided in Table 3; the histograms of the differences are determined in Figures 21 and 22.

The vertical profiles of horizontal currents, for one-meter ADCP profile depth bins are given in Figures 23 through 31. Vertical shear is large around the slack times, and can be as large as 0.5 knots per 10 feet (26 cm/s per 3 m) of depth at mid-depth, e.g. Figures 26a and 29b. In general, vertical shear is larger during ebb currents than during flood currents. For example, Figure 31b indicates a vertical shear on the order of 0.3 knots per 10 feet (17 cm/s per 3 m) of depth at mid-depth. Indications are that near-surface shear can be very large, e.g., Figures 23b and 24b. However, ADCP measurements are not sufficiently reliable close to the surface to make quantitative estimates of near-surface shear magnitude. In summary, the highest speeds usually occur near the surface but, subsurface currents may be stronger than surface currents by a few tenths of knots near the times of slack water.

Although the mean values of the differences between the ADCP data and the new predictions are generally smaller than the differences with 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.

Summary of Collected Data at Port Ingleside

The Port Ingleside ADCP system was attached to navigation aid #38, as a partial shelter from the intense bottom fishing for shrimp. On April 25, an unknown vessel struck the aid, causing the ADCP platform to tilt on its side. Prior to that day, data quality was determined to be good. Due to the shallowness of the area, only two ADCP bins produced useful data; the best quality data being in bin 2 approximately 2 m below the water surface. The along-channel time series of current speeds for the period of useful data collection are shown in Figures 32 through 36. The corresponding figures for Port Aransas are shown below for comparison. Statistics of the data at Port Ingleside are summarized in Table 4; statistics of Port Aransas are given in Table 5.

The maximum current speed during the measurement period was 94 cm/s in the flood direction, or 320 degrees. The standard deviation of the currents, 15 cm/s, indicates that non-tidal current variability is relatively small. There is more variability in the direction of the current at Port Ingleside than at Port Aransas. Current speeds at Port Ingleside are on the order of half those at Port Aransas. At Port Aransas, the highest observed currents were in the ebb direction, whereas at Port Ingleside, the largest observed currents were in the flood direction (Figure 37).

Conclusions and Recommendations

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

- Current predictions for Aransas Pass based on Table 2 corrections on Galveston as published in NOAA's Tidal Current Tables 1991 - Atlantic Coast of North America may deviate from the times of actual tidal currents by as much as 2 hours. Maximum observed current velocities may at times be double the predicted velocities.
- The amount of data collected in the miniproject is insufficient to develop updated predictions for Port Aransas and predictions for Port Ingleside; hence, an ADCP system should be deployed at Port Aransas for a period of at least 6 months to develop new tidal predictions.
- A real-time current, water-level, and wind-measuring system should be deployed at Port Ingleside. For prediction of the total current, a real-time system and a numerical hydrodynamic model are required.

References

Dennis, R.E., and E.E. Long, 1971. A users Guide to a Computer Program for Harmonic Analysis of Data at Tidal Frequencies. NOAA Technical Report NOS 41. U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration. 31 pages.

NOS, 1988. Tidal Current Tables, 1990, Atlantic Coast of North America. U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration. 243 pages.

RD Instruments, "Operation and Maintenance Manual, RD-DR and RD-SC Models Acoustic Doppler Current Profiler". RD Instruments, San Diego California. August 1988.

Hayes, J.G., H.R. Frey, R.G. Williams, J.M. Welch, and W.L.Wilmot "Charleston Harbor Oceanography Project: A New Era for Circulation Measurements and Predictions". Proceedings of Oceans 87. Mar. Tech. Soc. and IEEE Ocean Engineer. Soc., Halifax, Nova Scotia. September 28 - October 1, 1987, Vol Three. 887 pages.

Williams R.G., H.R. Frey, and T.D. Bethem, 1990. Houston Ship Channel, Galveston Bay Current Prediction Quality Assurance Miniproject. NOAA Technical Memorandum. NOS OMA 53. U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration.

Acknowledgements

Field support was provided by the U.S. Coast Guard Base, Corpus Christi. CWO Ed S. Anastacio was extremely helpful in coordinating Coast Guard support for the deployments and retrievals. The 50 ft USCG buoy tender, under the command of Chief William Hernandez provided outstanding vessel support. Chief Morgan supported the requirements of the project ashore.

Diving support was provided by the U.S. Army Special Forces Dive Team, Fort Sam Houston, Texas under the command of Major Dr. Alexander Moloff. MSG Larry Peters coordinated the Army participation, as well participating in the dives. The Army Team, led by Major Dr. Alex Moloff and Sgt. Larry Peters, supplemented by Marine Reservists, did a truly outstanding job.

Capt Fred Wilkerson, Aransas-Corpus Christi Pilots provided valuable advice for the conduct of the project, and provided the NOS team with a reconnaissance of the area to determine the best locations for instruments.

Oceanographic data as well as valuable advice were provided by Prof. Anthony Amos, University of Texas, Port Aransas, Texas, as well as by Dr. F. Michael Speed of Corpus Christi State University, Corpus Christi, Texas.

This miniproject could not have been accomplished without the assistance of our colleagues in the Estuarine and Ocean Physics Branch, especially Cary Wong, James Bascom, Brenda Via, Kelly Swiger, Sun Hahn, and Michael Evans.

TABLE 1

ADCP STATION DEPLOYMENTS

Station	Latitude	Longitude	Deployed	Retrieved	Depth
C-01 (Aransas Pass)	27 50.03 N	97 02.65 W	4/8/90	5/21/90	58 ft
C-02 (Port Ingleside)	27 48.98 N	97 12.78 W	4/9/90	5/21/90	15 ft

TABLE 2

TABLE OF DIFFERENCES STATISTICS

1990 OBSERVED - 1966 PREDICTED

Name (Units) of the NOS Parameter	Minimum	Lower 90%	SD	Mean	Upper 90%	Maximum
MFC Time (Minutes) at Station c01010	-109.0	-98.0	50.9	-36.1	59.0	109.0
MFC Speed (CM/S) at Station c01010	-5.5	-0.3	21.3	41.9	69.5	74.5
SBE Time (Minutes) at Station c01010	-102.0	-102.0	66.6	12.5	110.0	113.0
MEC Time (Minutes) at Station c01010	-114.0	-80.0	48.9	-21.6	68.0	108.0
MEC Speed (CM/S) at Station c01010	-77.2	-67.4	24.3	-34.0	9.5	25.9
SBF Time (Minutes)	-0.3	-102.0	45.5	-25.9	52.0	83.0

TABLE 3

TABLE OF DIFFERENCES STATISTICS

1990 OBSERVED - 1966 PREDICTED

Name (units) Of The Nos Parameter	Minimum	Lower 90%	SD	Mean	Upper 90%	Maximum
MFC Time (Minutes) at Station c01010	-64.8	-58.0	-33.34	-17.50	48.9	53.2
MFC Speed (CM/S) at Station c01010	-62.1	-28.3	19.9	8.84	29.1	49.2
SBE Time (Minutes) at Station c01010	-63.2	-42.1	33.47	-5.24	39.2	54.3
MEC Time (Minutes) at Station c01010	-62.5	-52.1	28.84	-8.44	49.9	54.0
MEC Speed (CM/S) at Station c01010	-45.2	-29.1	21.47	-5.45	28.7	29.8
SBF Time (Minutes)	54.2	42.1	31.37	7.78	44.2	63.1

TABLE 4

STATISTICS ON RADS CURRENT MEASUREMENTS AT PORT INGLESIDE

START TIME: 4/10/90 00:02 STOP TIME: 4/25/90 00:02

	SPEED (SCALAR)	SPEED (EBB)	DIRECTION (EBB)	SPEED (FLOOD)	DIRECTION (FLOOD)	TEMPERATURE
sample	4321.00	1495.00	1495.00	2348.00	2348.00	4321.00
maximum	71.01	53.75	119.35	71.01	309.49	25.07
minimum	0.39	0.73	80.00	1.37	270.03	19.89
range	70.62	53.02	39.35	69.64	39.46	5.18
mean	29.24	25.16	98.01	35.07	289.05	22.24
mode (estimated)	29.30	24.83	99.37	39.18	289.22	22.50
median	29.26	25.05	98.46	36.44	289.11	22.33
standard deviation	14.78	10.59	6.73	14.27	7.33	1.64
confidence lower level	28.80	24.62	97.66	34.49	288.76	22.20
confidence upper level	29.68	25.70	98.35	35.65	289.35	22.29

minimum scalar speed associated with direction	.39/226.21	
maximum scalar speed associated with direction	71.01/290.91	
confidence level percentage	95%	
flood/ebb criteria	80.00<ebb<120.00	270.00<flood<310.00

Units:	Speed	cm/s
	Direction	degrees from geographic north
	Temperature	degrees celsius

TABLE 5

STATISTICS ON ADCP MEASUREMENTS AT PORT ARANSAS

START TIME: 4/8/90 02:07 TOP TIME: 5/22/90 02:22

	SPEED (SCALAR)	SPEED (EBB)	DIRECTION (EBB)	SPEED (FLOOD)	DIRECTION (FLOOD)	TEMPERATURE
sample size	12676.00	6111.00	6111.00	5587.00	5587.00	12676.00
maximum	169.37	169.37	139.92	146.94	319.93	37.98
minimum	0.03	0.36	100.10	0.62	280.13	17.89
range	169.34	169.01	39.82	146.32	39.802	20.09
mean	55.28	57.64	118.11	60.30	301.20	23.25
mode (estimated)	46.76	50.57	120.13	52.63	300.71	24.30
median	52.44	55.28	118.78	57.74	301.04	23.60
standard deviation	34.89	32.74	5.54	34.57	4.67	2.11
confidence lower level	54.67	56.81	117.97	59.39	301.08	23.21
confidence upper level	55.89	58.46	118.25	61.20	301.33	23.28

minimum scalar speed associated with direction	.03/322.68	
maximum scalar speed associated with direction	169.37/119.06	
confidence level percentage	95%	
flood/ebb criteria for direction	100.00<ebb<140.00	280.00<flood<320.00

Units:	Speed	cm/s
	Direction	degrees from geographic north
	Temperature	degrees celsius

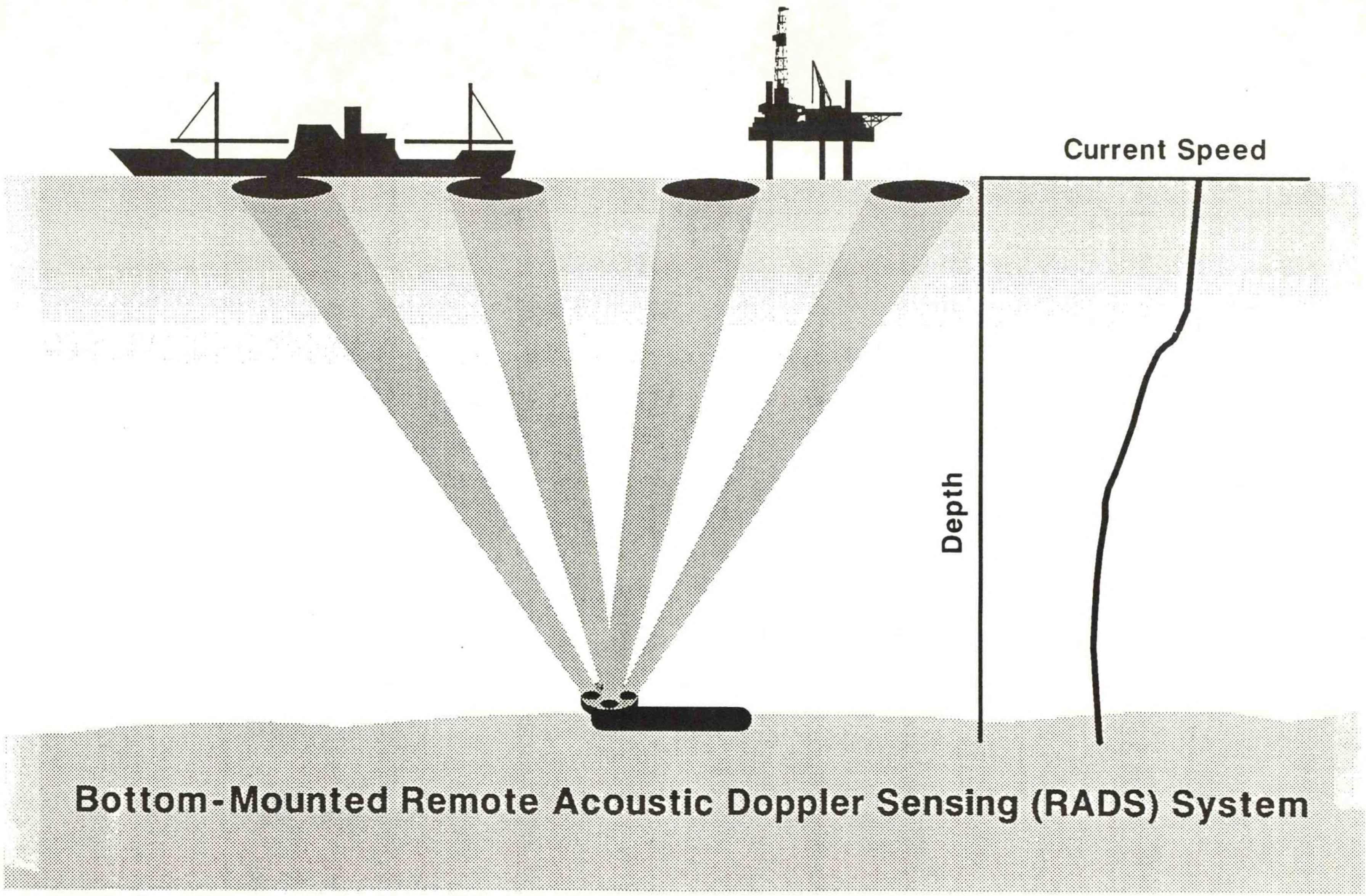


Figure 1. Bottom-mounted Remote Acoustic Doppler Sensing (RADS) system deployed in Corpus Christi Bay.

CORPUS CHRISTI BAY STATION LOCATIONS

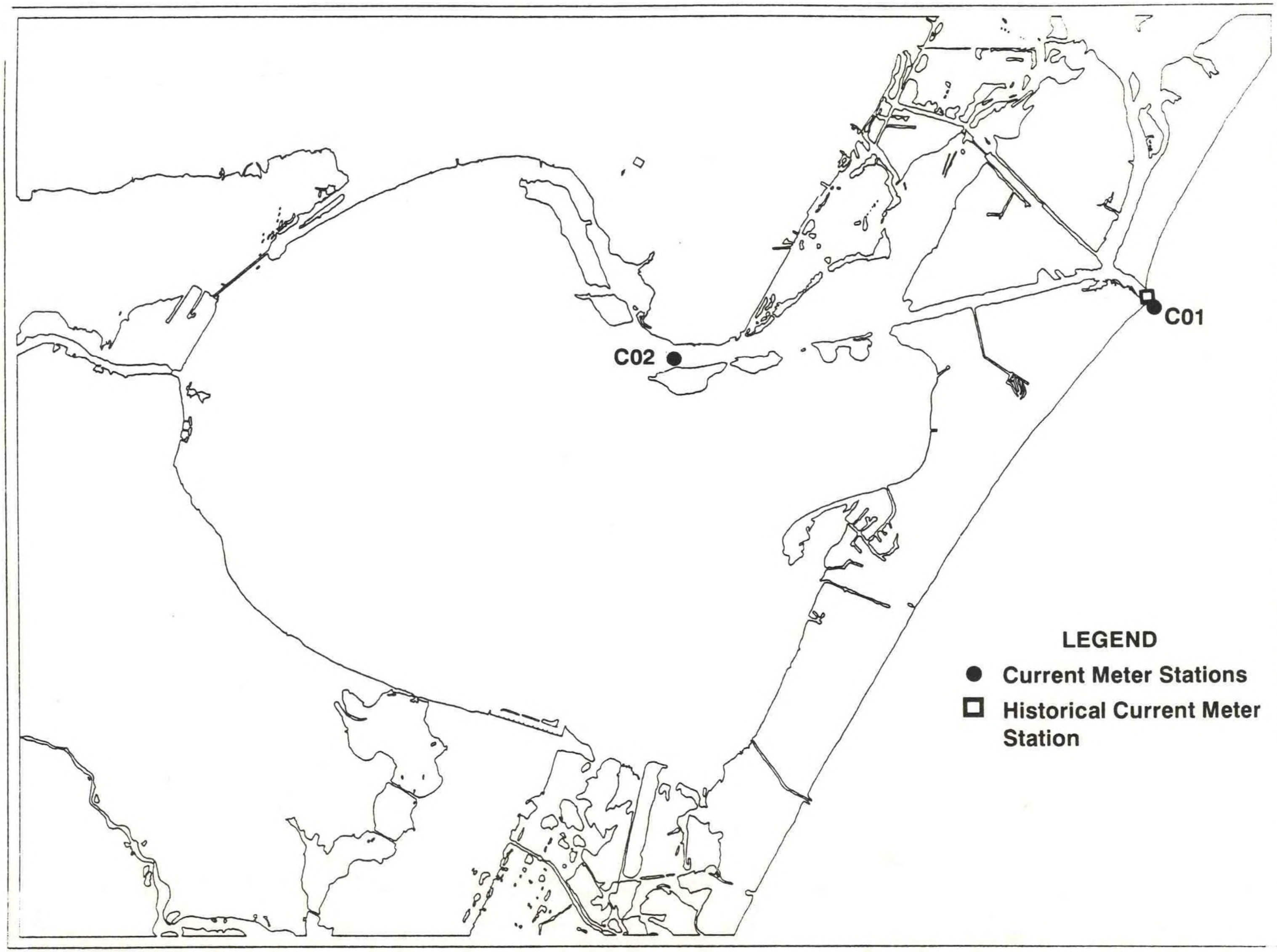


Figure 2. Station locations for Corpus Christi Bay QA miniproject.

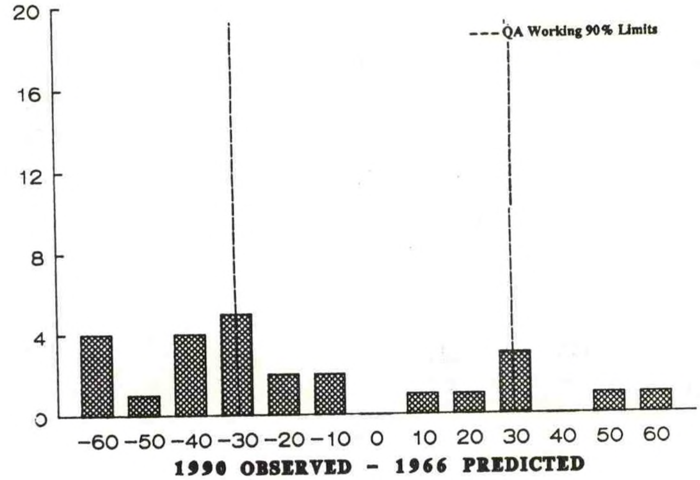
QA WORKING LIMITS

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

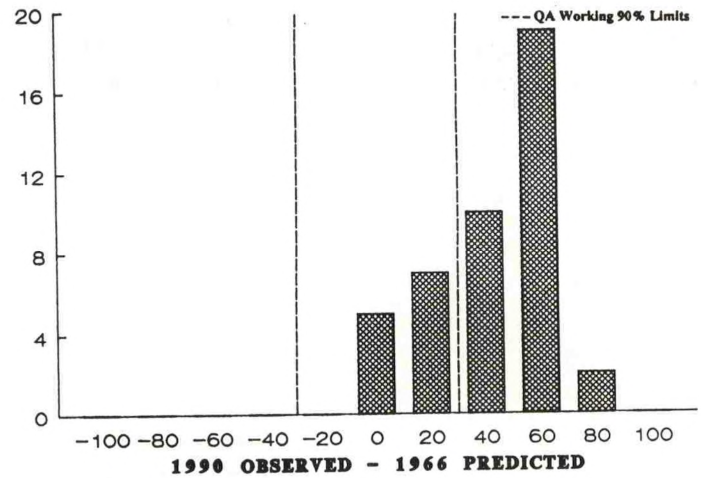
Figure 3. QA working limits for tidal currents and water-levels used for evaluation of Quality Assurance data.

PORT ARANSAS

TIME OF MAXIMUM FLOOD CURRENT (Minutes)



SPEED OF MAXIMUM FLOOD CURRENT (CM/S)



TIME OF SLACK BEFORE EBB (Minutes)

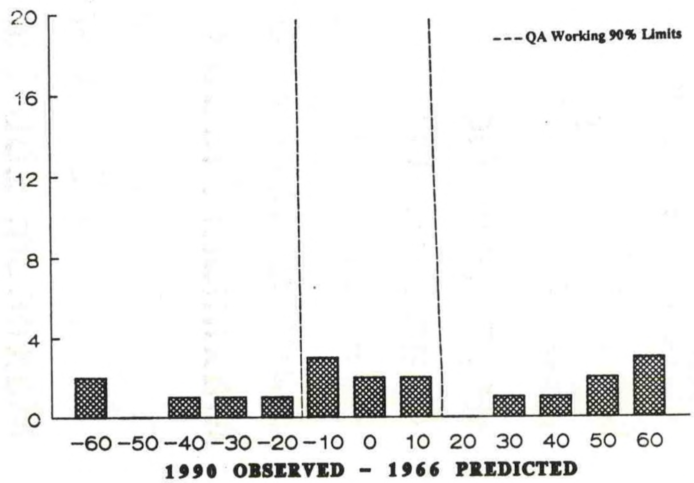


Figure 4. Histograms of differences between NOAA table-predicted currents and ADCP measured currents.

PORT ARANSAS

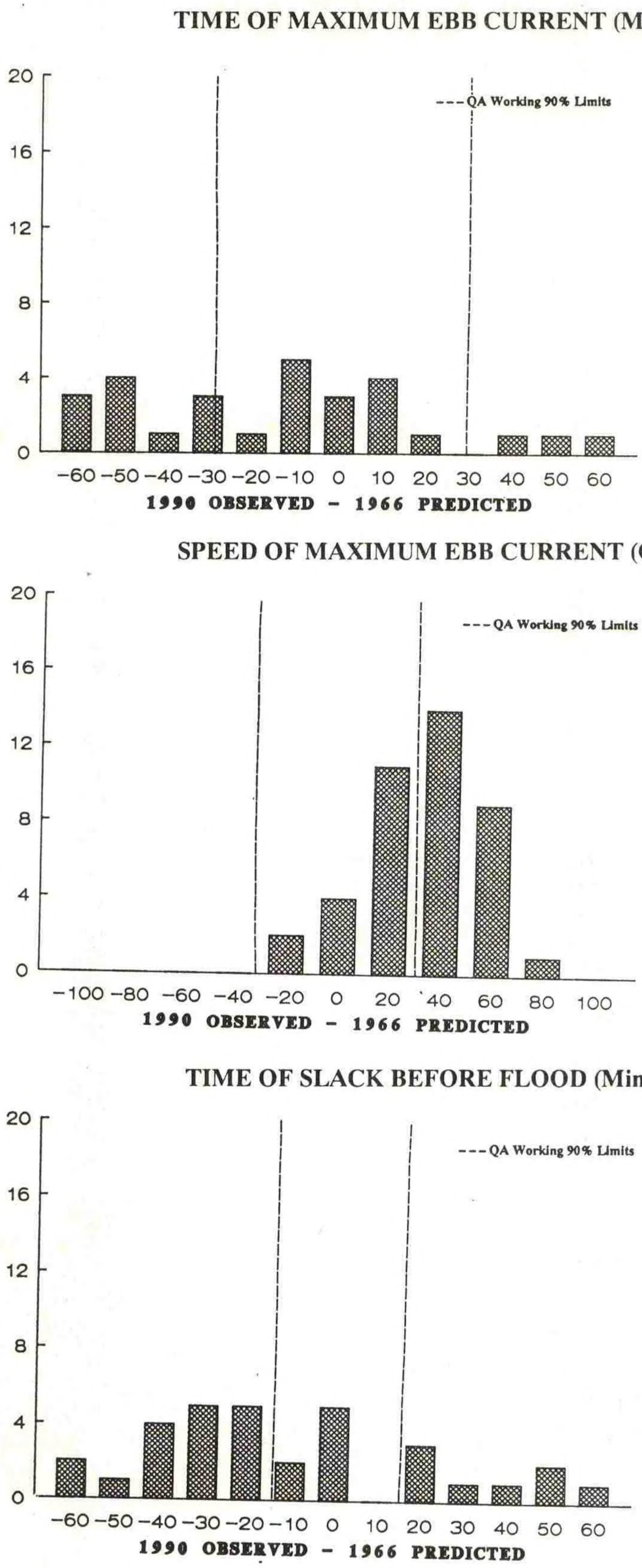


Figure 5. Histograms of differences between NOAA table-predicted currents and ADCP measured currents.

PORT ARANSAS

SPEED -DIRECTION HISTOGRAM

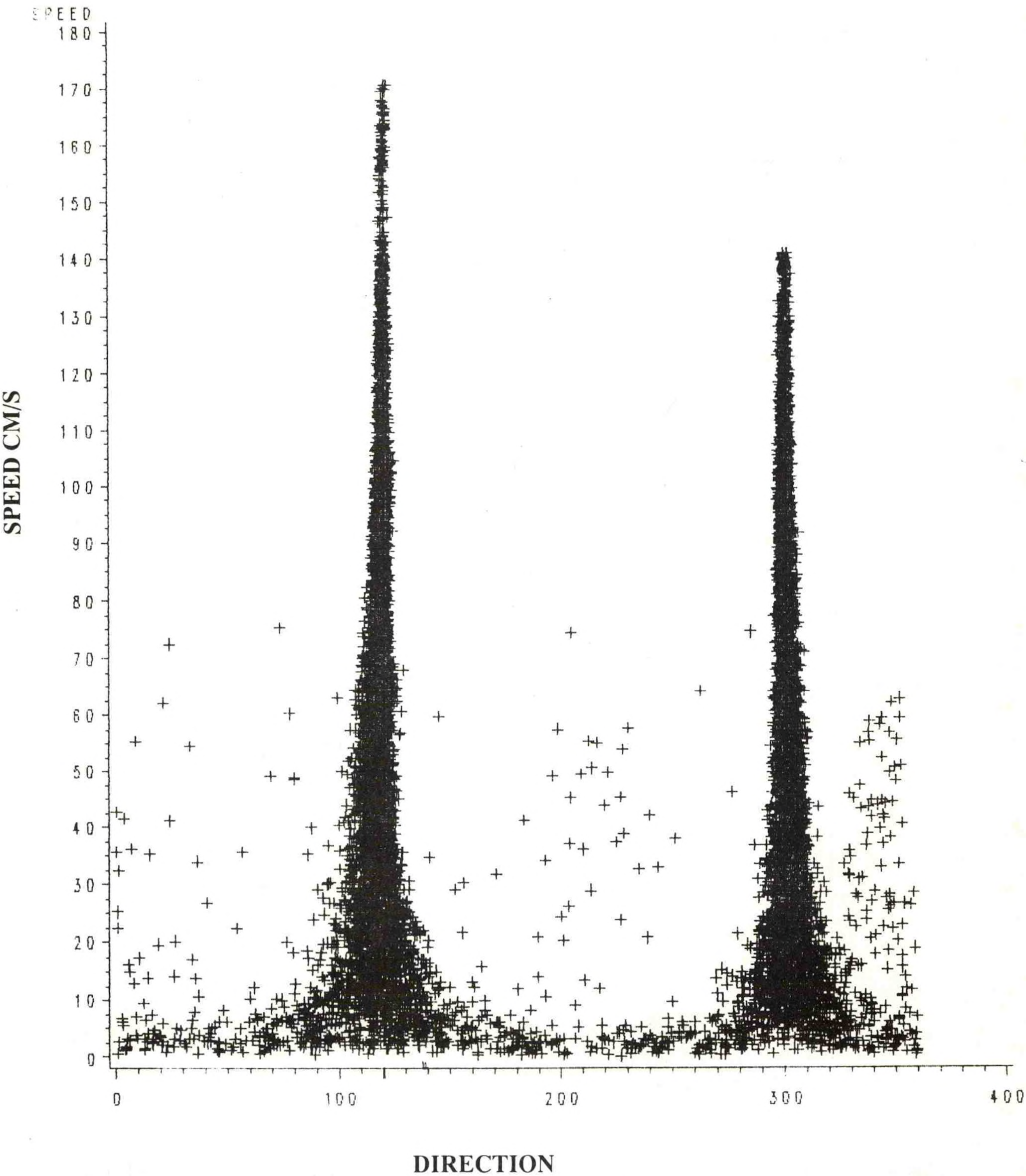


Figure 6. Speed-direction histogram of currents at Port Aransas

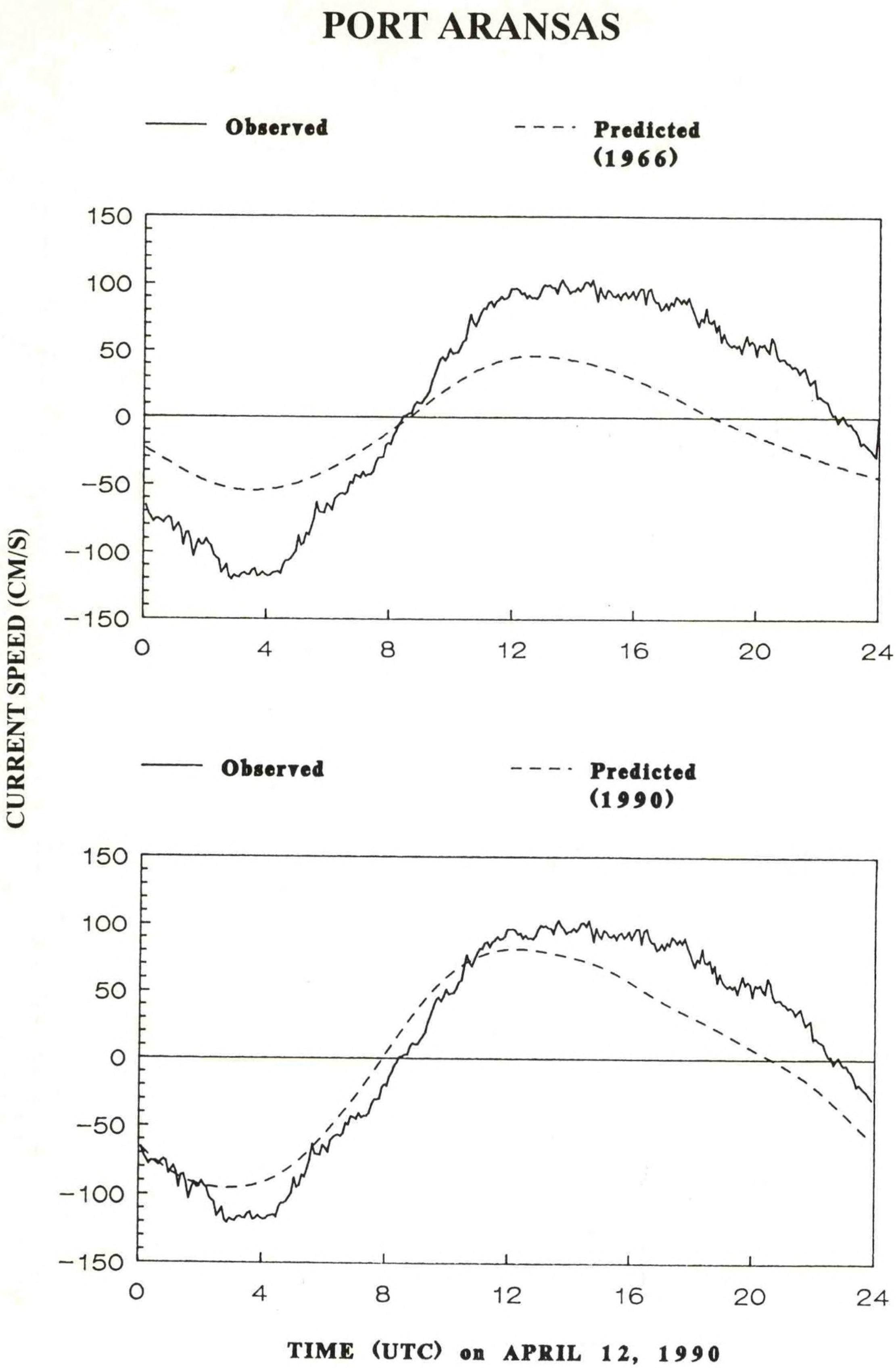


Figure 7. Time series of predicted and observed currents. Universal (Greenwich) Time beginning at 0000^h April 12 is indicated.

PORT ARANSAS

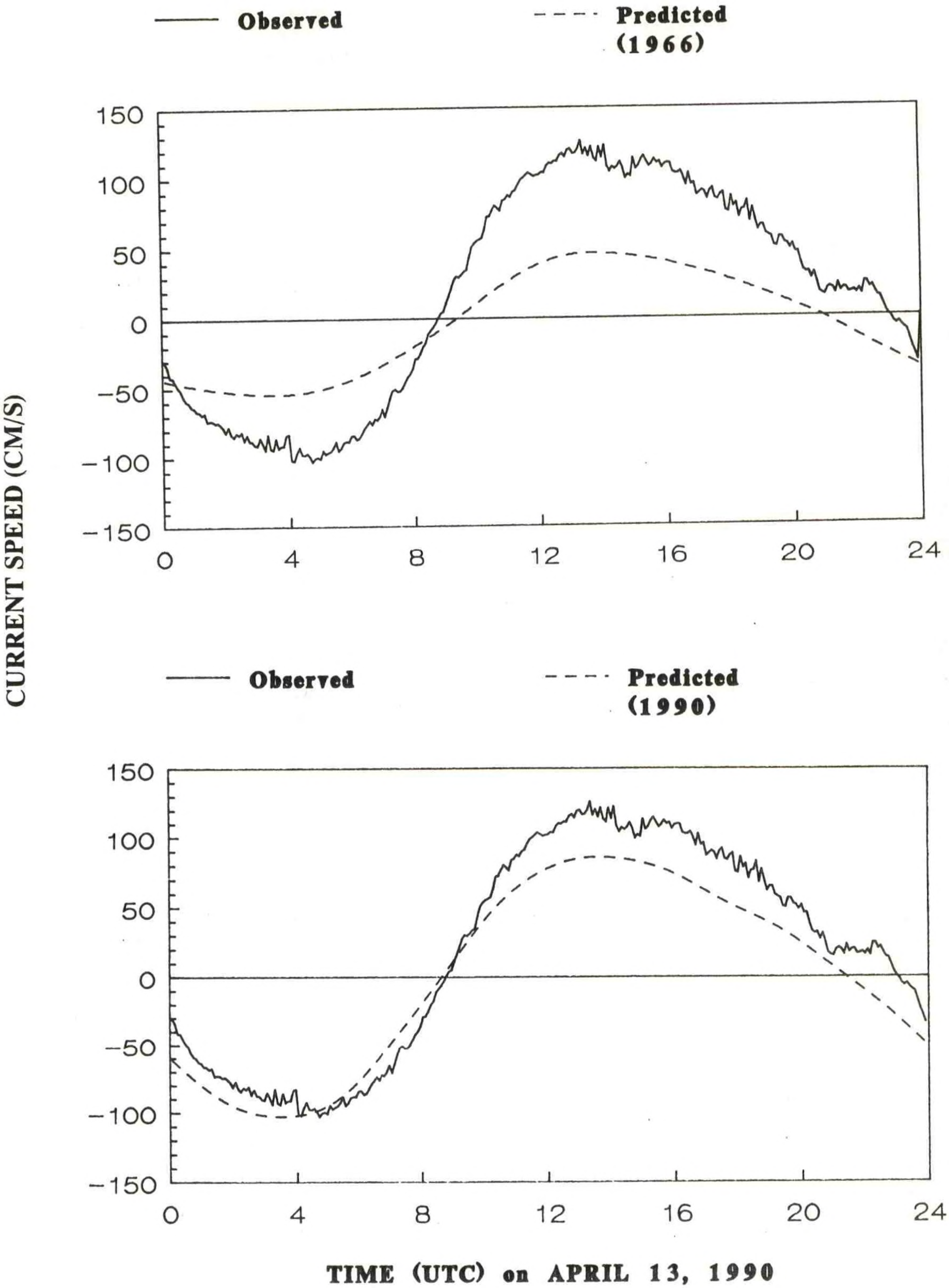


Figure 8. Time series of predicted and observed currents. Universal (Greenwich) Time beginning at 0000^h April 13 is indicated.

PORT ARANSAS

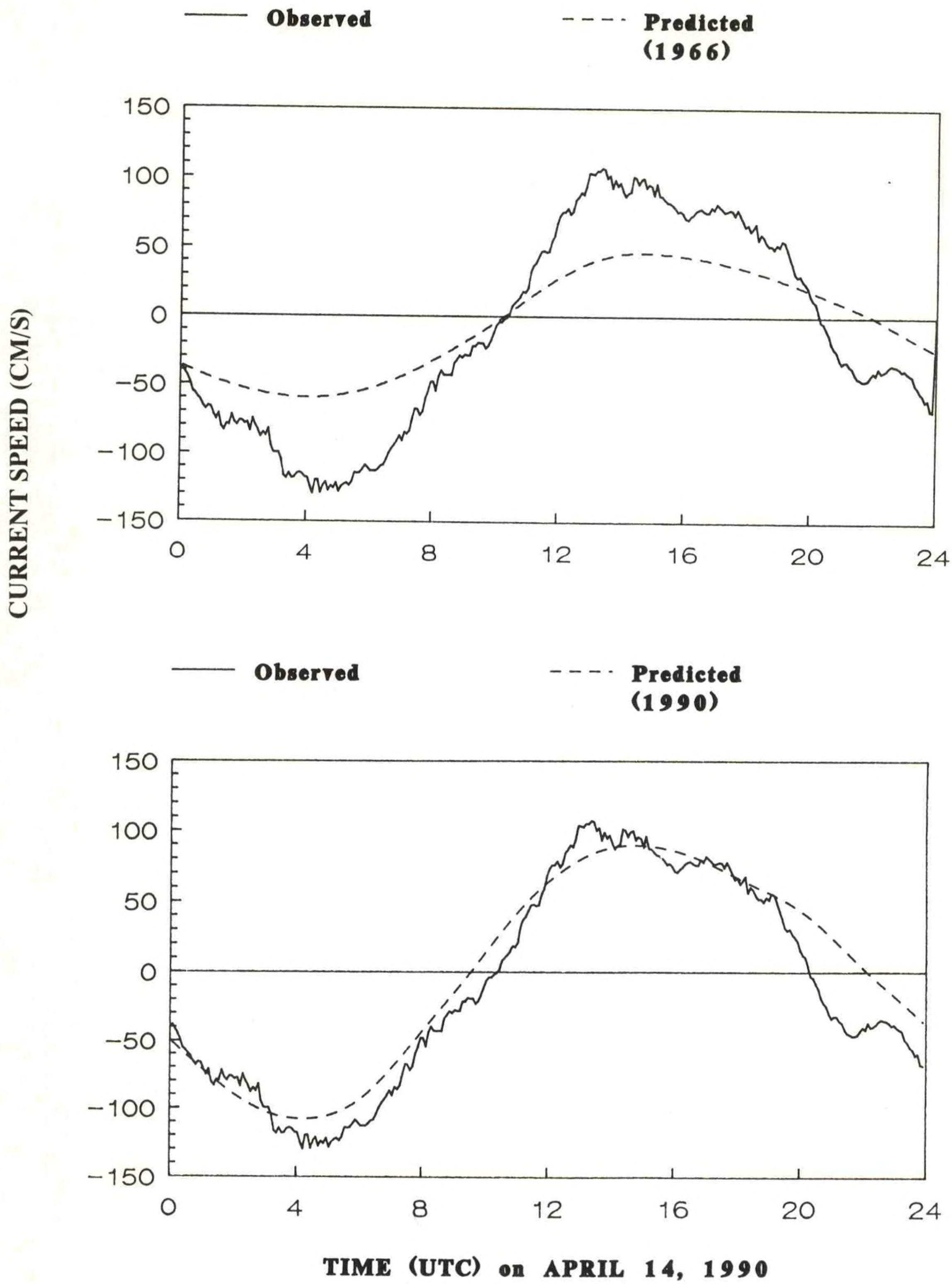


Figure 9. Time series of predicted and observed currents. Universal (Greenwich) Time beginning at 0000^h April 14 is indicated.

PORT ARANSAS

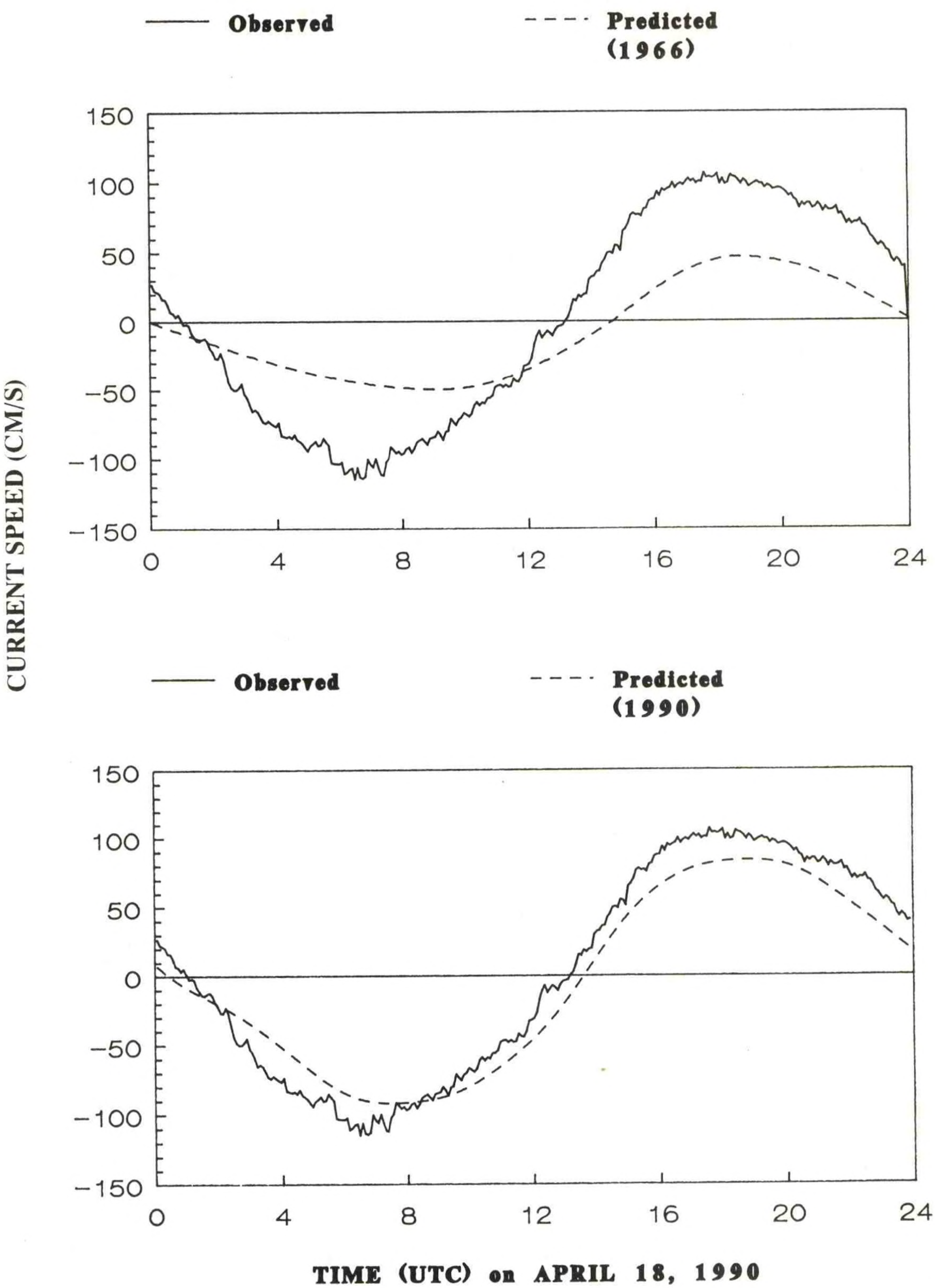


Figure 10. Time series of predicted and observed currents. Universal (Greenwich) Time beginning at 0000^h April 18 is indicated.

PORT ARANSAS

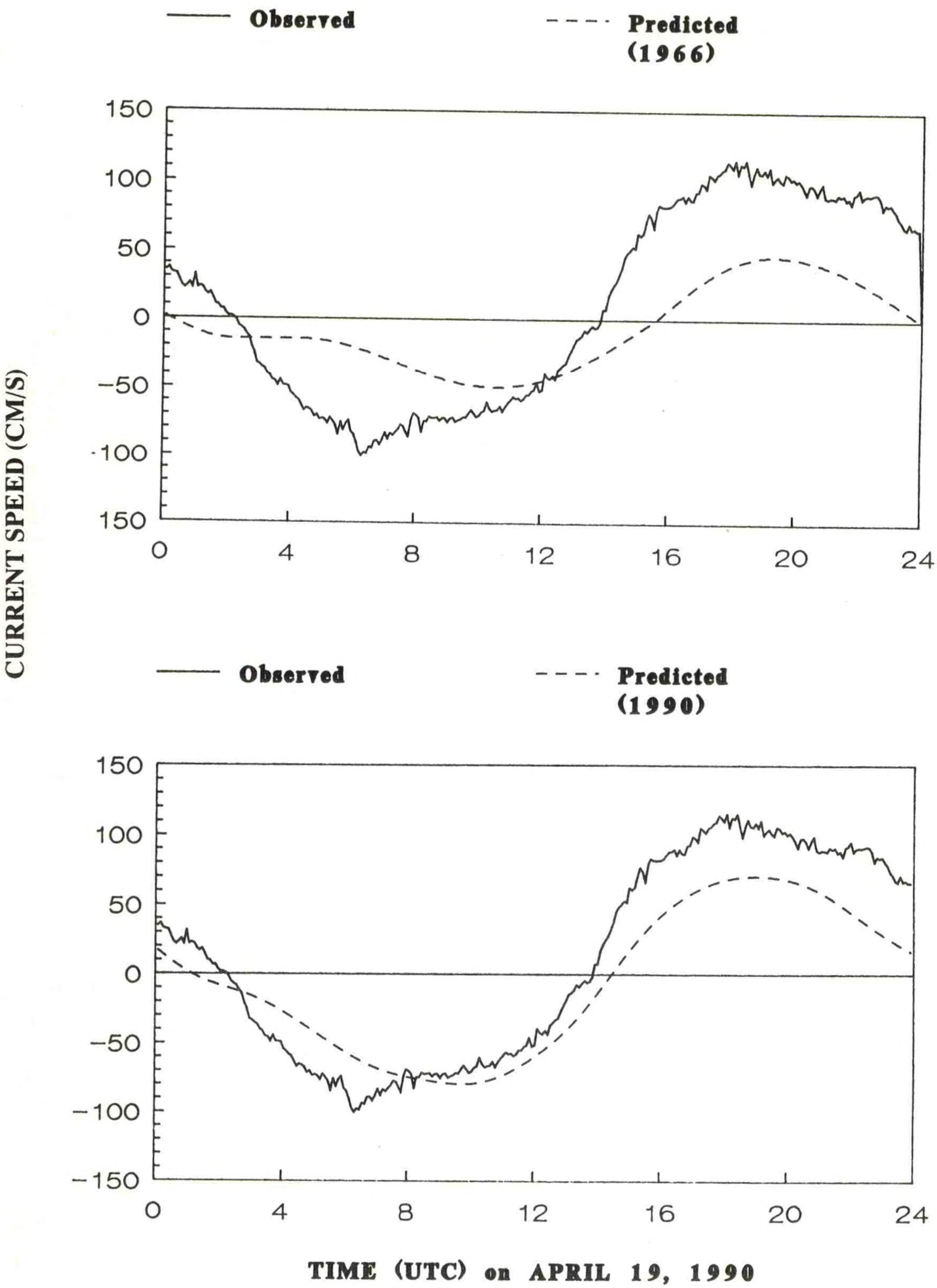


Figure 11. Time series of predicted and observed currents. Universal (Greenwich) Time beginning at 0000^h April 19 is indicated.

PORT ARANSAS

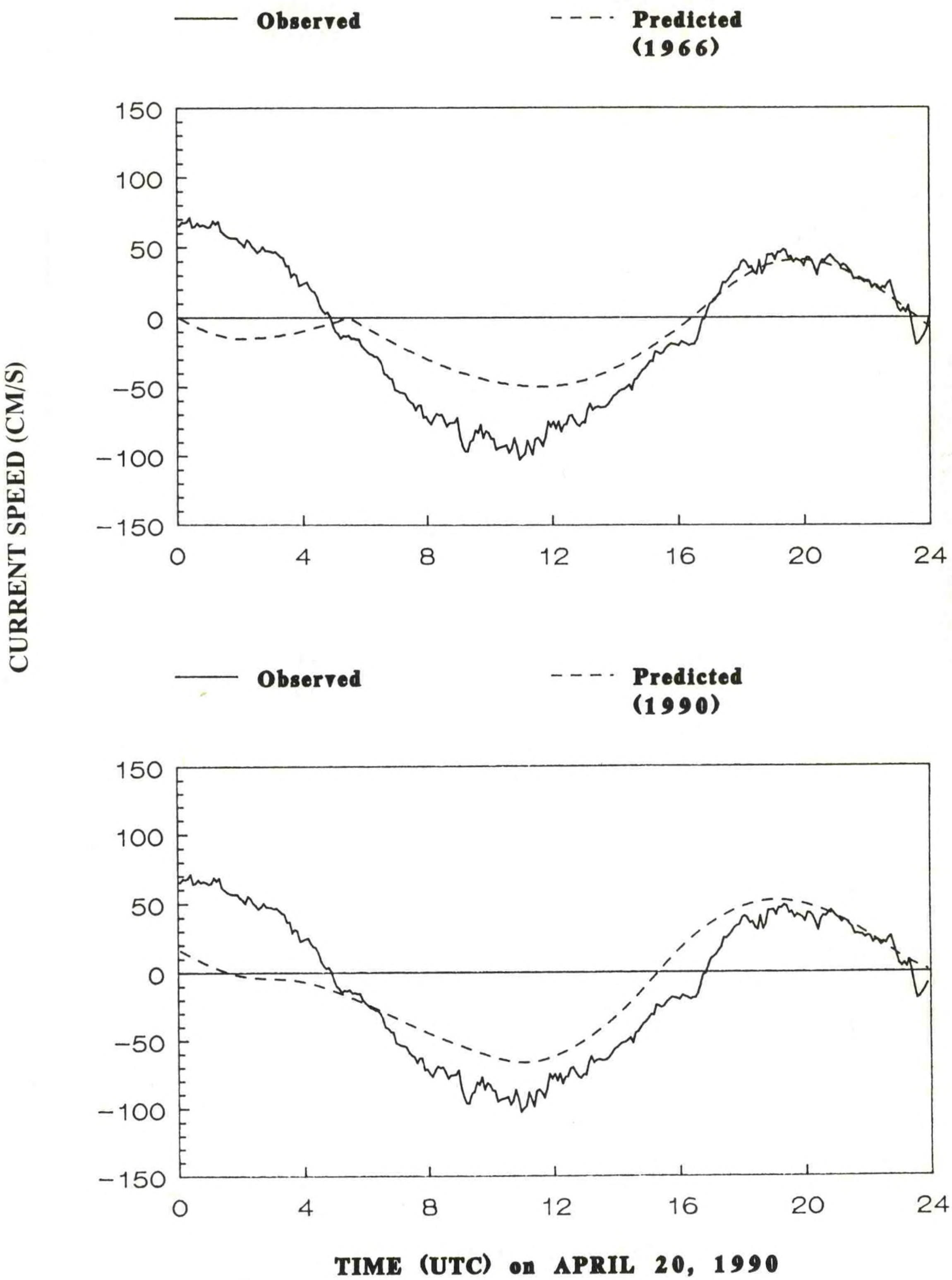


Figure 12. Time series of predicted and observed currents. Universal (Greenwich) Time beginning at 0000^h April 20 is indicated.

PORT ARANSAS

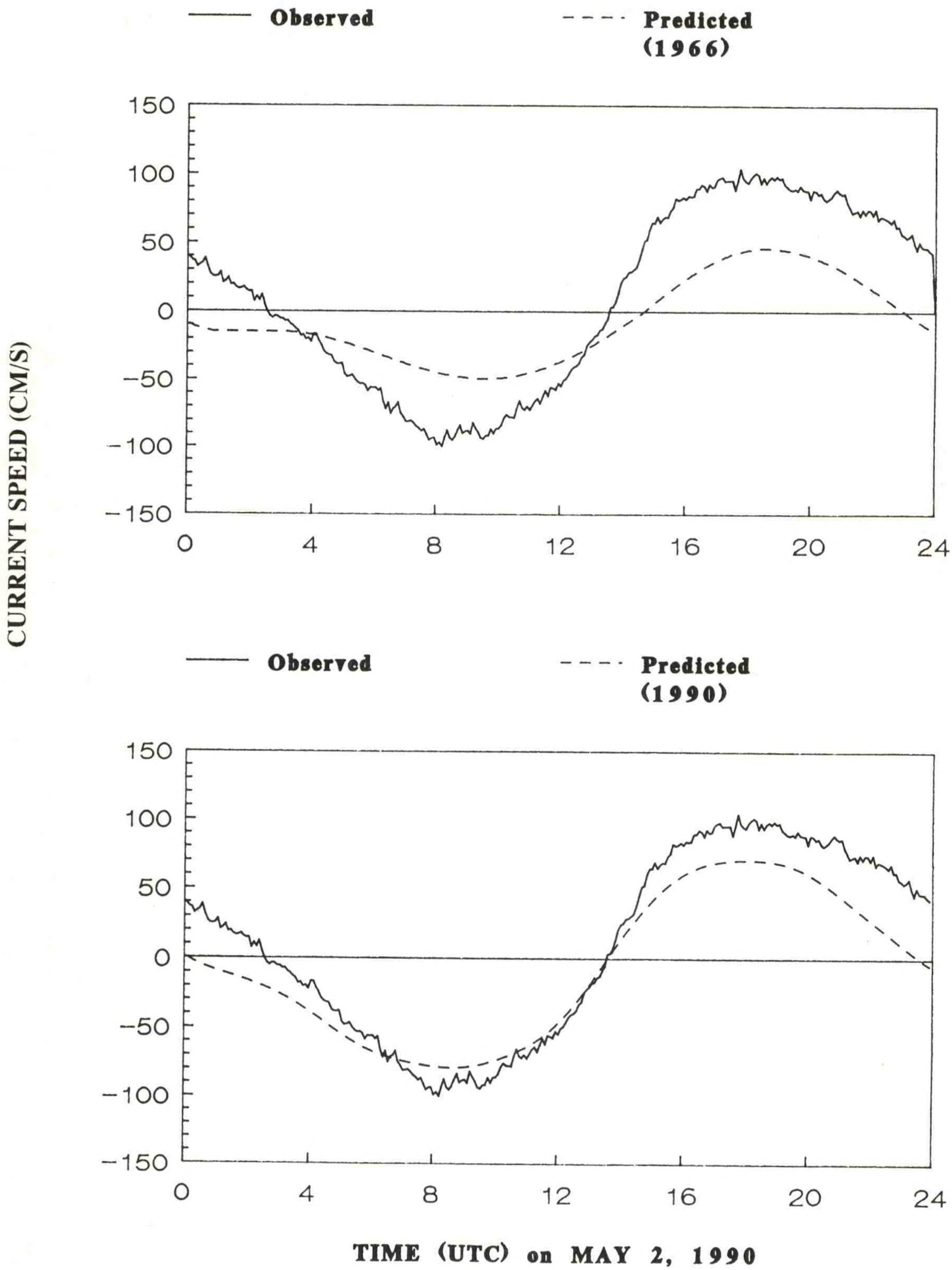


Figure 13. Time series of predicted and observed currents. Universal (Greenwich) Time beginning at 0000^h May 2 is indicated.

PORT ARANSAS

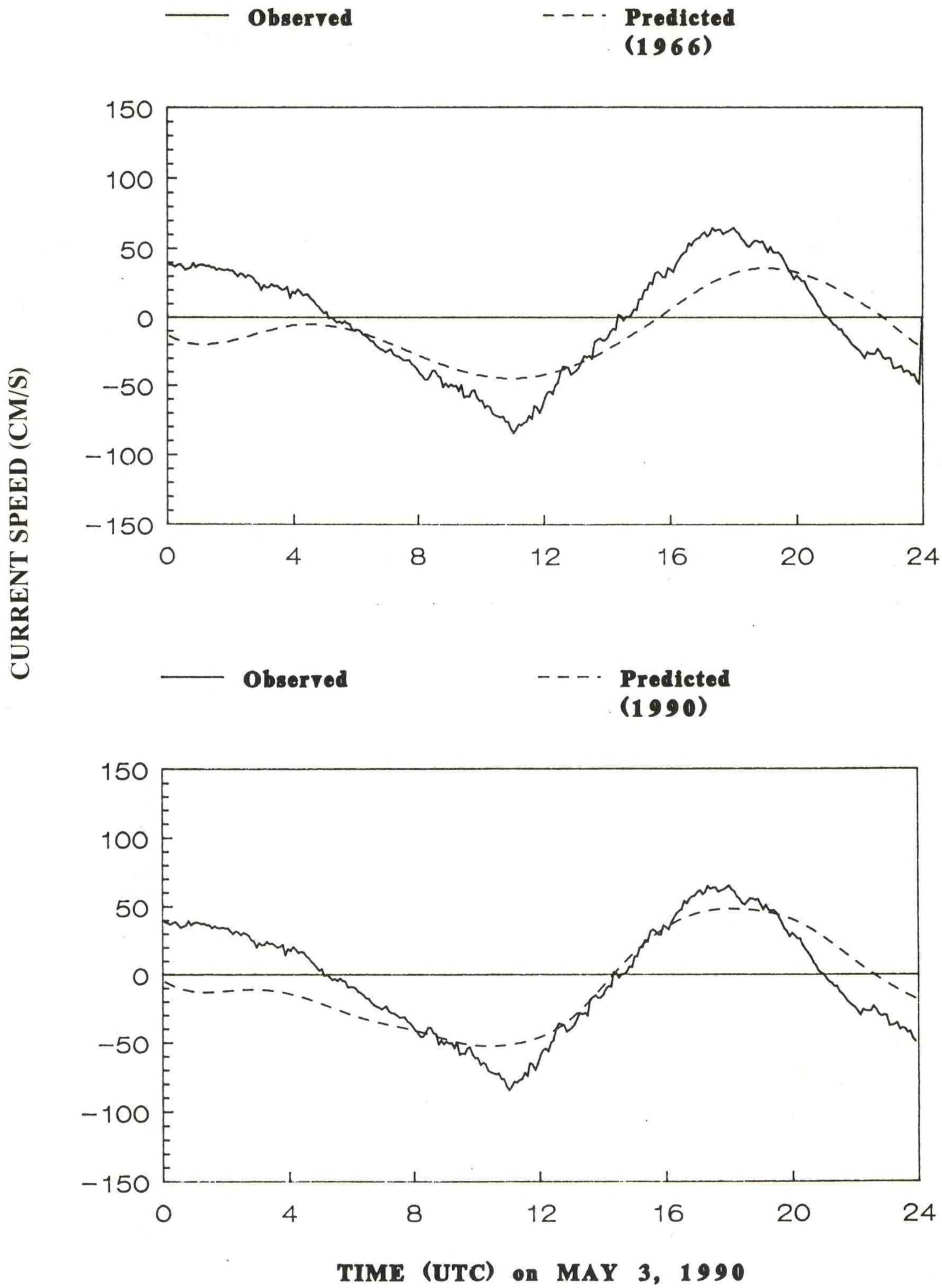


Figure 14. Time series of predicted and observed currents. Universal (Greenwich) Time beginning at 0000^h May 3 is indicated.

PORT ARANSAS

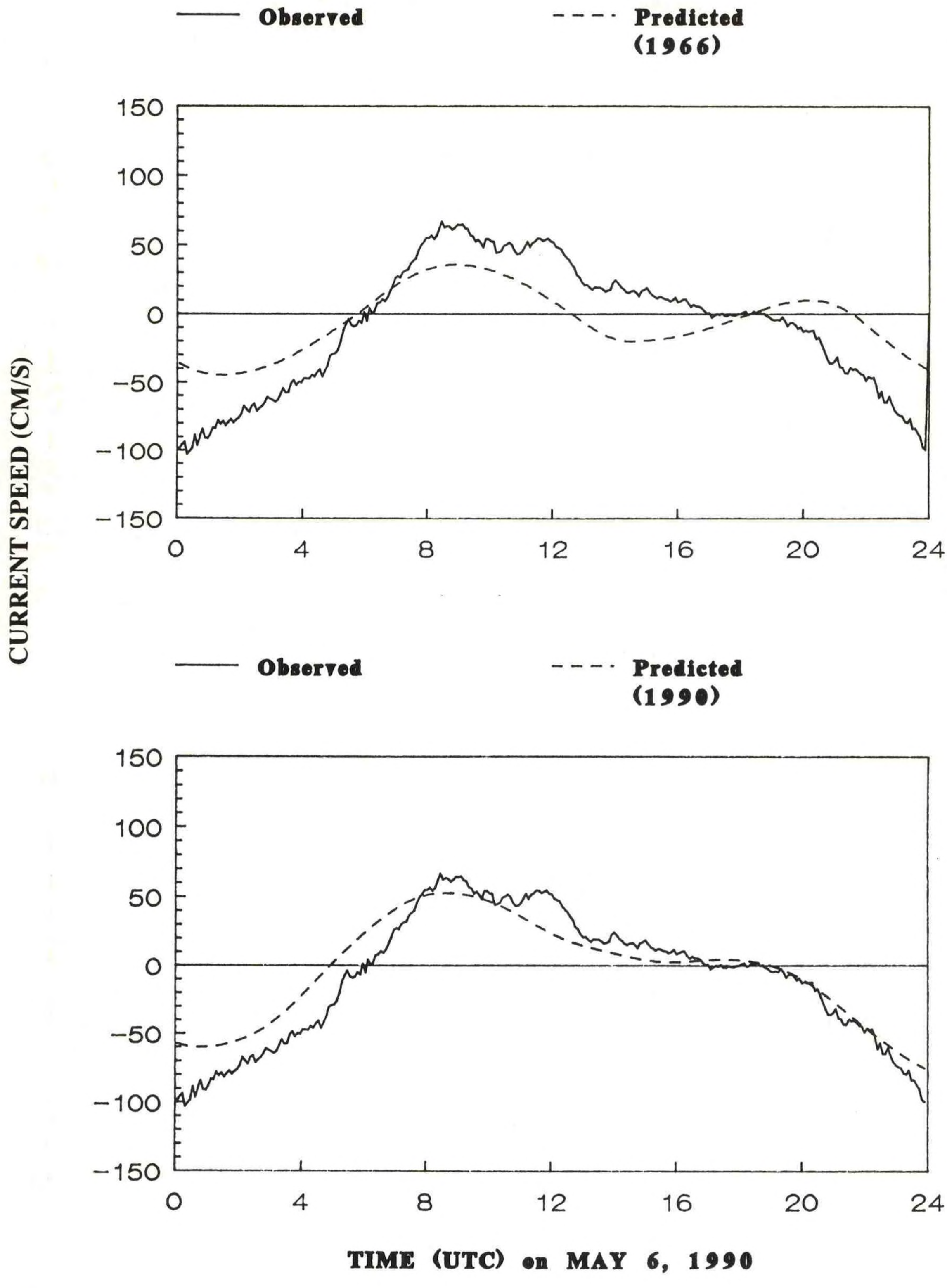


Figure 15. Time series of predicted and observed currents. Universal (Greenwich) Time beginning at 0000^h May 6 is indicated.

PORT ARANSAS

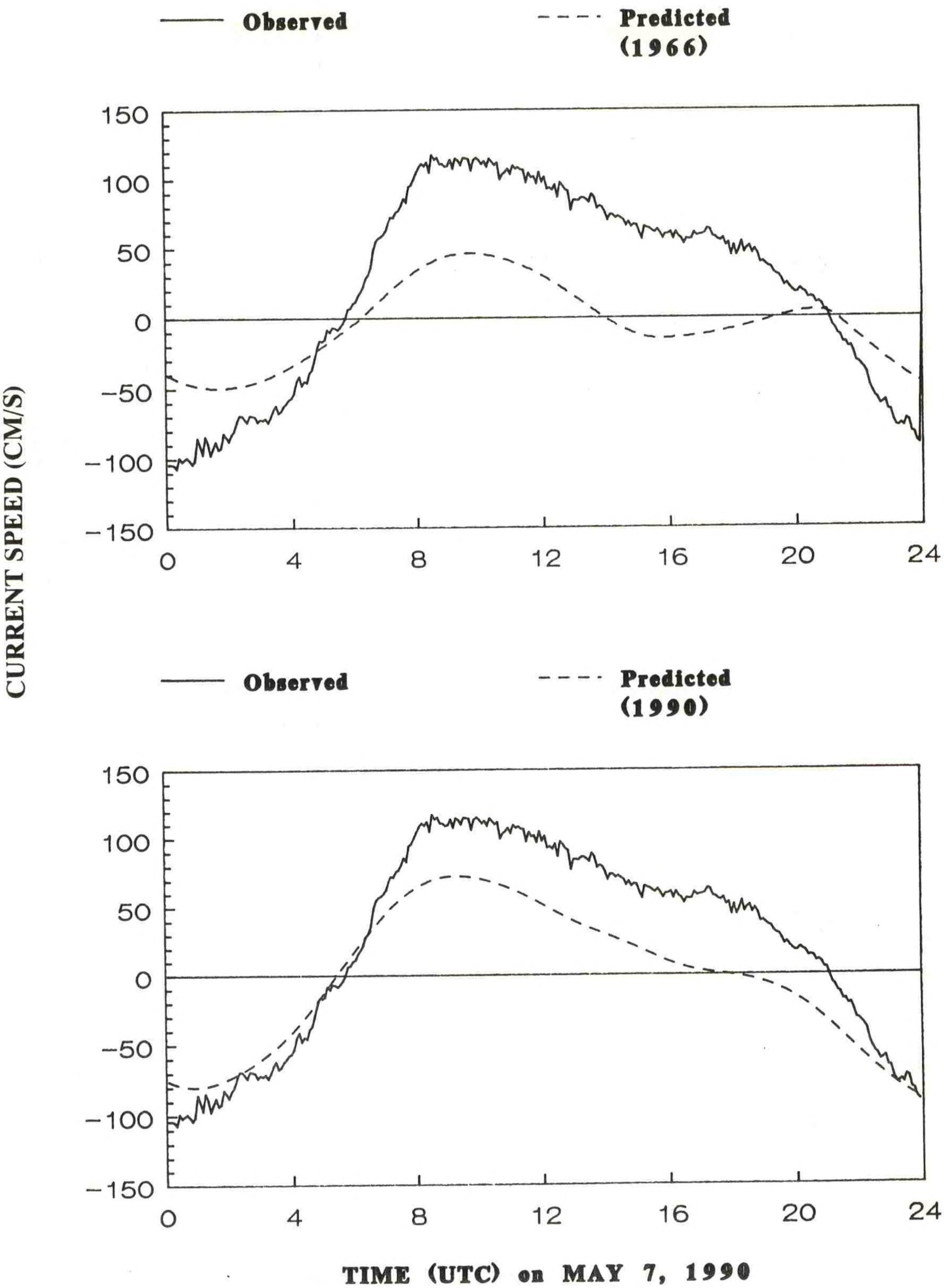


Figure 16. Time series of predicted and observed currents. Universal (Greenwich) Time beginning at 0000^{h} May 7 is indicated.

PORT ARANSAS

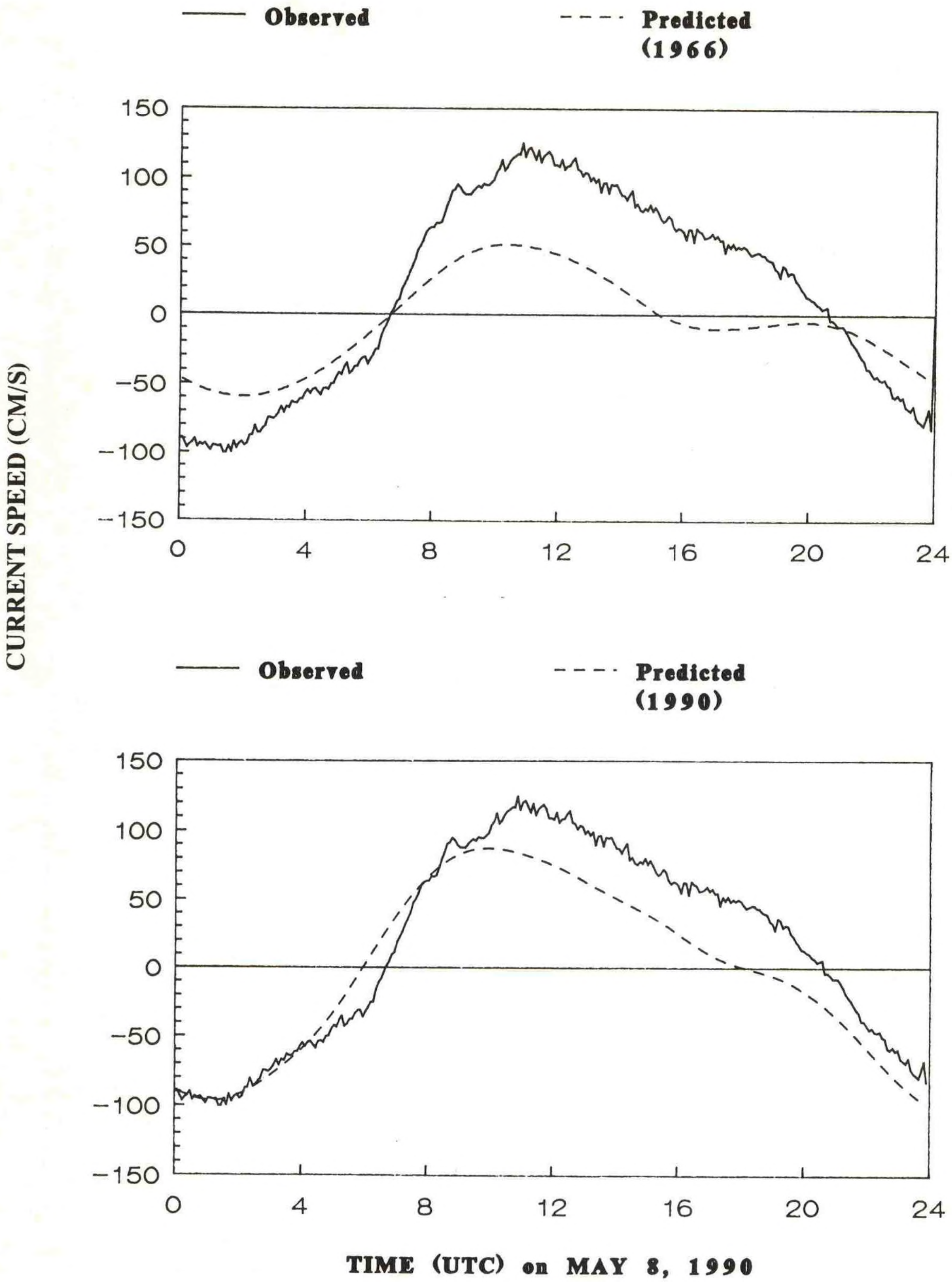


Figure 17. Time series of predicted and observed currents. Universal (Greenwich) Time beginning at 0000^h May 8 is indicated.

PORT ARANSAS

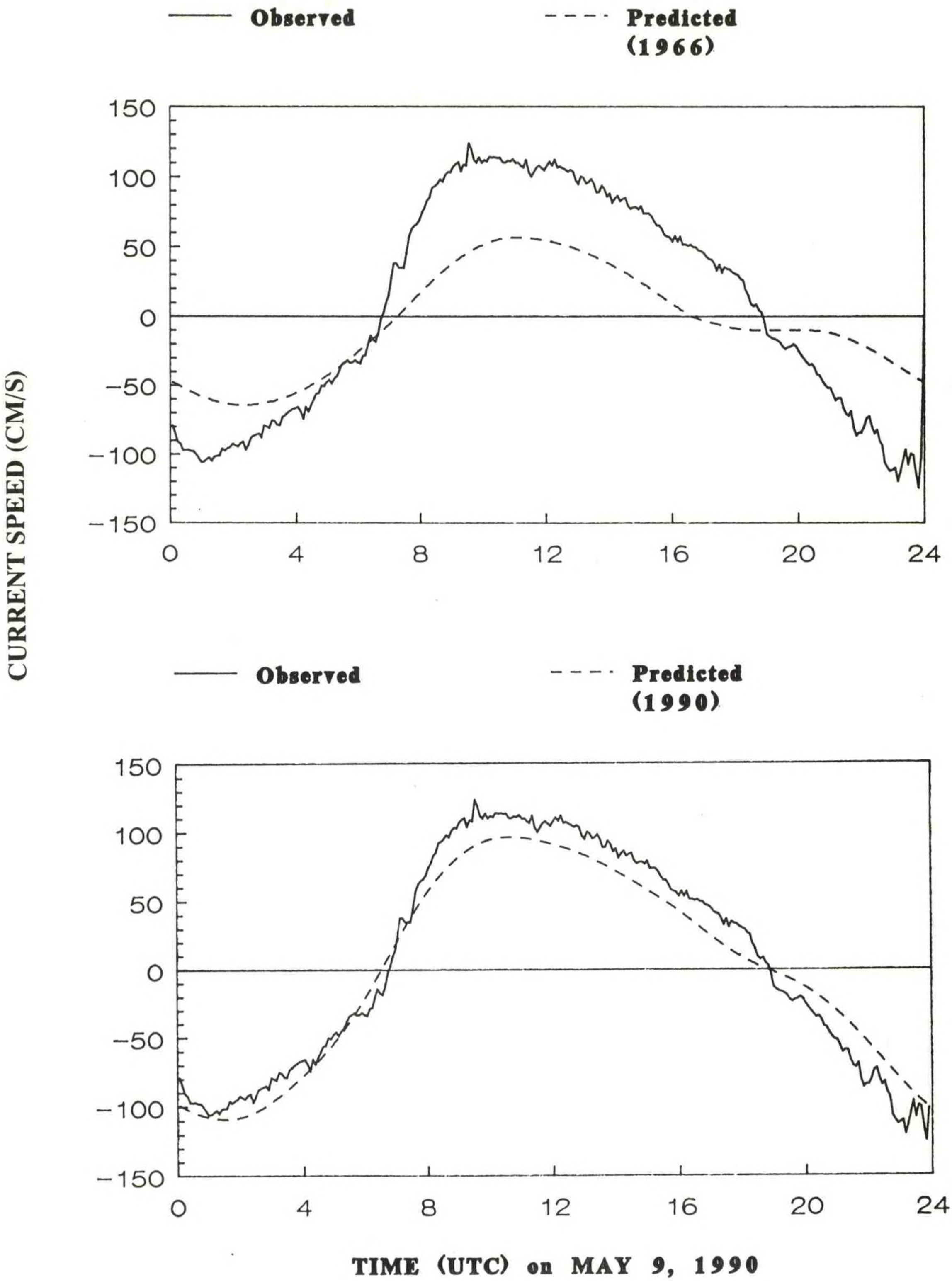


Figure 18. Time series of predicted and observed currents. Universal (Greenwich) Time beginning at 0000^h May 9 is indicated.

PORT ARANSAS

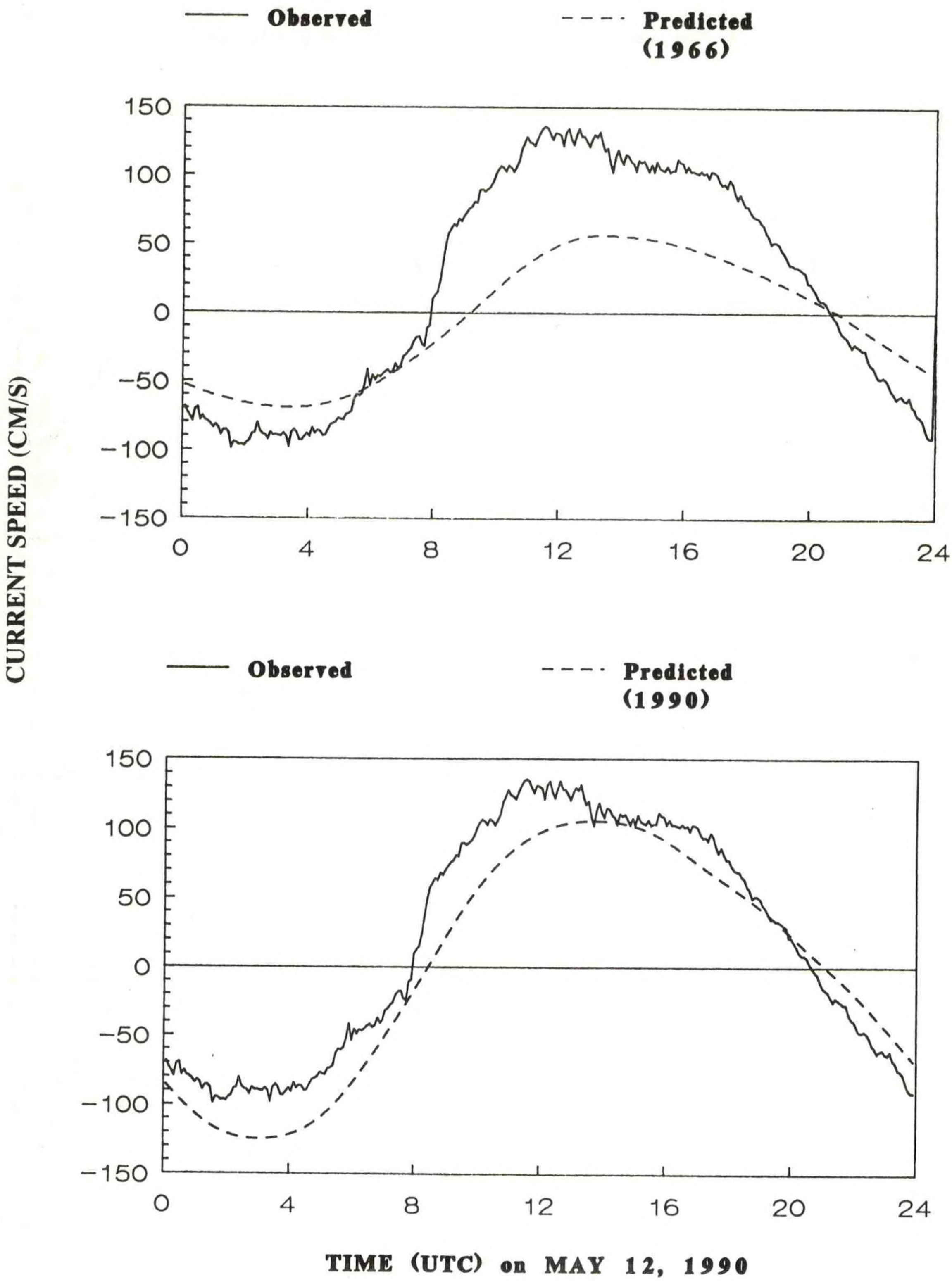


Figure 19. Time series of predicted and observed currents. Universal (Greenwich) Time beginning at 0000^h May 12 is indicated.

PORT ARANSAS

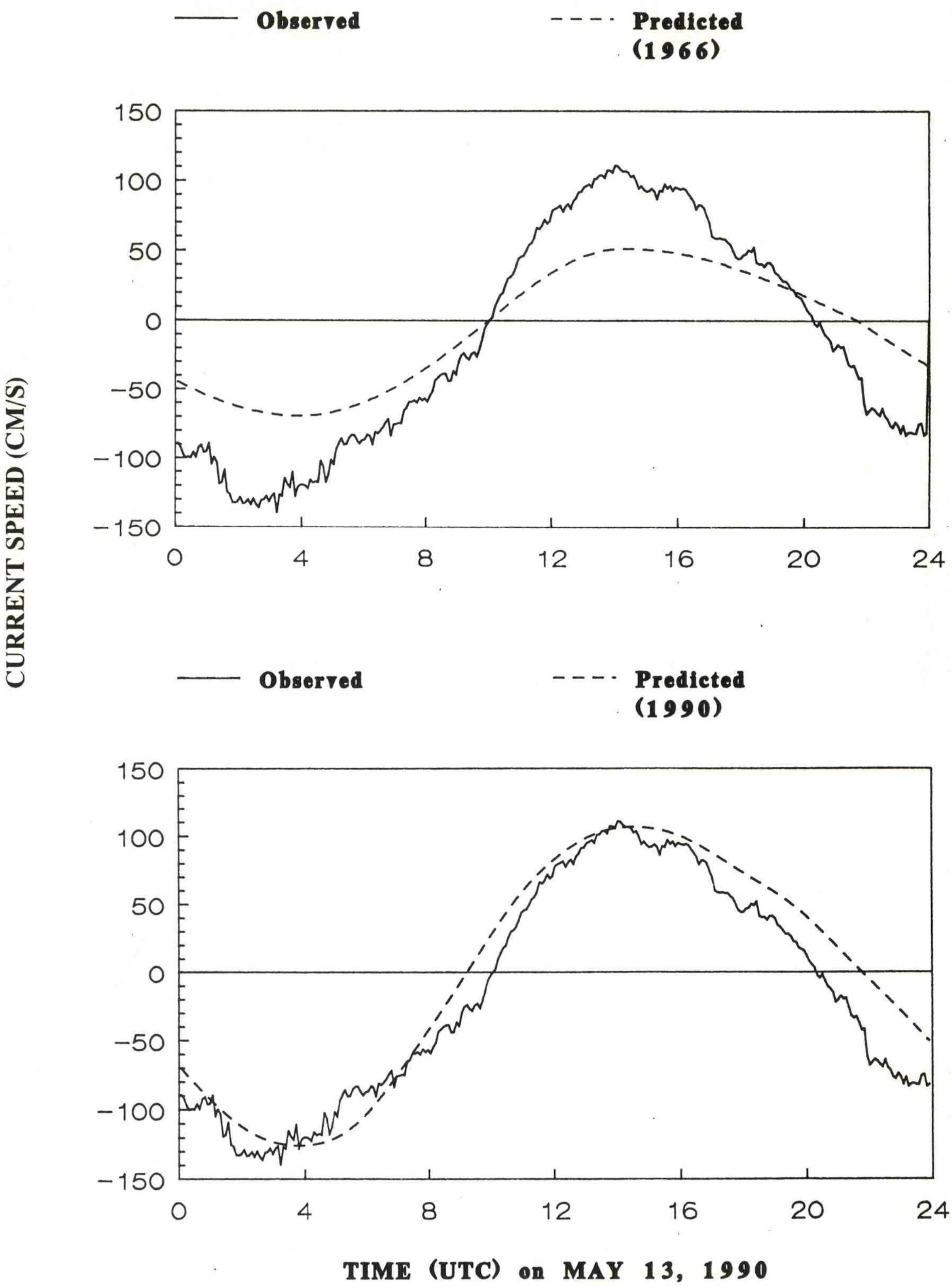


Figure 20. Time series of predicted and observed currents. Universal (Greenwich) Time beginning at 0000^h May 13 is indicated.

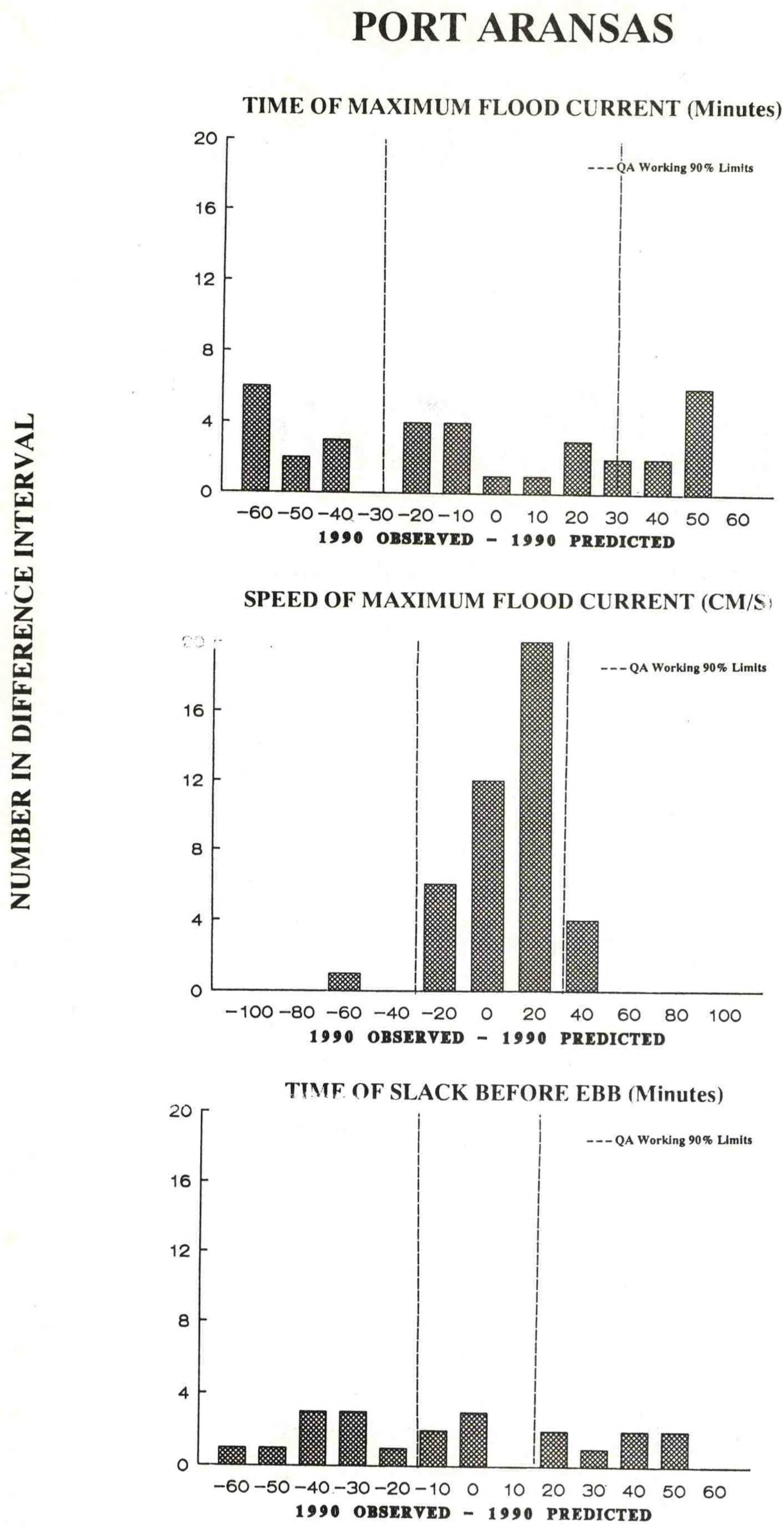


Figure 21. Histograms of differences between ADCP-measured currents and currents predicted from the ADCP data.

PORT ARANSAS

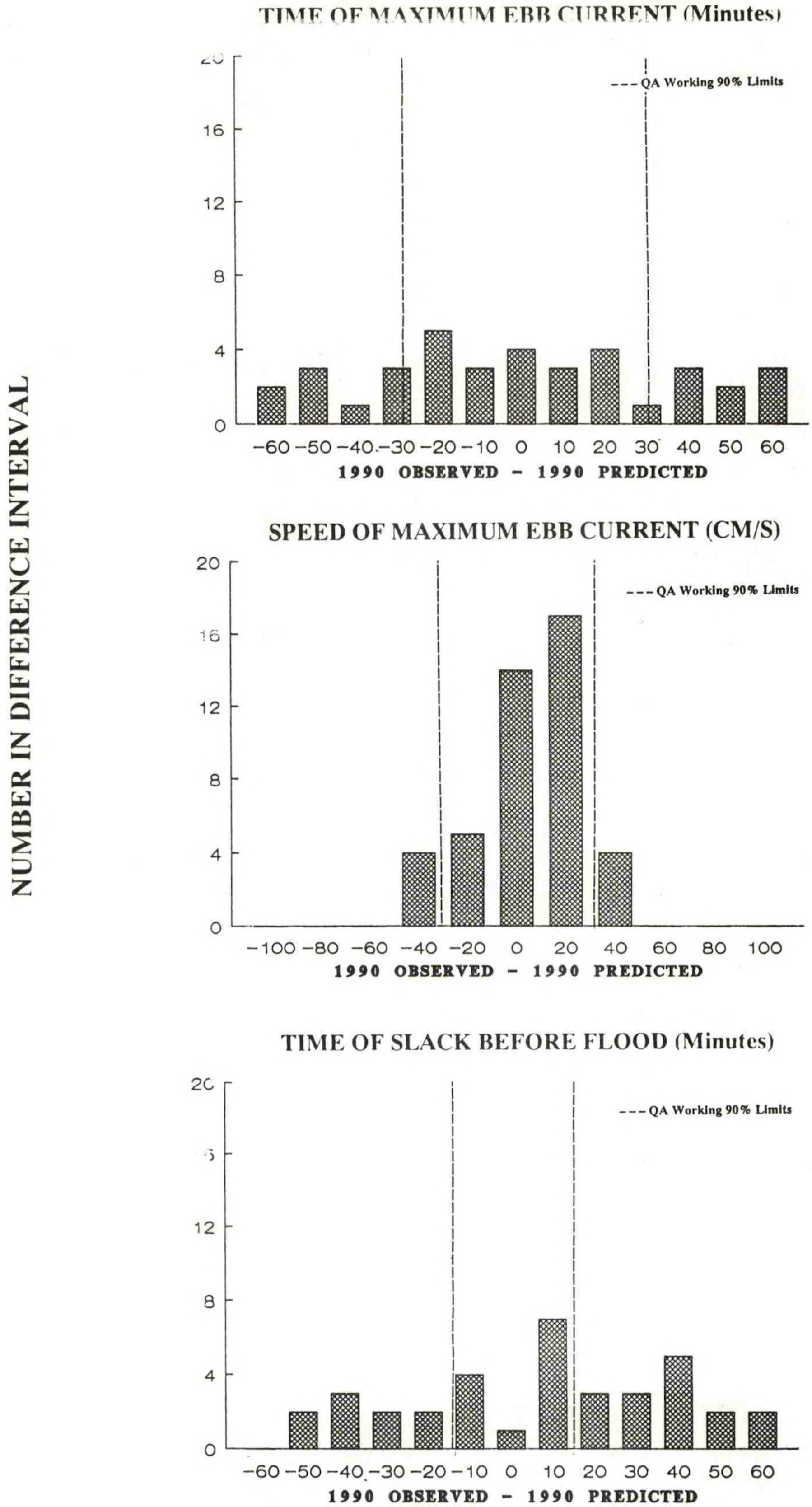


Figure 22. Histograms of differences between ADCP-measured currents and currents predicted from the ADCP data.

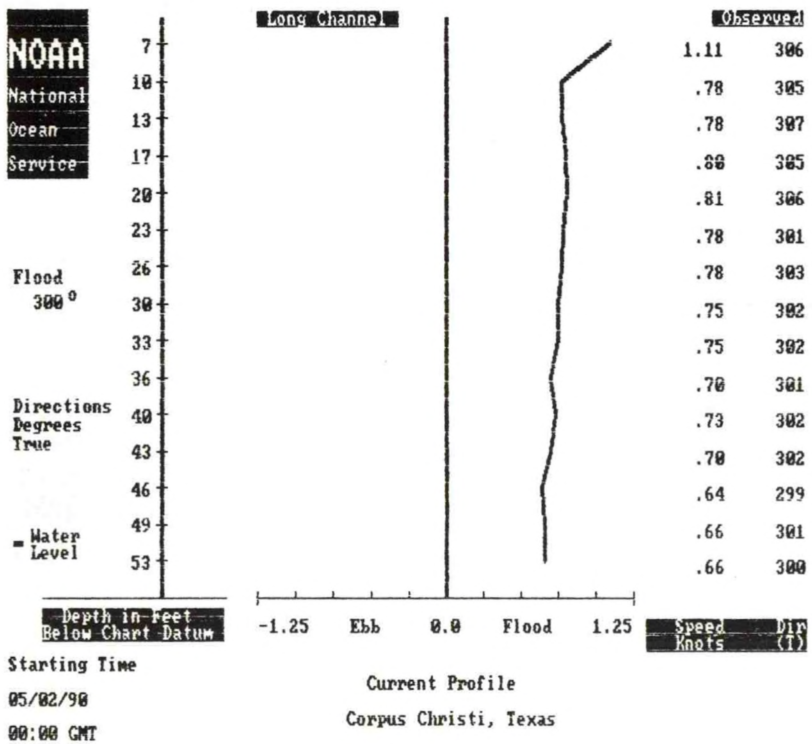


Figure 23a. 2 hours 30 minutes before SBE

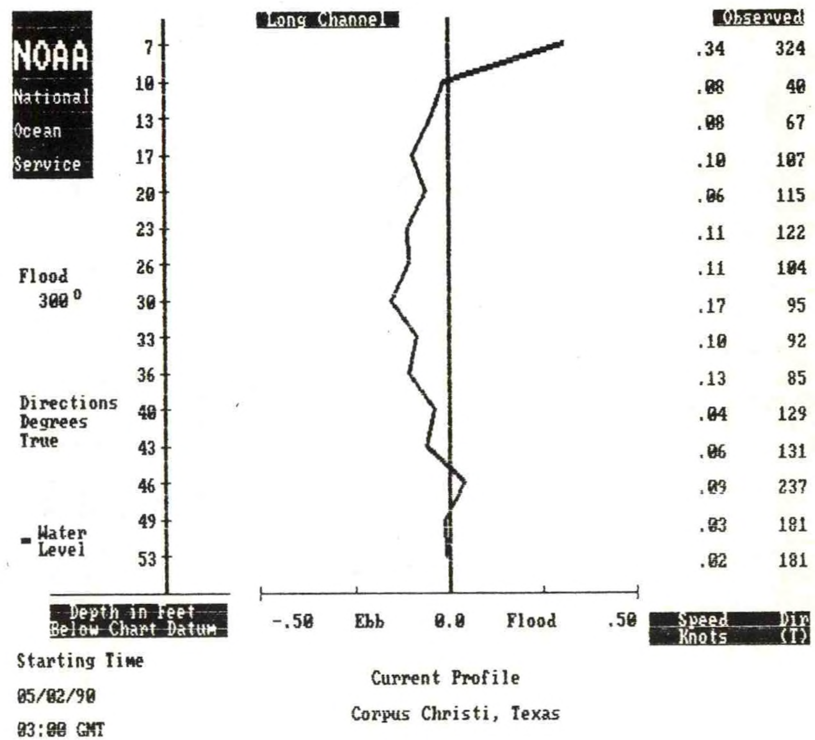


Figure 23b. 30 minutes after SBE

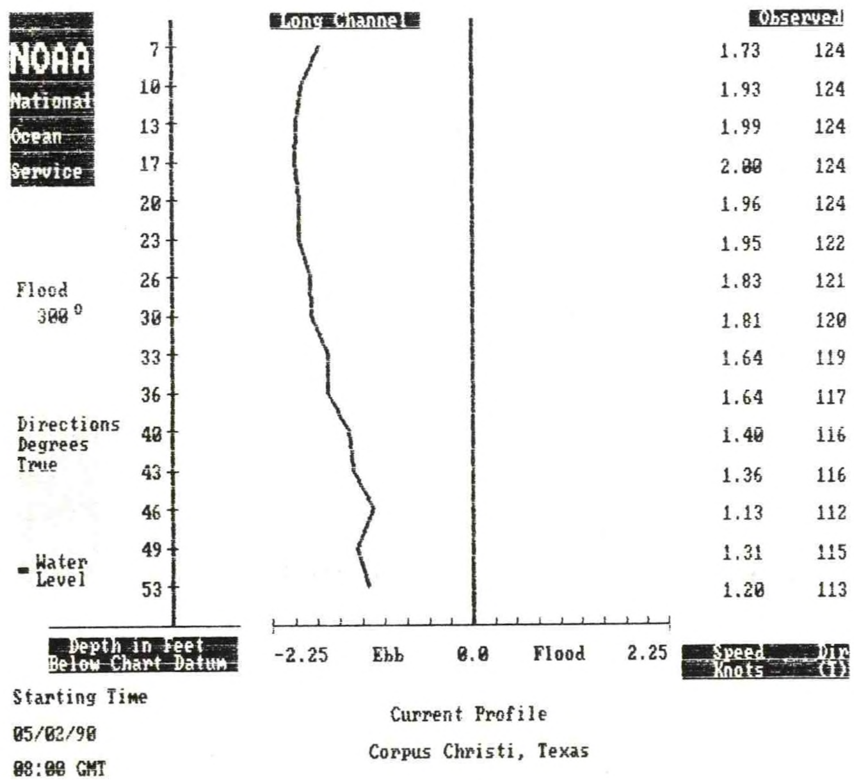


Figure 24a. MEC

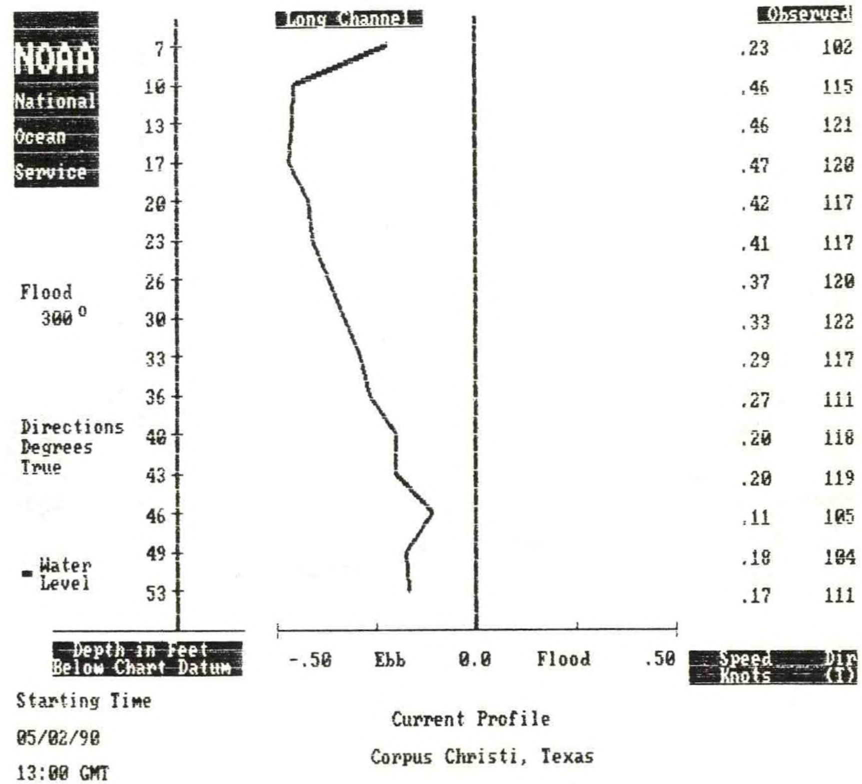


Figure 24b. 30 minutes before SBF

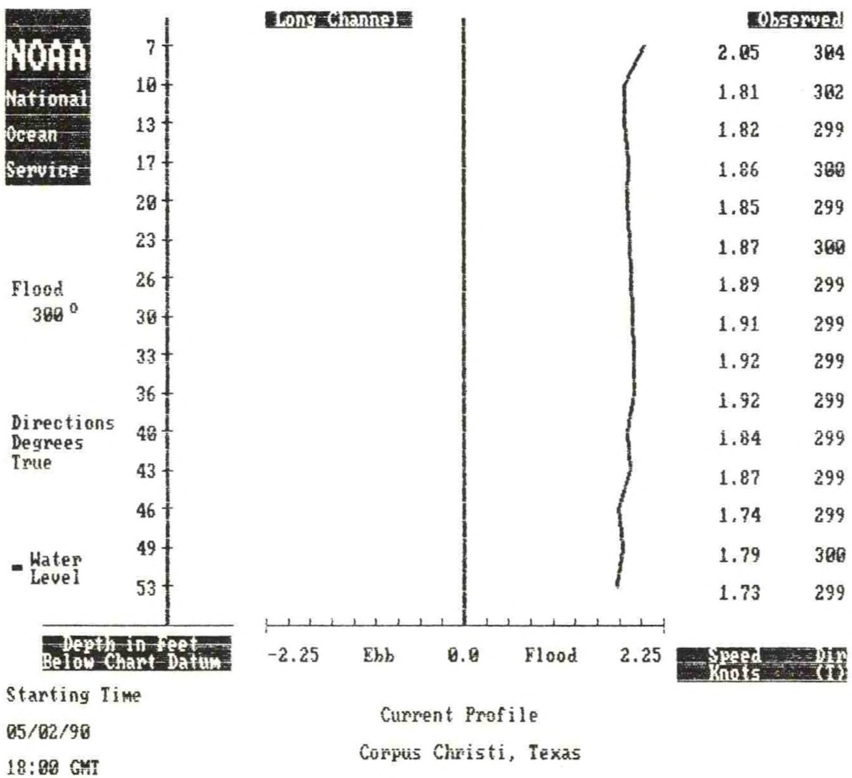


Figure 25a. MFC

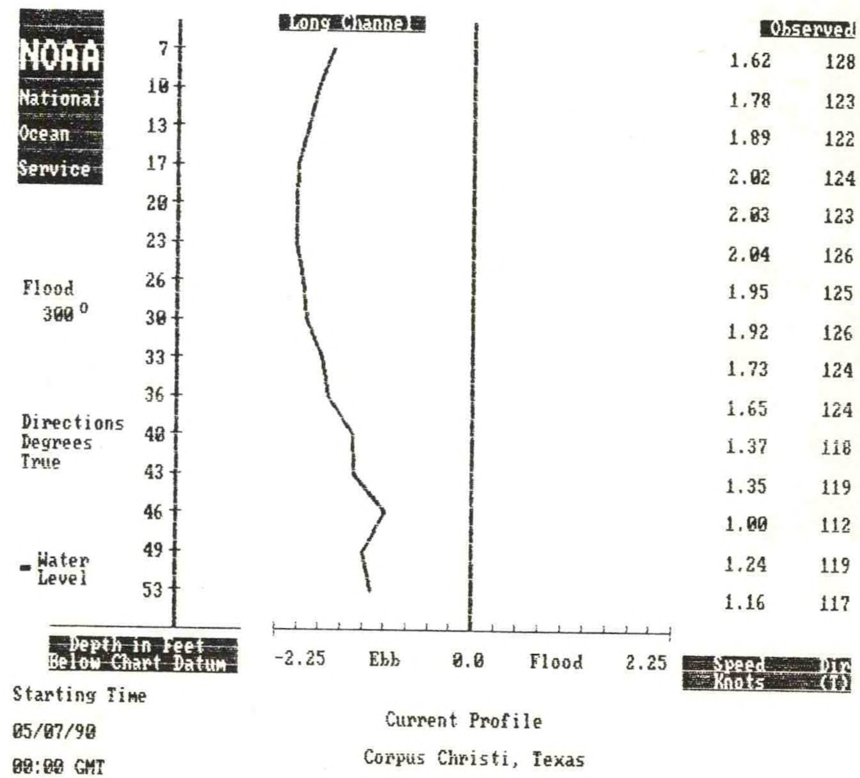


Figure 25b. 20 minutes beofre MEC

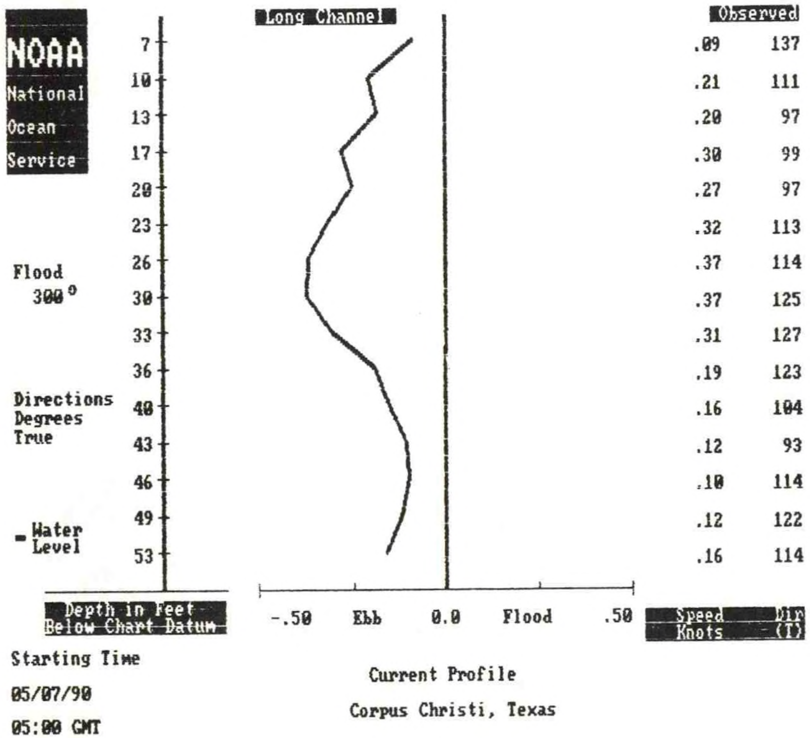


Figure 26a. 50 minutes before SBF

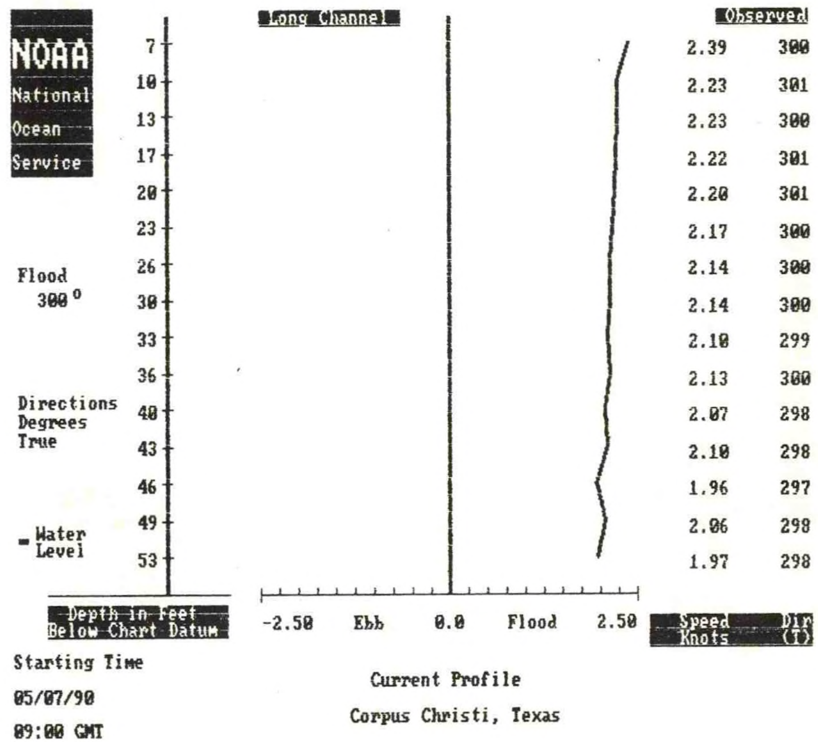


Figure 26b. MFC

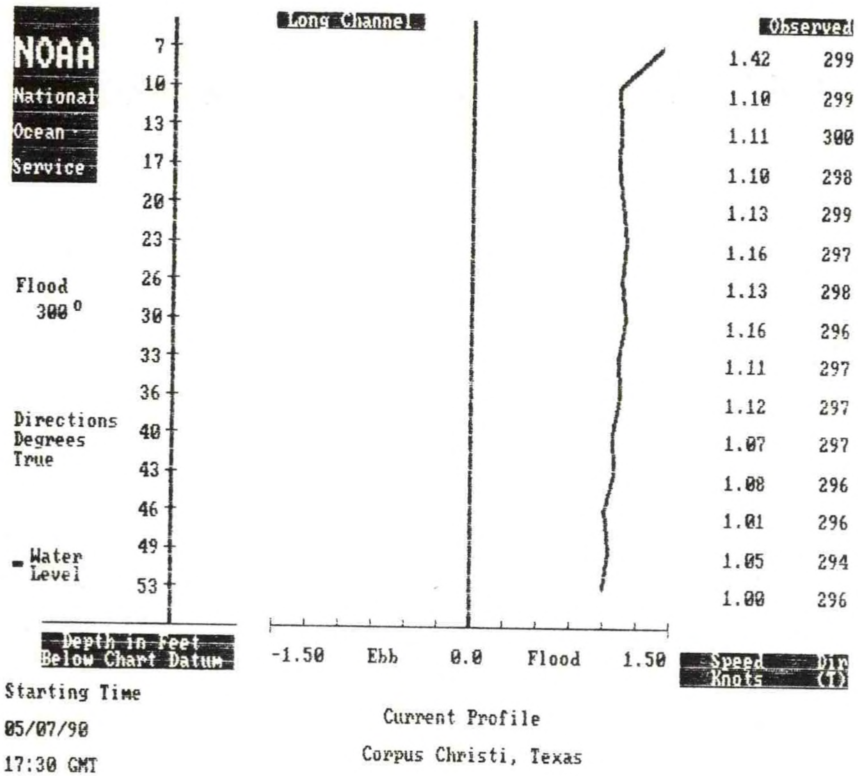


Figure 27a. 8 hours 30 minutes after MFC

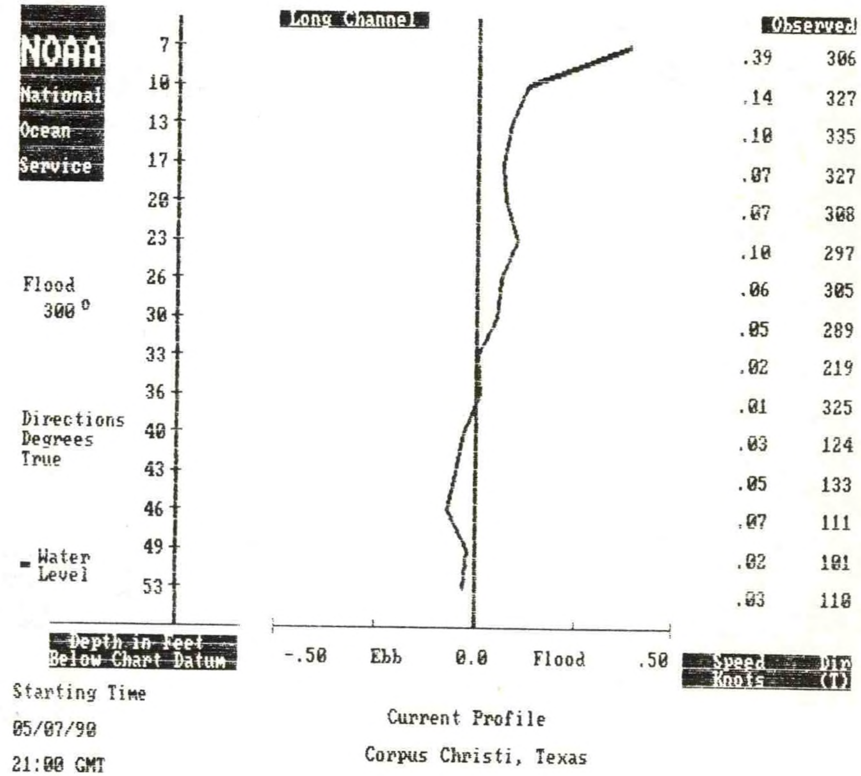


Figure 27b. SBE

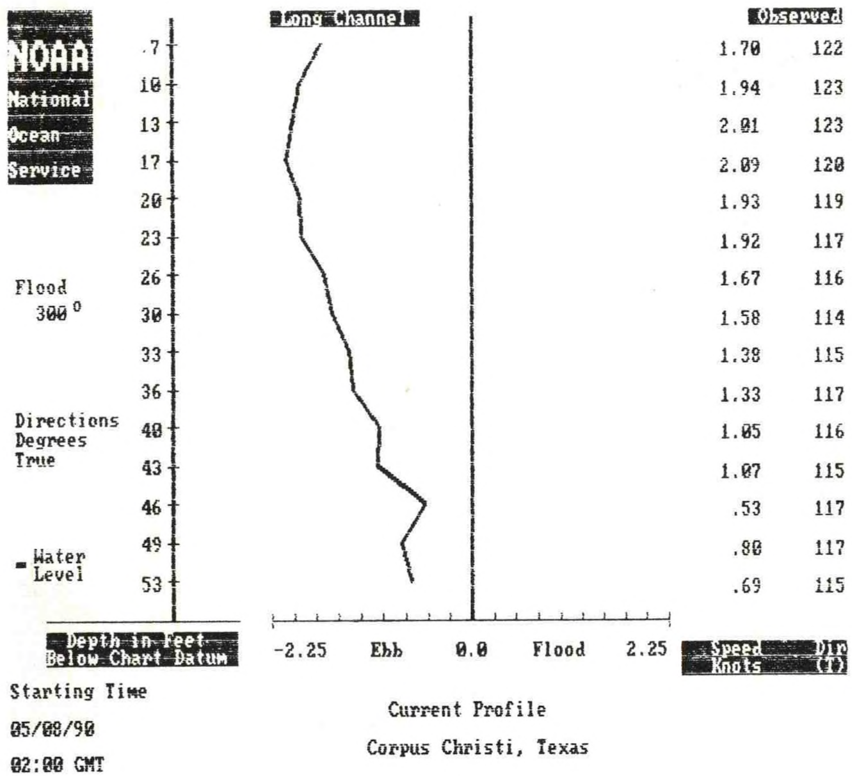


Figure 28a. 30 minutes after MEC

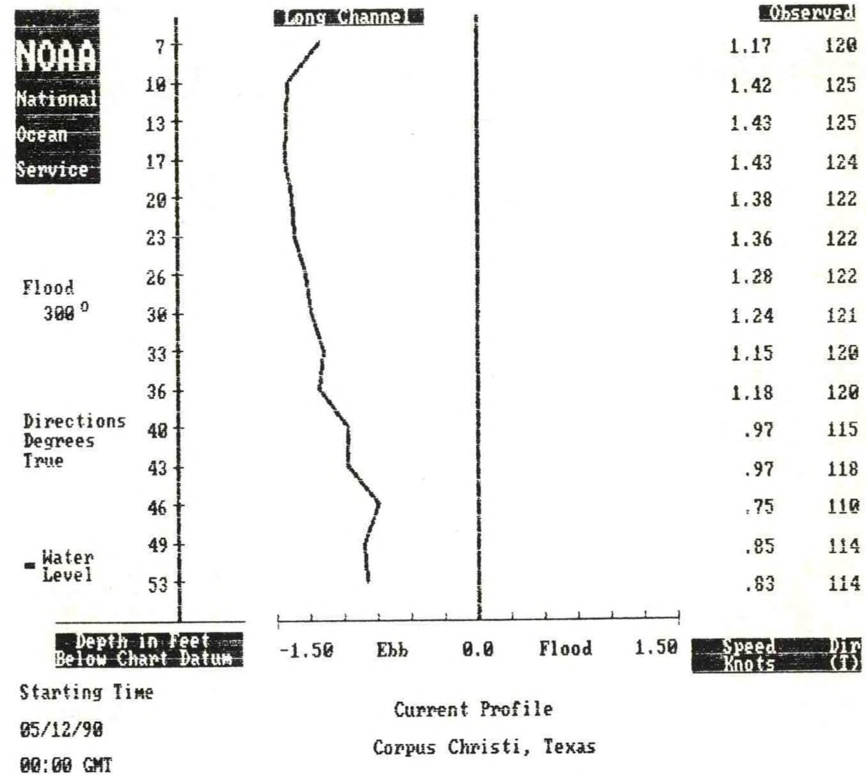


Figure 28b. 2 hours before MEC

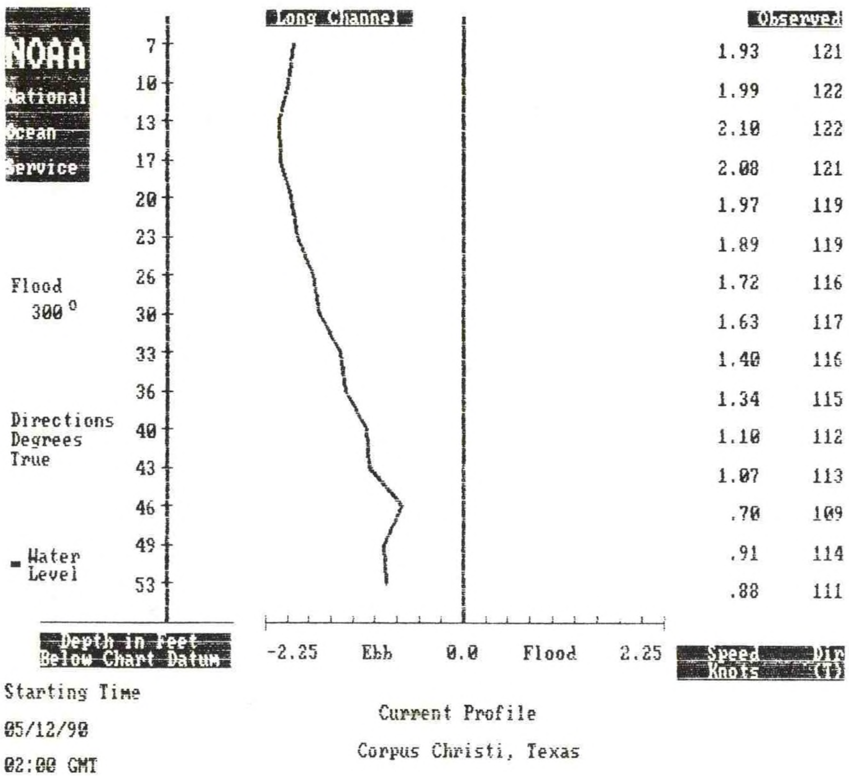


Figure 29a. MEC

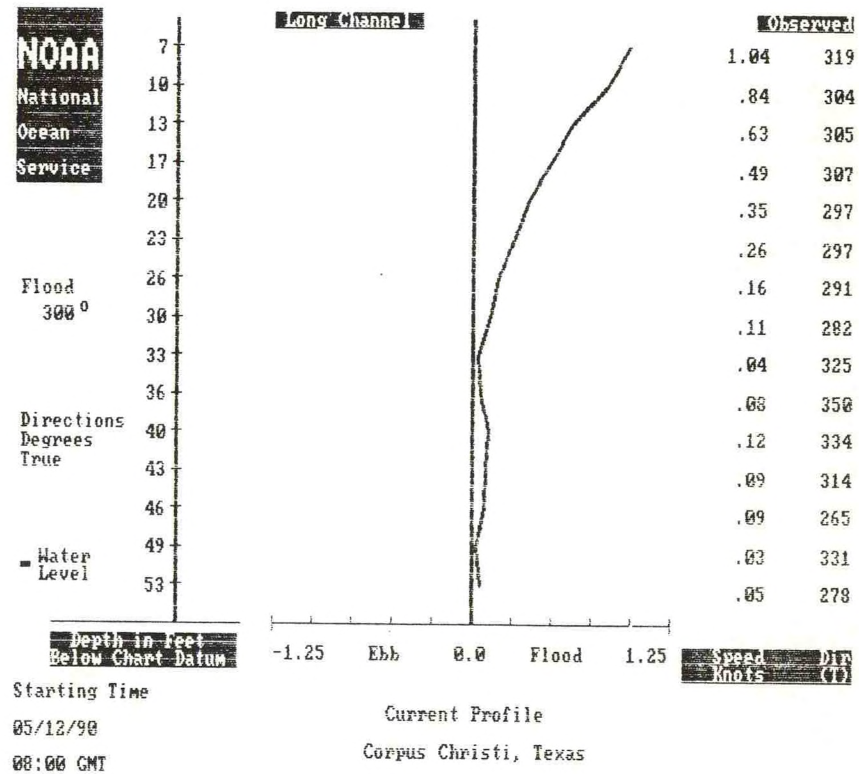


Figure 29b. 10 minutes after SBF

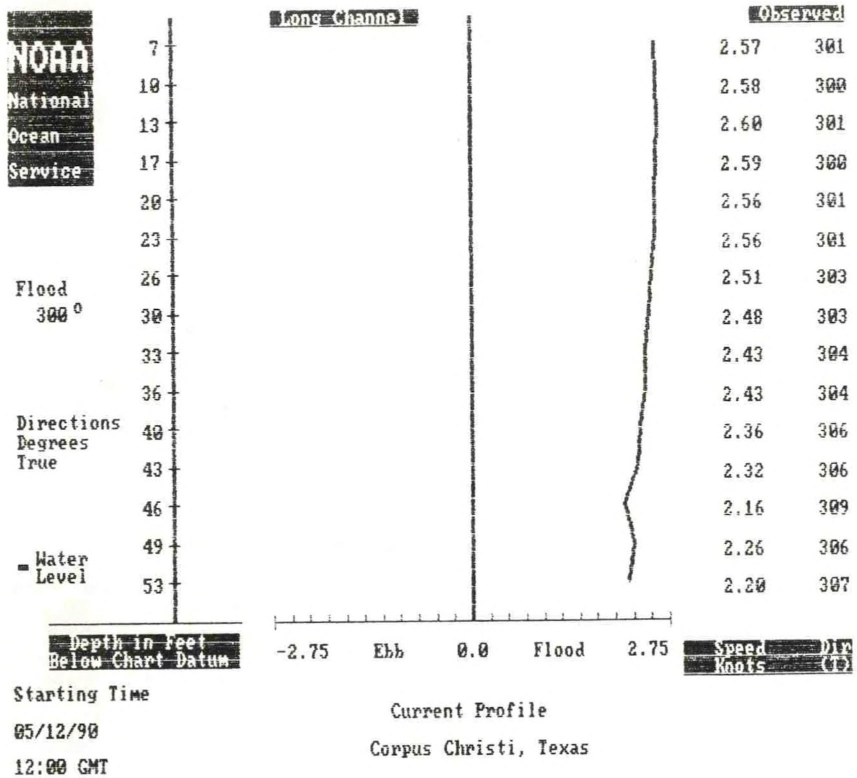


Figure 30a. MEC

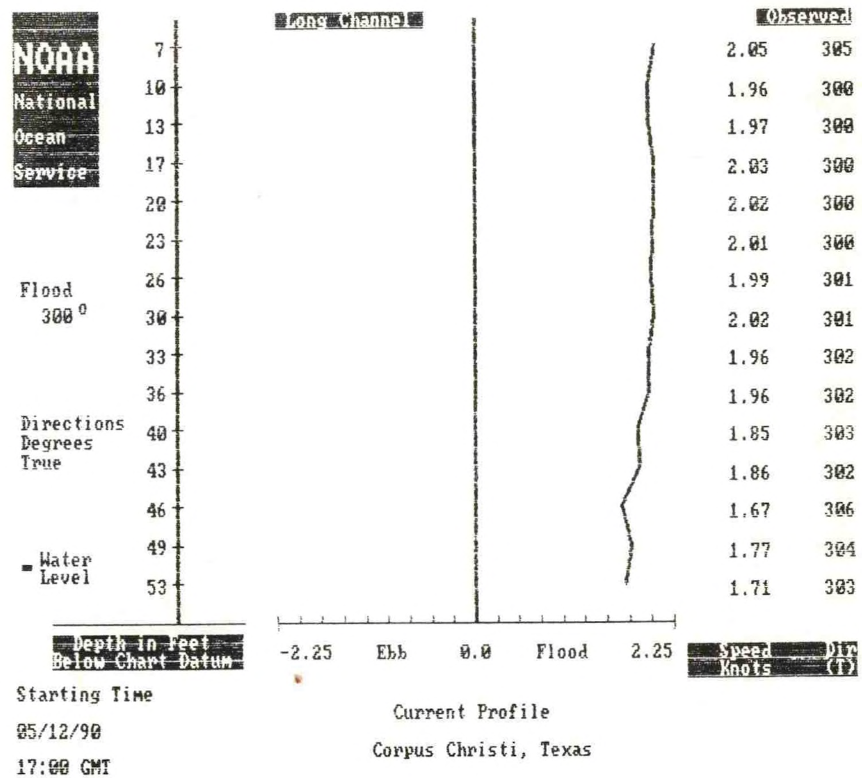


Figure 30b. 5 hours after MEC

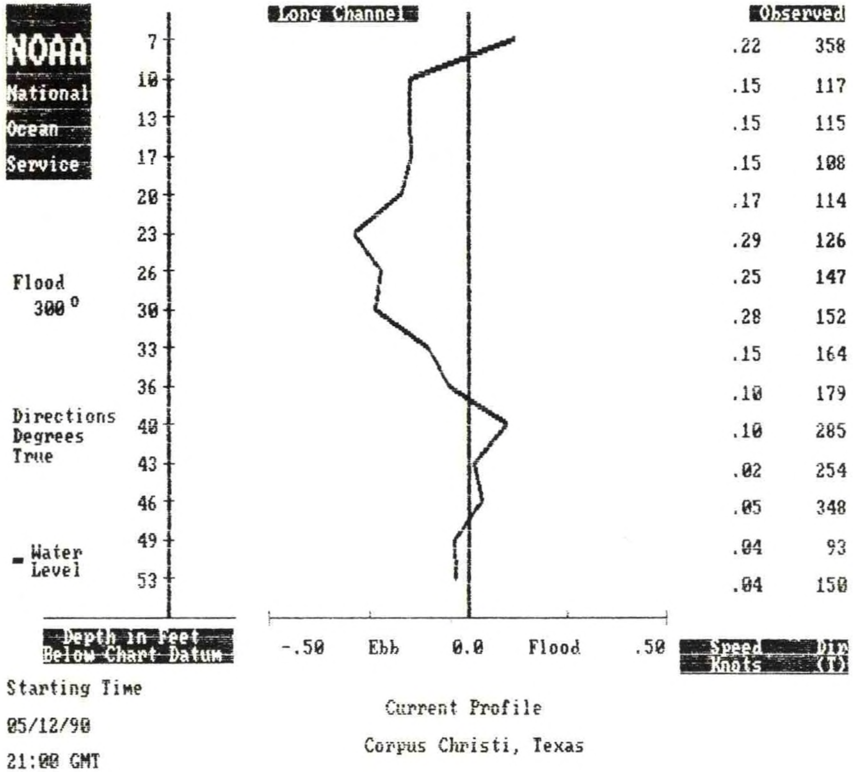


Figure 31a. 10 minutes after SBE

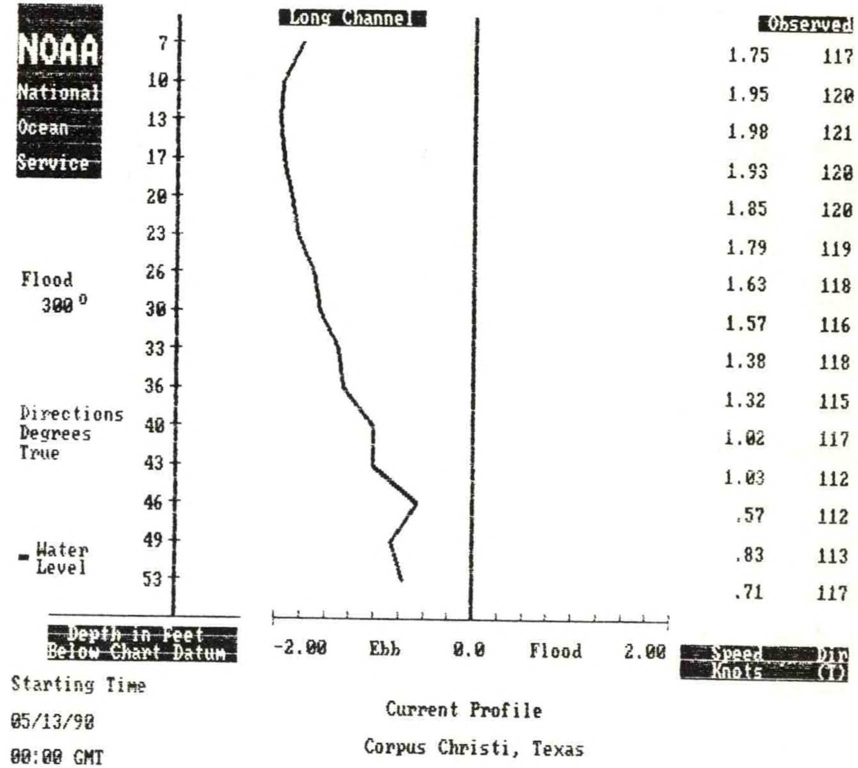


Figure 31b. 3 hours 10 minutes after SBE

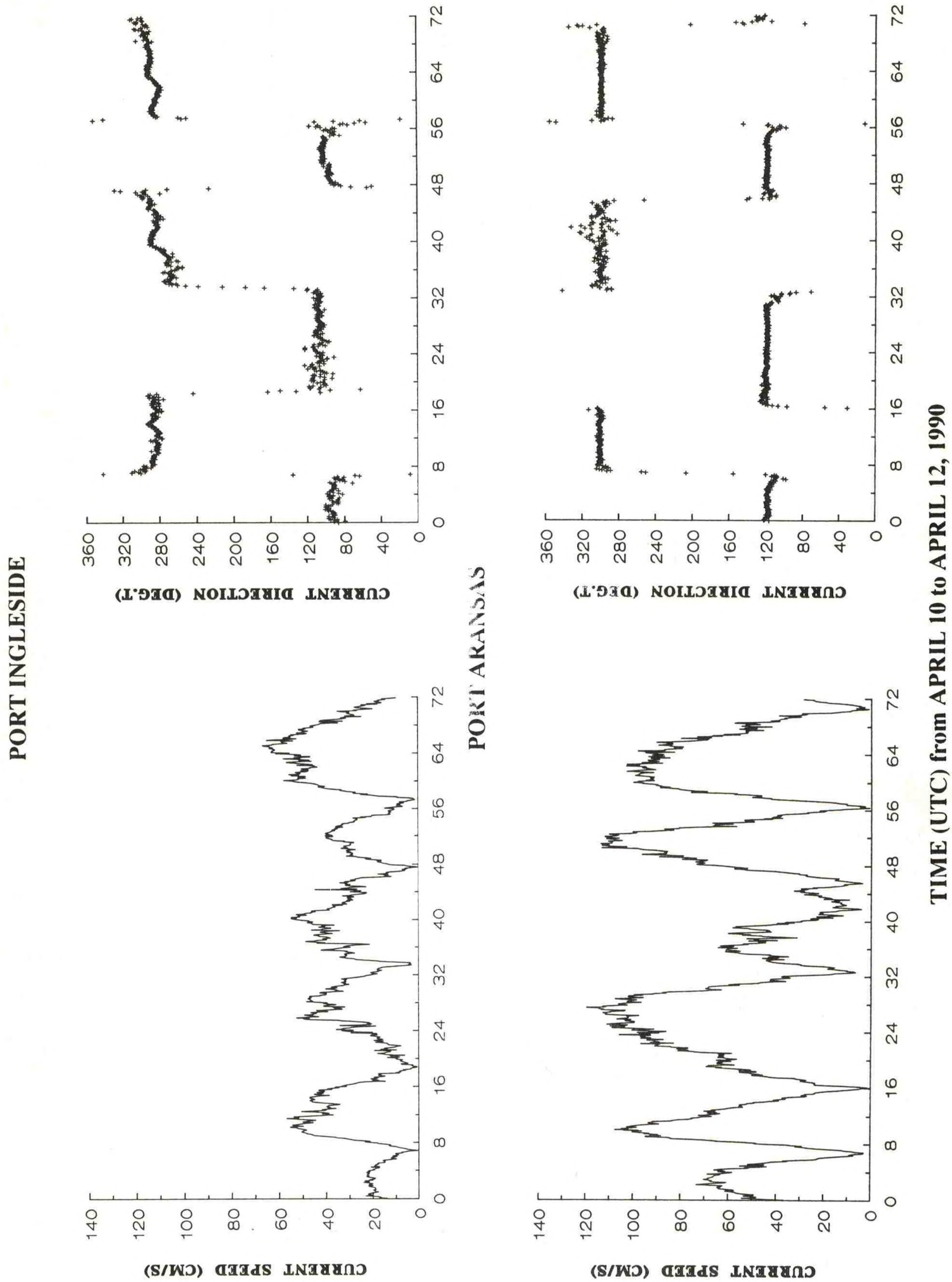


Figure 32. Corresponding time series of currents at Port Ingleside and Port Aransas

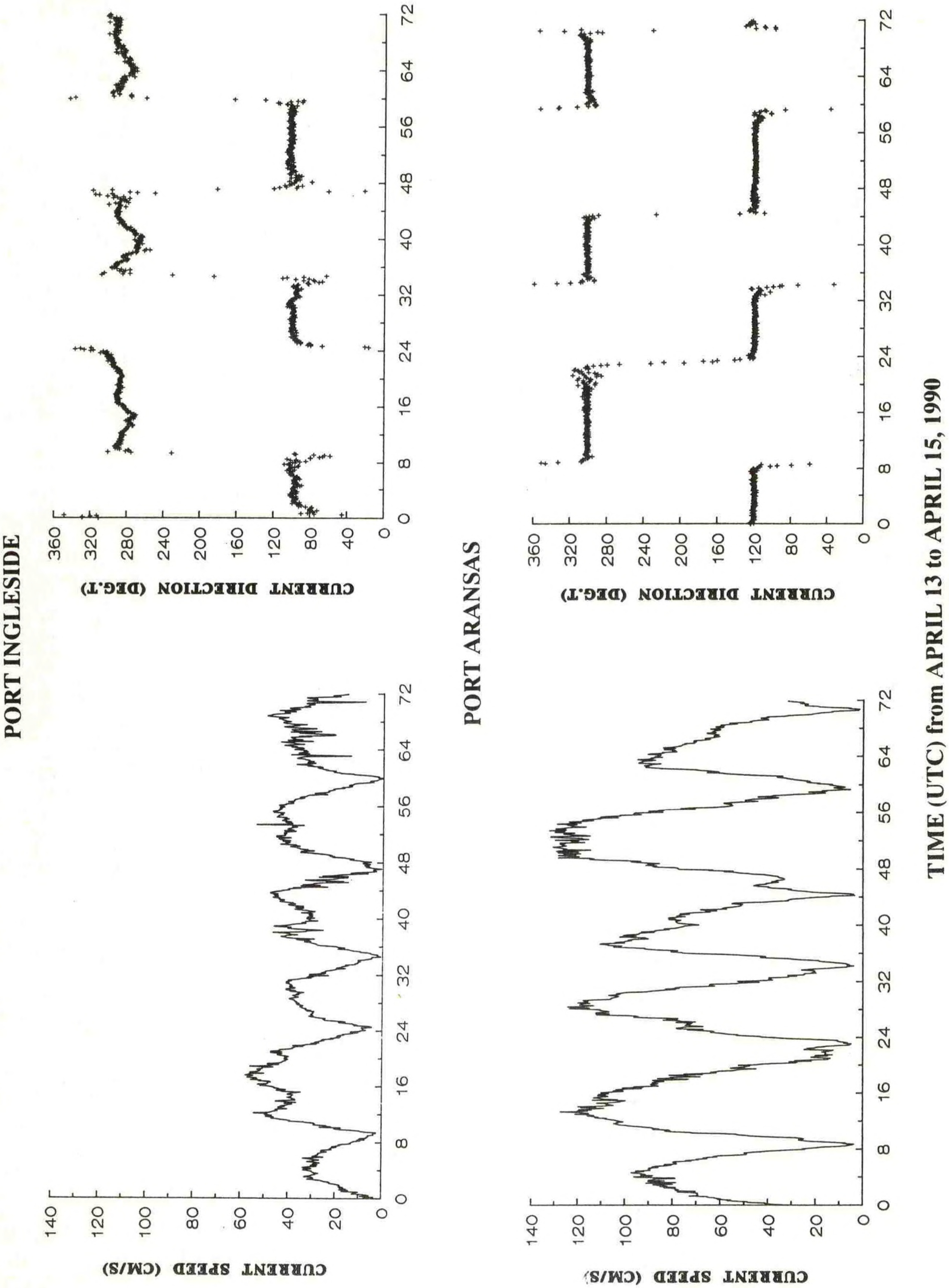


Figure 33. Corresponding time series of currents at Port Ingleside and Port Aransas

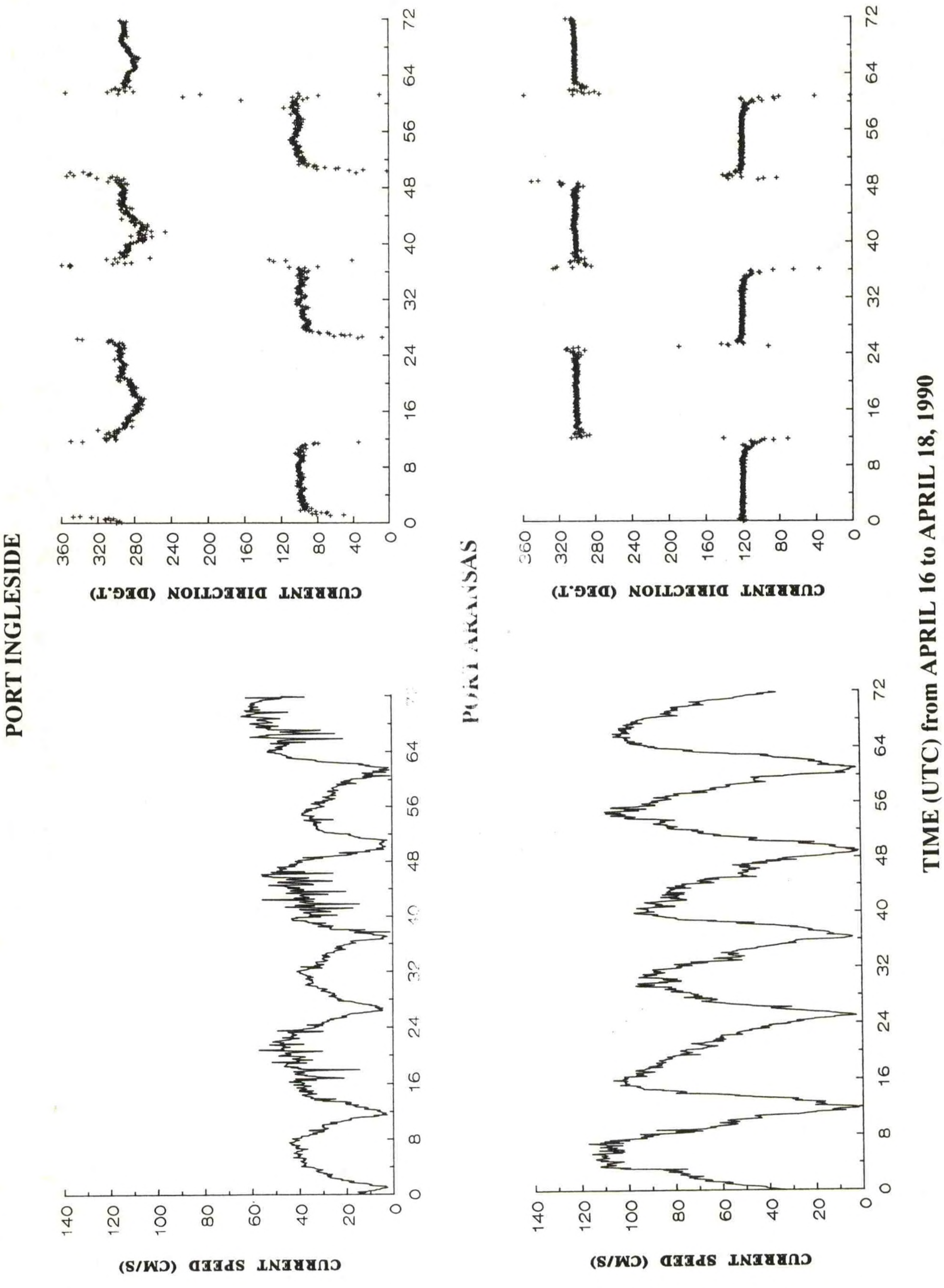


Figure 34. Corresponding time series of currents at Port Ingleside and Port Aransas

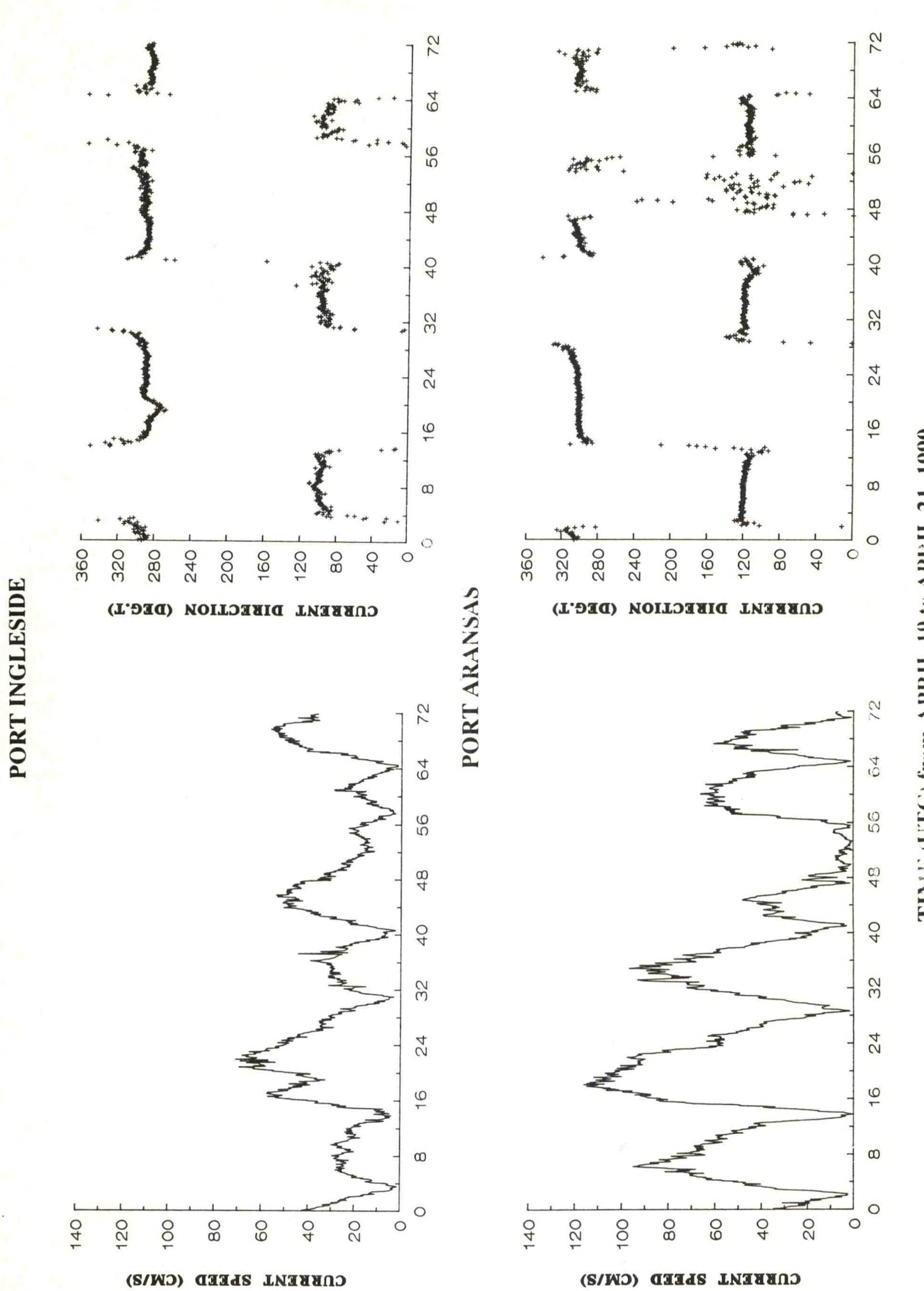


Figure 35. Corresponding time series of currents at Port Ingleside and Port Aransas

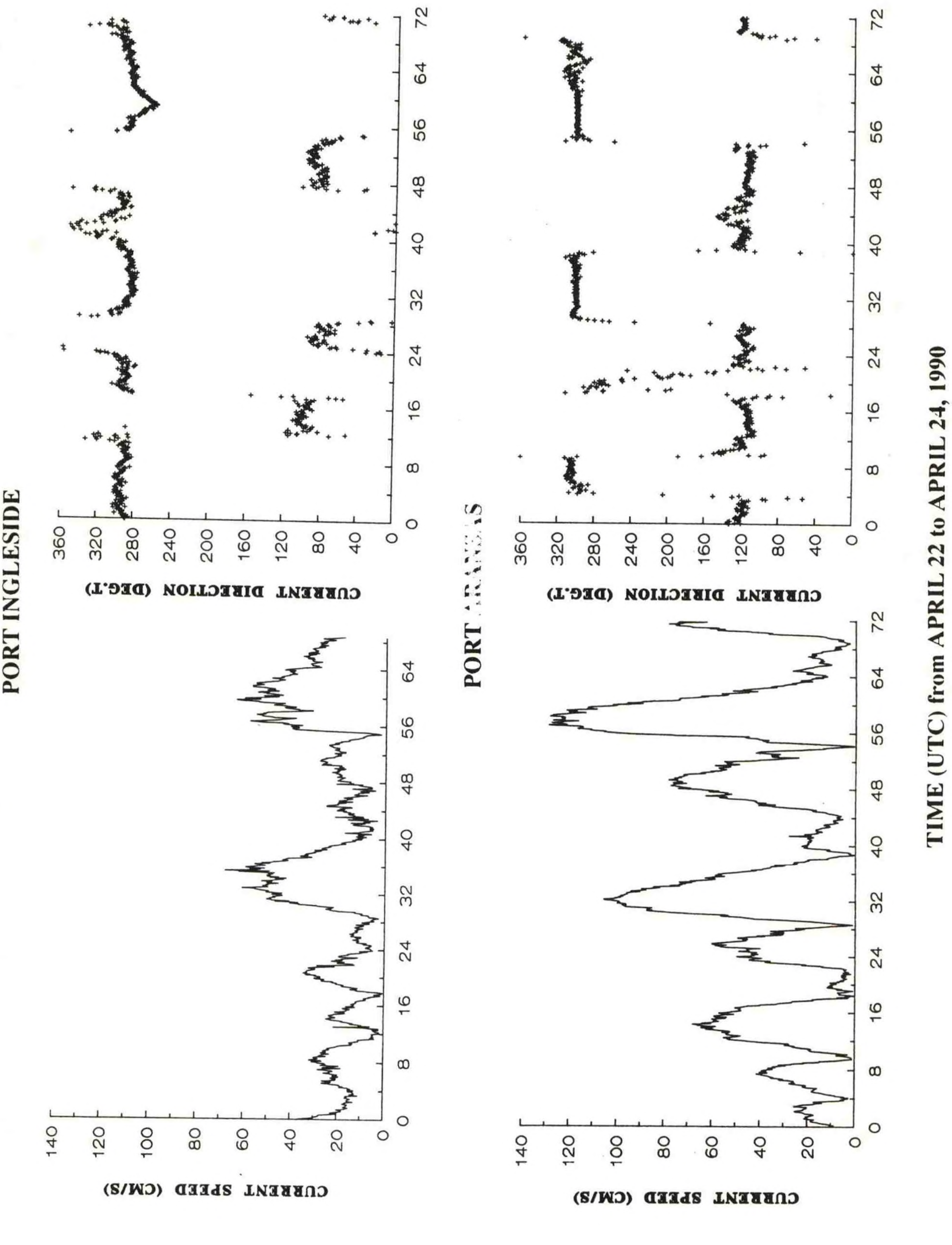


Figure 36 Corresponding time series of currents at Port Ingleside and Port Aransas

PORT INGLESIDE

SPEED-DIRECTION HISTOGRAM

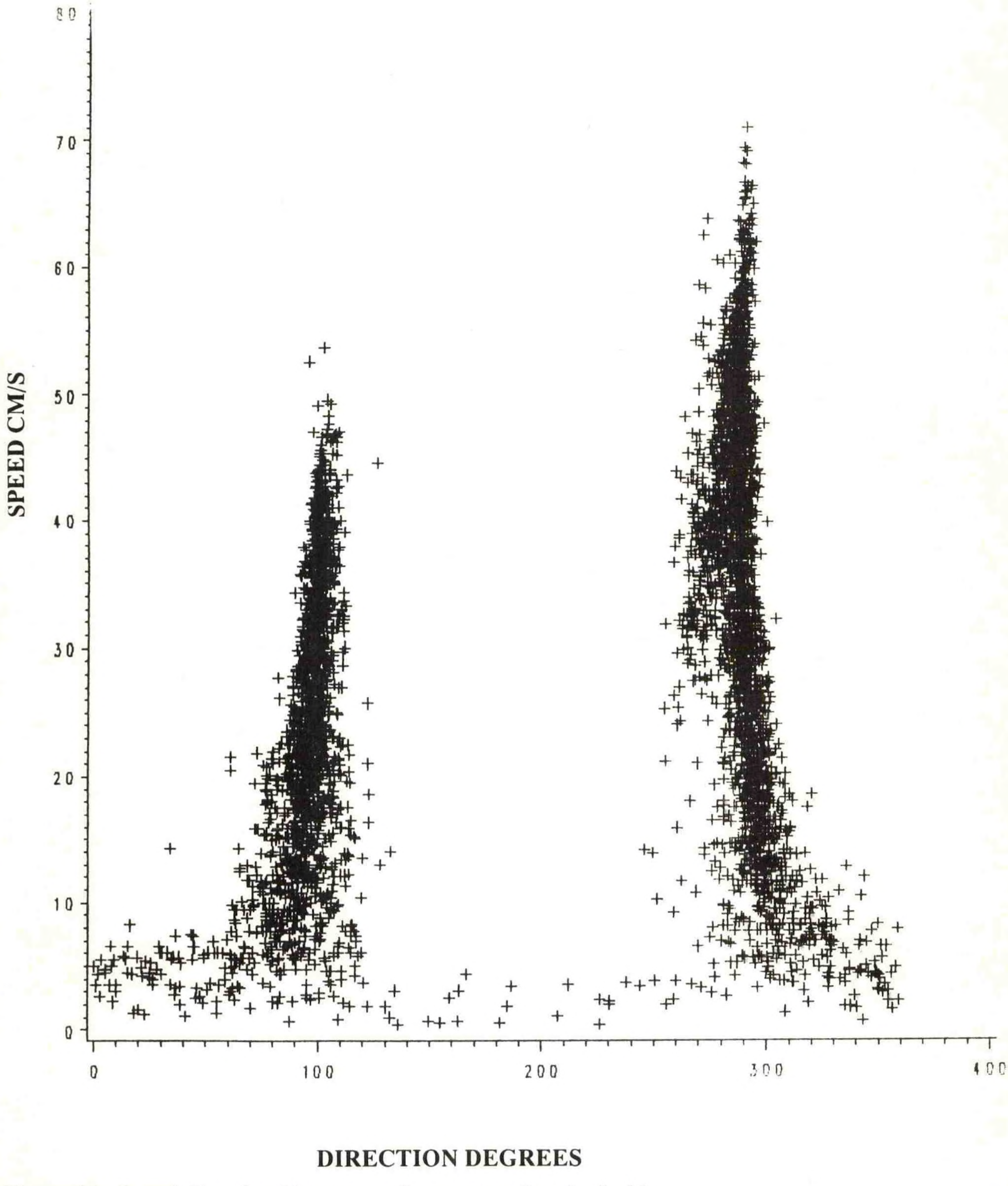


Figure 37. Speed-direction histogram of currents at Port Ingleside

* U.S. G.P.O.:1991-313-153:40051