CSDL Informal Technical Note No. 13

NOS HISTORICAL CIRCULATION SURVEY DATA RESTORATION: CASCO BAY (1979), LOS ANGELES AND LONG BEACH (1983), SAN DIEGO (1983), AND MIAMI (1985)

Silver Spring, Maryland
June 2012

noaa National Oceanic and Atmospheric Administration

U.S. DEPARTMENT OF COMMERCE
National Ocean Service
Coast Survey Development Laboratory

Office of Coast Survey
National Ocean Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

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ABSTRACT

The purpose of this report is to document the restoration of the National Ocean Service (NOS) historical circulation survey data in Casco Bay (1979), Los Angeles and Long Beach (1983), San Diego (1983), and Miami (1985). Previous computer programs developed for restoring Delaware River and Bay circulation survey data (2006) were used to analyze conductivity, temperature and current (CT/Current) data (Richardson and Schmalz, 2006). There were no CTD profile data available. Based on plots of salinity, temperature, current speed and direction at CT/Current moorings, temperature, salinity and current speed and direction data quality were assessed. Problematic time series were indicated in the dataset tables. Meteorological data (sea level atmospheric pressure, air temperature, and wind speed and wind direction) were either not collected or not considered due to data issues. This report is meant to serve as the circulation survey report for Casco Bay, Los Angeles and Long Beach, San Diego, and Miami.

While complete quality control has not been performed, the data processing algorithms, have been used to remove major spikes. Investigators may use these or other approaches for further quality control. Each estuary is presented in a separate chapter, including description of data inventories of both raw and processed data files. Discussion of the CT/current data is followed by regional oceanographic considerations. Major data preservation and data use issues are then addressed. In conclusion, an overall summary is provided along with recommendations for additional data analysis tasks.

1. INTRODUCTION

From 1979 through 1985, the National Ocean Service (NOS) conducted circulation surveys in Casco Bay (1979), Los Angeles and Long Beach (1983), San Diego (1983), and Miami (1985). Due to corruption in computer system transfer and lost media, these datasets have been lost. To restore the available datasets, the remaining conductivity-temperature and current (CT/Current) collected during these surveys were obtained from the NOS/Center for Operational Oceanographic Products and Services (CO-OPS) and analyzed.

The primary use of these restored circulation survey datasets is anticipated to support the model evaluation and the development of possible NOS nowcast/forecast oceanographic forecast modeling systems for these water bodies.

While complete quality control of the data was not performed, the data quality control and analysis programs previously used by Loeper (2006) and Richardson and Schmalz (2006) are reviewed in Chapter 2. These programs can be used to further quality control the datasets, but it may be necessary to develop additional filtering techniques after comparing these datasets to model predictions. In Chapters 3-6, Casco Bay, Los Angeles and Long Beach, San Diego, and Miami circulation survey data processing and analysis are described, respectively. In each chapter, raw and processed data inventories of CT and current data are presented. Time series of salinity, water temperature, current speed and direction data at CT/Current moorings at representative estuarine stations are plotted. Water temperature, salinity, and current speed and direction spikes were minimal and were not edited out of the record. Some further filtering and editing may be required prior to model-data comparison. CTD vertical profiles and meteorological data were either not collected or not available. In Chapter 7, data preservation and data use issues are considered. In Chapter 8, conclusions and recommendations for future work are addressed.

2. DATA PROCESSING ALGORITHMS

An initial quality control of the current and CT data can be performed using the program currnt.f developed during the Delaware Bay circulation survey data restoration (Richardson and Schmalz, 2006). This program can be used to initially plot salinity, temperature, current speed, and current direction data. After these plots have been reviewed, one can determine which data sets require removal of bad data segments. This step was first performed during this study to analyze the datasets and inventory bad data as given in the station inventory tables. Subsequent steps are as follows: 1) clipping of current direction data to remove spikes, 2) application of a box-car type filter to remove spikes in salinity, temperature, current speed and direction data. The use of the program is outlined in the following paragraphs.

The first variable read from the control file is initplot, which when set to 1, enables the plotting of the unfiltered, unedited data. For any changes, brought about either through filtering or through editing, to be observed in the plots, initplot must be set to 0. With initplot equal to 0, spikes in salinity, temperature, and current speed data will be automatically eliminated (filtered) using a box car type filter. However, other bad portions, such as multiple spikes or noise in salinity, temperature, and current speed data will not be handled. When multiple spikes occur, the nedit option must be used.

The nedit portion substitutes null values for bad data. Bad data segments are considered to be those in which there is clear evidence of instrument malfunction. With nedit equal to 0, no editing will occur. If there are n segments of data requiring editing, then nedit will be set to n. The parameters which are required in the control file for a segment of data to be edited include: the station name, the depth of the reading, and the year in which the data was recorded. Also required are the beginning and ending dates for the bad data segment, and the integer indicator for each data type. If the salinity data is good, iedt_s is set to 0. If the salinity data requires editing, iedt_s is set to 1. The indicators for temperature and current data are iedt_t and iedt_cur, respectively.

During this study, only those data segments of 15 days or longer are plotted with information printed to output file time.out2. The information printed to time.out2 is particularly useful when editing data plots. This information includes the station number, the depth of the reading, the year of the reading, and the beginning and ending dates (Julian days) for the data segment. Also printed to time.out2 is the plot number. The plot number is used to determine which dataset needs further editing. No editing of data was performed during this study.

3. CASCO BAY

NOS performed an intensive survey in 1979 to study the circulation in Casco Bay, Maine. The study was performed during the late summer, early fall. The Ticus current meter recorded and measured current speed and direction, but did not include temperature and conductivity and pressure sensors. Here, we summarize the recovered data and discuss related regional oceanographic characteristics.

Data Inventory and Summary

The datasets available from CO-OPS on compact disc are listed in Table 3.1 and constitute the recoverable data. It was necessary to carefully inventory these datasets and determine their data quality. No meteorological data were collected.

Table 3.1. Casco Bay Circulation Survey Raw Data Inventory.

Directory Name	Number of Files	Data Period	Data Description	Data Quality
ICECAS2	42	1979	Ticus Current Meter	OK

In Table 3.2, the raw, edited, and final quality controlled datasets are given along with their location in the CSDL/MMAP SAN. The processed data files were correspondingly named following the original data files. Each dataset was plotted and then written to output files in exactly the same format as the original data. It should be noted that since the focus was on data for model validation and harmonic analysis, only stations with record lengths of 15 days or greater were considered. In general, data quality was high and no editing was performed. However, some of the station time series exhibited high frequency spikes, which may need to be further filtered and edited prior to model-data comparison.

Table 3.2. Casco Bay Circulation Survey Processed Data File Inventory

Data Type	Location	Filename
CT/Current Raw	~/ICECAS2/	FILE1 – FILE42
CT/Current	~/icecas2/	file_cas2
CT/Current Qc	~/qc/	file_cas2.qc

~ = /disks/NASUSER/philr/cascobay

CT/Current Data

The salinity, temperature and current data were distributed in one directory: icecas2. The data files in these directories (FILE1 through FILEn) were concatenated to create a cumulative data file file_cas2. The data in each individual data file (FILE1 through FILEn) represent current and CT data at one specific station location, over a given time period.

The datasets are inventoried in Table 3.3 in terms of station location, measurement and station depths and measurement dates and durations. Station depths are estimated relative to MLLW using Nautical Chart 13290, 39th Edition. At stations C-5 and C-49, the measurement depths are greater than the depths indicated on the nautical chart. Stations locations are shown in Figure 3.1.

Table 3.3. Casco Bay Dataset

Station No.	Latitude (°N)	Longitude (°W)	M-Depth (ft)	S-Depth (ft)	Measurement Dates mm/dd/yr		Data Length Days	Data Quality AD
C-2	43.645	70.258	19	36	8/30/79	9/27/79	27.66	
C-6	43.670	70.175	81	101	8/29/79	9/20/79	21.87	
C-6	43.670	70.175	67	101	8/29/79	9/27/79	28.91	
C-6	43.670	70.175	7	101	8/29/79	9/27/79	28.91	
C-8	43.665	70.205	8	11	9/18/79	10/19/79	30.87	
C-13	43.703	70.165	7	53	10/ 3/79	10/19/79	16.33	
C-19	43.725	70.215	15	6	10/ 1/79	10/19/79	17.66	
C-23	43.738	70.138	10	13	10/ 1/79	10/19/79	17.78	
C-14	43.708	70.178	20	55	10/ 1/79	11/ 7/79	36.91	
C-14	43.708	70.178	7	55	10/ 1/79	11/ 7/79	36.91	
C-16	43.675	70.248	7	18	10/21/79	11/ 7/79	16.91	
C-17	43.688	70.242	7	16	10/21/79	11/ 6/79	15.91	
C-18	43.708	70.208	10	28	10/22/79	11/ 7/79	16.08	
C-20	43.738	70.192	7	36	10/22/79	11/ 7/79	15.91	x
C-25	43.637	70.153	88	108	8/29/79	9/15/79	16.58	
C-25	43.637	70.153	7	108	8/29/79	9/15/79	16.58	
C-1	43.665	70.215	12	24	8/30/79	9/15/79	15.91	
C-5	43.630	70.208	53	49*	8/30/79	9/21/79	21.58	
C-5	43.630	70.208	53	49*	10/ 4/79	10/19/79	15.12	
C-5	43.625	70.208	53	49*	10/19/79	11/ 7/79	18.62	
C-5	43.630	70.208	38	49*	8/30/79	10/ 1/79	31.99	
C-5	43.625	70.208	7	49*	10/19/79	11/ 7/79	18.70	
C-12	43.707	70.145	7	16*	8/30/79	10/ 1/79	31.99	
C-12	43.707	70.145	25	16*	8/30/79	10/ 1/79	32.03	
C-7	43.687	70.180	71	88	8/30/79	9/15/79	15.78	
C-9	43.653	70.205	32	40	9/15/79	10/ 1/79	15.99	
C-9	43.651	70.205	7	40	9/15/79	10/ 1/79	15.83	
C-3	43.662	70.237	15	26	9/15/79	10/19/79	33.66	
C-4	43.650	70.218	7	55	9/27/79	10/19/79	21.91	
C-13	43.703	70.165	41	53	10/ 3/79	10/19/79	16.24	
C-25	43.637	70.153	75	108	8/29/79	9/14/79	15.95	
C-4	43.650	70.218	34	55	8/30/79	9/15/79	15.74	
C-24	43.757	70.123	34	44	9/15/79	10/ 7/79	22.24	
C-24	43.757	70.123	7	44	9/15/79	10/14/79	29.12	
C-6	43.670	70.175	67	101	9/27/79	11/ 7/79	40.58	
C-20	43.738	70.192	25	36	10/22/79	11/ 7/79	15.99	
C-1	43.665	70.215	7	24	8/30/79	9/15/79	15.91	
C-5	43.630	70.208	38	49*	10/ 4/79	10/19/79	15.12	

Notes: M-Depth=measurement depth with respect to MLLW, where positive numbers are distance above the bottom and negative numbers are distance below the surface. S-Depth=station depth with respect to MLLW. Note x denotes bad data within the AD station matrix where, A=current speed, and D=current direction. *Note at Stations C-5 and C-12 measurement depth exceeds station depth.

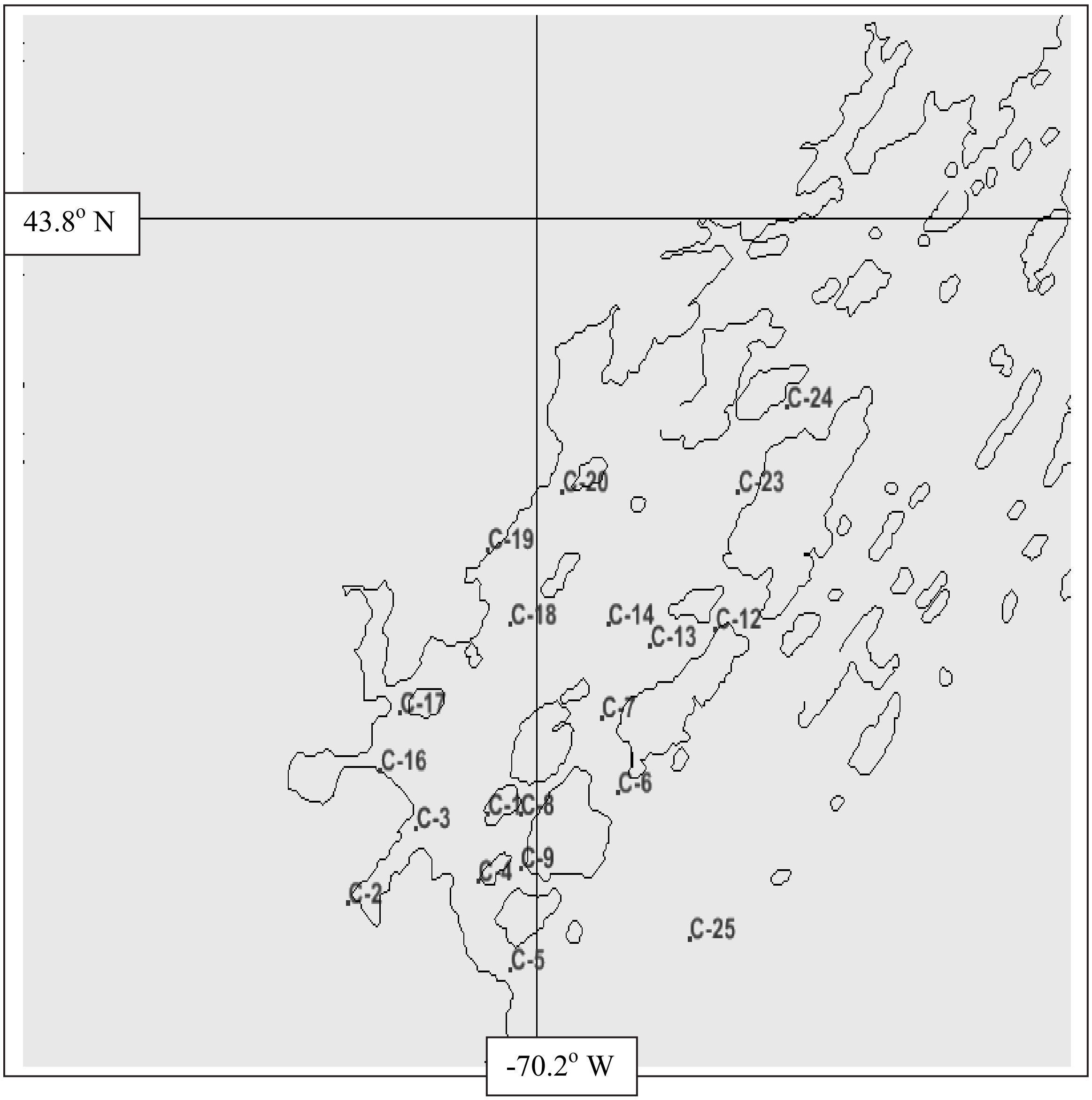


Figure 3.1. Station Locations for Casco Bay Dataset 1.

Regional Oceanographic Characteristics

Casco Bay is an inlet of the Gulf of Maine on the southern coast of Maine. Its easternmost approach is Cape Small and its westernmost approach is Two Lights in Cape Elizabeth. The city of Portland sits along its southern edge and the Port of Portland lies within the Bay. Casco Bay is characterized by a complex series of peninsulas, numerous small islands, and some intertidal zones. An intertidal zone occurs when foreshore and seabed areas become submerged at high water levels and exposed at low water levels. Casco Bay is a source region of toxic algal bloom and such events are closely related to variations of sea surface salinity. Freshwater inflow volumes reach about 1.3×10^{10} m^3 annually and the resultant plume is a key factor that drives salinity variability in Casco Bay.

Casco Bay has a complex topography. Fresh water discharge from the Kennebec-Androscoggin River intrudes into the Bay from time to time, which also carries nutrients into the region. Observations indicate that there is a strong correlation between the salinity and algal abundance and suggest the Casco Bay region is a source region for toxic algal bloom.

Buoyant forcing due to the river water outflow has significant dynamic contributions in the region. When river discharge reaches a peak value, both the alongshore and the cross-shore extension of the river plume are significantly increased. Low salinity plume water forms a large anti-cyclonic circulation due to the Coriolis forcing, and the highest river discharge generates the biggest bulge near the estuary mouth. At the same time, sea surface salinity in Casco Bay is largely influenced by the plume extension. During springtime, sea surface salinity can decrease by 2 PSU and most of the Casco Bay area is covered by low salinity water (<30 PSU).

In the absence of the buoyancy forcing, the effect of strong winds can also be observed. During a downwelling favorable wind event, the plume is elongated in a downstream direction but constrained along the coastline. During an upwelling favorable wind event, the direction of the plume is offshore and upstream, indicating that the upstream transport driven by the wind overwhelms the rotation effect. Also, salty water rises from the subsurface to compensate the wind-induced offshore movement of the surface water.

Here we examine the current time series during September 1979 at Stations C-1 and C-12, which are in the Bay inside the coastal island chain. During September 1979 at Station C-1 at 12 ft above the bottom in Figure 3.2, we note peak current speeds of order 60 cm/s with rectilinear current characteristics. In Figure 3.3, for C-12 at 7 ft above the bottom, peak current speeds are on the order 65 cm/s again with distinct ebb/flood directions. Note CT data were not measured with the Ticus current meter systems.

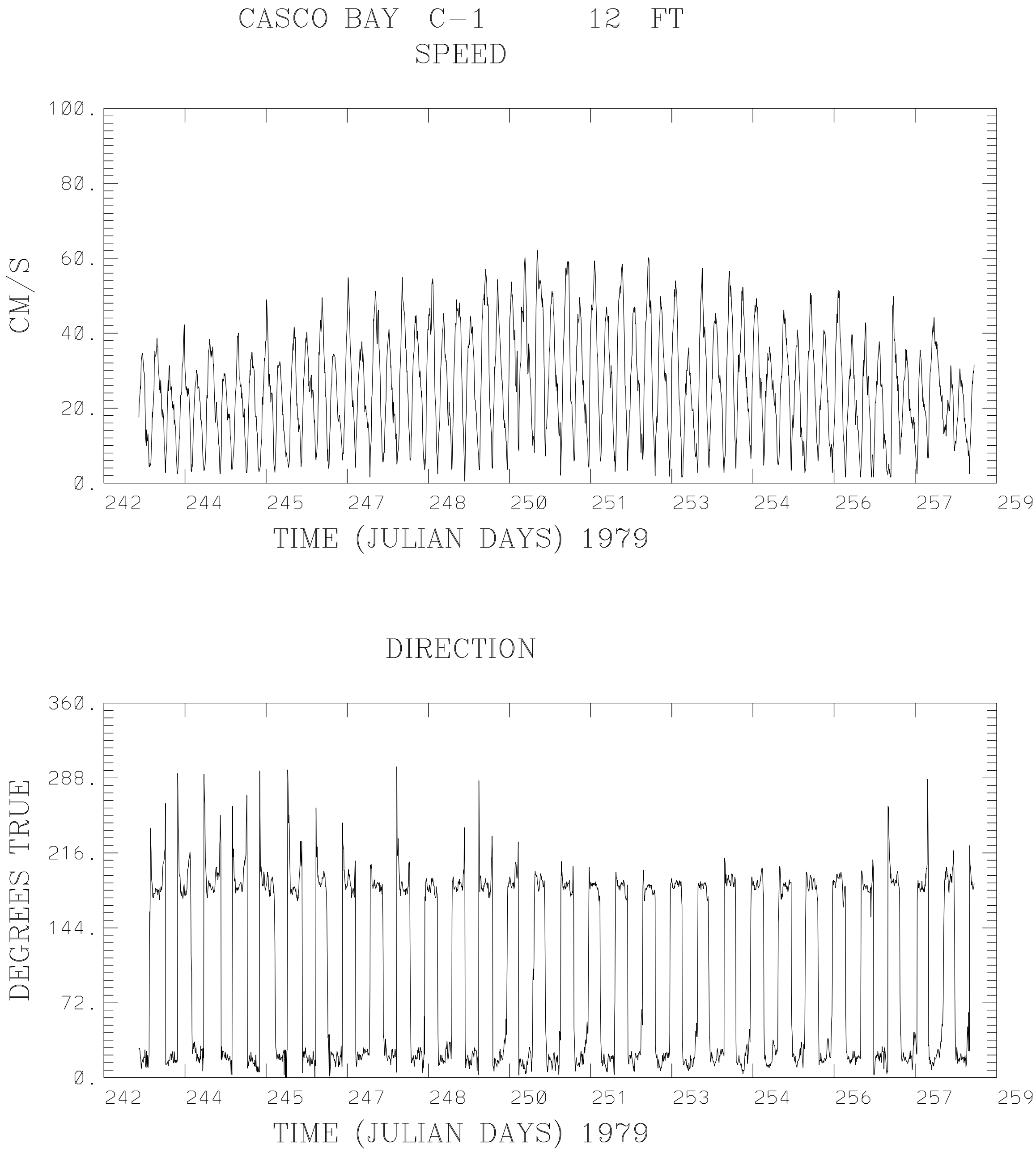


Figure 3.2. Station C-1 Casco Bay Current Speed and Direction at 12 ft above the bottom in September 1979.

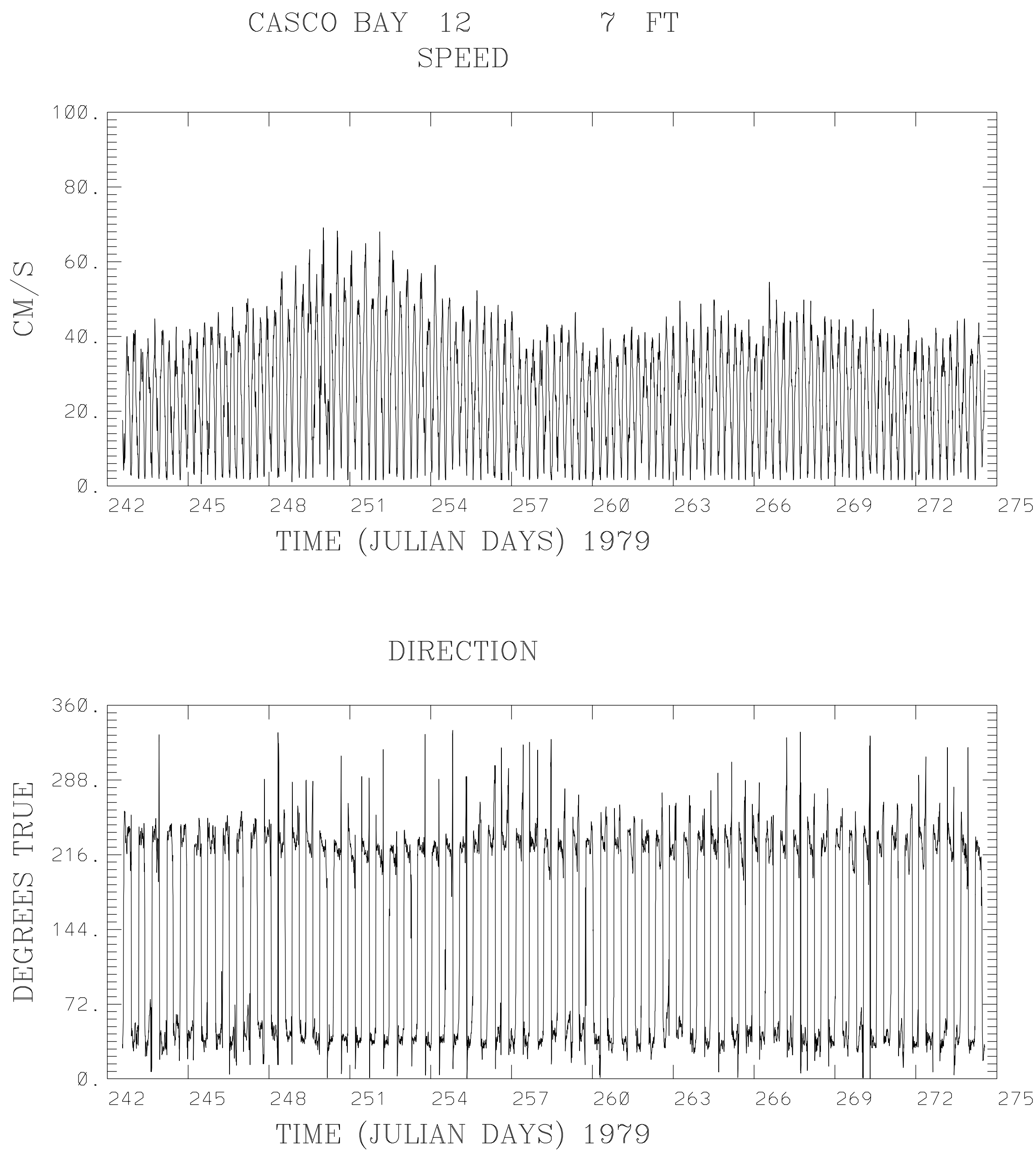


Figure 3.3. Station C-12 Casco Bay Current Speed and Direction at 7 ft above the bottom in September 1979.

4. LOS ANGELES AND LONG BEACH

NOS performed a survey in 1983 to study the circulation in Los Angeles and Long Beach Harbors, California. The Aanderaa Model RCM-4 current meter recorded and measured current speed and direction and included temperature and conductivity and pressure sensors. Here, we summarize the recovered data and discuss related regional oceanographic characteristics.

Data Inventory and Summary

The datasets obtained from CO-OPS on compact disc are listed in Table 4.1. It was necessary to carefully inventory these datasets and determine their data quality.

Table 4.1. Los Angeles and Long Beach Circulation Survey Raw Data Inventory.

Directory Name	Number of Files	Data Period	Data Description	Data Quality
LABSP1	54	1983	Aanderaa Current Meter	OK
LABSP2	24	1983	Aanderaa Current Meter	OK

CT/Current Data

The salinity and temperature and current data inventoried in Table 4.2 were contained in two directories: labsp1 and labsp2. The data files in these directories (FILE1 through FILEn) were concatenated to create cumulative data files: such as file_la1 and file_la2. The data in each individual data file (FILE1 through FILEn) represent current and CT data at one specific station location, over a given time period. It should be noted that since the focus was on data for model validation and harmonic analysis, only stations with record lengths of 15 days or greater were considered. In general, data quality was sufficient, such that no editing was performed.

The datasets are described in Tables 4.3 and Table 4.4, respectively, in terms of station location, measurement and station depths and measurement dates and durations. Note in these tables the station depths are estimated with respect to MLLW from Nautical Chart 18751, 46th Edition and from Nautical Chart Number 18749, 43rd Edition. Note Station C-22 in Table 4.3 is located on land based on the nautical chart. Stations locations are shown in Figure 4.1 for both datasets.

Table 4.2. Los Angeles and Long Beach Circulation Survey Processed Data File Inventory.

Data Type	Location	Filename
CT/Current Raw	~/LABSP1/ ~/LABSP2/	FILE1 – FILE54, FILE1 – FILE24
CT/Current Edited	~/labsp1/ ~/labsp2/	file_la1 file_la2
CT/Current Qc	~/qc/	file_la1.qc file_la2.qc

~ = /disks/NASUSER/philr/westcoast/la

Table 4.3. Los Angeles and Long Beach Dataset 1.

Station No.	Latitude (°N)	Longitude (°W)	M-Depth (ft)	S-Depth (ft)	Measurement Dates mm/dd/yr		Data Length Days	Data Quality STAD
C-13	33.717	118.176	5	61	6/ 1/83	6/17/83	15.88	
C-13	33.717	118.176	35	61	6/ 1/83	6/17/83	15.92	x
C-13	33.717	118.176	45	61	6/ 1/83	6/17/83	15.93	x
C-12	33.699	118.244	40	84	6/ 1/83	6/17/83	15.87	
C-12	33.699	118.244	30	84	6/ 1/83	6/17/83	15.87	
C-20	33.727	118.225	25	47	6/ 2/83	6/20/83	17.91	x
C-20	33.727	118.225	5	47	6/ 2/83	6/20/83	17.91	x
C-12	33.699	118.244	5	84	6/ 1/83	6/17/83	15.81	
C-22	33.726	118.254	5	n/a	6/ 1/83	6/17/83	16.01	
C-30	33.734	118.153	35	43	6/ 1/83	6/17/83	15.76	
C-30	33.734	118.153	5	43	6/ 1/83	6/17/83	15.76	
C-19	33.718	118.230	35	45	6/ 1/83	6/22/83	20.90	
C-19	33.718	118.230	25	45	6/ 1/83	6/22/83	20.89	
C-19	33.718	118.230	5	45	6/ 6/83	6/22/83	15.77	
C-23	33.712	118.245	5	65	6/15/83	7/ 1/83	16.06	
C-23	33.712	118.245	37	65	6/15/83	7/ 1/83	16.06	x
C-25	33.727	118.194	53	65	6/15/83	7/ 2/83	16.21	x
C-25	33.727	118.194	43	65	6/15/83	7/ 2/83	16.22	x
C-25	33.727	118.194	5	65	6/15/83	7/ 1/83	15.78	x
C-21	33.717	118.268	5	53	6/16/83	7/ 5/83	18.96	
C-33	33.763	118.220	28	45	6/15/83	7/ 5/83	19.83	x
C-35	33.763	118.252	32	44	6/16/83	7/ 5/83	18.96	
C-25	33.727	118.194	53	65	7/ 2/83	7/18/83	16.69	xx
C-25	33.727	118.194	43	65	7/ 2/83	7/18/83	16.69	xx
C-25	33.727	118.194	5	65	7/ 1/83	7/18/83	17.01	x
C-26	33.740	118.211	48	85	6/30/83	7/18/83	17.90	
C-26	33.740	118.211	5	85	6/30/83	7/18/83	17.90	
C-15	33.719	118.108	26	35	7/14/83	8/ 2/83	19.12	x
C-12	33.699	118.244	40	84	7/15/83	8/ 2/83	18.17	
C-12	33.699	118.244	30	84	7/15/83	8/ 2/83	18.17	
C-12	33.699	118.244	5	84	7/15/83	8/ 2/83	18.21	x x
C-14	33.719	118.126	5	45	7/15/83	8/ 2/83	18.05	x
C-13	33.717	118.176	45	61	7/15/83	8/ 2/83	17.93	x
C-13	33.717	118.176	35	61	7/15/83	8/ 2/83	17.94	x
C-13	33.717	118.176	5	61	7/15/83	8/ 2/83	17.98	x
C-24	33.737	118.193	25	53	7/14/83	8/ 3/83	20.03	x
C-23	33.712	118.245	37	65	7/15/83	8/ 3/83	18.93	
C-23	33.712	118.245	5	65	7/15/83	8/ 3/83	18.94	

Notes: M-Depth=measurement depth with respect to MLLW, where positive numbers are distance above the bottom and negative numbers are distance below the surface. S-Depth=station depth with respect to MLLW. Note x denotes bad data within the STAD station matrix where S=salinity, T=temperature, A=current speed, and D=current direction.

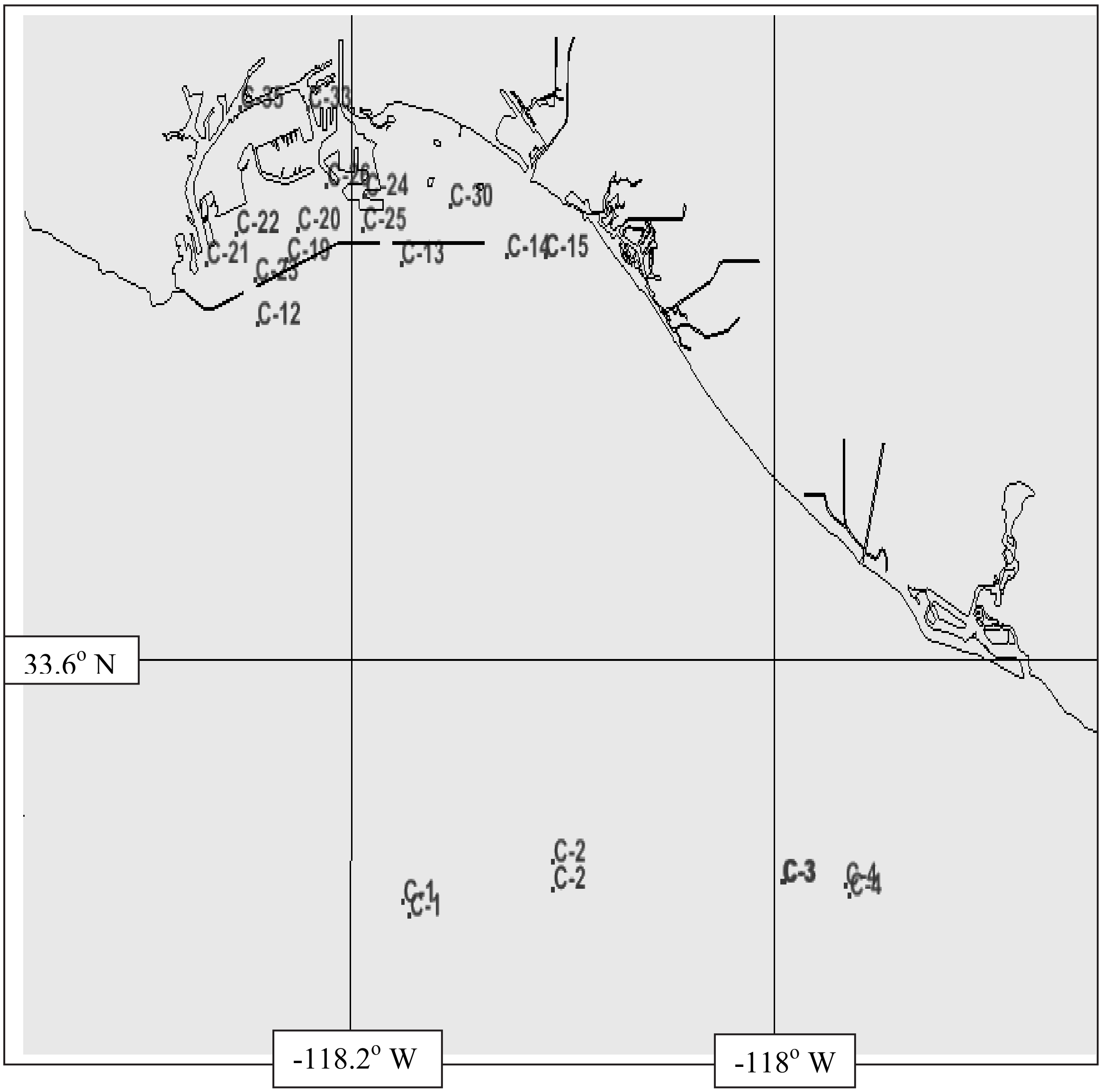


Figure 4.1. Station Locations for Los Angeles and Long Beach Datasets 1 and 2.

Table 4.4. Los Angeles and Long Beach Dataset 2.

Station No.	Latitude (°N)	Longitude (°W)	M-Depth (ft)	S-Depth (ft)	Measurement Dates mm/dd/yr		Data Length Days	Data Quality STAD
C-1	33.524	118.172	328	1200	5/31/83	8/ 1/83	61.94	x
C-1	33.524	118.172	164	1200	5/31/83	8/ 1/83	61.94	x
C-3	33.534	117.996	164	1200	5/31/83	8/ 1/83	61.90	
C-1	33.524	118.172	492	1200	5/31/83	8/ 1/83	61.92	x
C-2	33.532	118.104	492	1230	5/31/83	8/ 1/83	61.92	
C-2	33.532	118.104	328	1230	5/31/83	8/ 1/83	61.92	
C-3	33.534	117.996	492	1200	5/31/83	8/ 1/83	61.90	
C-3	33.534	117.996	17	1200	5/31/83	8/ 1/83	61.90	x
C-4	33.530	117.964	492	1320	6/ 1/83	8/ 1/83	61.79	
C-5	33.533	117.840	492	1500	6/ 1/83	8/ 1/83	61.92	
C-5	33.533	117.840	328	1500	6/ 1/83	8/ 1/83	61.92	
C-4	33.530	117.964	164	1320	6/ 1/83	8/ 1/83	61.81	
C-1	33.528	118.175	492	1200	8/ 3/83	10/ 5/83	63.60	x
C-2	33.540	118.104	328	1230	8/ 4/83	10/ 4/83	60.98	
C-3	33.534	117.995	492	1200	8/ 3/83	10/ 4/83	61.94	
C-1	33.528	118.175	328	1200	8/ 3/83	10/ 5/83	63.60	
C-2	33.540	118.104	164	1230	8/ 4/83	10/ 4/83	60.96	
C-3	33.534	117.995	164	1200	8/ 3/83	10/ 4/83	61.94	
C-3	33.534	117.995	17	1200	8/ 3/83	10/ 4/83	61.94	x
C-4	33.533	117.966	492	1320	8/ 3/83	10/ 4/83	61.96	
C-4	33.533	117.966	164	1320	8/ 3/83	10/ 4/83	61.96	
C-5	33.536	117.842	492	1500	8/ 3/83	10/ 4/83	61.96	
C-5	33.536	117.842	328	1500	8/ 3/83	10/ 4/83	61.96	
C-5	33.536	117.842	164	1500	8/ 3/83	10/ 4/83	61.96	x

Notes: M-Depth=measurement depth with respect to MLLW, where positive numbers are distance above the bottom and negative numbers are distance below the surface. S-Depth=station depth with respect to MLLW. Note x denotes bad data within the STAD station matrix where S=salinity, T=temperature, A=current speed, and D=current direction.

Regional Oceanographic Characteristics

The Port of Los Angeles, also called Los Angeles Harbor, is a port complex that occupies 7,500 acres of land and 43 miles of waterfront. The port is located on San Pedro Bay, California, approximately 20 miles south of downtown. The Port of Los Angeles adjoins the separate Port of Long Beach. The two harbors share a common breakwater system. Ocean waters circulate into, out of, and between both harbors due to the tides and winds. Angel's Gate and Queen's Gate are the two major entrances to the harbors, in addition to an opening at the eastern end.

The basic feature of the wind pattern for the harbors is a land-sea breeze regime caused primarily by differential heating of water and land. In summer, this pattern is characterized by onshore winds from west to southwest during the day, peaking at about 20 mph. Typically, the daily duration of onshore winds is reduced when daily air temperatures cool in fall and winter seasons. Winter winds are characterized by strong winds from the southeast and north-northwest, associated with approaching and passing of a front. Northwest winds are intensified for several days after passage of a front, with sustained winds of up to 20 knots.

Here we examine CT/Current time series in July 1983 at Station C-15 at the eastern entrance at 26 ft above the bottom. For salinity and temperature time series in Figure 4.2, there is some high frequency content, which may need filtering. In Figure 4.3 peak current speeds are order 40 cm/s with some breakdown in the rectilinear current structure. We next examine three levels of response during June 1983 at Station C-1 outside the harbor on the near shelf. In Figure 4.4 for C-1 at 164 ft above the bottom, the salinity is above 35 PSU, while the temperature exhibits some jumps between 8.5 and 10 ^{o}C, which may be associated with bio-fouling. Peak currents are on the order 40 cm/s with some interruption of rectilinear direction behavior as shown in Figure 4.5. At Station C-1 at 328 ft above the bottom shown in Figure 4.6, the salinity is below 35 PSU with the temperature time series warmer by about 1 ^{o}C from the lower measurement level. Current time series shown in Figure 4.7 exhibit peak speeds of 45 cm/s with interruptions in rectilinear directions. For Station C-1 at 492 ft above the bottom no salinity data are available and temperature is elevated by 1 ^{o}C from the next lowest measurement level as shown in Figure 4.8. In Figure 4.9, the peak current speeds are slightly elevated to near 50 cm/s with interruptions in rectilinear direction behavior.

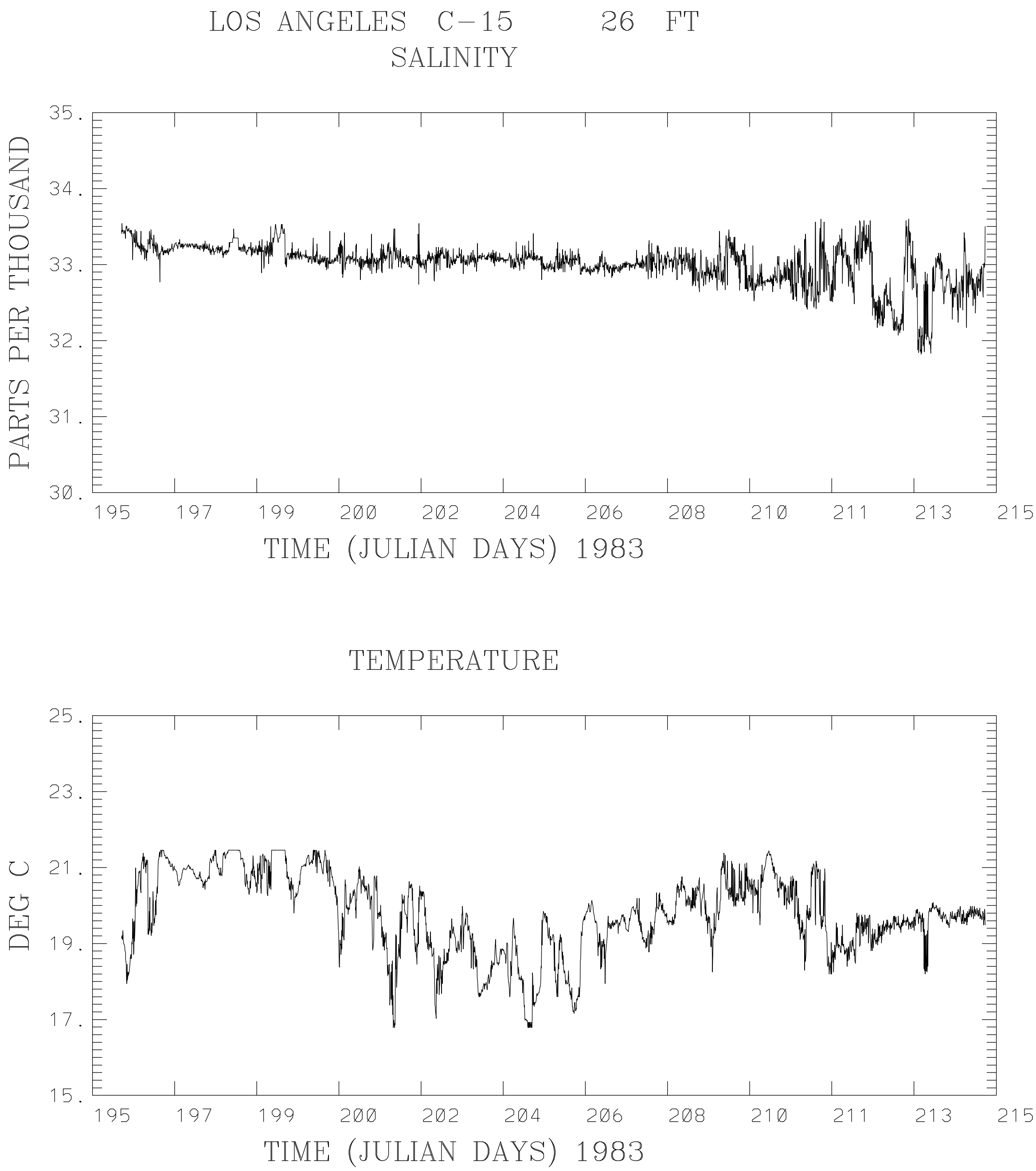


Figure 4.2. Station C-15 Los Angeles and Long Beach Salinity and Temperature at 26 ft above the bottom in July 1983.

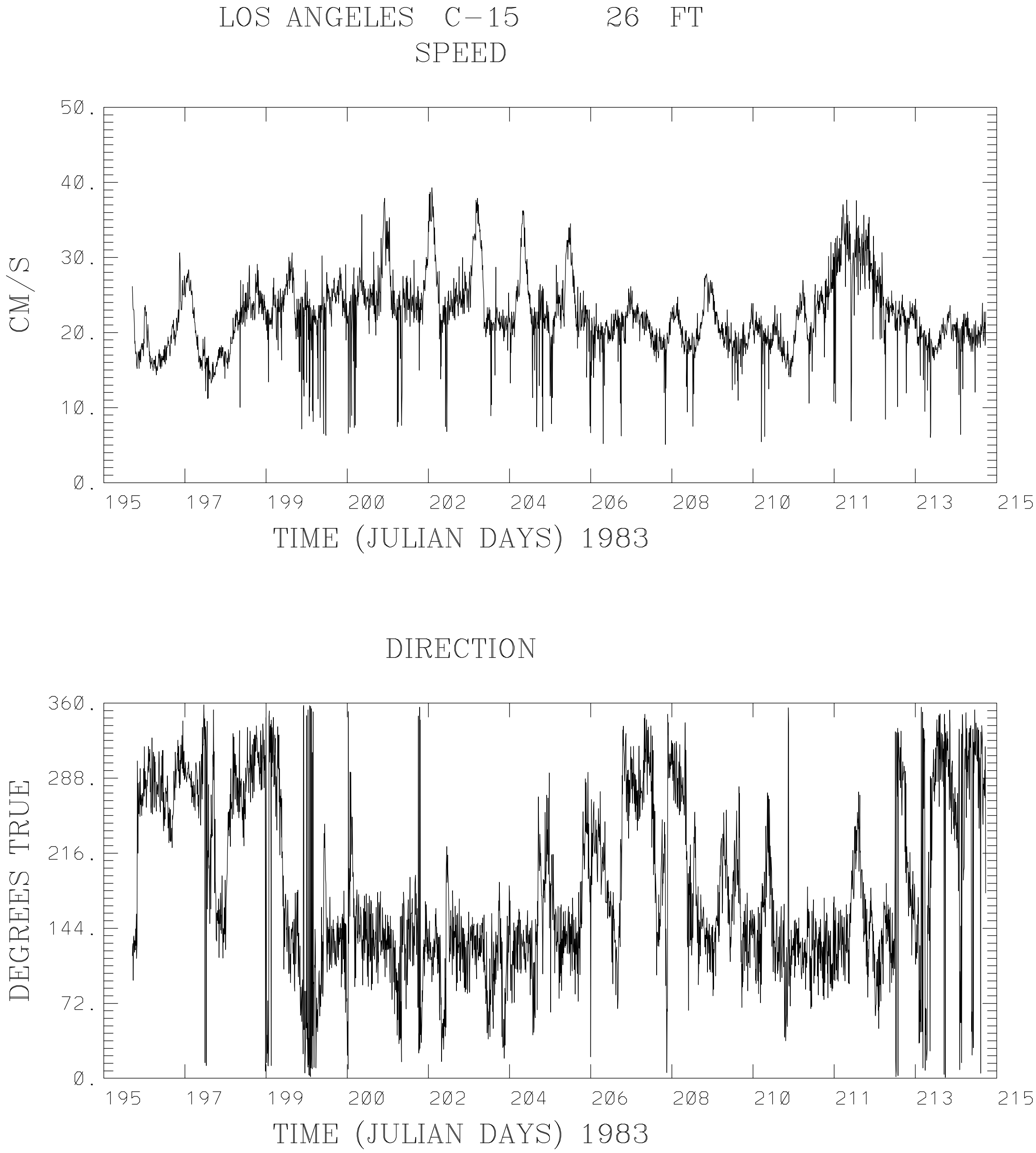


Figure 4.3. Station C-15 Los Angeles and Long Beach Current Speed and Direction at 26 ft above the bottom in July 1983.

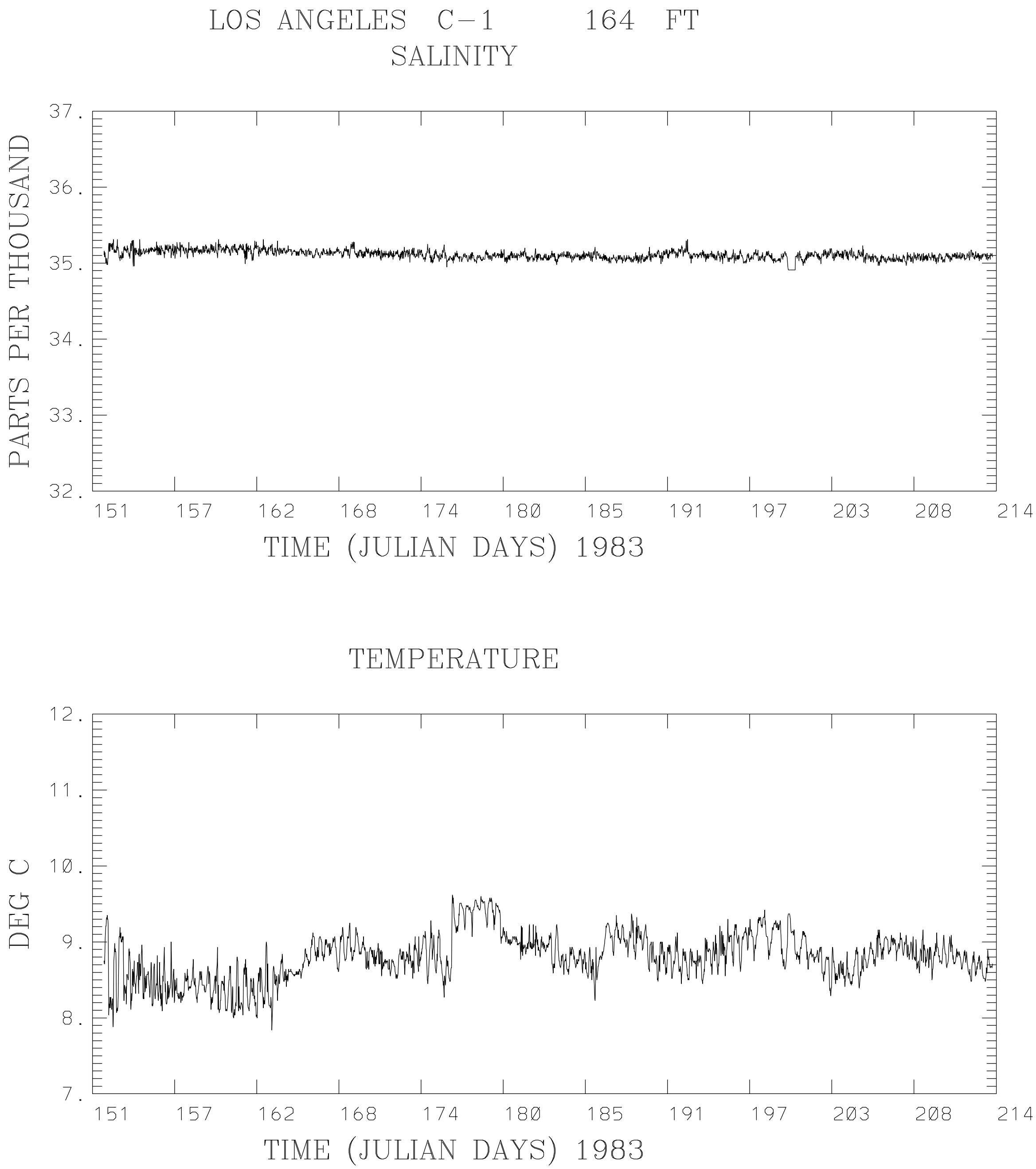


Figure 4.4. Station C-1 Los Angeles and Long Beach Salinity and Temperature at 164 ft above the bottom in June 1983.

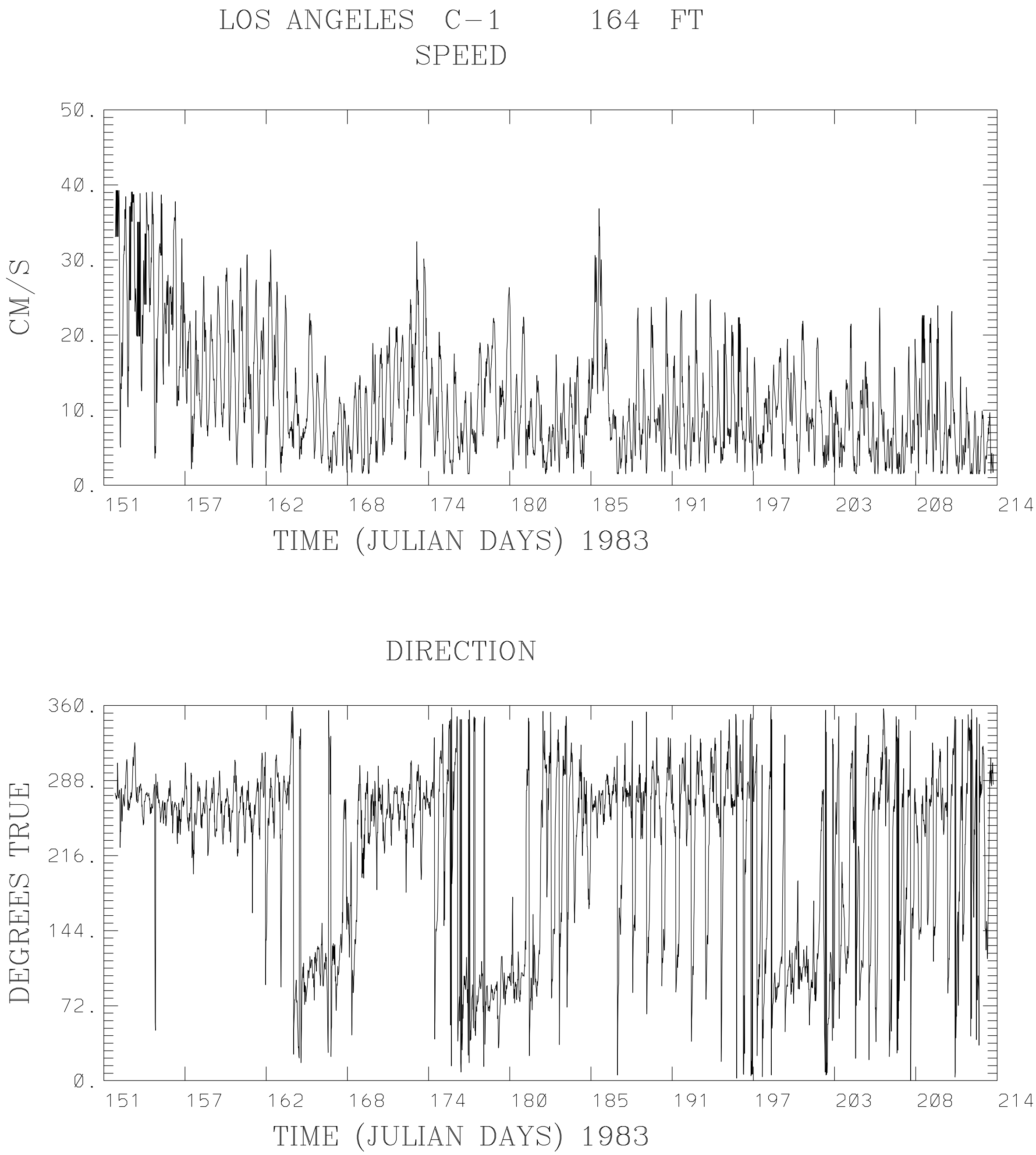


Figure 4.5. Station C-1 Los Angeles and Long Beach Current Speed and Direction at 164 ft above the bottom in June 1983.

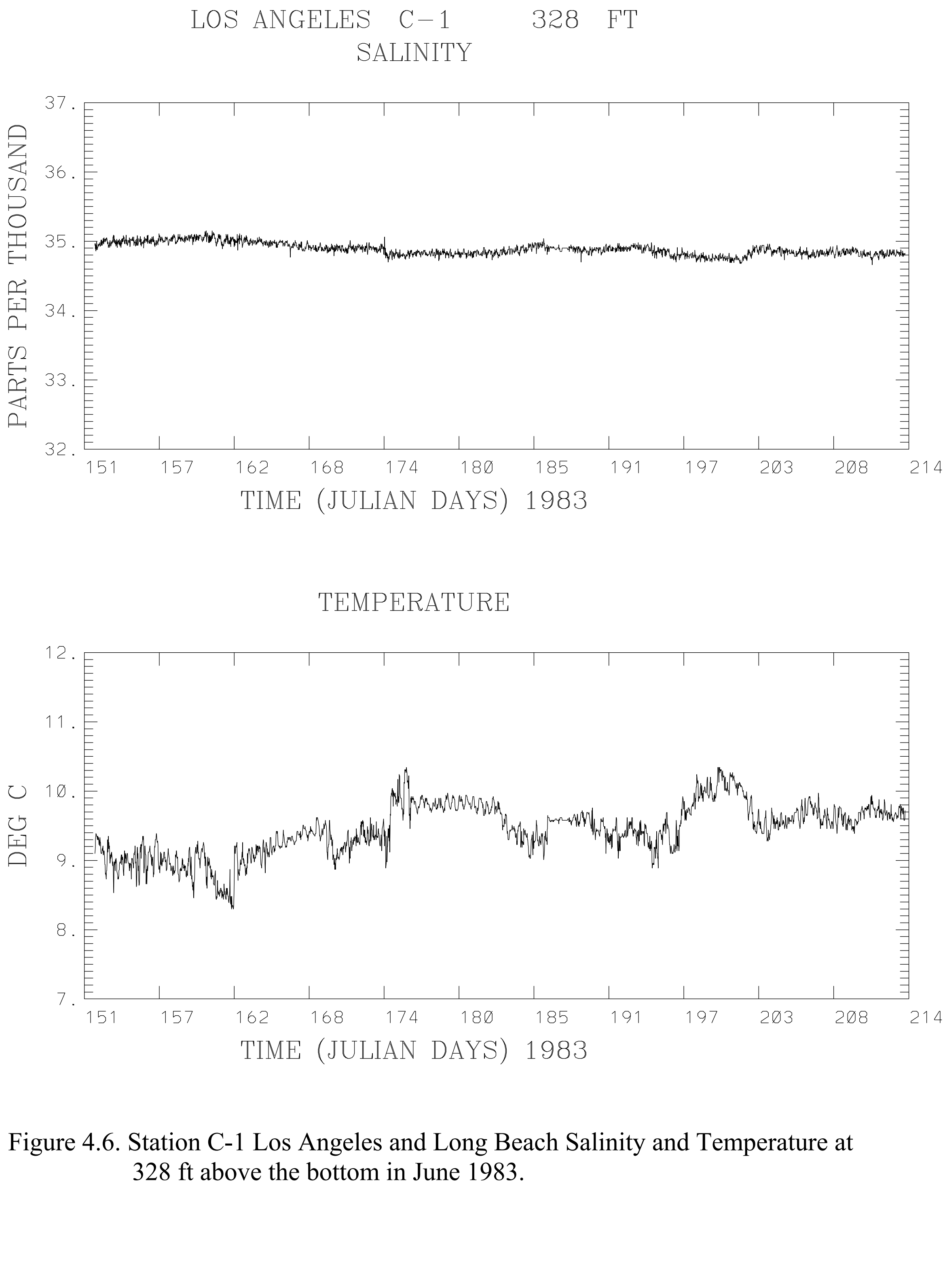


Figure 4.6. Station C-1 Los Angeles and Long Beach Salinity and Temperature at 328 ft above the bottom in June 1983.

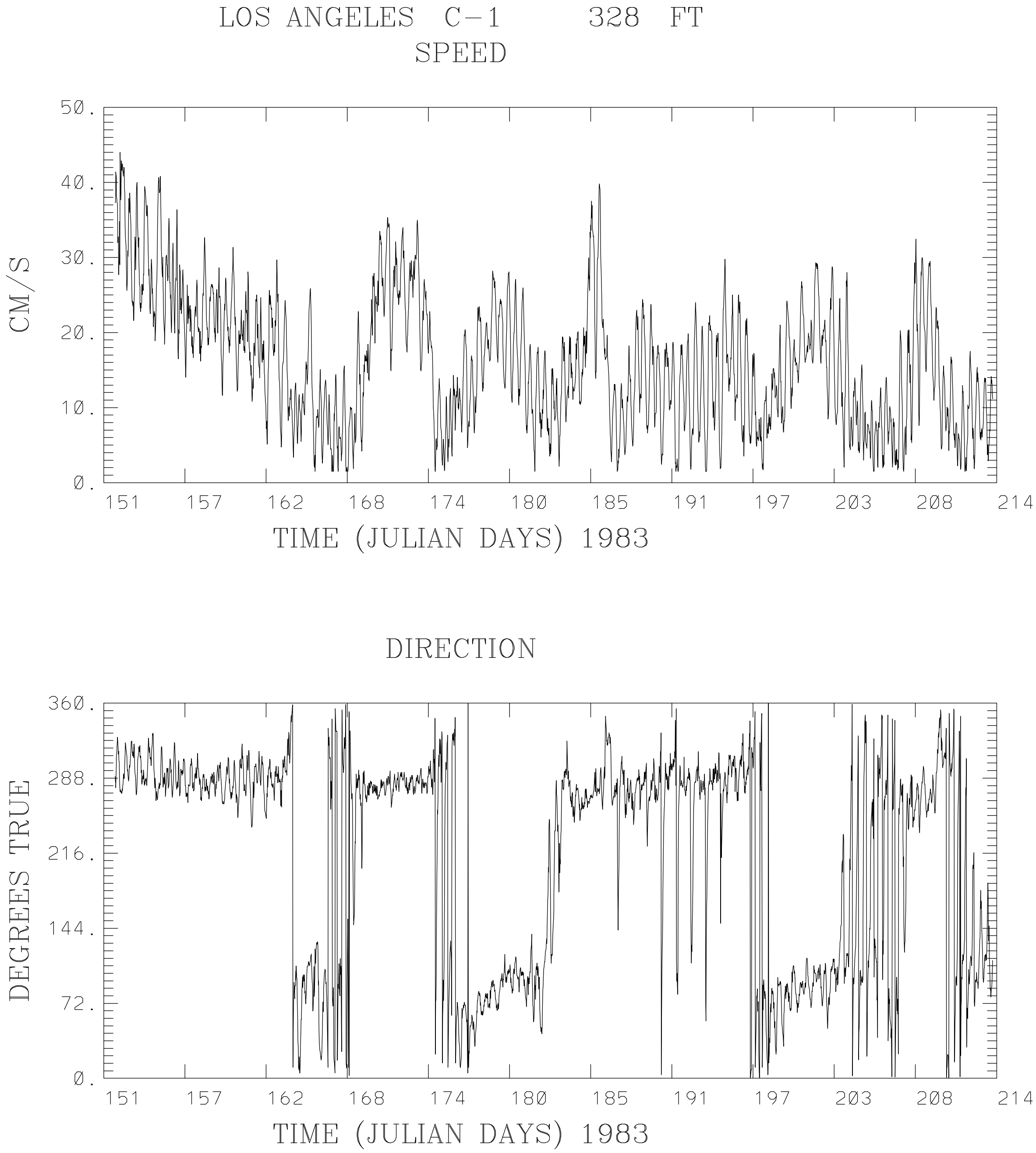


Figure 4.7. Station C-1 Los Angeles and Long Beach Current Speed and Direction at 328 ft above the bottom in June 1983.

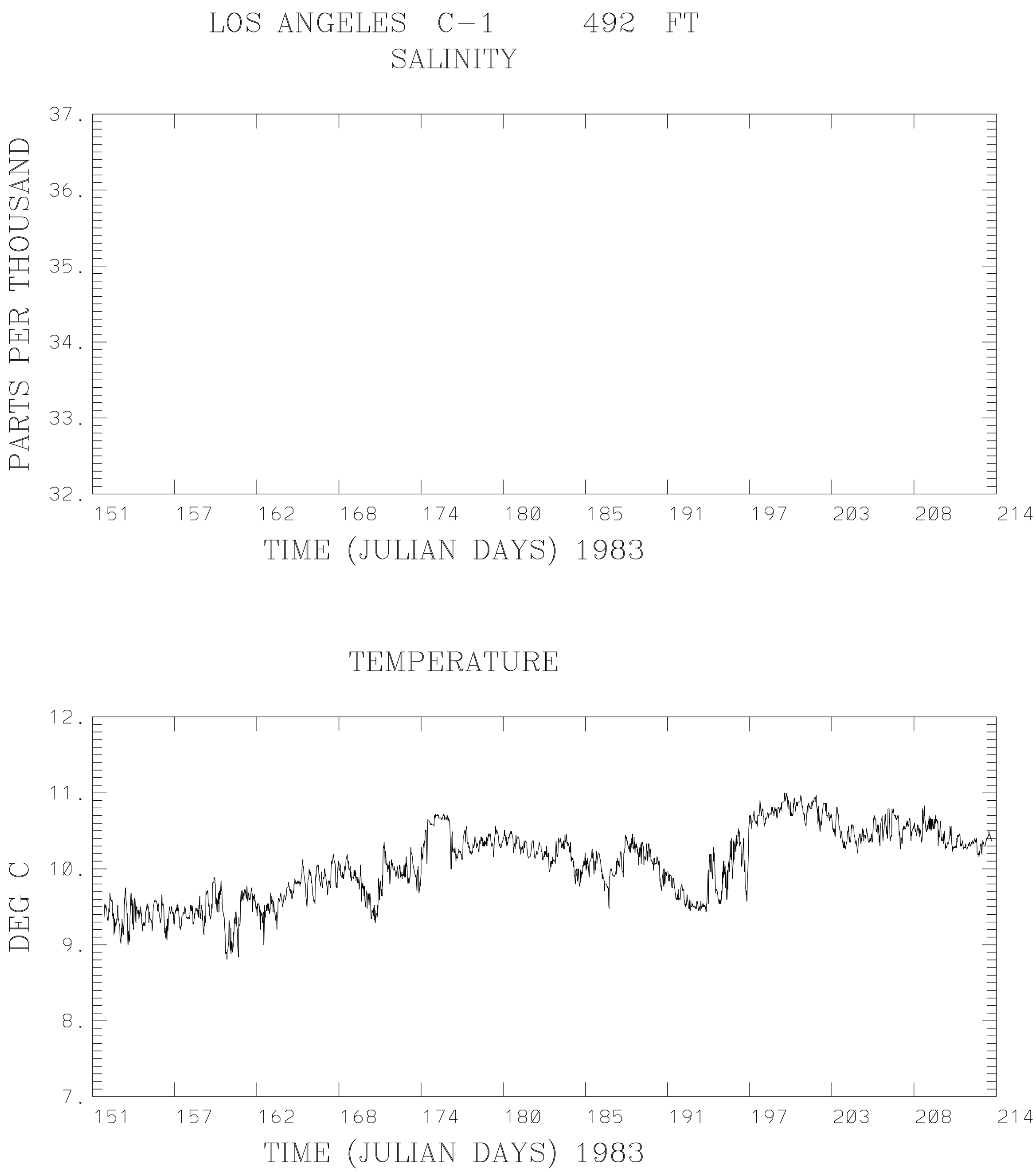


Figure 4.8. Station C-1 Los Angeles and Long Beach Salinity and Temperature at 492 ft above the bottom in June 1983. Note no salinity data are available.

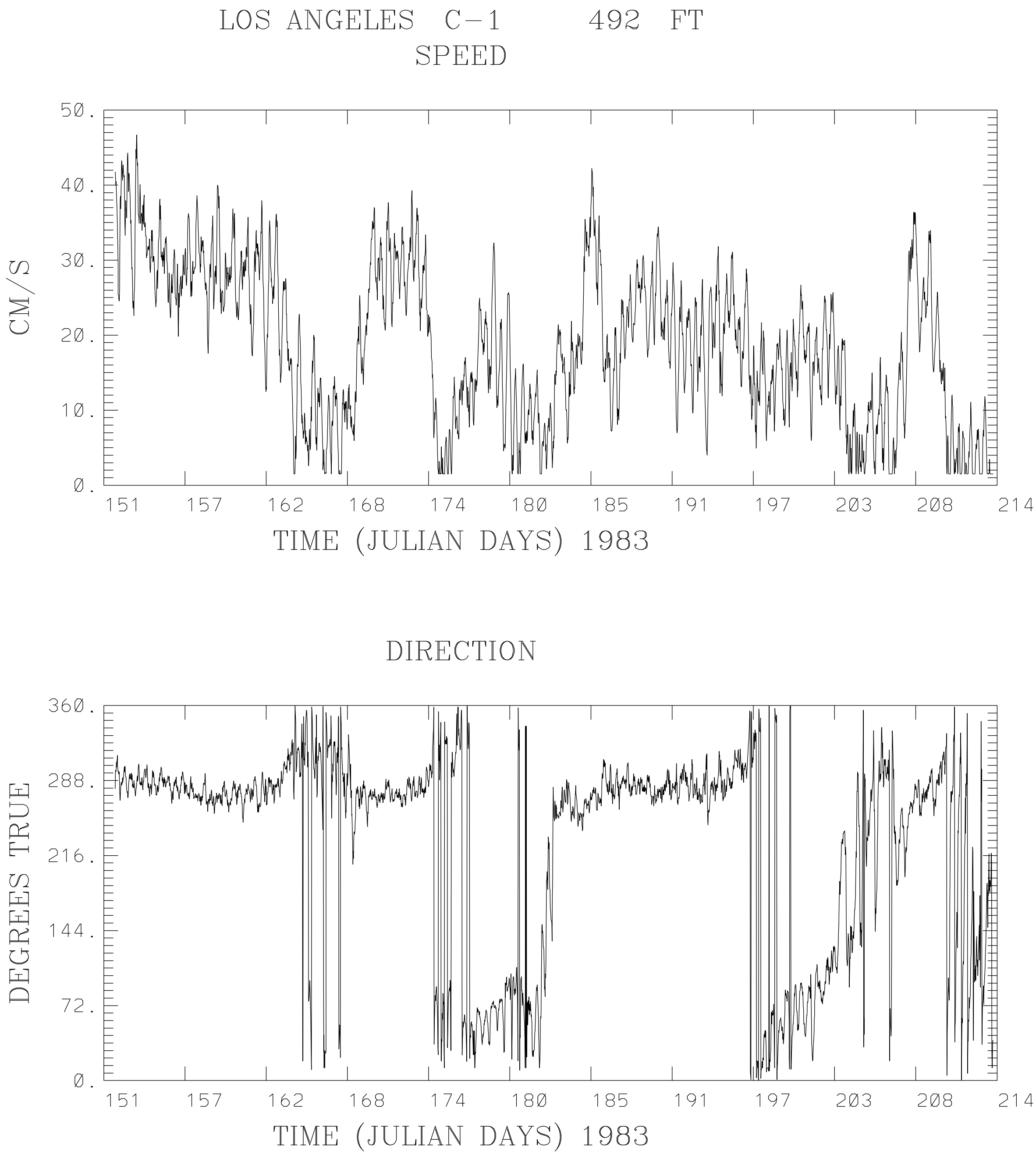


Figure 4.9. Station C-1 Los Angeles and Long Beach Current Speed and Direction at 492 ft above the bottom in June 1983.

5. SAN DIEGO

NOS performed a survey in 1983 to study the circulation in San Diego Bay, California. The Aanderaa Model RCM-4 current meter recorded and measured current speed and direction and included temperature and conductivity and pressure sensors. Here, we summarize the recovered data and discuss related regional oceanographic characteristics.

Data Inventory and Summary

The datasets obtained from CO-OPS on compact disc are listed in Table 5.1 and constitute the recoverable data. It was necessary to carefully inventory these datasets and determine their data quality. Note neither meteorological data (wind speed and direction, and sea level atmospheric pressure) nor CTD profile data were available.

Table 5.1. San Diego Circulation Survey Raw Data Inventory.

Directory Name	Number of Files	Data Period	Data Description	Data Quality
SANDIEGO1	27	1983	Aanderaa Current Meter	OK

CT/Current Data

The salinity and temperature and current data inventoried in Table 5.2 were distributed in one directory: Sandiego1. These data files (FILE1 through FILEn) were concatenated to create a cumulative data file: file_sandiego. The data in each individual data file (FILE1 through FILEn) represent current and CT data at one specific station location over a given time period. It should be noted that since the focus was on data for model validation and harmonic analysis, only stations with record lengths of 15 days or greater were considered. In general, data quality was sufficient, such that no editing was performed. Station locations in sandiego1 are shown in Figure 5.1.

Table 5.2. San Diego Circulation Survey Processed Data File Inventory.

Data Type	Location	Filename
CT/Current Raw	~/SANDIEGO1/	FILE1 – FILE27
CT/Current Edited	~/sandiego1/	file_sandiego
CT/Current Qc	~/qc/	file_sand.qc

~ = /disks/NASUSER/philr/westcoast/sandiego1

Dataset 1 is described in Table 5.3, in terms of station location, measurement and station depths and measurement dates and durations. Station depths with respect to MLLW are estimated from Nautical Chart 18773, 42nd Edition. Station locations are shown in Figure 5.1.

Table 5.3. San Diego Dataset 1.

Station No.	Latitude (°N)	Longitude (°W)	M-Depth (ft)	S-Depth (ft)	Measurement Dates mm/dd/yr		Data Length Days	Data Quality STAD
C-47	32.683	117.143	-14	36	8/22/83	9/12/83	20.87	
C-47	32.683	117.143	5	36	8/22/83	9/ 7/83	15.47	
C-39	32.696	117.232	-14	46	8/18/83	9/ 9/83	21.42	
C-43	32.722	117.178	-14	18	8/19/83	9/11/83	22.53	x
C-43	32.722	117.178	5	18	8/21/83	9/12/83	22.86	x
C-45	32.708	117.177	-14	41	8/19/83	9/ 7/83	18.30	
C-45	32.708	117.177	5	41	8/19/83	9/12/83	23.94	
C-38	32.684	117.232	5	46	9/ 6/83	9/26/83	20.01	x
C-40	32.713	117.213	-14	18	9/ 6/83	9/26/83	20.07	x
C-40	32.713	117.213	5	18	9/ 8/83	9/26/83	18.63	
C-46	32.698	117.164	-14	42	9/ 9/83	9/27/83	17.80	
C-46A	32.706	117.165	5	15	9/ 6/83	9/27/83	20.83	
C-50	32.645	117.123	-14	30	9/ 7/83	9/28/83	20.89	
C-48	32.675	117.149	5	12	8/22/83	9/25/83	33.42	
C-49	32.662	117.126	5	36	9/ 9/83	9/28/83	18.89	
C-37	32.666	117.226	23	31	8/18/83	9/ 8/83	20.55	
C-37	32.666	117.226	23	31	9/ 8/83	9/26/83	18.33	
C-37	32.666	117.226	5	31	8/18/83	9/ 5/83	17.55	
C-39	32.696	117.232	5	46	8/18/83	9/ 6/83	18.91	
C-44	32.717	117.176	5	34	8/19/83	9/ 8/83	19.52	
C-46	32.698	117.164	5	42	9/ 9/83	9/27/83	17.84	x
C-42	32.719	117.192	28	37	8/18/83	9/ 6/83	18.88	

Notes: M-Depth=measurement depth with respect to MLLW, where positive numbers are distance above the bottom and negative numbers are distance below the surface. S-Depth=station depth with respect to MLLW. Note x denotes bad data within the STAD station matrix where S=salinity, T=temperature, A=current speed, and D=current direction.

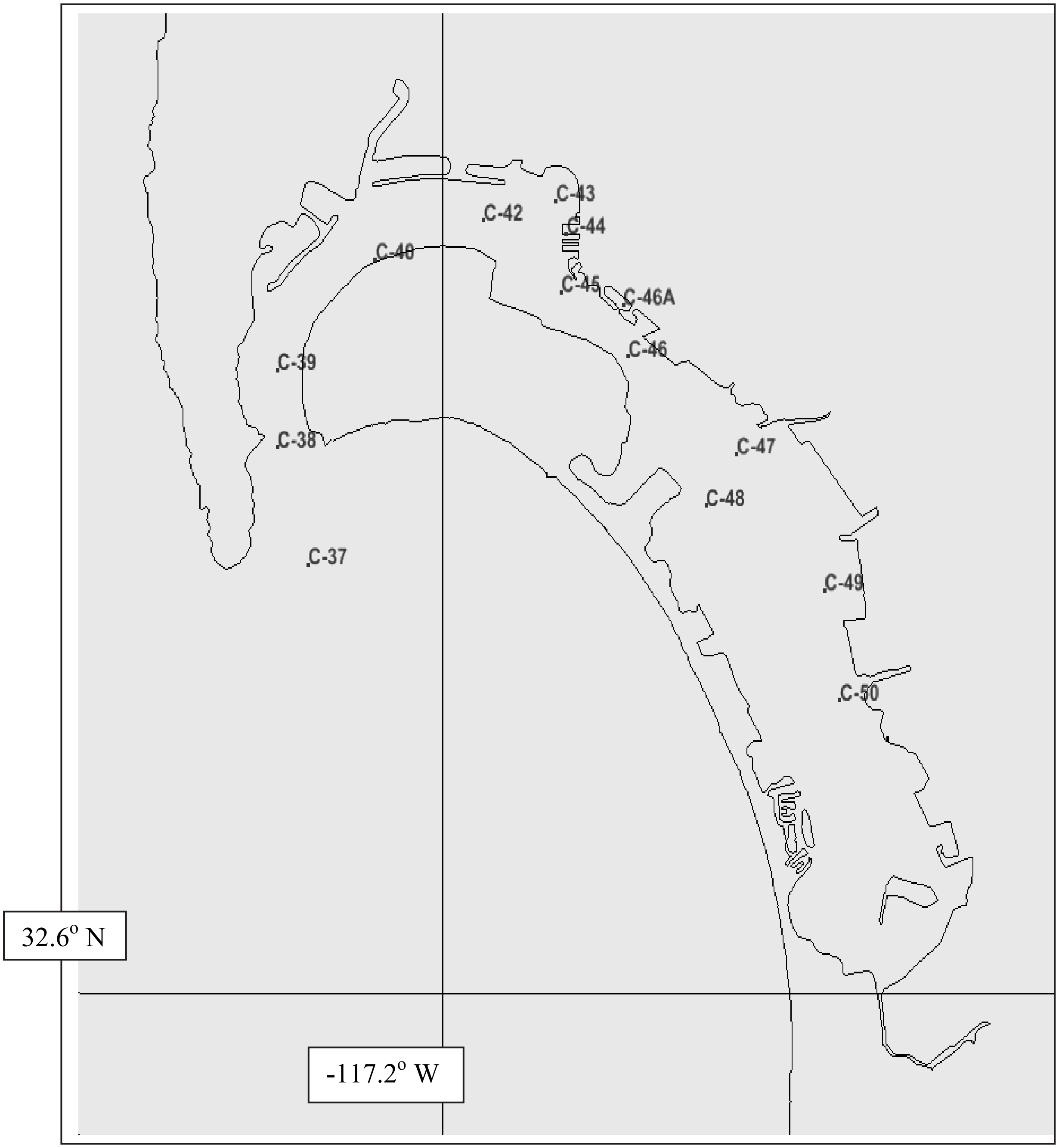


Figure 5.1. Station Locations for San Diego Dataset 1.

Regional Oceanographic Characteristics

San Diego Bay is a naturally formed, crescent-shaped embayment in the southwestern corner of California. The axial length of the Bay from the tip of Point Loma to the mouth of the Otay River is about 24.5 km. The outer half of the Bay is relatively narrow, averaging 1-2 km while the inner Bay is broader, between 2 and 4 km wide. This broad, shallow region lies south of the narrowest section of the Bay and is referred to as South Bay. The South Bay is mostly shallow (1-4 m deep) except along the northeastern shore where shipping channels have been dredged. The North Bay is relatively deep (on average 12 m). The mouth of the Bay is about 1 km wide and aligned north-south, between the rocky Point Loma and the constructed Zuniga Jetty. Immediately outside the Bay, there are shoals on either side of the approach channel.

The climate of San Diego is characterized as semi-arid, with an average annual rainfall of about 0.25 m. The period of winter rainfall extends from November through March. The summer rainfall is negligible. Evaporation exceeds precipitation during spring, summer, and fall. This is a seasonally arid environment, with hypersalinity being observed in South Bay every summer. Winds over the Bay and coastal regions are typically less than 10 knots. In summer, the wind over San Diego Bay exhibits a strong diurnal cycle. In winter, stronger winds are observed at times during the passage of a cold front associated with a propagating mid-latitude low pressure system. Mean air temperature for the region is 16.4^{o}C, with an annual range of only about 8^{o}C. Warmest temperatures are experienced during easterly Santa Ana winds. Coldest temperatures occur in clear winter nights.

Tides in San Diego are classified as mixed diurnal/semi-diurnal, with a dominant semi-diurnal component. The interaction of the lunar M2 and solar S2 tidal components results in a spring-neap cycle with a period of 14.3 days. The tidal range (difference between MLLW and MHHW) is about 1.7 m with extreme tidal ranges of 3 m. In general, currents are strongest near the mouth with the maximum velocities of 0.5-1.0 m/s and decrease towards the head of the Bay due to the reduction in upstream tidal prism volume. Currents are strong in the narrow region between North Bay and South Bay. In South Bay, currents speeds are typically less than 10 cm/s.

Thermal stratification is well developed in the waters off the mouth of San Diego Bay during summer and vertical temperature differences of about 10^{o}C are observed. In winter, vertical temperature differences are about 2^{o}C. The thermocline is typically found between 10 and 20 m, though weak in winter. Cold, deeper ocean water tends to move into the Bay on the flood tide.

Here we examine CT/Current time series in August 1983 at Station C-47 inside the Bay and at Station C-37 in September 1983 outside the Bay entrance. For salinity and temperature time series at 14 ft below the surface in Figure 5.2, there is a rapid decrease in salinity from Julian Day 244 through Julian Day 256, which needs further investigation. This may be associated with a storm event, which seems not likely during August or it could be due to bio-fouling. The temperature response is flat indicating a potential issue with the temperature sensor as well. In Figure 5.3, the peak current speeds are near 40 cm/s and are rectilinear. At C-47 at 5 ft above the bottom shown in Figure 5.4, there appears to be some high frequency content, which may need filtering in the salinity while the temperature signal appears nearly flat with some high frequency contamination. In Figure 5.5 at C-47 for currents 5 ft above the bottom, peak current speeds are reduced to near 20 cm/s with a slight change in flood direction from currents at 14 ft below the surface shown in Figure 5.3. At Station C-37 at 23 ft above the bottom, the salinity and temperature signals exhibit some bio-fouling as shown in Figure 5.6. In Figure 5.7, the peak currents at 23 ft above the bottom are near 60 cm/s and exhibit a predominant ebb/flood structure. At Station C-37 at 5 ft above the bottom the salinity is nearly constant at near 34 PSU, while the temperature exhibits temperature fluctuations between 2 and 4 ^{o}C at nearly 2 day intervals with some clipping as shown in Figure 5.8. In Figure 5.9 current speeds at C-37 at 5 ft above the bottom show a predominate ebb/flood structure with peak speeds of order 40 cm/s.

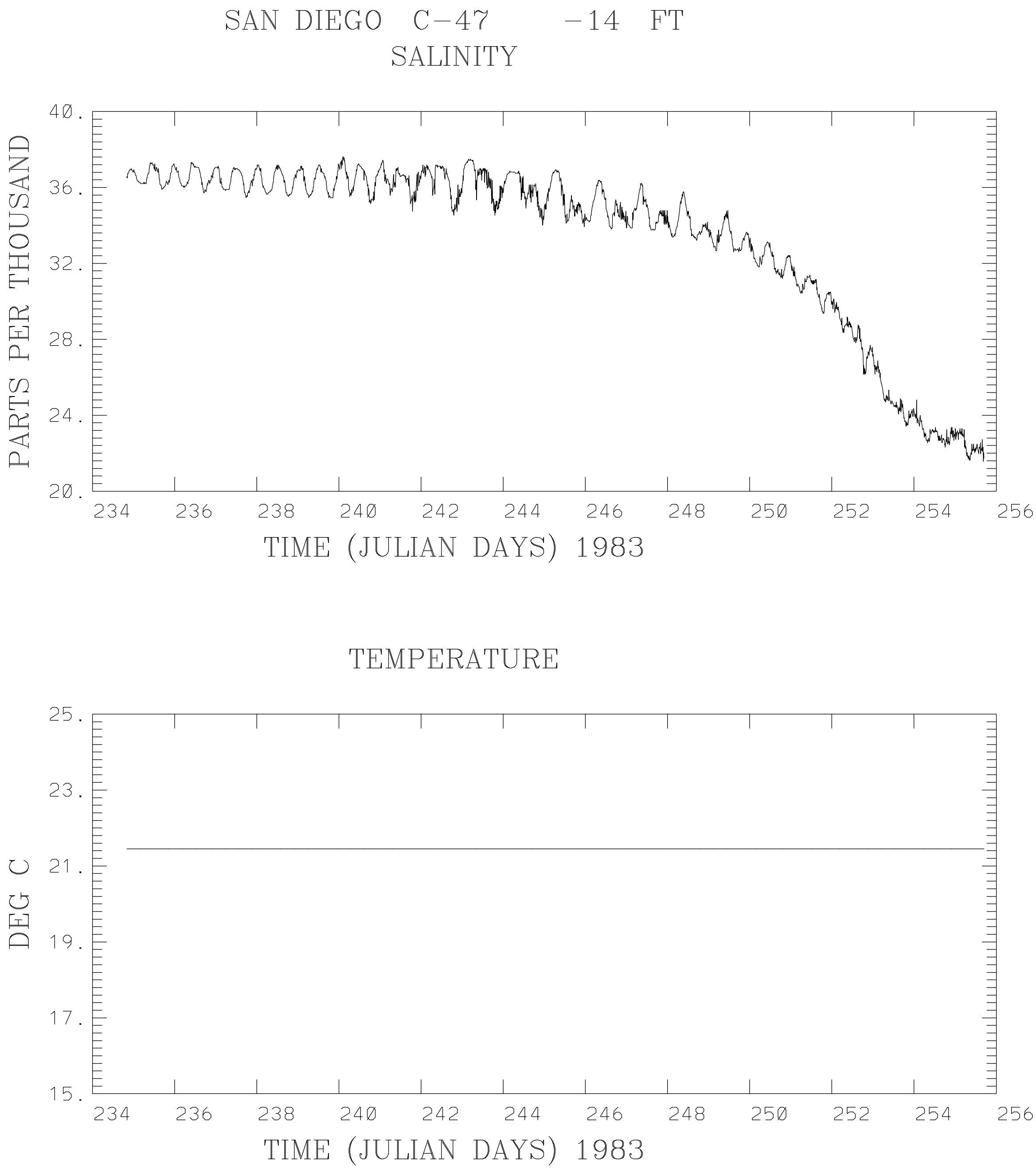


Figure 5.2. Station C-47 San Diego Salinity and Temperature at 14 ft below the surface in August 1983.

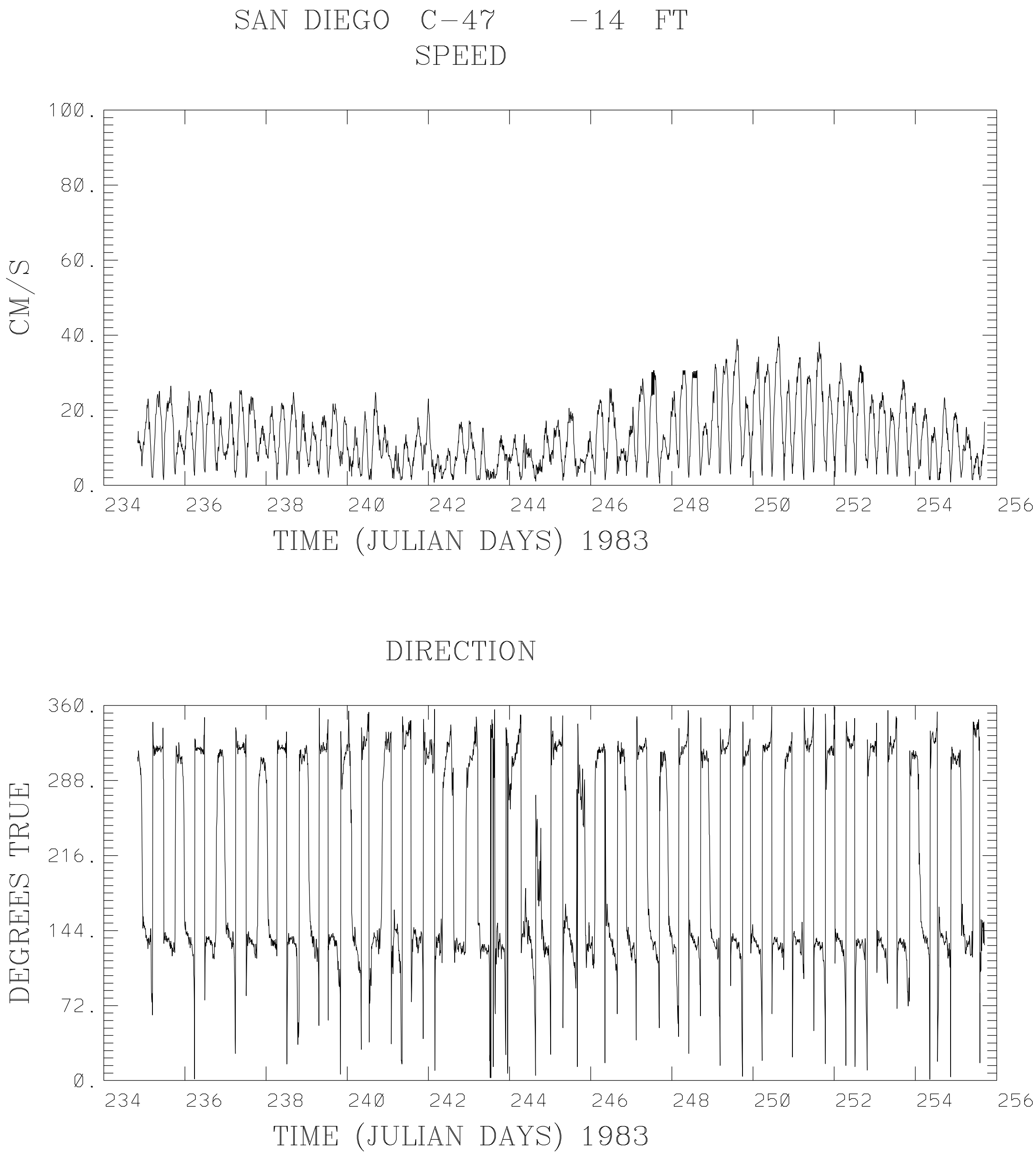


Figure 5.3. Station C-47 San Diego Current Speed and Direction at 14 ft below the surface in August 1983.

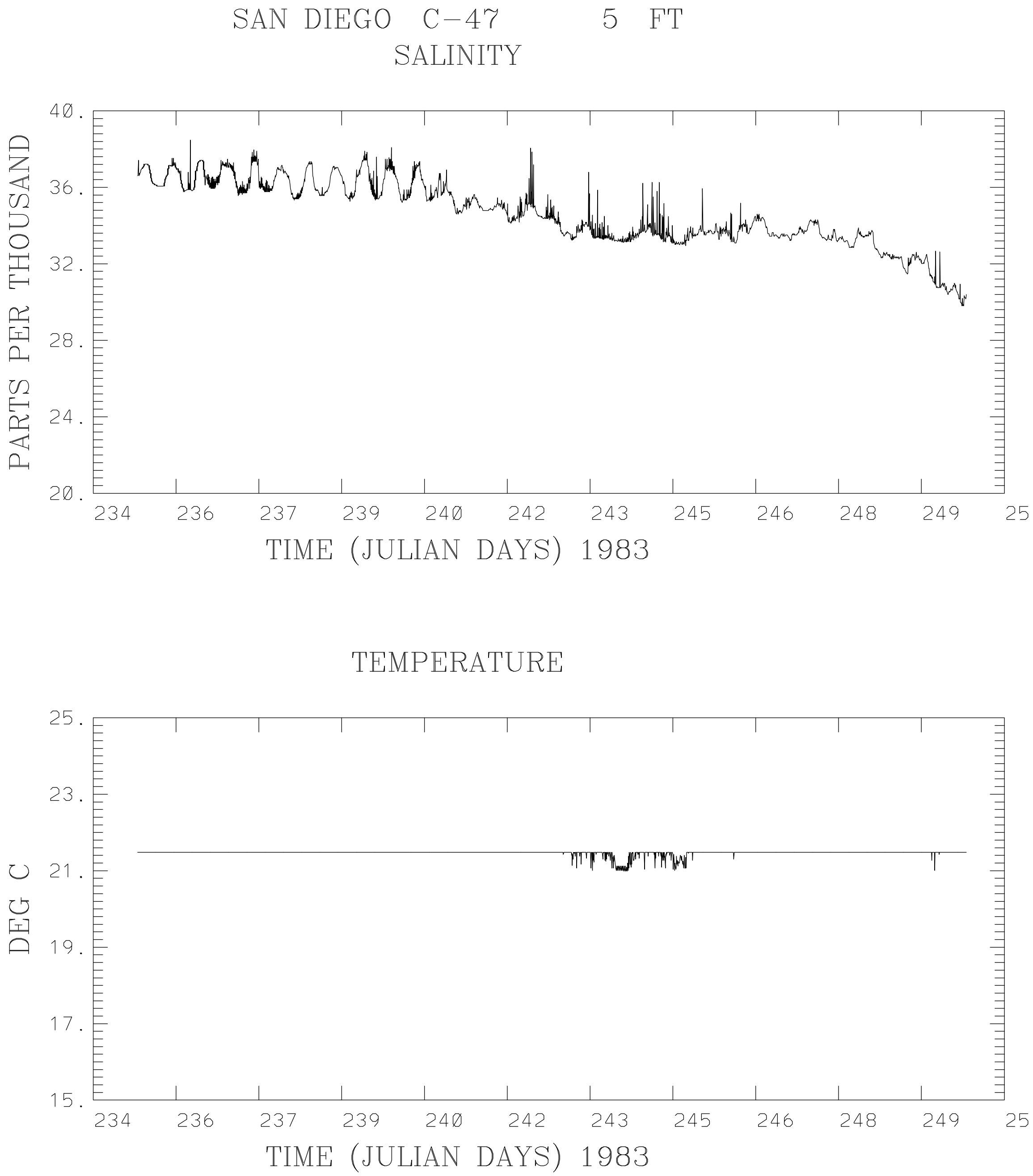


Figure 5.4. Station C-47 San Diego Salinity and Temperature at 5 ft above the bottom in August 1983.

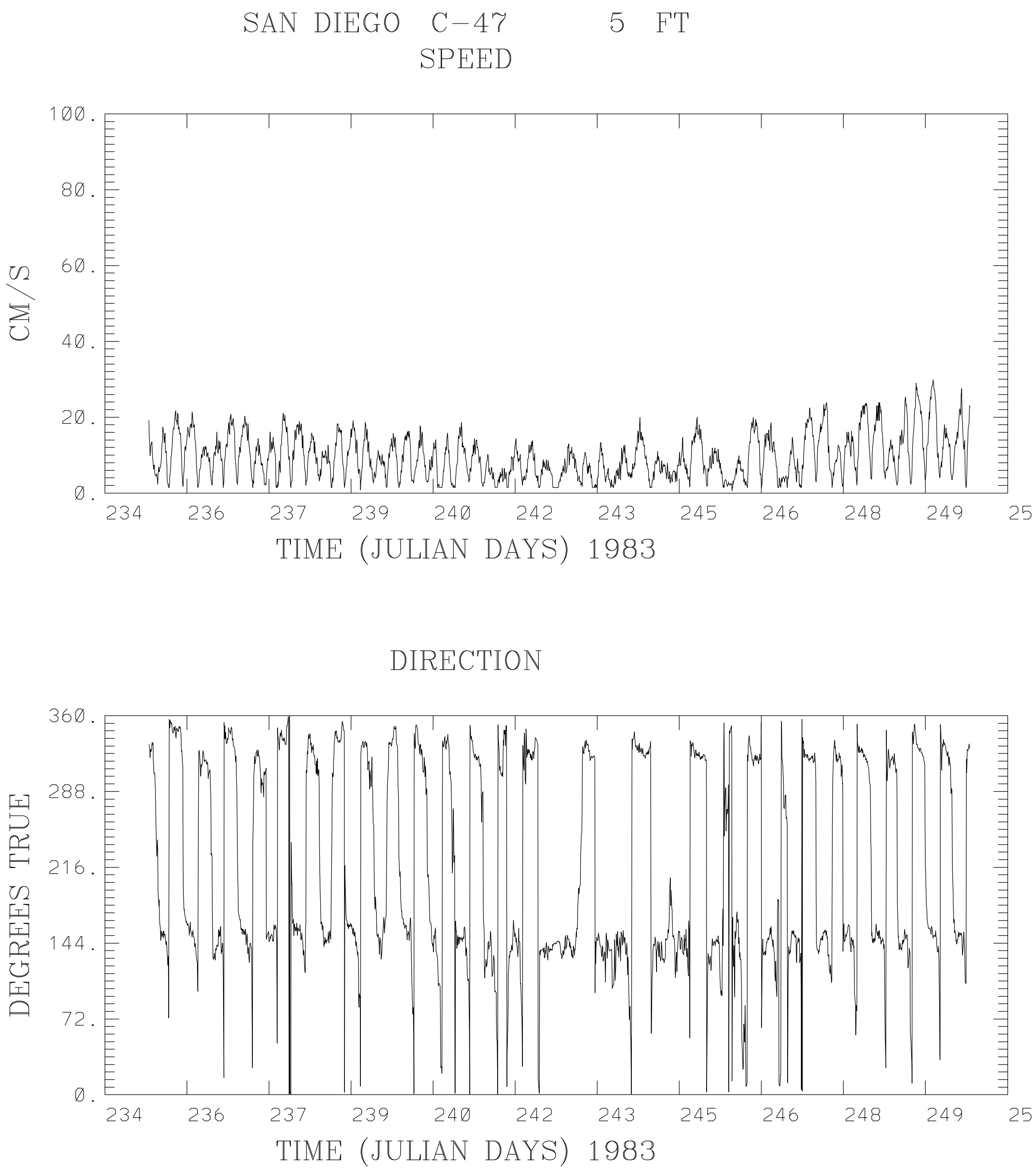


Figure 5.5. Station C-47 San Diego Current Speed and Direction at 5 ft above the bottom in August 1983.

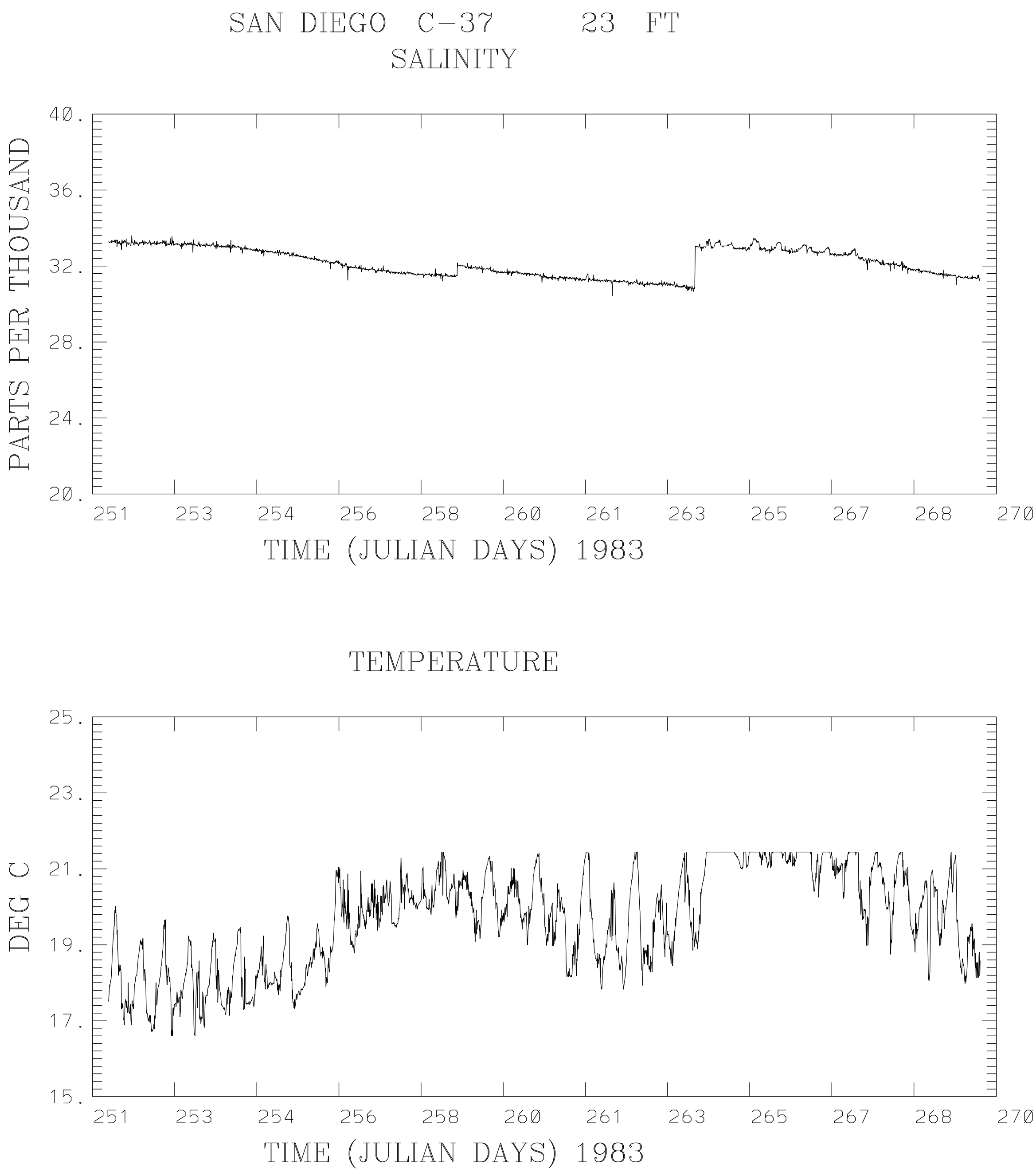


Figure 5.6. Station C-37 San Diego Salinity and Temperature at 23 ft above the bottom in September 1983.

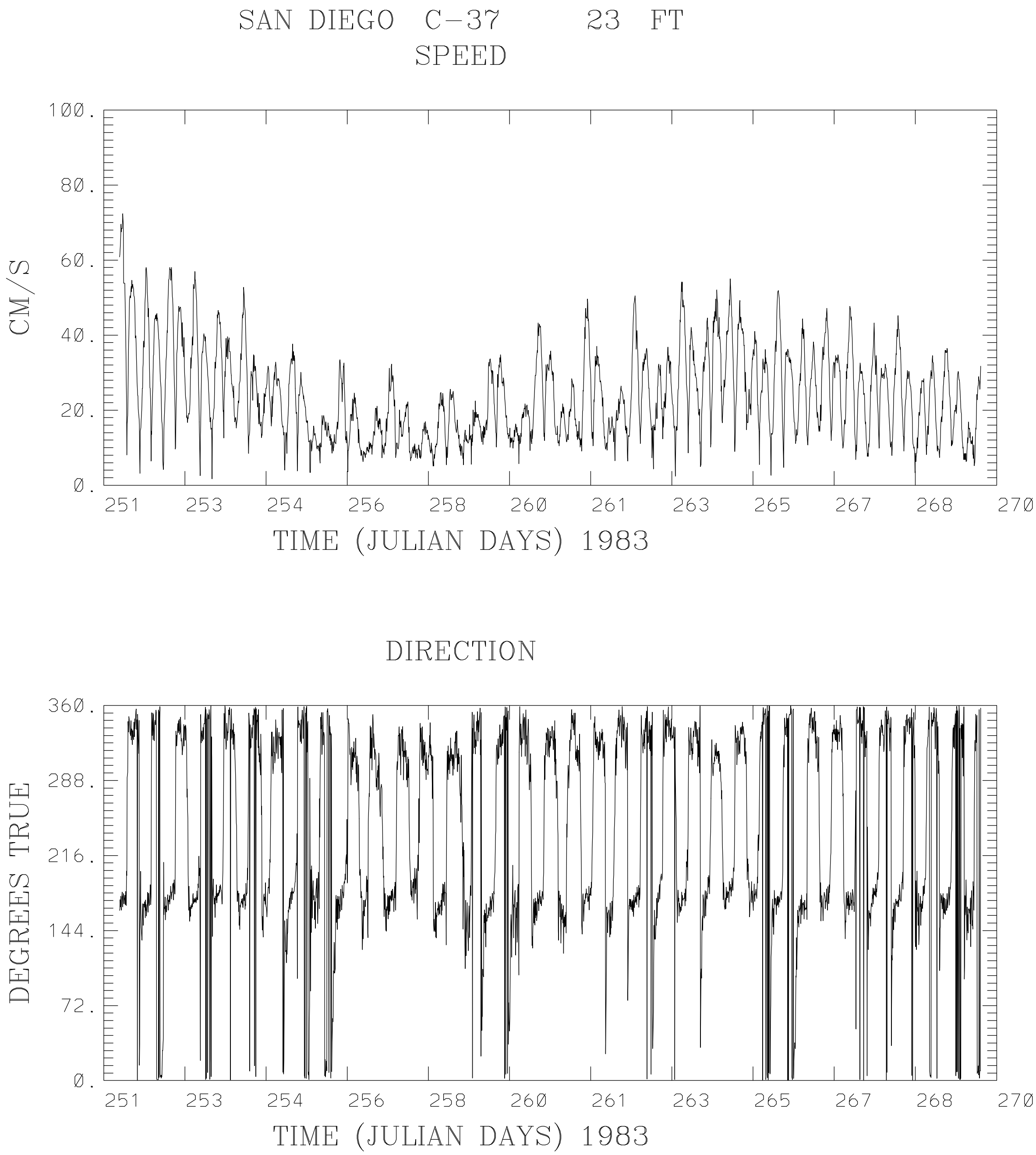
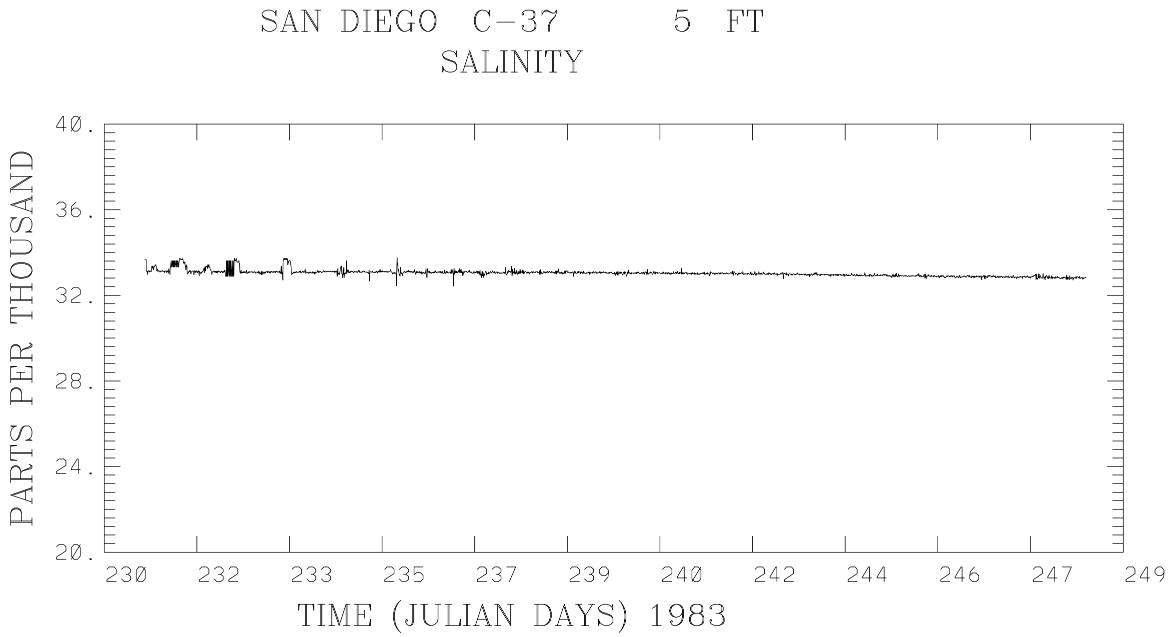


Figure 5.7. Station C-37 San Diego Current Speed and Direction at 23 ft above the bottom in September 1983.



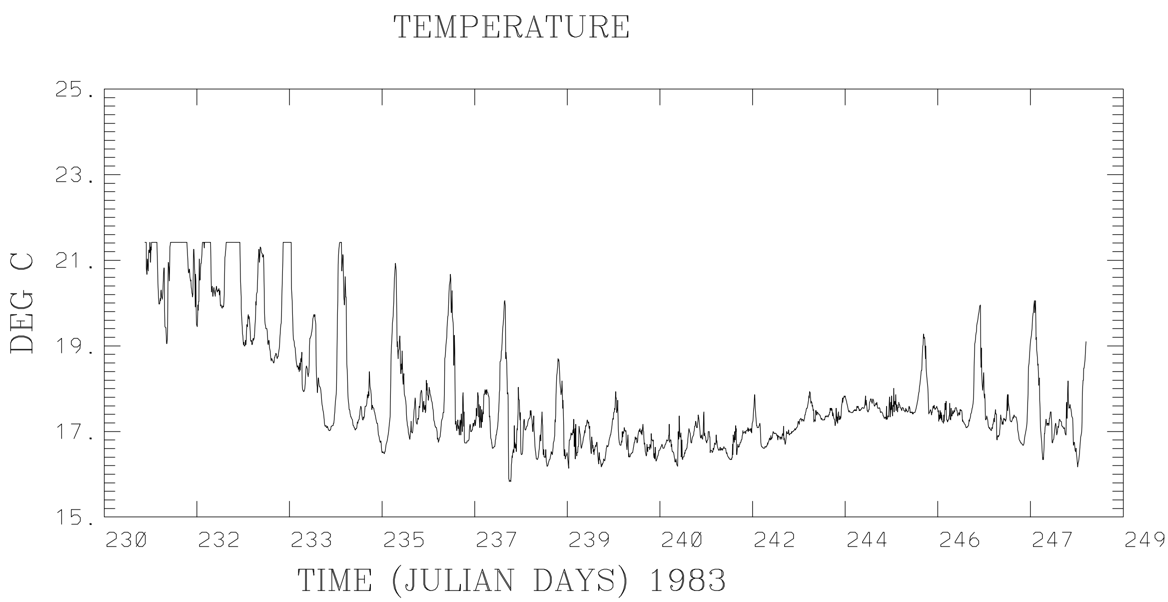


Figure 5.8. Station C-37 San Diego Salinity and Temperature at 5 ft above the bottom in September 1983.

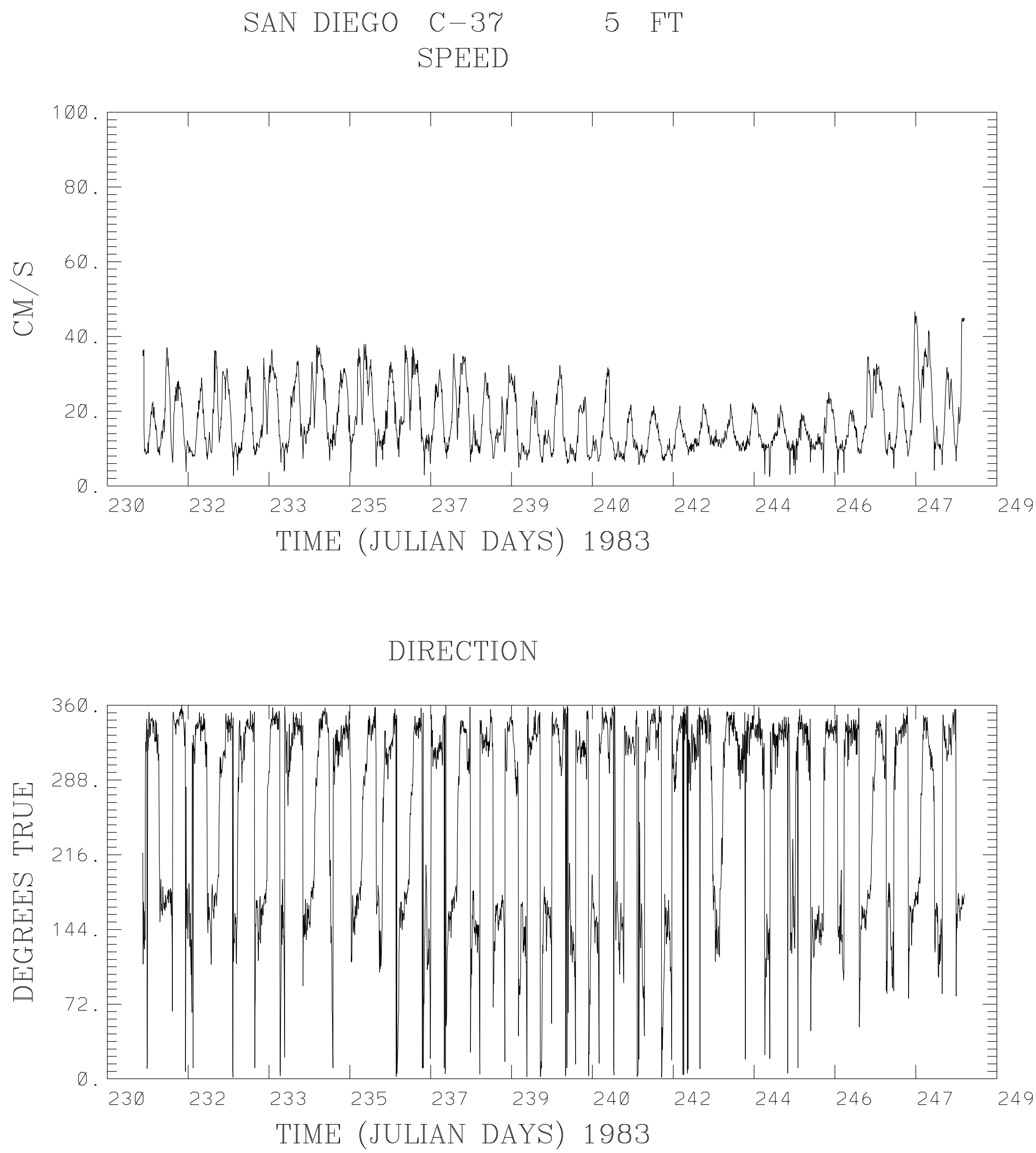


Figure 5.9. Station C-37 San Diego Current Speed and Direction at 5 ft above the bottom in September 1983.

6. MIAMI

NOS performed an intensive survey from April through June 1984 to study the circulation in coastal sections of Miami, Florida. The Ticus current meters were used to measure current speed and direction. No temperature and conductivity and pressure sensors were deployed. Here, we summarize the recovered data and discuss related regional oceanographic characteristics.

Data Inventory and Summary

The datasets obtained from CO-OPS on compact disc are listed in Table 6.1 and constitute the recoverable data. It was necessary to carefully inventory these datasets and determine their data quality. Note neither meteorological data (wind speed and direction, and sea level atmospheric pressure) nor CTD profile data were available.

Table 6.1. Miami Circulation Survey Raw Data Inventory.

Directory Name	Number of Files	Data Period	Data Description	Data Quality
MIAMI1	24	1985	Ticus Current Meter	OK

CT/Current Data

The salinity and temperature and current data inventoried in Table 6.2 were distributed in one lone directory: Miami1. These data files (FILE1 through FILEn) were concatenated to create a cumulative data file: file_miami1. The data in each individual data file (FILE1 through FILEn) represent current and CT data at one specific station location over a given time period. It should be noted that since the focus was on data for model validation and harmonic analysis, only stations with record lengths of 15 days or greater were considered. In general, data quality was sufficient, such that no filtering or editing was performed. Station locations in Miami1 are shown in Figure 6.1, which uses the NOS medium resolution shoreline data. Note with respect to this shoreline, Stations 18T3, 12T1, 09T1, and 07T3 appear to be on land. Dataset 1 is described in Table 6.3, in terms of station location, measurement and station depths and measurement dates and durations. Station depths are estimated with respect to MLLW from Nautical Chart 11468, 43rd Edition. Note with respect to this nautical chart, Stations 12T1 and 09T1 are on land and depths at Stations 18T3, 11T1, and 07T3 exceed measurement depths.

Table 6.2. Miami Circulation Survey Processed Data File Inventory.

Data Type	Location	Filename
CT/Current Raw	~/MIAMI1/	FILE1 – FILE24
CT/Current Edited	~/miami1/	file_miami1
CT/Current Qc	~/qc/	file_miami.qc

~ = /disks/NASUSER/philr/eastcoast/Miami

Table 6.3. Miami Dataset 1.

Station No.	Latitude (°N)	Longitude (°W)	M-Depth (ft)	S-Depth (ft)	Measurement Dates mm/dd/yr		Data Length Days	Data Quality AD
03T1	25.760	80.122	-14	22	1/16/85	2/ 6/85	20.99	
04T1	25.760	80.128	-13	17	1/18/85	2/ 4/85	16.99	
05B1	25.764	80.133	-28	41	1/16/85	2/ 4/85	18.78	
06T1	25.765	80.136	-16	41	1/18/85	2/ 4/85	16.74	
06B1	25.765	80.136	-31	41	1/18/85	2/ 4/85	16.74	
08T1	25.768	80.143	-13	38	1/19/85	2/ 4/85	15.99	
11T1	25.764	80.151	-15	9*	1/19/85	2/ 4/85	16.24	
12T1	25.772	80.158	-16	n/a	1/18/85	2/ 4/85	16.87	
14T1	25.782	80.182	-12	37	1/18/85	2/ 4/85	16.87	
14B1	25.782	80.182	-26	37	1/18/85	2/ 4/85	16.83	
09T1	25.767	80.145	-14	n/a	1/16/85	2/ 4/85	18.78	
05B2	25.764	80.133	-28	41	2/ 4/85	2/25/85	21.12	
06T2	25.765	80.136	-16	41	2/ 4/85	2/25/85	21.03	
06B2	25.765	80.136	-31	41	2/ 4/85	2/25/85	21.08	
10T2	25.766	80.145	-10	42	2/ 6/85	2/25/85	18.87	
13T2	25.765	80.162	-15	40	2/ 6/85	2/25/85	18.99	
14T2	25.782	80.182	-12	37	2/ 4/85	2/25/85	20.91	
17T2	25.777	80.183	-10	12	2/ 6/85	2/25/85	18.99	
19T2	25.773	80.179	-12	32	2/ 6/85	2/25/85	19.03	
05T3	25.764	80.133	-13	41	2/25/85	4/17/85	50.95	
05B3	25.764	80.133	-28	41	2/25/85	4/17/85	50.91	
07T3	25.764	80.137	-15	8*	2/25/85	4/17/85	50.74	
18T3	25.770	80.187	-10	5*	2/25/85	4/17/85	50.95	

Notes: M-Depth=measurement depth with respect to MLLW, where positive numbers are distance above the bottom and negative numbers are distance below the surface. S-Depth=station depth with respect to MLLW. Note x denotes bad data within the STAD station matrix where A=current speed, and D=current direction. *Note at Stations 11T1, 07T3, and 18T3 measurement depths exceed station depths.

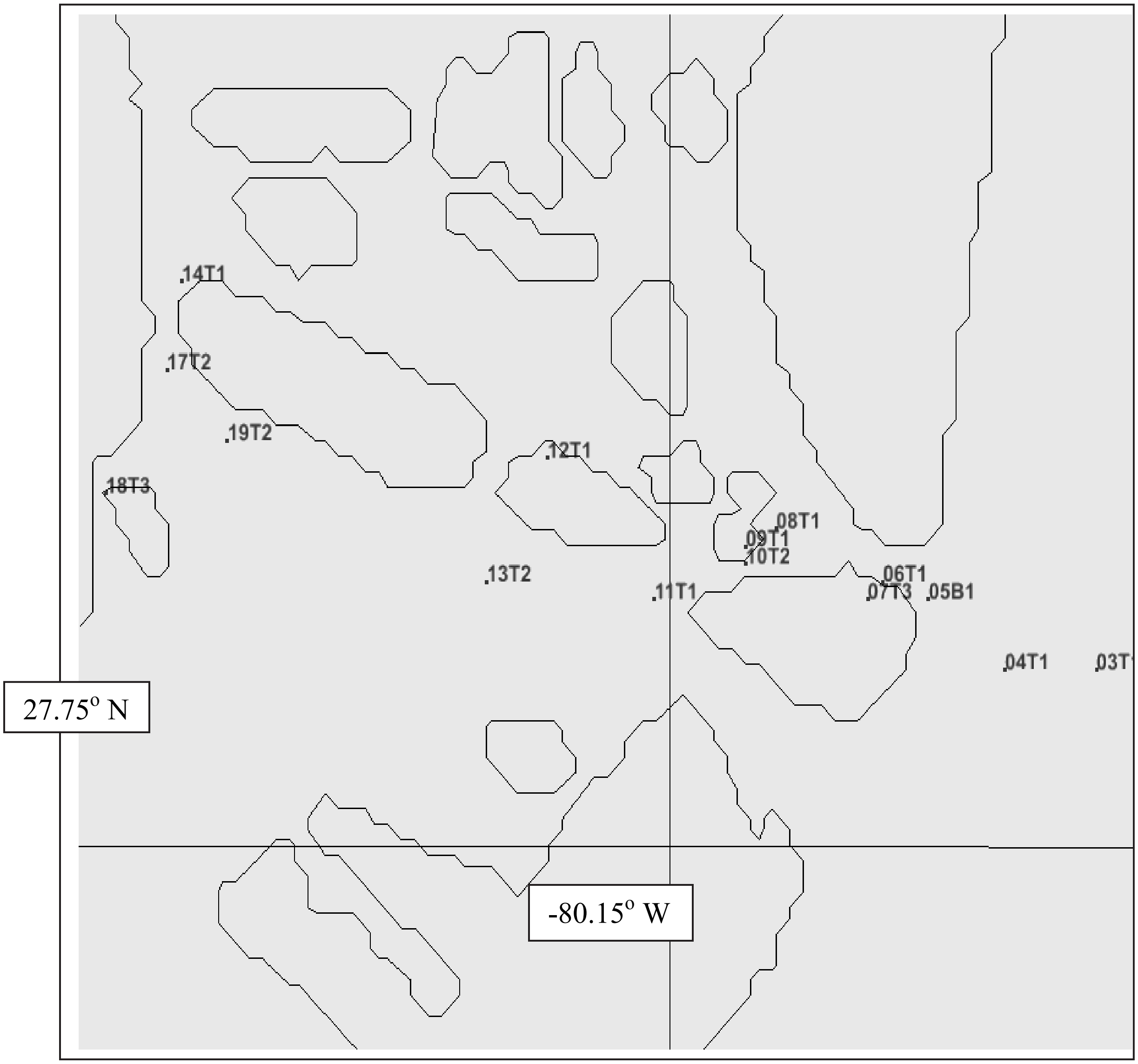


Figure 6.1. Station Locations for Miami Dataset 1.

Regional Oceanographic Characteristics

Biscayne Bay is a subtropical estuary located in Miami-Dade and Monroe Counties on the southeastern coast of Florida. Biscayne Bay extends approximately 55 miles in a southwesterly direction from Dumfounding Bay in the north to Barnes Sound in the south. The bay varies in width from 1 to 10 miles and it is divided into three major regions: north, central, and south. Depths generally range from 1-10 feet. In some dredging areas, the depth may be as much as 30 to 40 feet.

Biscayne Bay was in a relatively natural condition when the City of Miami was founded in 1896. Major development of the area began in 1905 with the construction of an artificial inlet called Government Cut, and the associated Miami Ship Channel. Peak development occurred in the 1920's with causeway constructions and another artificial inlet, Baker's Haulover, in 1925. As a result, circulation and salinity patterns in the Bay were altered due to the enhanced exchange of water between the Bay and the Atlantic Ocean.

In the present system, salinity variations in Biscayne Bay result primarily from canal discharges through gated control structures managed to meet municipal water supply, agricultural, and flood control objectives. Additional, but smaller freshwater exchanges in the Bay are driven by overland runoff, rainfall, and evaporation. Along with the creation of the canals, profound changes in groundwater seepage to the Bay occurred over the past several decades.

South Biscayne Bay, Card Sound, and Barnes Sound form a barrier island lagoon system exhibiting estuarine characteristics near points of freshwater inflow during the wet and early dry season. Although instantaneous currents are dominated by (M_2) tides, subtidal currents are strongly influenced by wind. These subtidal currents have a significant effect on residence times in Biscayne Bay.

The northern portion Biscayne Bay, about 10% of the total bay area, is defined as that portion of the bay that extends from the Broward/Miami-Dade County line south to the Rickenbacker Causeway. Major tributaries to northern Biscayne Bay include Snake Creek, Arch Creek, Biscayne Canal, Little River, and the Miami River. Tidal exchanges with the Atlantic Ocean can occur at Bear Cut, Government Cut, Baker's Haulover Cut and Norris Cut, and through seasonally-changing circulation patterns. The slow flowing Miami River is the largest river flowing into Biscayne Bay, and suffers from a history of contamination with industrial runoff and untreated sewage effluent. Water clarity in northern Biscayne Bay is chronically lower than in other parts of the Bay due to past dredging and filling of the bay's bottom and its coastal wetlands. Concentrations of coliform bacteria, ammonia, and dissolved oxygen have often been documented at levels which fail to achieve state and county water quality standards.

The central region of Biscayne Bay is in some respects a transition zone between the north region, which is directly adjacent to urban Miami, and the south region, which is part of Biscayne National Park. Tidal exchange with the Atlantic Ocean occurs through a complex series of shoals called the Safety Valve, as well as Norris and Bear Cut. The portion of central Biscayne Bay which is included in Biscayne National Park generally has the best water quality.

Southern Biscayne Bay is defined as that extent of the bay between Featherbed Banks in the north to Card and Barnes Sounds (lagoons within the Florida Keys National Marine Sanctuary) to the south. Exchange with the Atlantic Ocean is driven by general circulation patterns and through the tidal creeks between the northern islands of the Florida Keys. Although this area of Biscayne Bay receives less urban and industrial runoff, water quality concerns remain, principally the elevated loads of nitrogen being discharged into the Bay through primary drainage canals and through groundwater. Unlike lakes, where the main concern is often phosphorus, estuary eutrophication processes are often the result of continuously increased loads of nitrogen.

Here we examine the current response at Stations 04T1 in January 1985 and 19T2 in February 1985, proceeding from east (at the ocean entrance) to west (inside the harbor). At Station 04T1 at 13 ft below the surface peak current speeds are order 160 cm/s and exhibit distinct ebb and flood directions as shown Figure 6.2. At Station 19T2 at 12 ft below the surface peak current speeds are reduced to order 20 cm/s with a flood direction of near 200 ^{o}T and ebb direction near 72 ^{o}T, respectively, as shown in Figure 6.3. Note the Ticus current meter system did not measure conductivity and temperature.

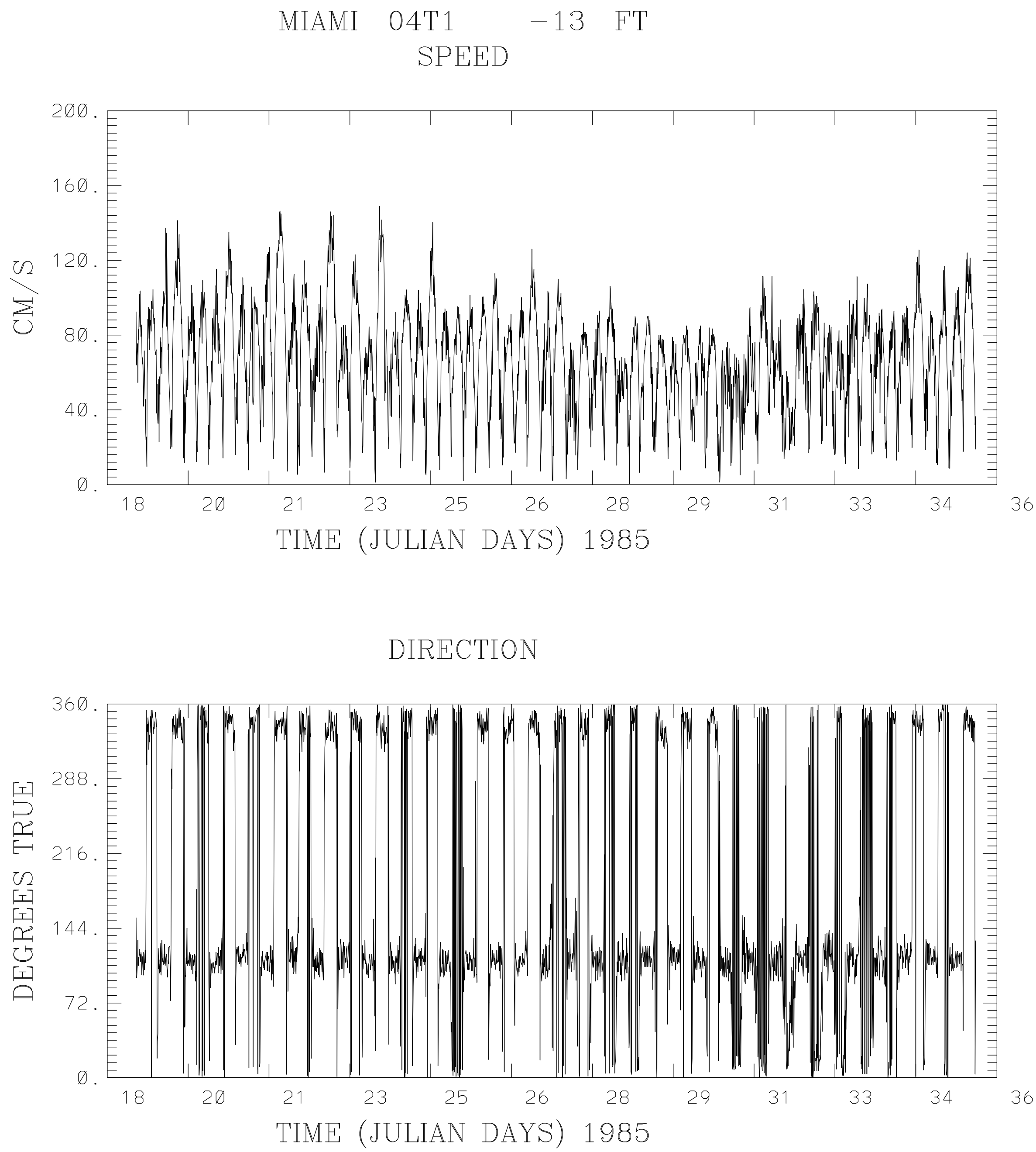


Figure 6.2. Station 04T1 Miami Current Speed and Direction at 13 ft below the surface in January 1985.

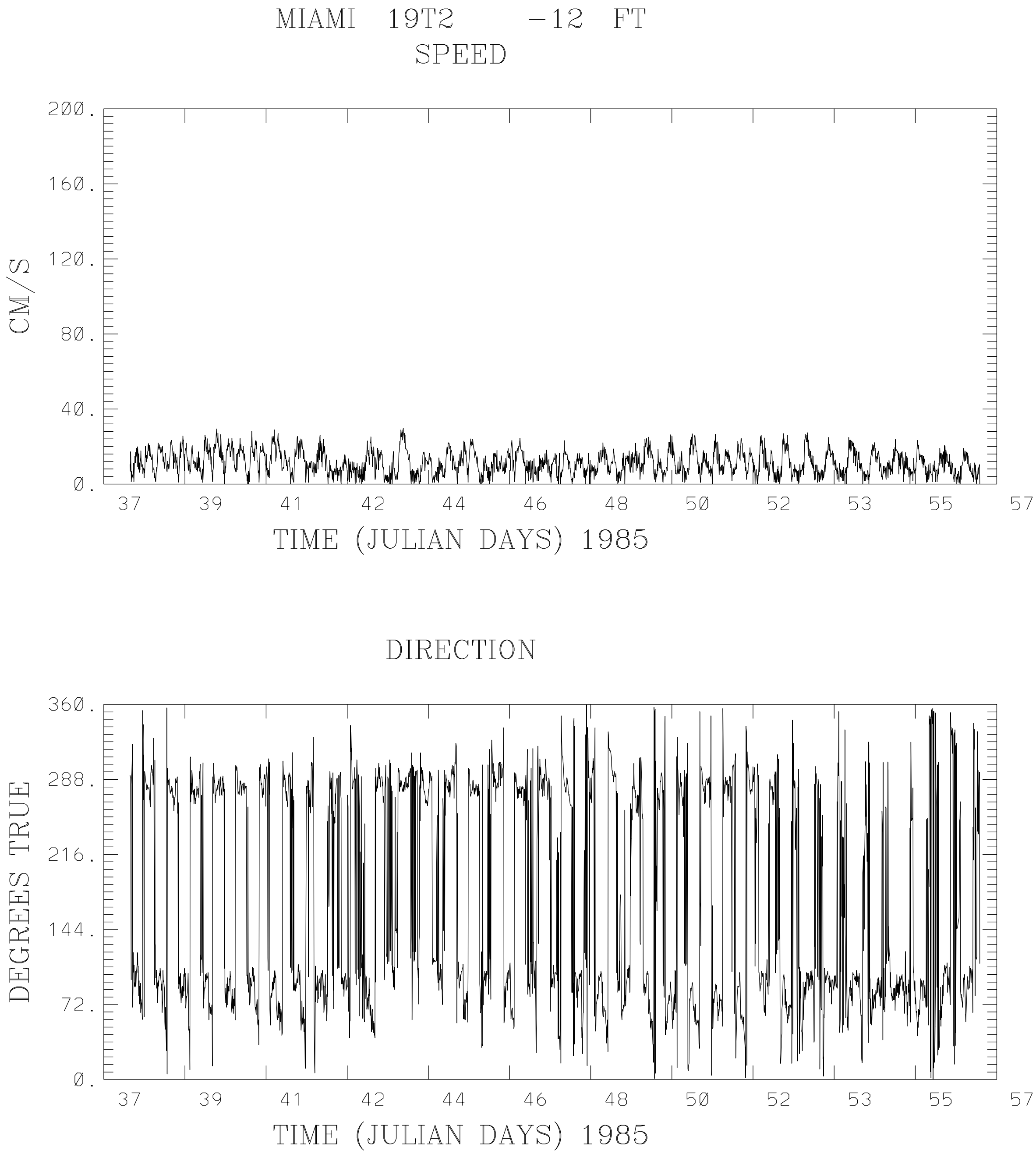


Figure 6.3. Station 19T2 Miami Current Speed and Direction at 12 ft below the surface in February 1985.

7. DATA PRESERVATION AND USE ISSUES

Preservation

Neither NOS circulation survey reports nor final project reports are available for Casco Bay, Los Angeles and Long Beach, San Diego, and for the Miami survey. The data corruption and preservation issues are discussed in CO-OPS (1999), particularly with respect to CTD time stamp corruption. In large measure data were corrupted in migration from storage media associated with each new computer system. To prevent this, data redundancy and backup procedures need to be addressed.

Use

The primary use of these processed circulation survey datasets is anticipated to support model evaluation environments and the development of nowcast/forecast systems. This effort was focused on the restoration and quality control of these datasets. It should be noted that the final processed data were written in the same format as the original data and no rearrangement of the data file structures was undertaken. No data editing and filtering were performed to remove bad portions of data. Therefore additional consistency checking should be performed by each user. Based on station locations, approximate station depths with respect to MLLW from the appropriate nautical charts were estimated.

For current meter data, computer programs developed by Richardson and Schmalz (2006) can be used to determine the principal component directions using the Preisendorfer scheme and to automatically prepare control and input data files for the NOS 29-day harmonic analysis program (Zervas, 1999). These programs may be used to perform 29 day harmonic analysis of currents in the other estuaries.

8. SUMMARY AND RECOMMENDATIONS

Three sets of programs have been developed to analyze the circulation survey data. The first set of programs was not used to plot and edit CTD profiles since no CTD data were available. The second program set was used to analyze the CT/Current meter files. The first program in program set two was used to plot station time series data in Casco Bay, Los Angeles and Long Beach, San Diego and Miami. Since this effort focused on the data restoration and inventory of available data, no formal data quality was performed. However, within the present plot program, editing, and filtering steps are included and can be exercised in the future as required. All time series greater than 15 days were written for incorporation in the CSDL Oracle database.

The first program in program set two was modified to write out the final quality control station data in NOS skill assessment format as discussed by Zhang et al. (2009) but was not used. The second program is available to determine the principal current direction using the Preisendorfer scheme and to prepare the control and data files for use in the NOS 29-day harmonic analysis program. Minor modification may be required to prepare the inputs for the NOS 15-day harmonic analysis program.

In summary, this report has documented the restoration of the NOS historical circulation surveys in Casco Bay, Los Angeles/Long Beach, San Diego and Miami Harbor. The report serves as a circulation survey report for each of these survey areas. All restored files will be available on CSDL/MMAP servers on /disks/NASUSER until they are transferred to NODC and CO-OPS for data request, redundancy and archival purposes.

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REFERENCES

CO-OPS Historical Circulation Survey Data (1973-1985). Inventory and General Users Guide, **NOS CO-OPS, Information Systems Division, Internal Report**, Silver Spring, MD.

Loeper, Thomas, 2006. Restoration of CTD Data from the 1984-1985 Delaware River and Bay Circulation Survey, **CSDL Informal Technical Note No. 6**, Silver Spring, MD.

Richardson, P.H. and R.A. Schmalz, 2006. Restoration of Delaware River and Bay Circulation Survey, Current Meter and CTD Observation 1984-1985: Computer Programs and Documentation, **CSDL Informal Technical Note No. 5**, Silver Spring, MD.

Zervas, C. E., 1999. Tidal Current Analysis Procedures and Associated Computer Programs, **NOAA Technical Report NOS CO-OPS 0021**, Silver Spring, MD.

Zhang, A., K.W. Hess, E. Wei, and E. Myers, 2009: Implementation of Model Skill Assessment Software for Water Level and Current in Tidal Regions, **NOAA Technical Report NOS CS 24**, Silver Spring, MD.