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Monitoring Completed Navigation Projects Program

Morro Bay Harbor, California, Wave and Current Data Summary Report

Andrew W. Garcia

September 2001

**Coastal and Hydraulics
Laboratory**

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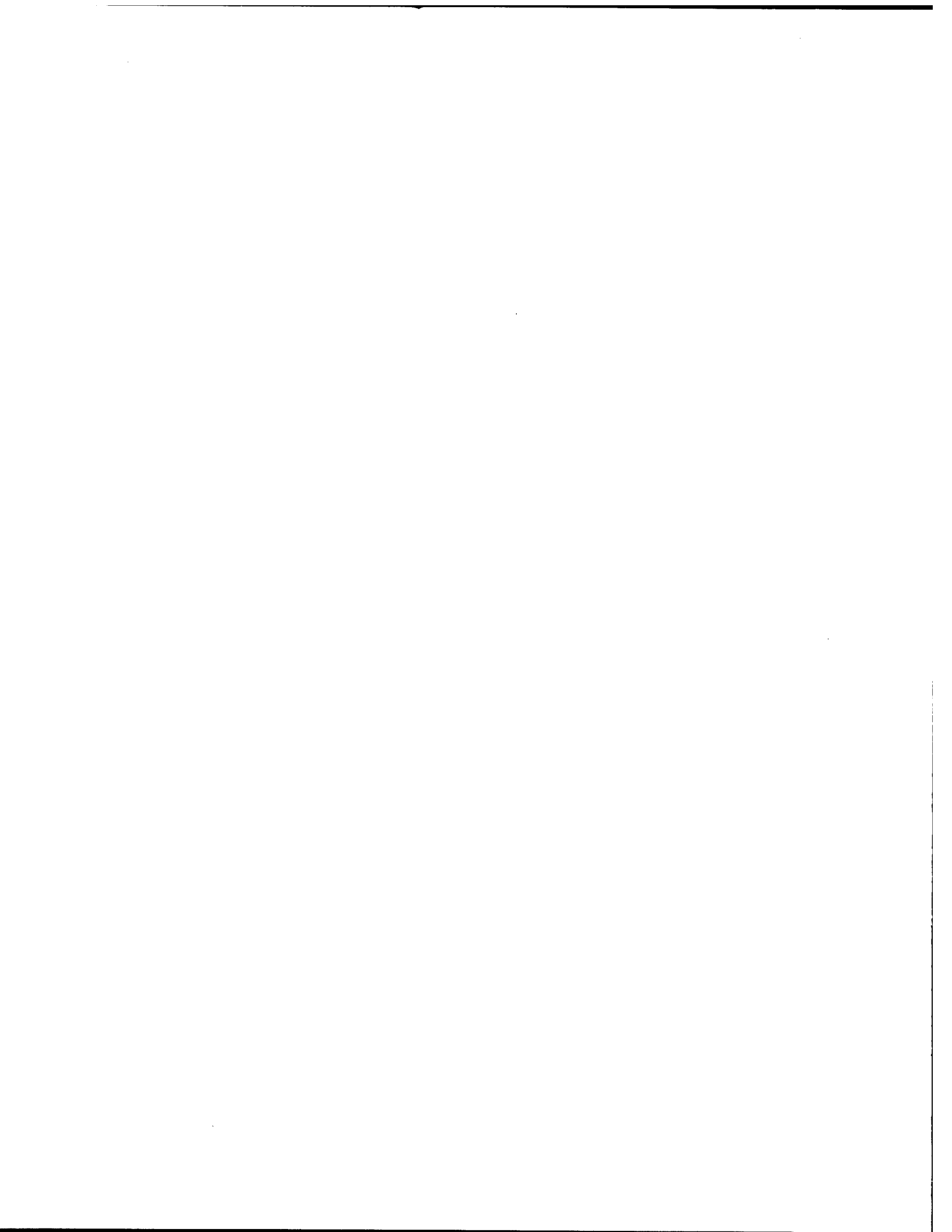
Morro Bay Harbor, California, Wave and Current Data Summary Report

by Andrew W. Garcia

Coastal and Hydraulics Laboratory
U.S. Army Engineer Research and Development Center
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

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Preface

The work described in this report was authorized by the Operations and Maintenance Division, Headquarters, U.S. Army Corps of Engineers (HQUSACE) and completed as part of the Monitoring Completed Navigation Projects (MCNP) Program. It is a product of the U.S. Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL), under the direction of Mr. Thomas W. Richardson, Acting Director, CHL; and the direct guidance of Mr. William L. Preslan, Chief of the Prototype Measurement and Analysis Branch (PMAB). Dr. Andrew Garcia of PMAB was manager for the Morro Bay field studies reported herein.

Messrs. Larry G. Caviness and Ralph E. Ankeny, both of PMAB, conducted wave gauge deployments and maintenance. Wave gauge data were processed and analyzed by Mr. James P. McKinney. Ms. Margaret A. Sabol generated wave summary plots and data tables.

Mr. Michael W. Tubman, also of PMAB, conducted the Acoustic Doppler Current Profiler (ADCP) deployment, retrieval, and data analysis. Evans Hamilton, Inc., a PMAB contractor, deployed a surface following Waverider buoy, and collected and analyzed the data.

This report was written by Dr. Andrew W. Garcia, and prepared by Ms. Terri L. Prickett for publication.

At the time of publication of this report, Dr. James R. Houston was Director of ERDC, and COL John W. Morris III, EN, was Commander and Executive Director.

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1 Introduction

This document summarizes the U.S. Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL), Prototype Measurement and Analysis Branch (PMAB) wave and current data collection activities at Morro Bay Harbor, CA. The objective of this data collection was to provide wave and current information to evaluate recent modifications to the Morro Bay Harbor entrance.

Morro Bay Harbor, CA, is the only small-craft, commercial harbor between Monterey and Santa Barbara, CA. The harbor entrance is protected from the open ocean by two permeable rubble-mound breakwaters, an inner harbor groin, and a stone revetment. A plan view of the harbor entrance and navigation channel is shown in Figure 1. The Morro Bay Harbor has been considered dangerous because of large-breaking waves at the entrance that cause treacherous and hazardous passage. Since 1962, 19 boating accidents have occurred in the harbor entrance, resulting in 20 deaths, 67 injured individuals, and more than \$600,000 in vessel damages and losses (Bottin 1993). In 1995, the U.S. Army Corps of Engineers modified the harbor entrance channel to reduce the hazardous wave conditions.

Morro Bay Harbor was selected for inclusion in the Monitoring Completed Navigation Projects (MCNP) program in 1997. The Coastal Engineering Research Board (CERB), which oversees the conduct and research of Corps of Engineers coastal engineering projects, met in January 1997 to review various Corps projects in California, including Morro Bay Harbor. During the meeting, the CERB concurred with the monitoring program to evaluate the performance of completed modifications to the Morro Bay Harbor entrance. The recommended monitoring program included wave and current measurements inside the harbor entrance, wave measurements outside the harbor entrance, periodic bathymetric surveys, and ground and photogrammetric surveys of the south breakwater. Planning for the Morro Bay Harbor monitoring program took place in 1997 and monitoring was initiated in 1998. Wave and tide gauges were initially deployed in September 1998 and data collection continued for approximately 2 years. Currents were measured during a 3-week period in the spring of 1999.

2 Instrumentation and Data Collection

From September 1998 to August 2000, a surface-following buoy and a bottom-mounted directional slope-array collected wave measurements outside of the harbor entrance. In addition, a combined water-level/wave gauge was deployed between the inner and outer harbors. Tidal currents between the inner and outer harbors were measured for a 3-week period in 1999. Figure 1 shows the approximate locations of the instruments.

Waves

Waves near the harbor entrance were measured with a surface-following Datowell Waverider buoy anchored seaward of the south breakwater. The Waverider buoy transmitted data via radio-telecommunication, in real-time, to a receiving system located in a nearby U.S. Coast Guard facility. A surface-following buoy was selected for measurements near the harbor entrance because a bottom-mounted pressure array was considered too vulnerable to vessel traffic in the narrow confines of the entrance channel. Moreover, sufficient bottom sediment movement at this location could have buried or undermined a bottom-mounted gauge. Both effects posed significant risk to survival of a bottom-mounted gauge.

Directional wave data were desired seaward of the north breakwater to help define the wave conditions incident to the breakwater and harbor entrance. A bottom-mounted, internally-recording surface slope array was selected. Such an arrangement was considered low-risk in terms of vulnerability to extreme wave conditions and offshore vessel traffic. However, because the instrument was self-contained and recorded internally, there was no way to know if the gauge functioned properly once it was deployed. The slope array gauge system (designated CA002) was deployed on the seafloor approximately 305 m (1,000 ft) due west of the north breakwater (lat. 35.360 N and long. 120.876 W) in approximately 14.3-m (47-ft) water depth.

A second internally recording bottom-mounted gauge system (designated CA001) was deployed in the outer harbor to collect nondirectional wave measurements and tide information. From September 1998 to April 2000, the system was deployed approximately 183 m (600 ft) due east of the north

breakwater on the western edge of the navigation channel in about 6.1-m (20-ft) water depth (see Site 1 in Figure 1). The gauge system was moved in April 2000, and redeployed approximately 366 m (1,200 ft) due east of the north breakwater (lat. 35.367 N and long. 120.866 W) on the eastern edge of the navigation channel in about 7.9-m (26-ft) water depth (Site 2 in Figure 1). Both wave gauges (CA001 and CA002) collected measurements in sample bursts of 2,048 sec (35 min) every 120 min. Tide level data from CA001 were sampled every 3.75 min.

Following the September 1998 deployment, both bottom-mounted systems were retrieved four times during the 2-year monitoring period to check instrument function and download data. Once the data were downloaded from the gauge, the batteries were replaced and the instruments were redeployed to continue collecting data. The retrievals and redeployments took place in March and June 1999, and in January and April 2000. Data collection ended in August 2000 and both gauge systems were retrieved.

The slope-array instruments deployed for the Morro Bay study were specified by the vendor as having sufficient memory and battery capacity to operate for 12 months in the data acquisition format used. The Morro Bay Harbor project was the first time that the CHL-owned instruments were deployed in the long duration mode. Despite thorough inspection to ensure that batteries were fully charged and there were no apparent instrument abnormalities, the experience at Morro Bay showed battery life to be consistently between 4 and 6 months. Queries to the gauge manufacturer as to similar problems experienced by other users revealed there were only two other users of these type instruments at the time. Neither of these users had operated the gauges in multimonth duration deployments, and did not experience battery failure.

Currents

A 1,200 KHz Broad Band Acoustic Doppler Current Profiler (BBADCP) was deployed from 17 May to 9 June 1999 in the center of the navigation channel between the inner and outer harbors (lat. 35.367 and long. 120.866) to internally record tidal current direction and speed (see Figure 1). The operational time period was chosen to encompass spring and neap tide conditions. The BBADCP was deployed in a water depth of approximately 6.7 m (22 ft), with 5.8 m (19 ft) over the instrument. The BBADCP recorded data an average of 30 sec every 6 min.

3 Data Analyses

Data Processing and Display

The Waverider data were processed and analyzed by contract field personnel using vendor-supplied software. The data were summarized in monthly plots of maximum and significant wave heights (Figures 2 through 12) and average wave periods and periods of maximum energy (Figures 13 through 23). Maximum wave heights were determined based on statistical relations given in Longuet-Higgins (1952).

Data acquired by all the internal recording instruments (the directional gauge seaward of the north breakwater, the gauge inside the harbor, and the short-term deployment ADCP) were processed using the Prototype Measurement Analysis System (PMAS) software package (Sabol 1998).

Monthly wave data summary plots consisting of wave height, period, and direction from the bottom-mounted wave gauges were generated using the PMAS software. Data plots from the wave gauge deployed inside the harbor (CA001) are given in Figures 24 through 45 and data plots from the gauge offshore of the harbor (CA002) are given in Figures 46 through 61. The monthly plots and tabulated data from both CA001 and CA002 wave gauges are also available for public access on the Internet at: <http://sandbar.wes.army.mil>. Near-bottom, near-middepth, and near-surface current speeds and directions from the BBADCP deployment are given in Figures 62 and 63, respectively. Figures 64 and 65 are time series of ebb and flood near-surface currents during the current monitoring period.

Summary

Based upon the observations made during the field investigation, the following general comments can be made:

- a. For significant wave heights exceeding 1.3 m, dominant wave directions outside the breakwaters were confined to a narrow band of approximately 275 ± 15 deg.

b. Dominant wave periods exceeding 20 sec occurred occasionally.

This report presents wave and current data obtained during the monitoring effort. A detailed analysis of hydrodynamic conditions versus harbor performance will subsequently be performed and published in a comprehensive monitoring report.

References

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- Longuet-Higgins, M. S. (1952). "On the statistical distribution of the heights of sea waves," *Journal of Marine Research* 11, 245-266.
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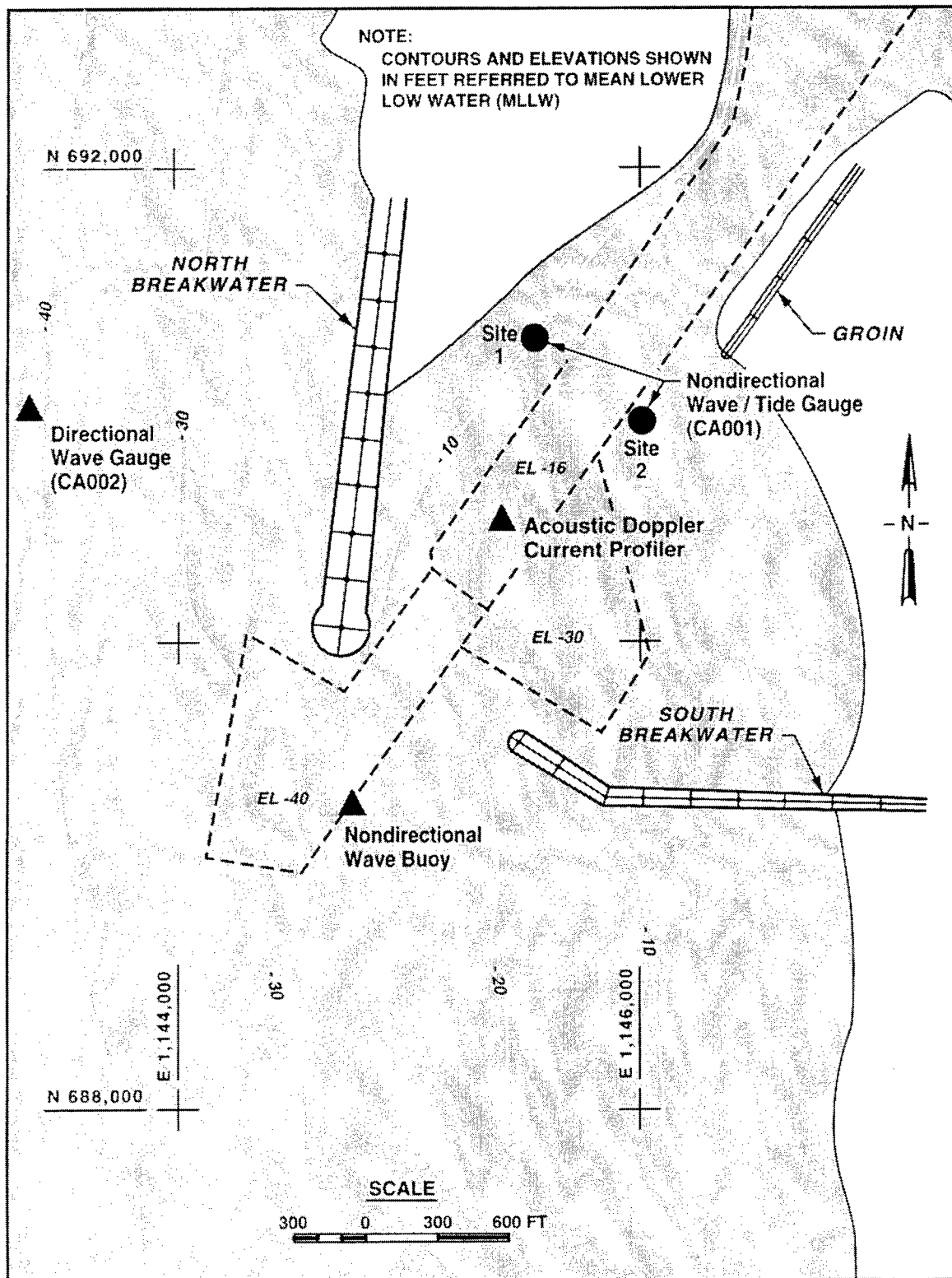


Figure 1. Plan view of Morro Bay Harbor (to convert feet to meters, multiply by 0.3048)

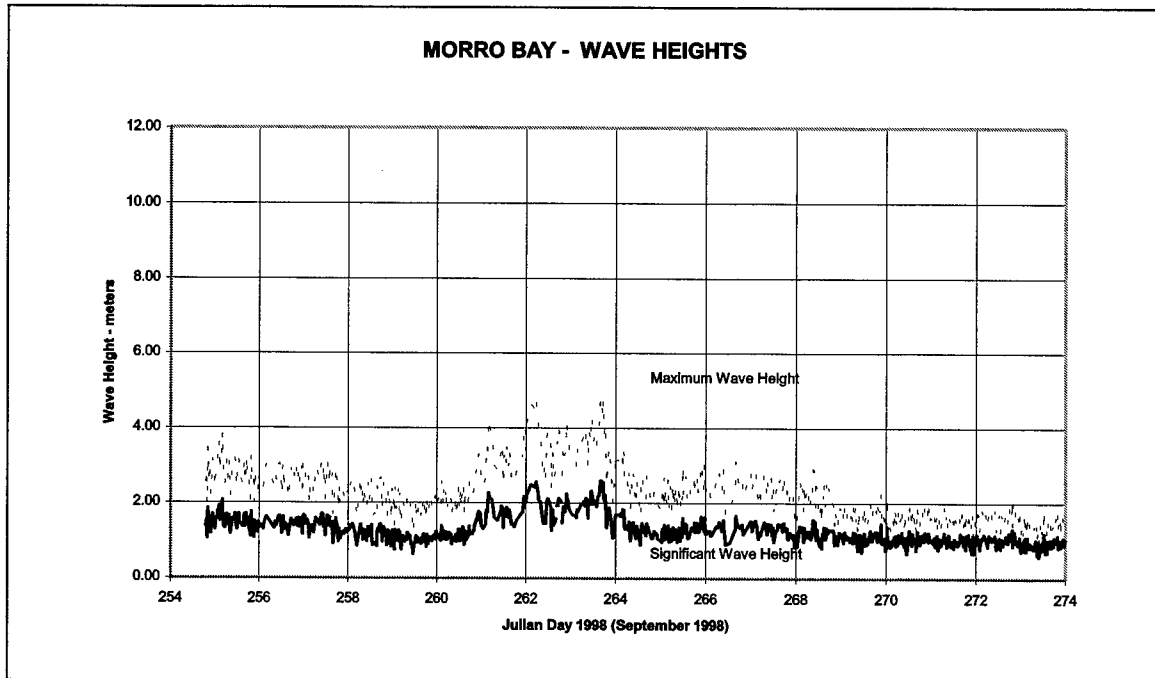


Figure 2. September 1998 maximum and significant wave heights

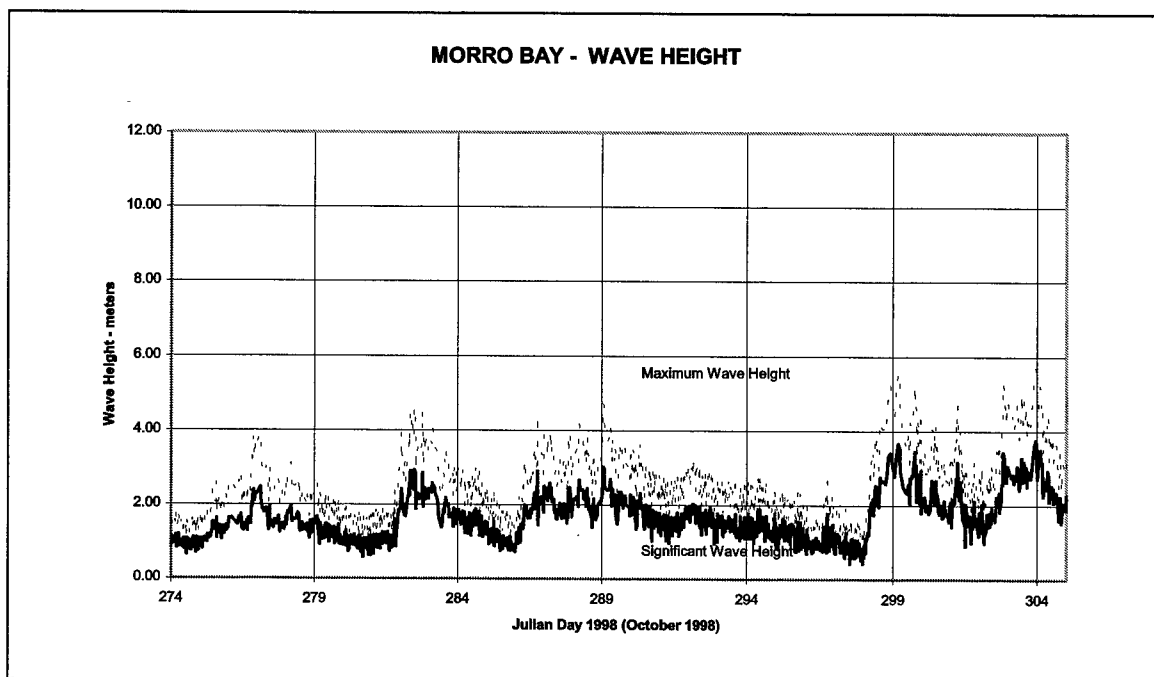


Figure 3. October 1998 maximum and significant wave heights

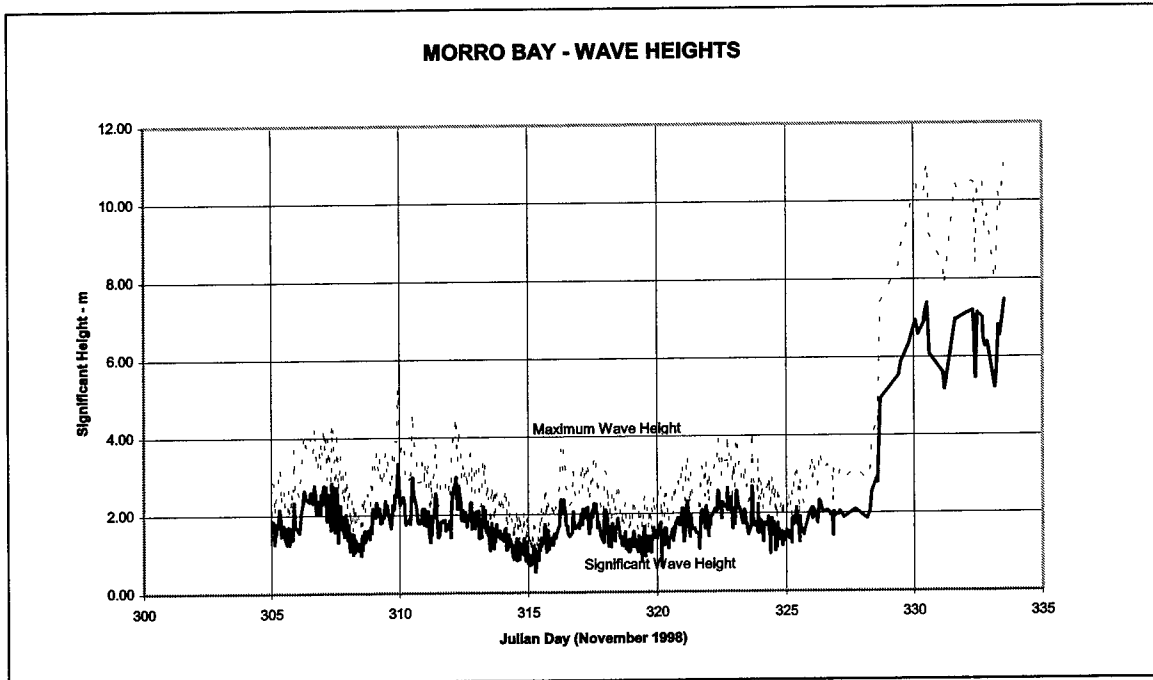


Figure 4. November 1998 maximum and significant wave heights

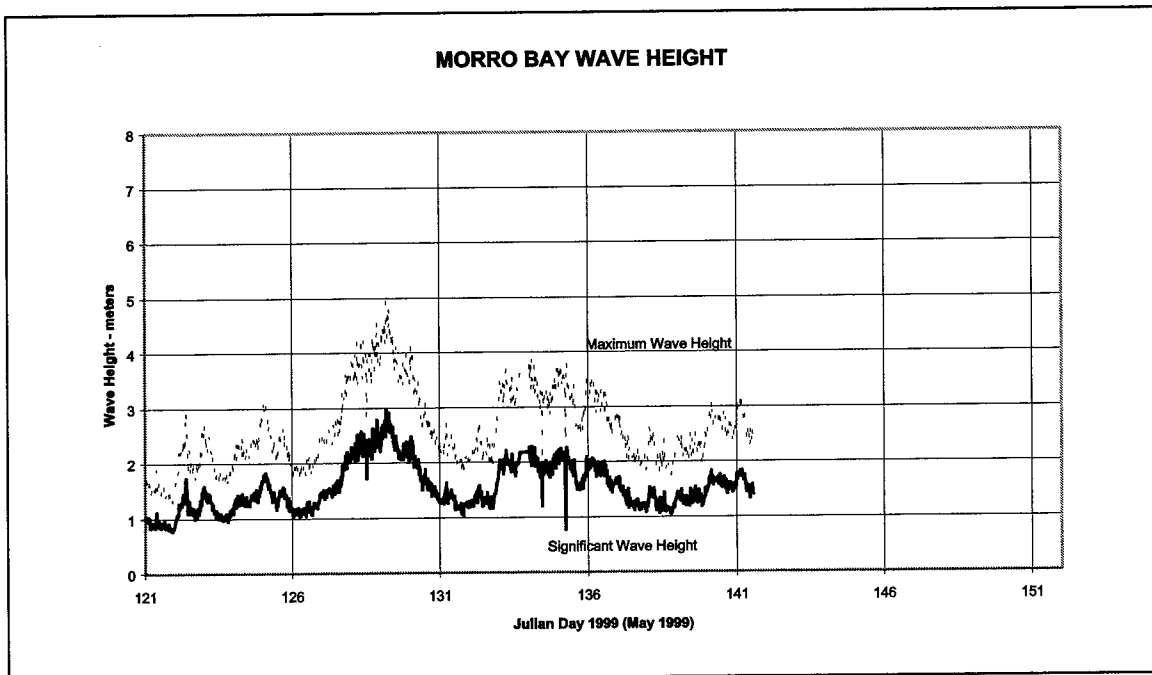


Figure 5. May 1999 maximum and significant wave heights

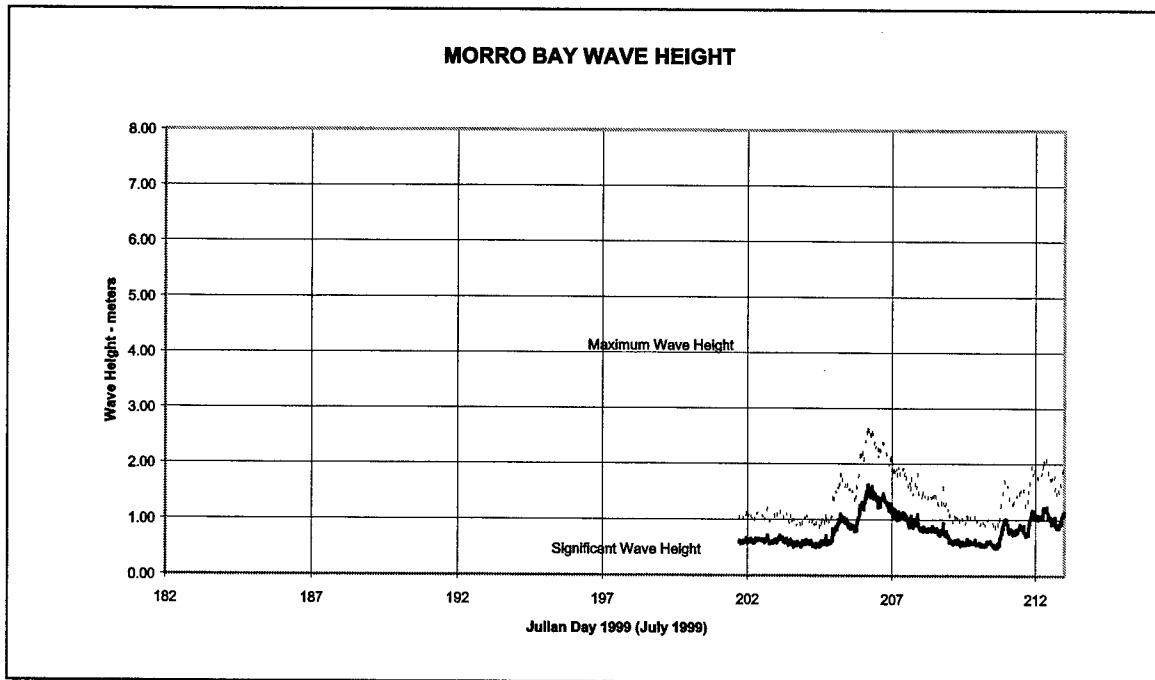


Figure 6. July 1999 maximum and significant wave heights

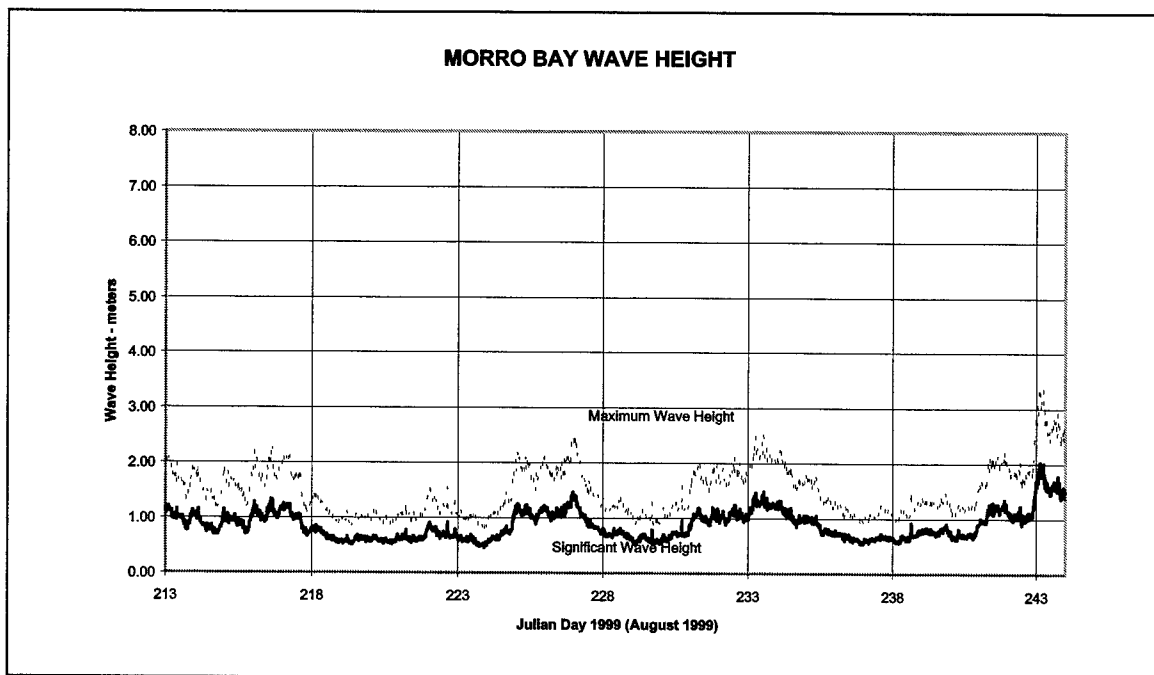


Figure 7. August 1999 maximum and significant wave heights

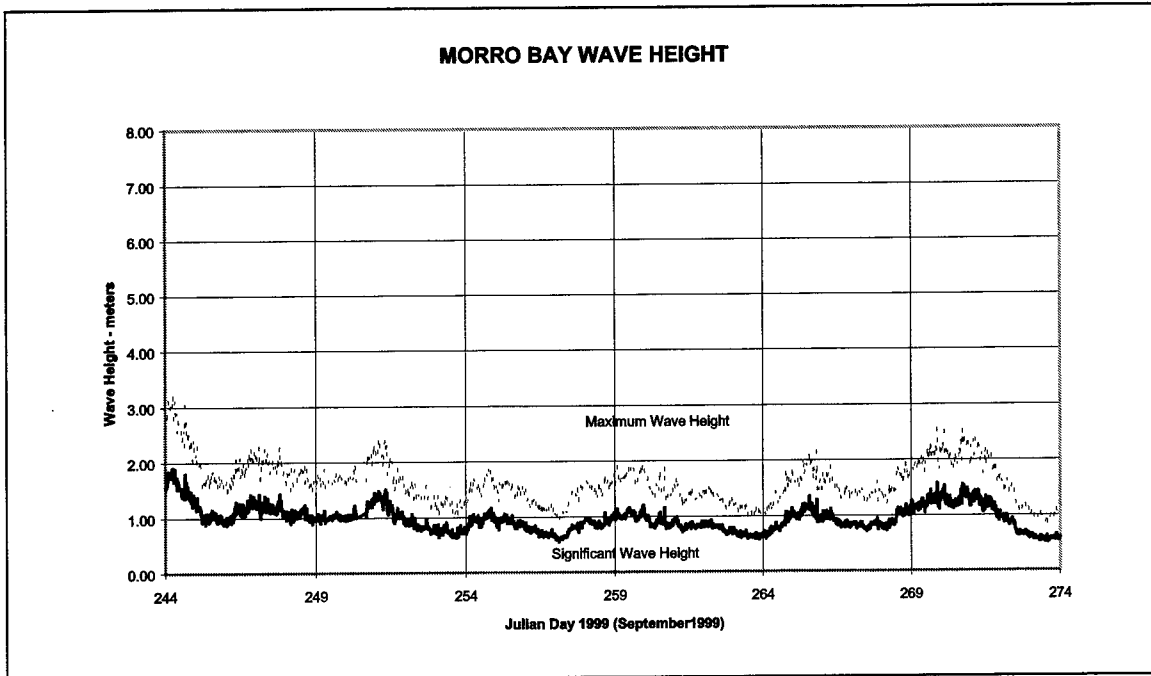


Figure 8. September 1999 maximum and significant wave heights

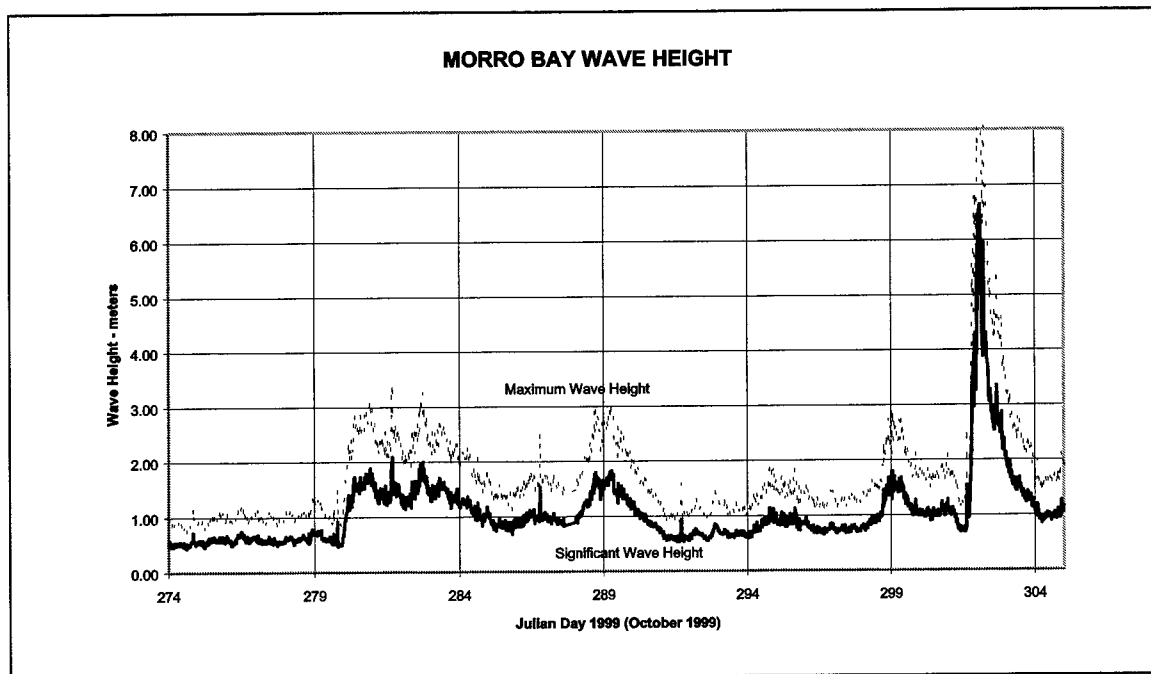


Figure 9. October 1999 maximum and significant wave heights

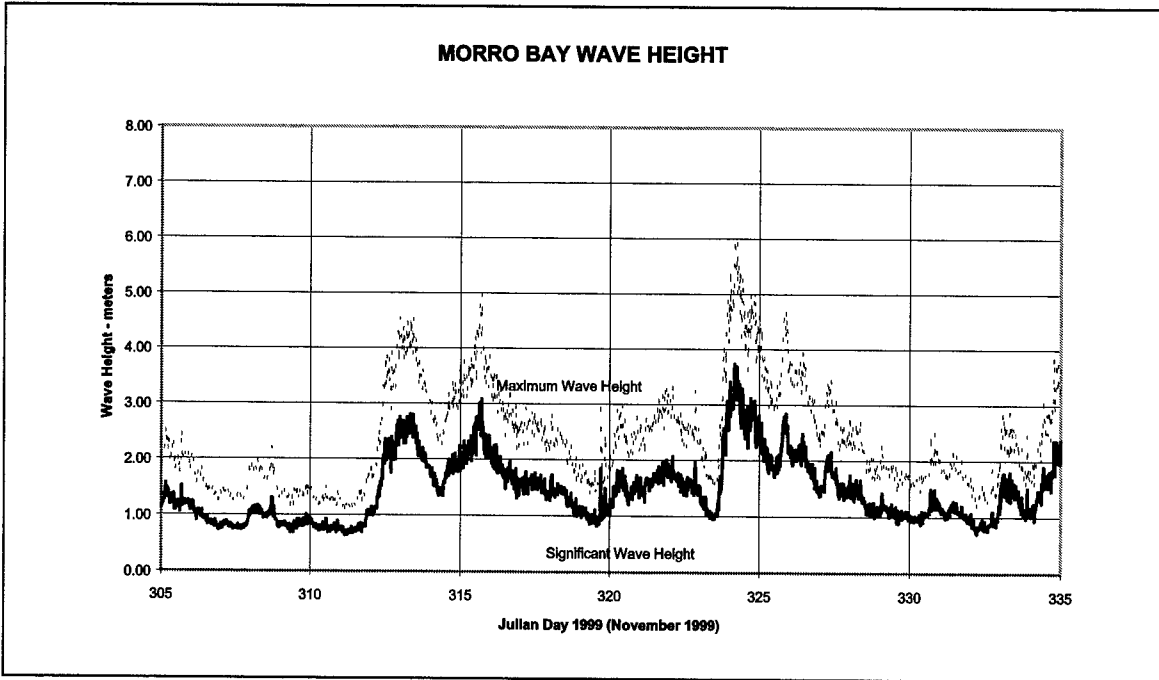


Figure 10. November 1999 maximum and significant wave heights

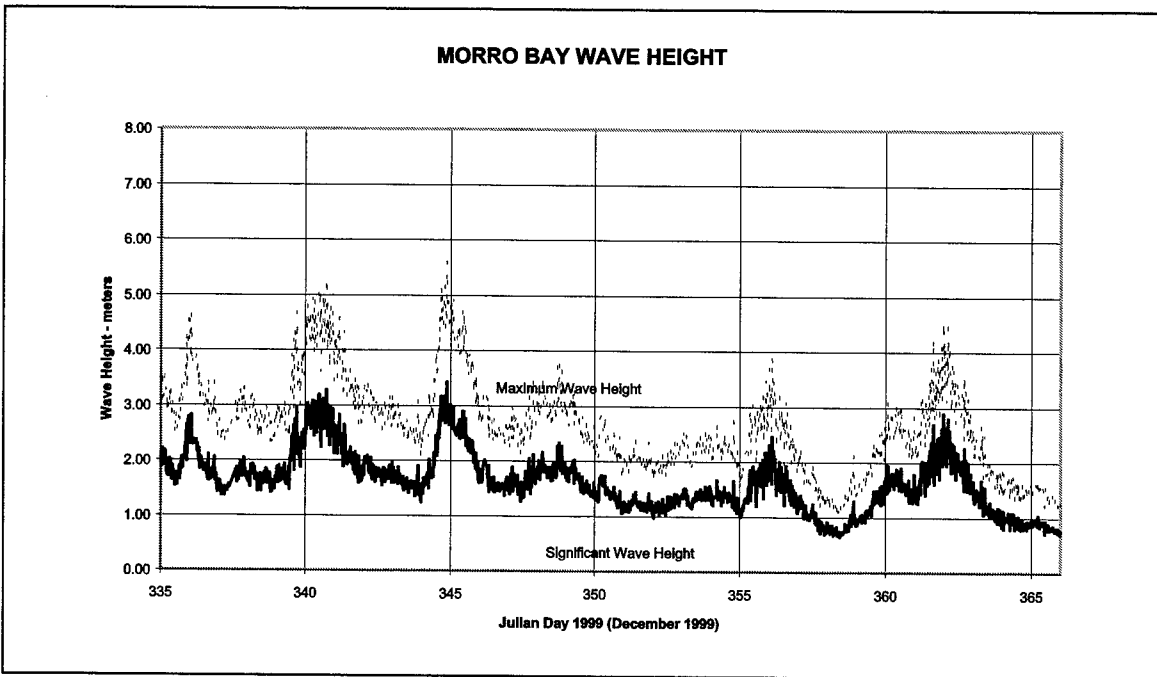


Figure 11. December 1999 maximum and significant wave heights

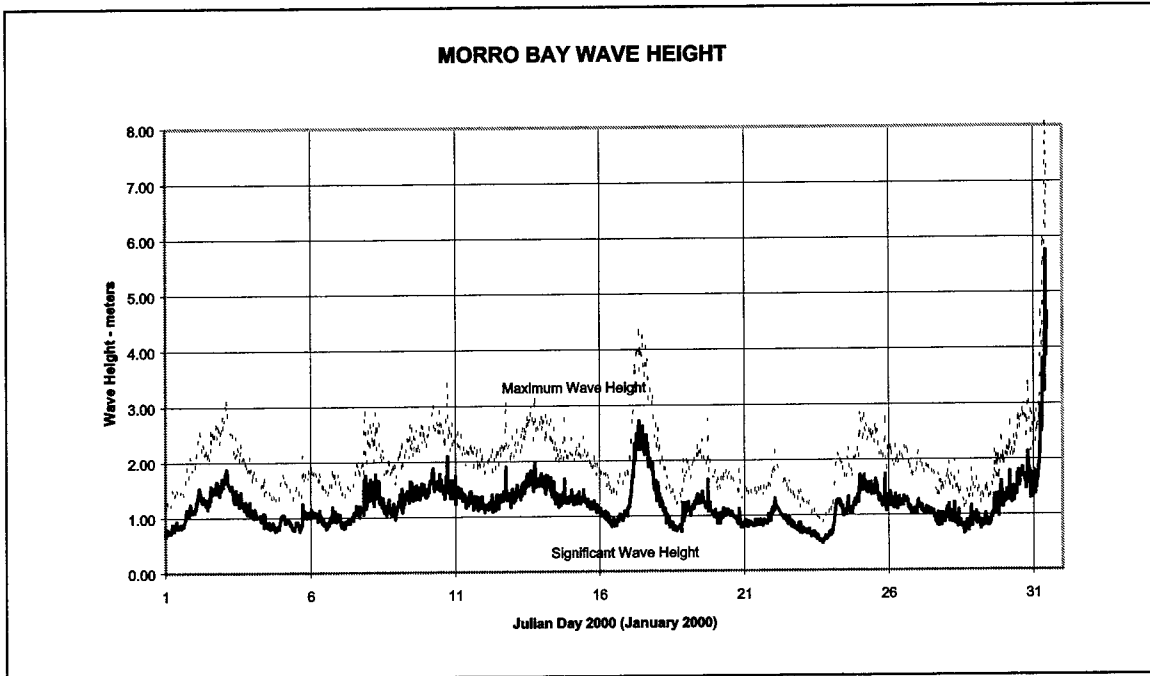


Figure 12. January 2000 maximum and significant wave heights

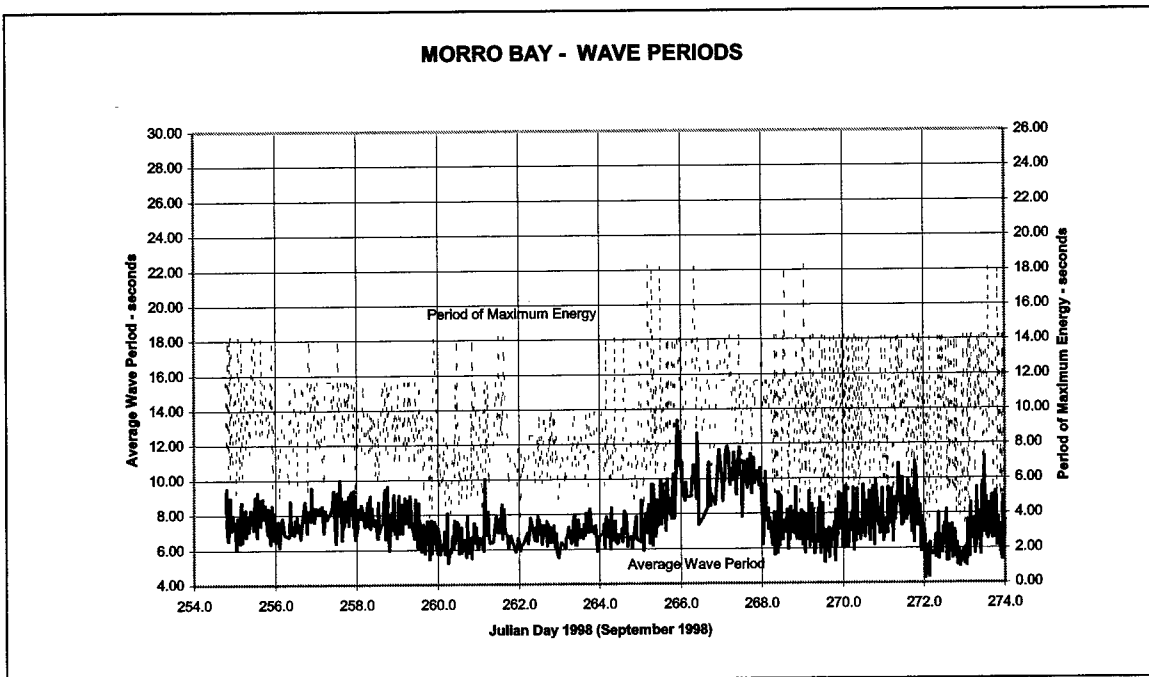


Figure 13. September 1998 average wave periods and periods of maximum energy

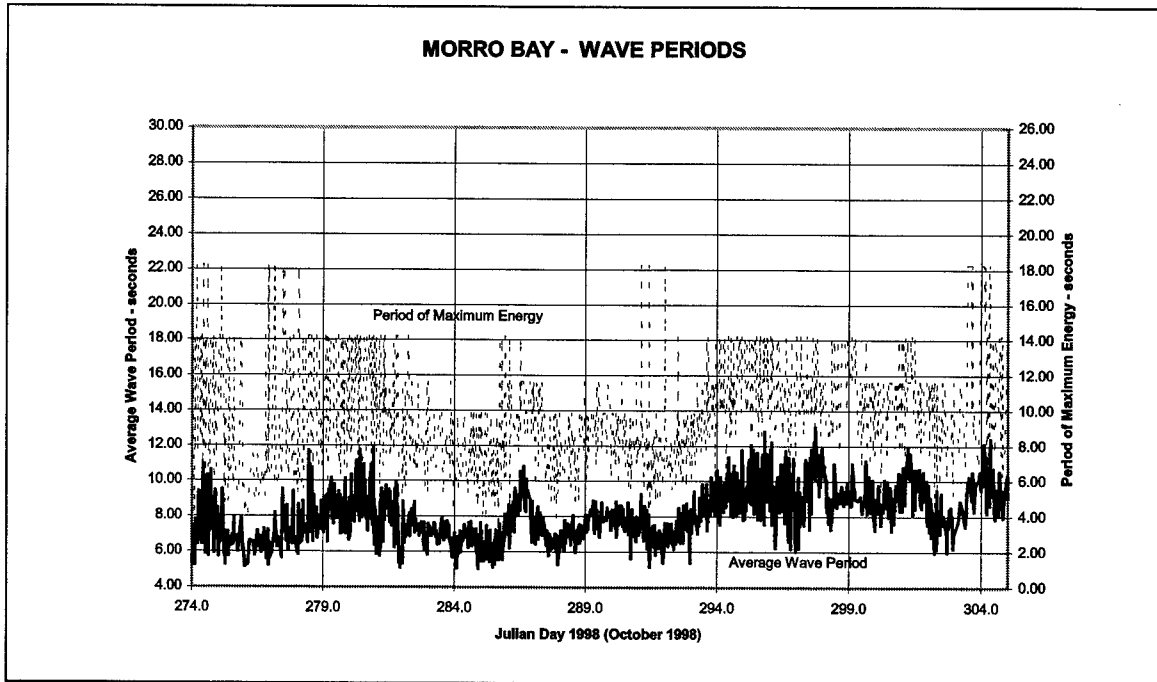


Figure 14. October 1998 average wave periods and periods of maximum energy

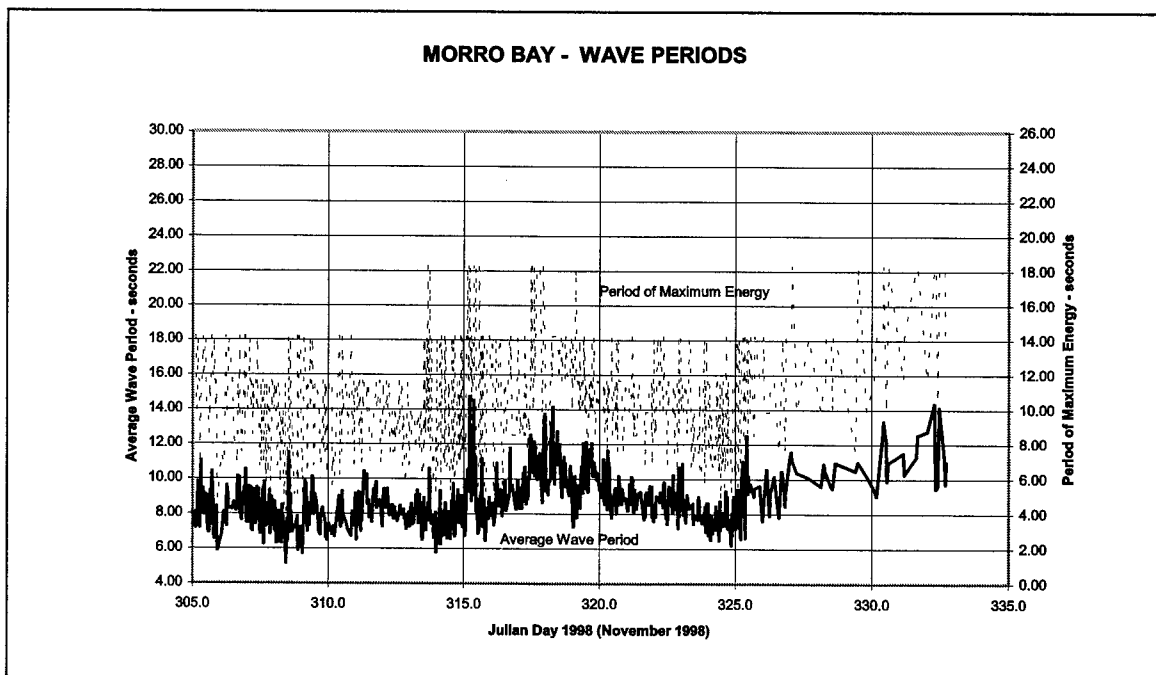


Figure 15. November 1998 average wave periods and periods of maximum energy

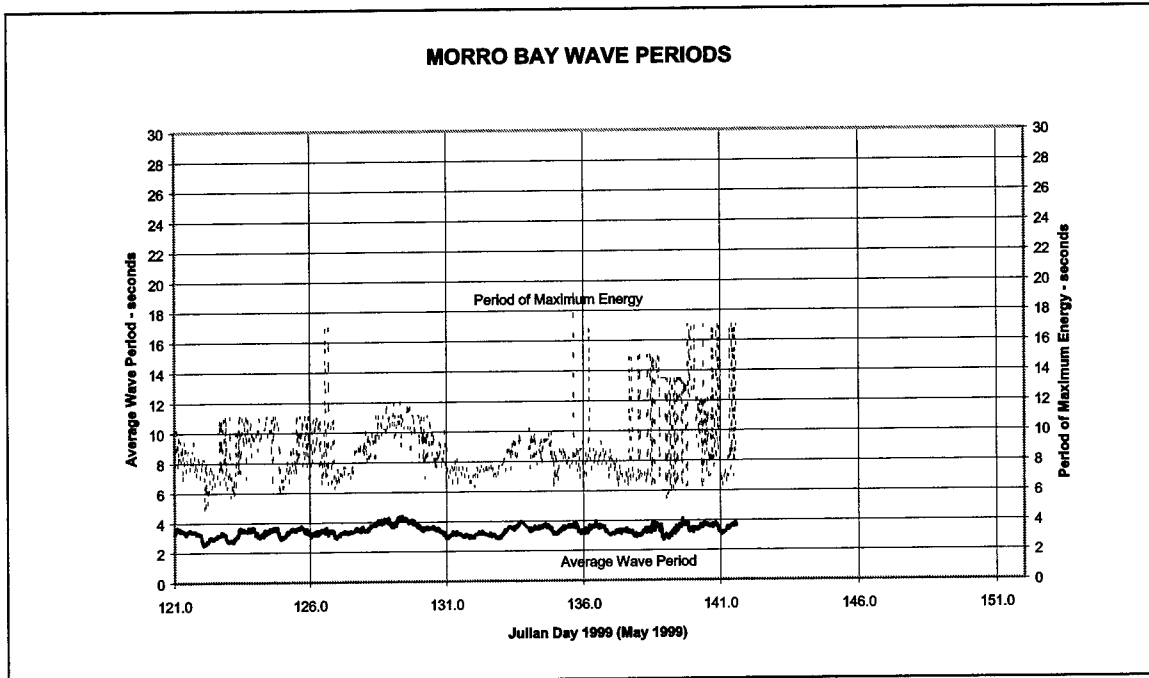


Figure 16. May 1999 average wave periods and periods of maximum energy

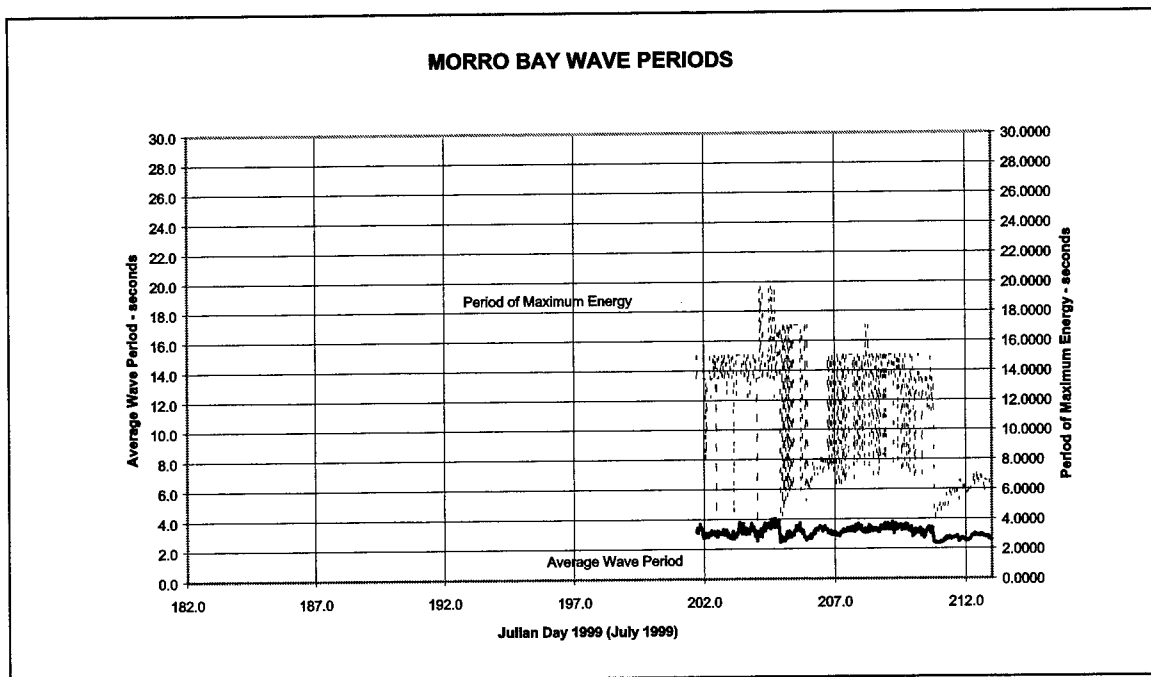


Figure 17. July 1999 average wave periods and periods of maximum energy

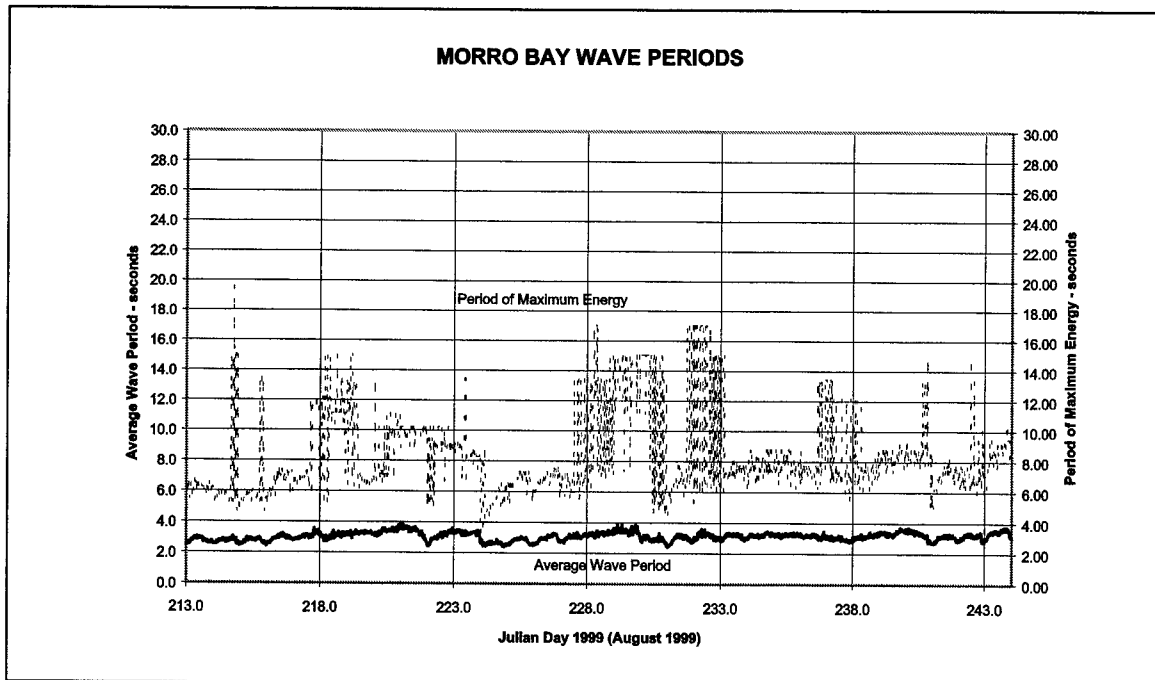


Figure 18. August 1999 average wave periods and periods of maximum energy

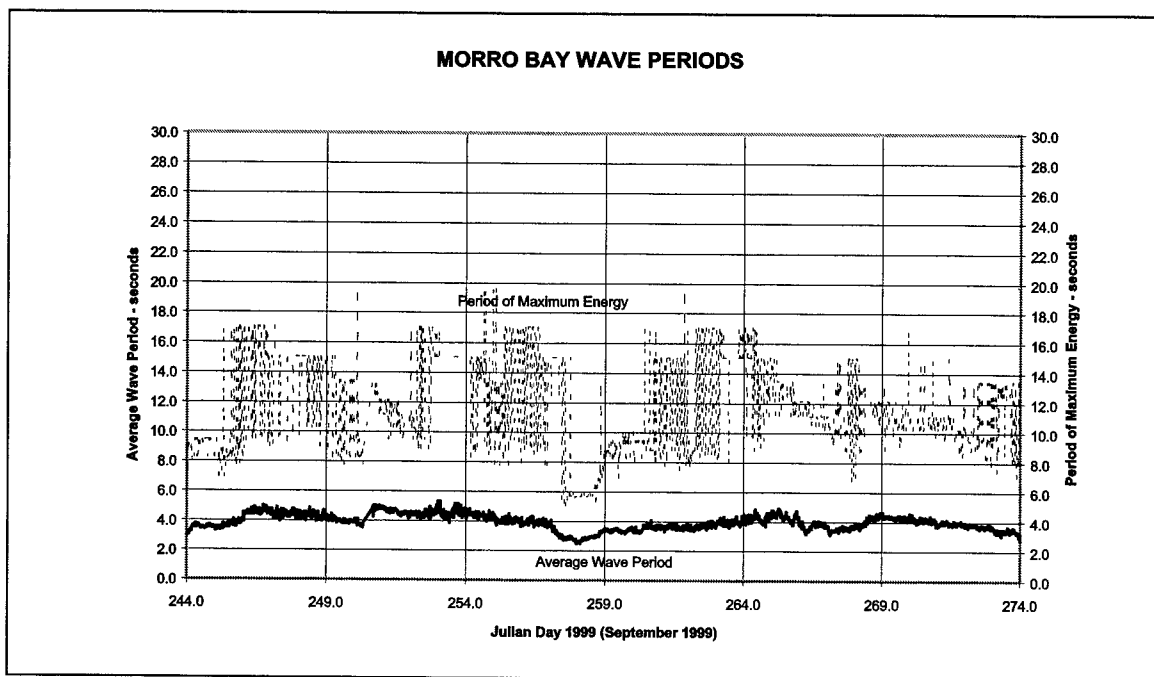


Figure 19. September 1999 average wave periods and periods of maximum energy

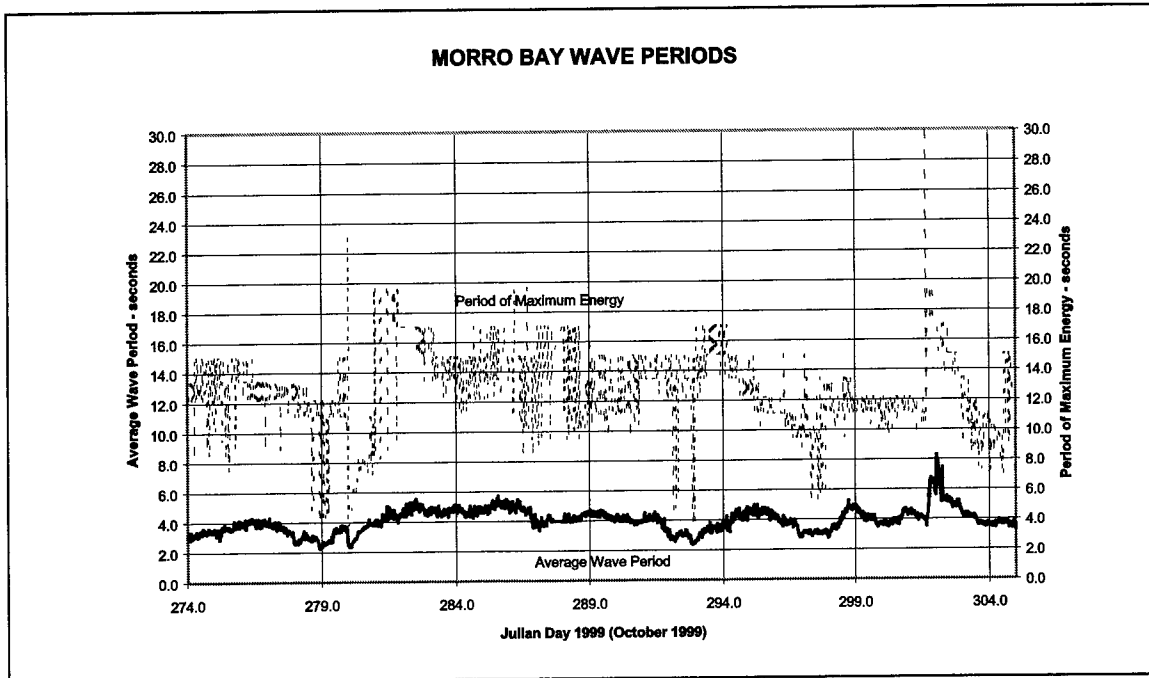


Figure 20. October 1999 average wave periods and periods of maximum energy

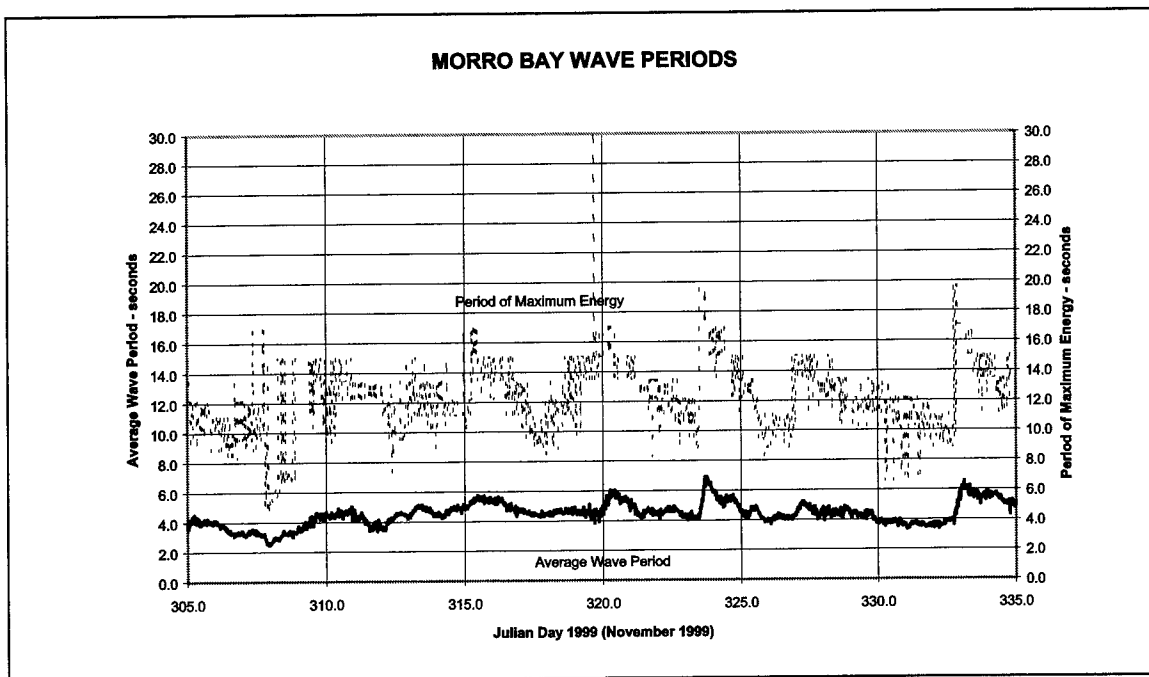


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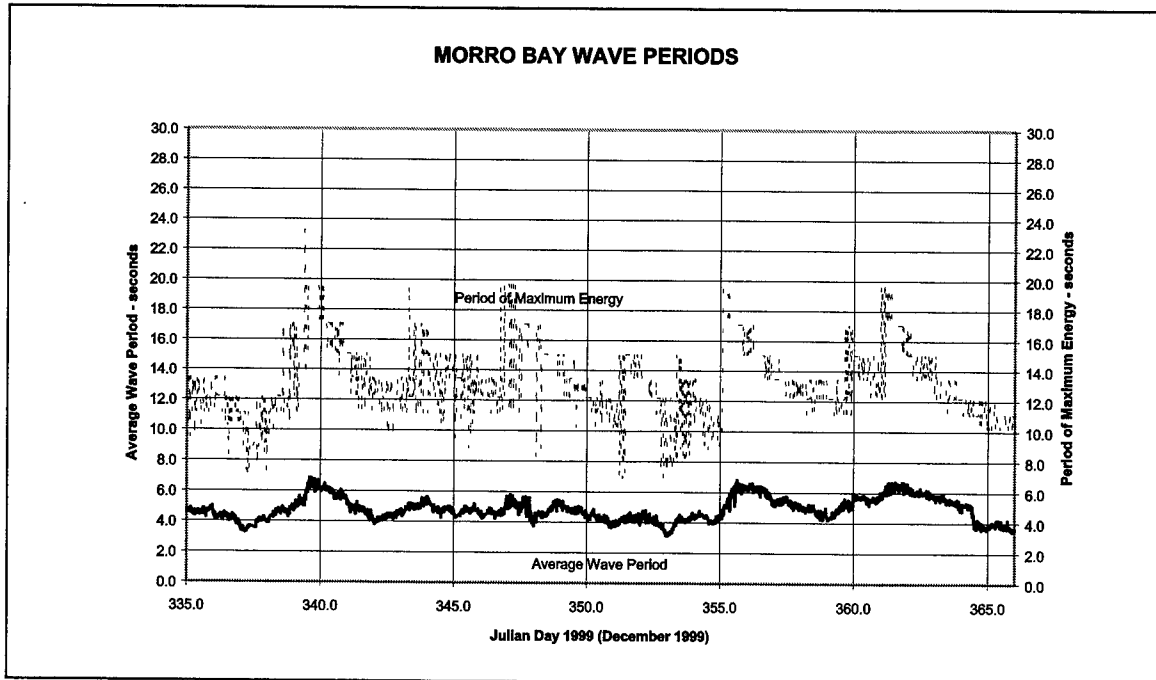


Figure 22. December 1999 average wave periods and periods of maximum energy

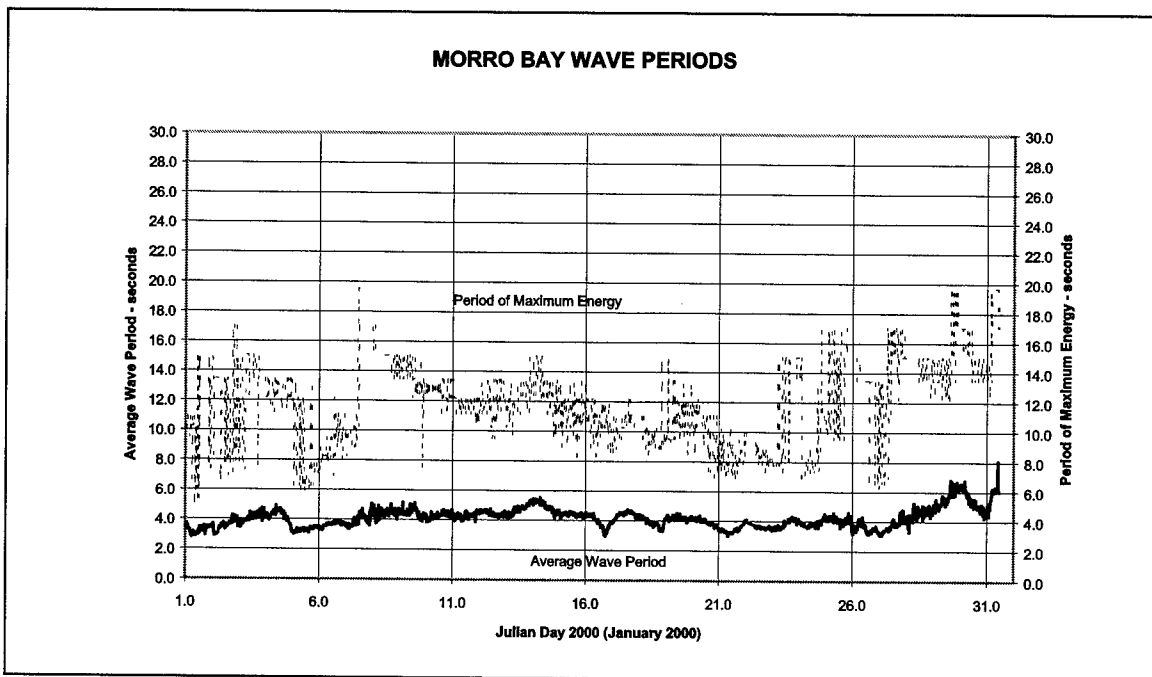


Figure 23. January 2000 average wave periods and periods of maximum energy

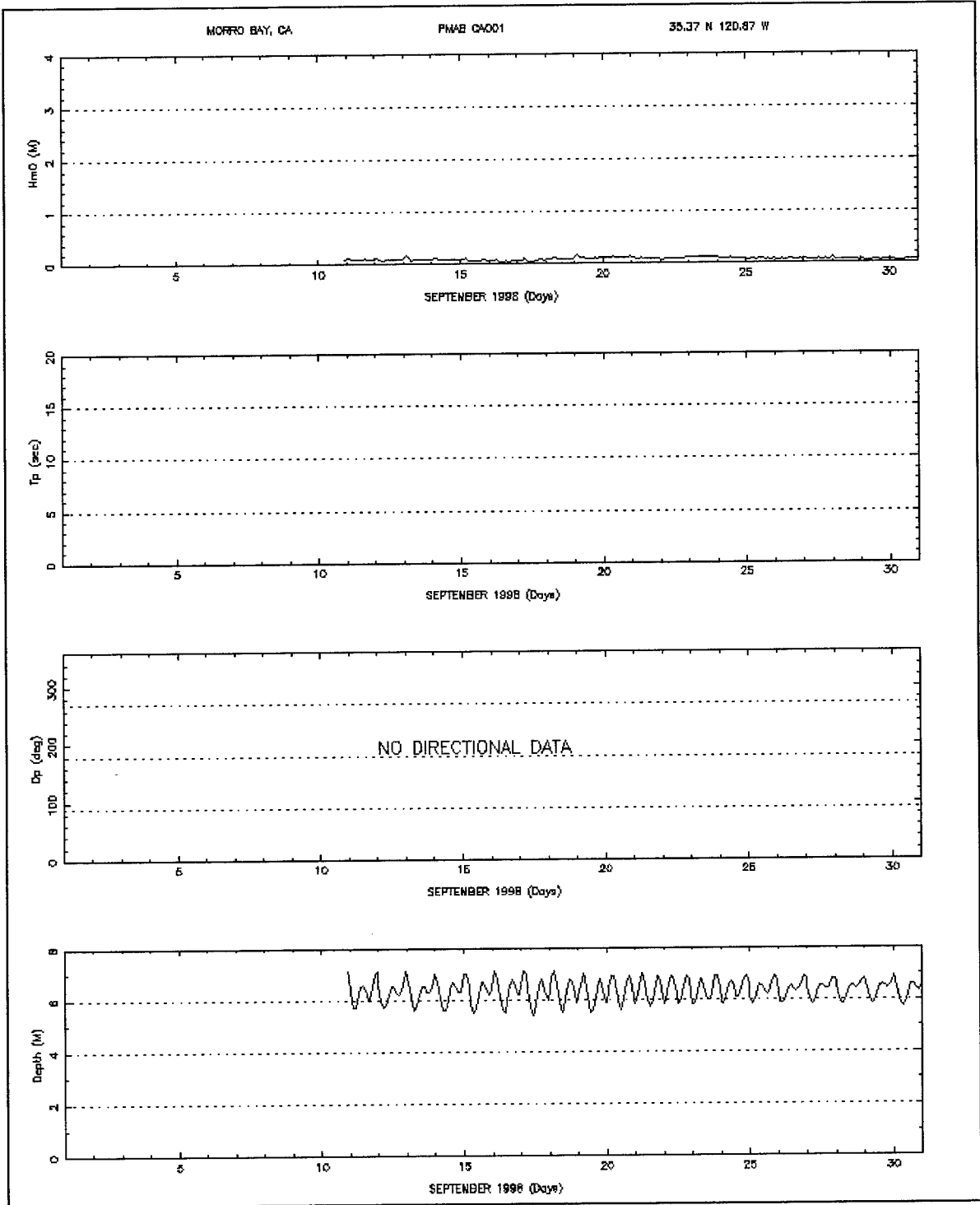


Figure 24. September 1998 monthly time series (CA001)

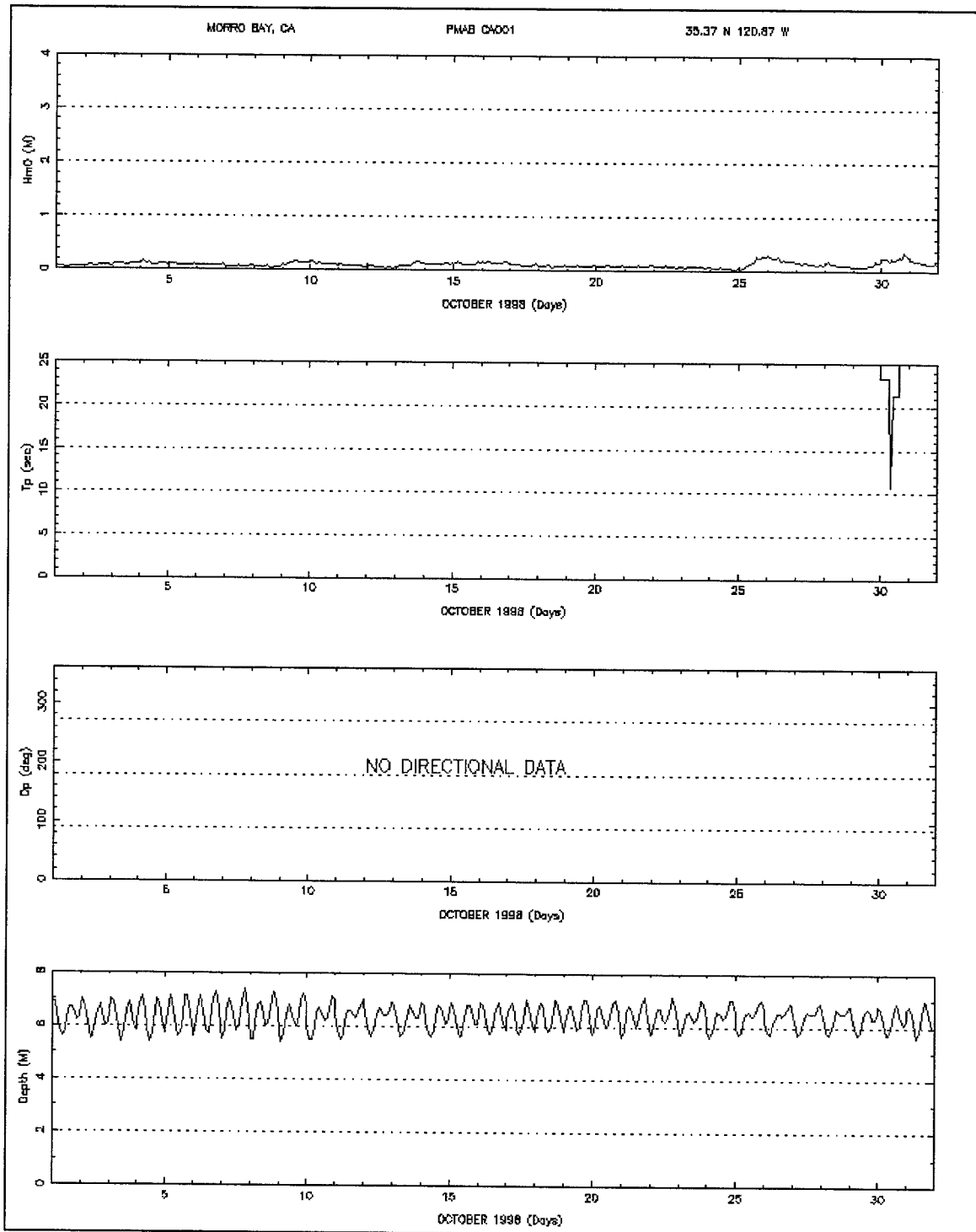


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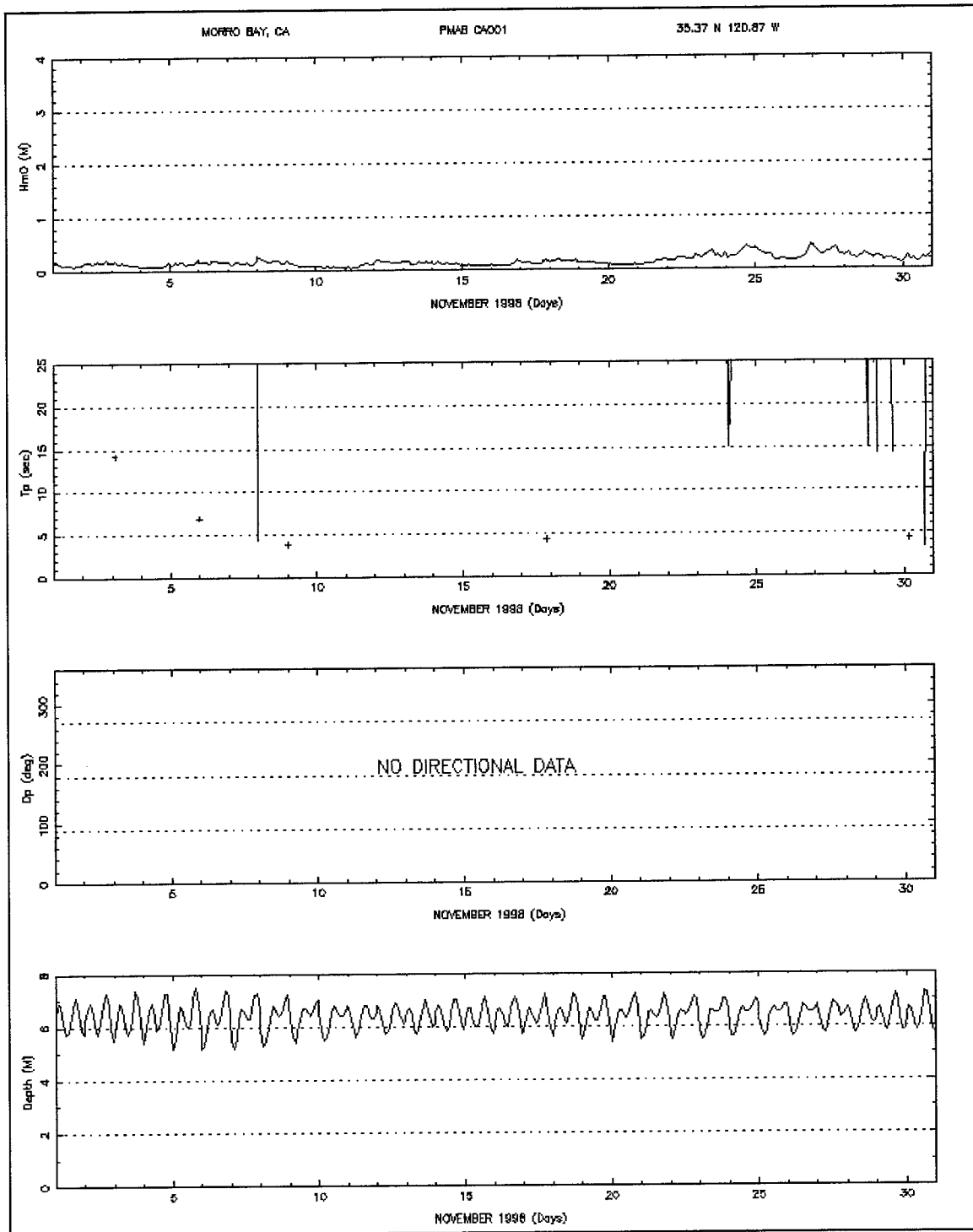


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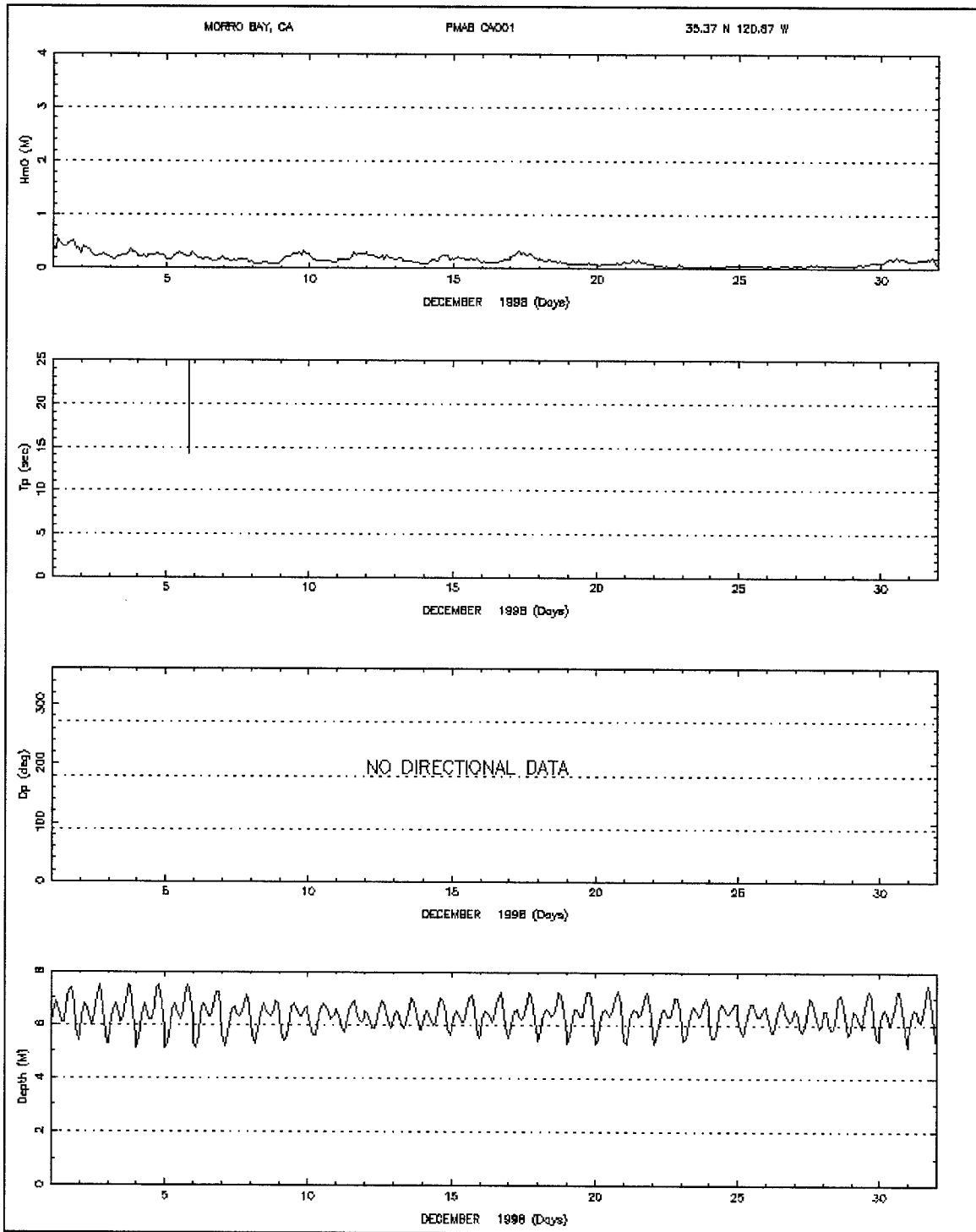


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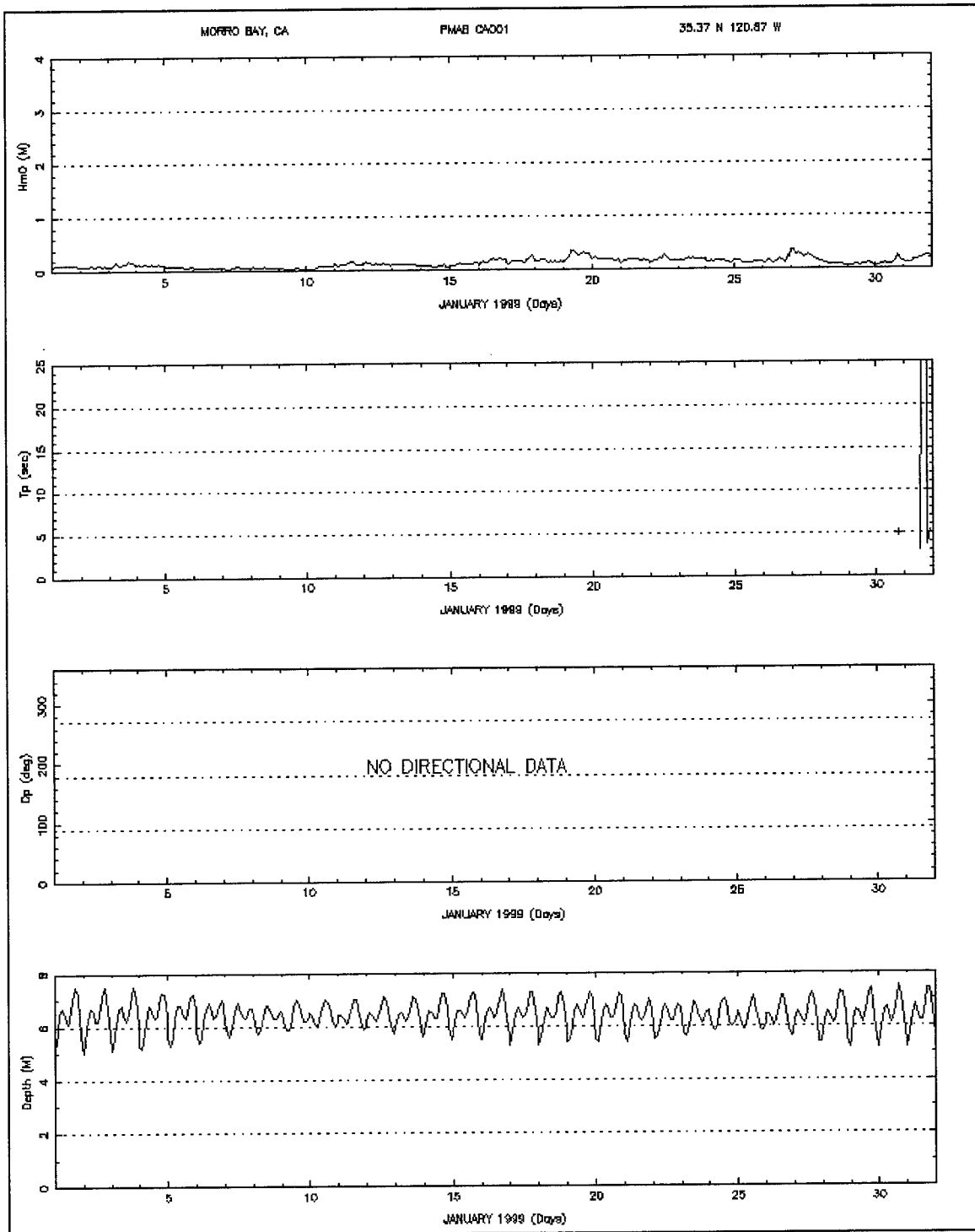


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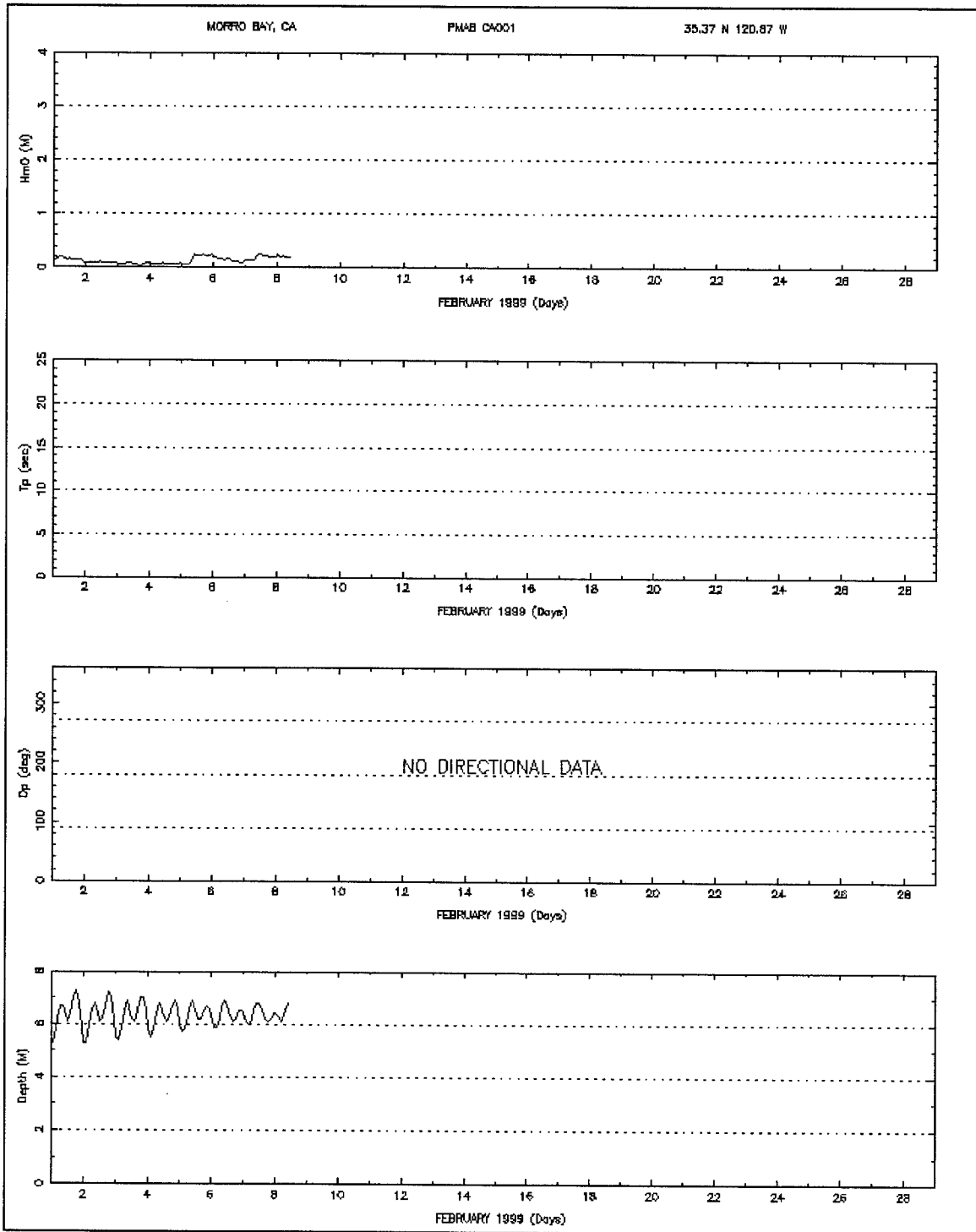


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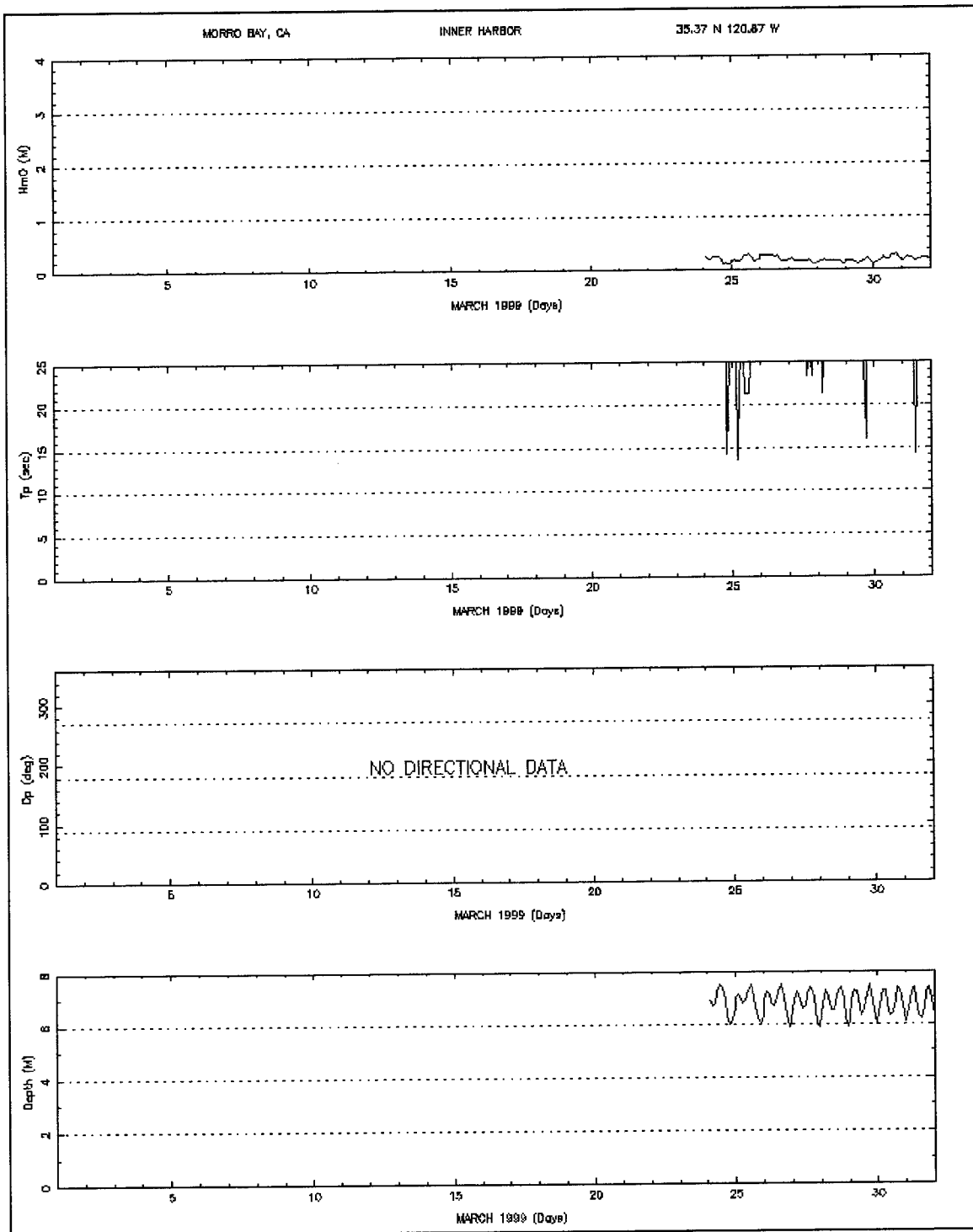


Figure 30. March 1999 monthly time series (CA001)

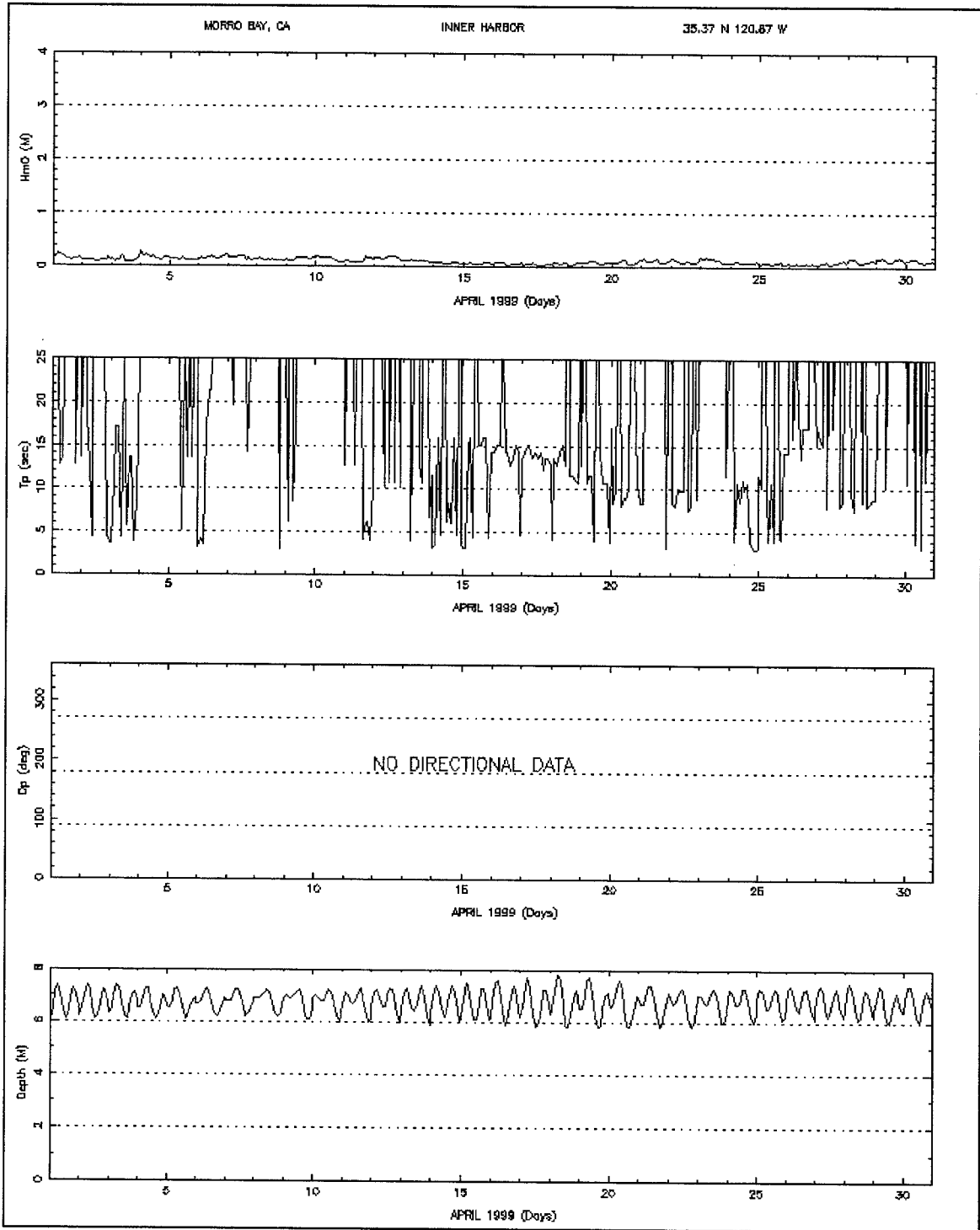


Figure 31. April 1999 monthly time series (CA001)

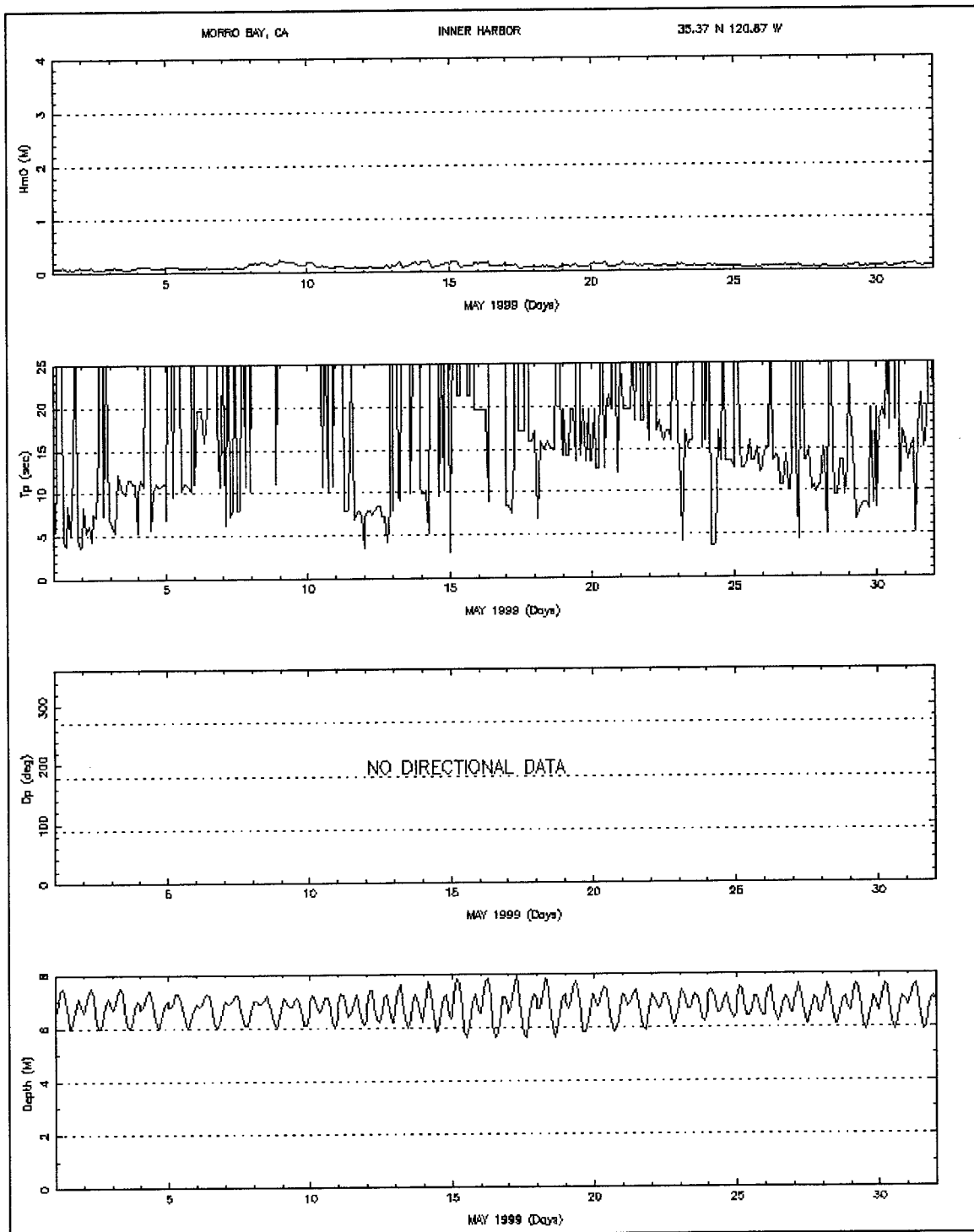


Figure 32. May 1999 monthly time series (CA001)

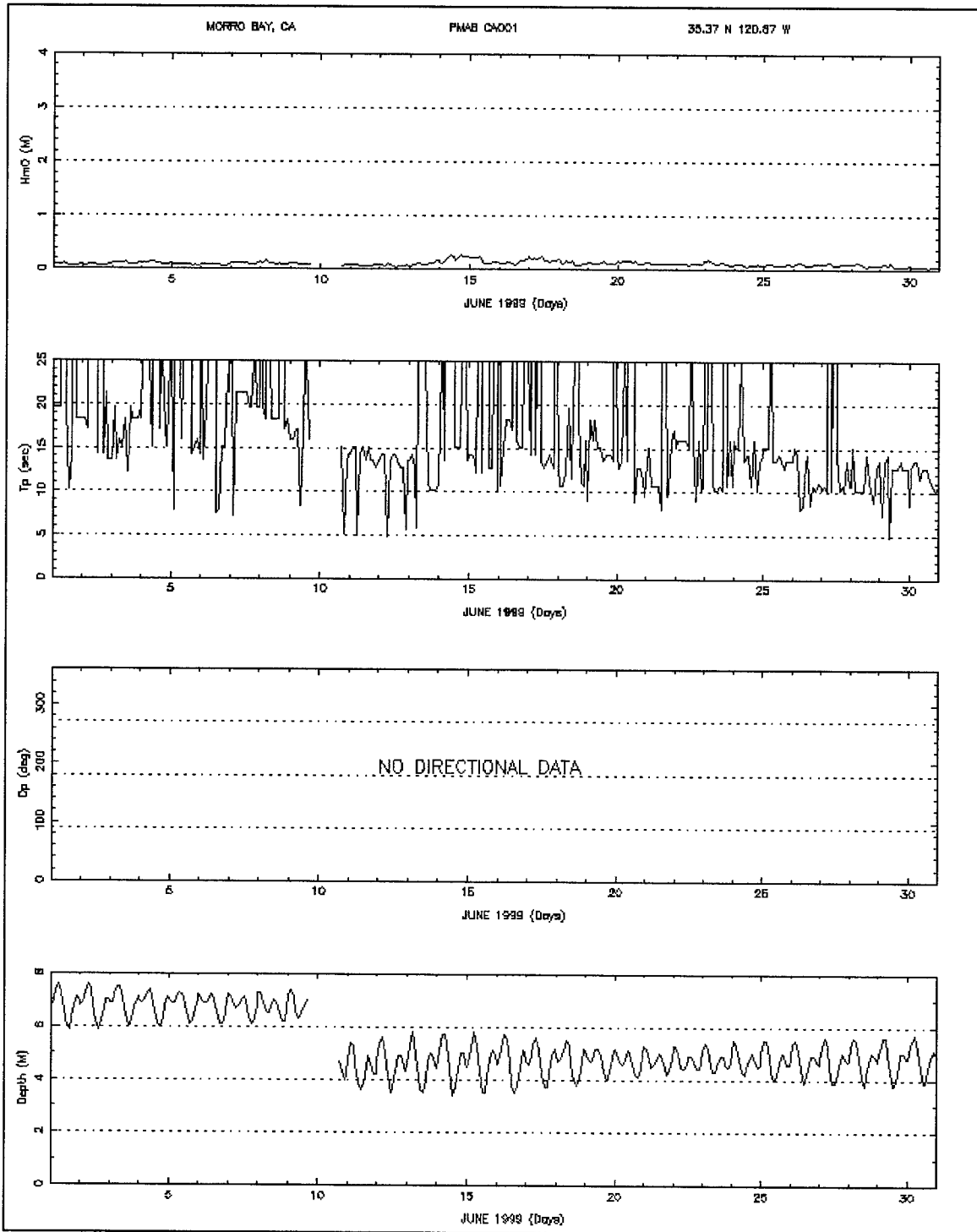


Figure 33. June 1999 monthly time series (CA001)

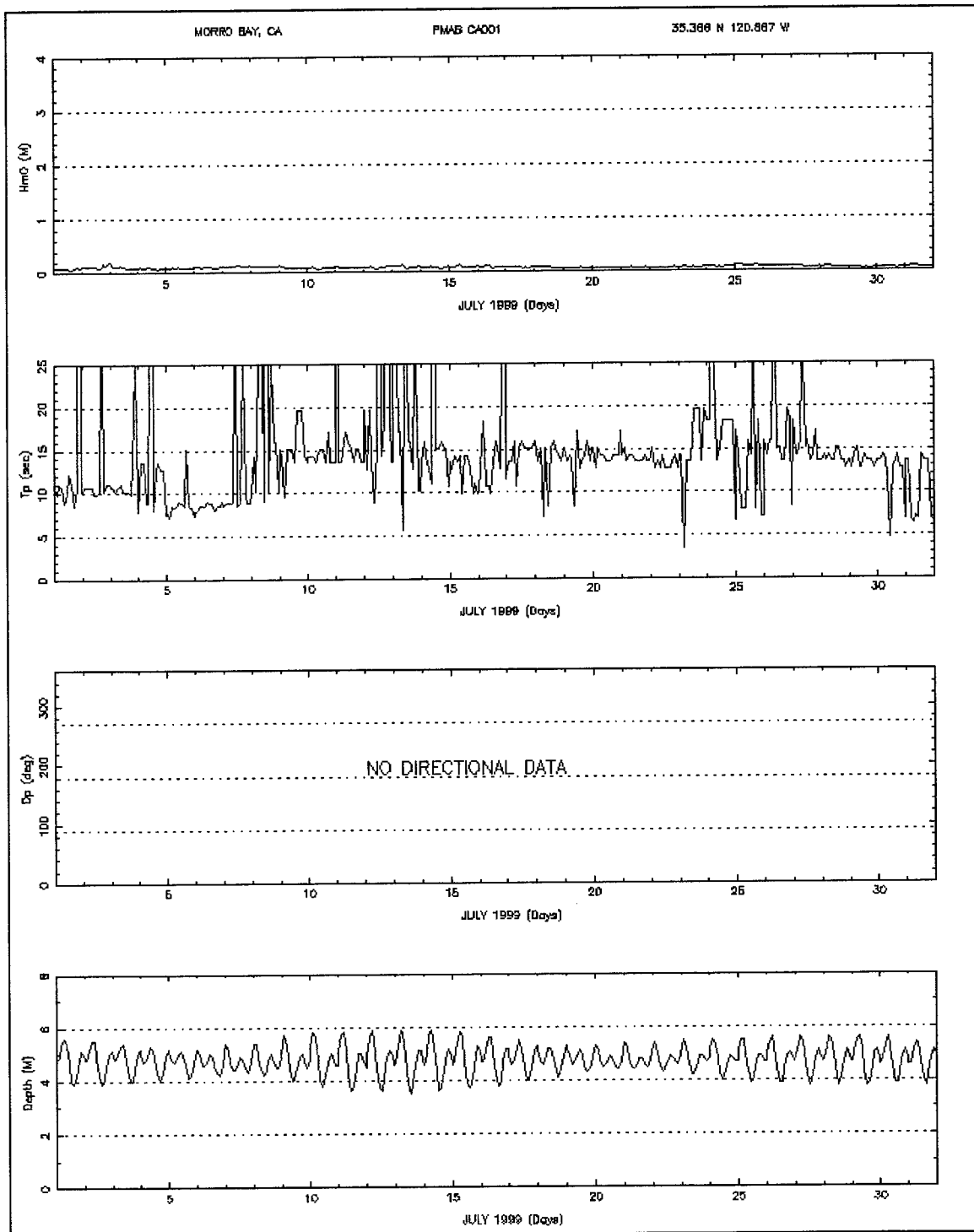


Figure 34. July 1999 monthly time series (CA001)

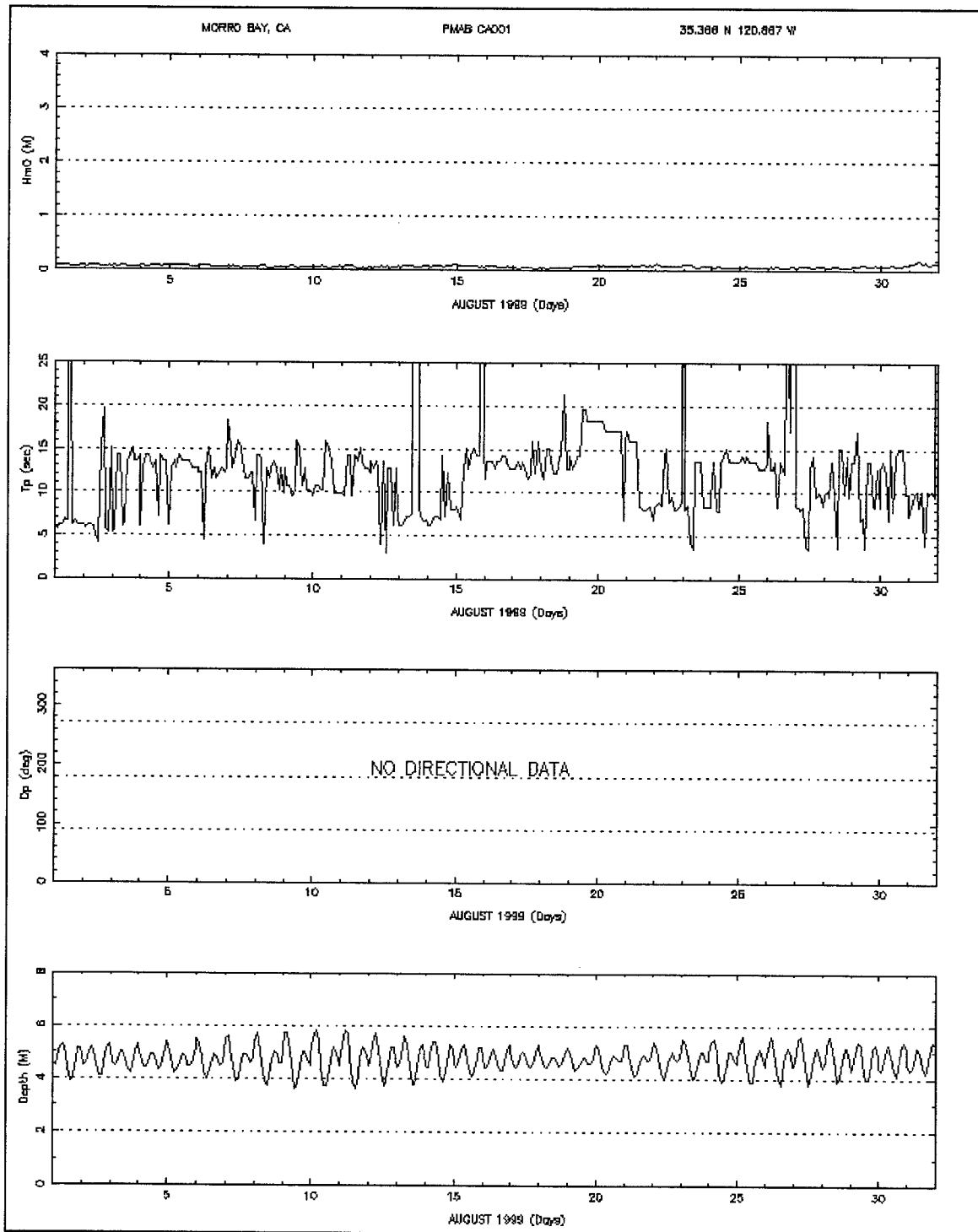


Figure 35. August 1999 monthly time series (CA001)

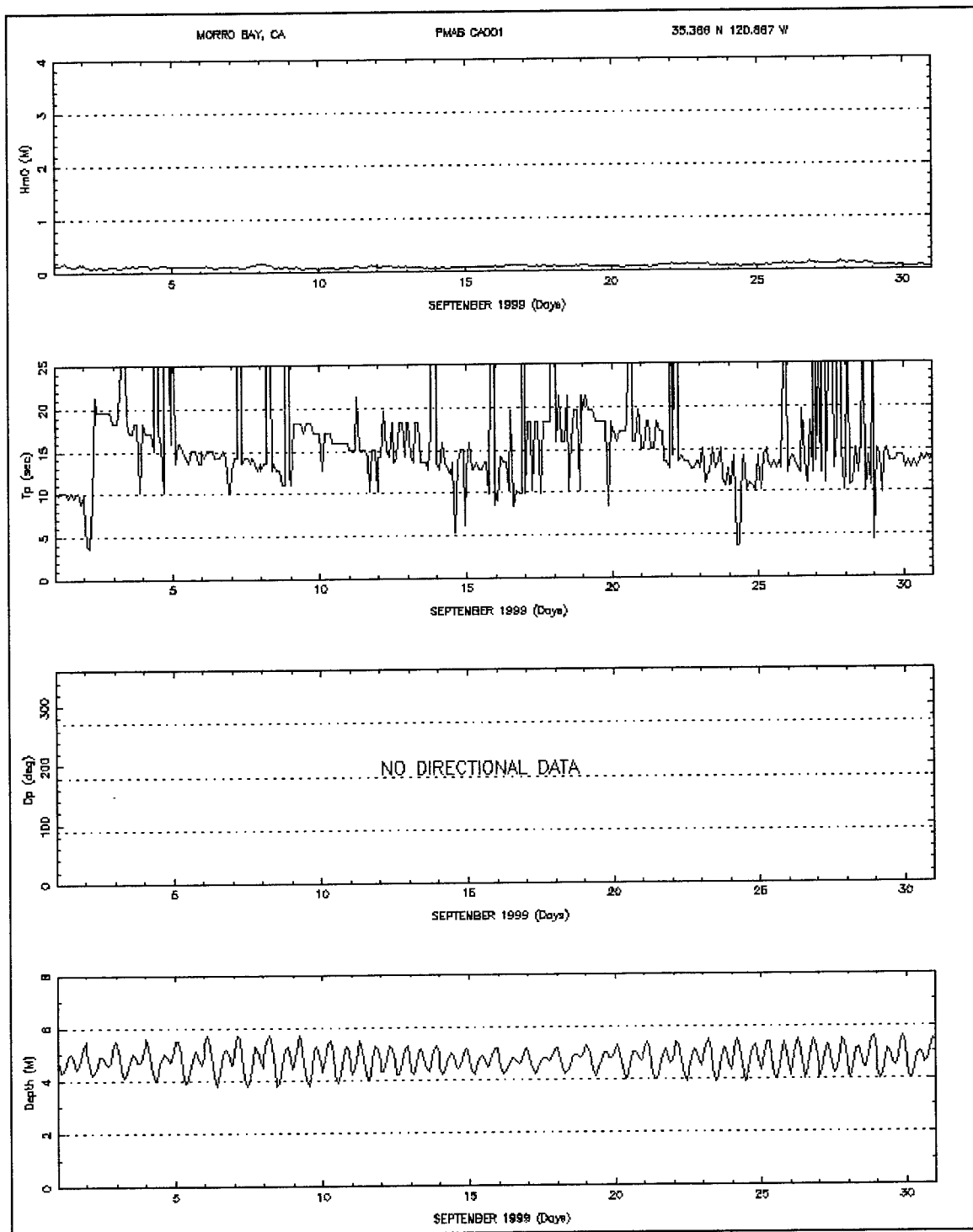


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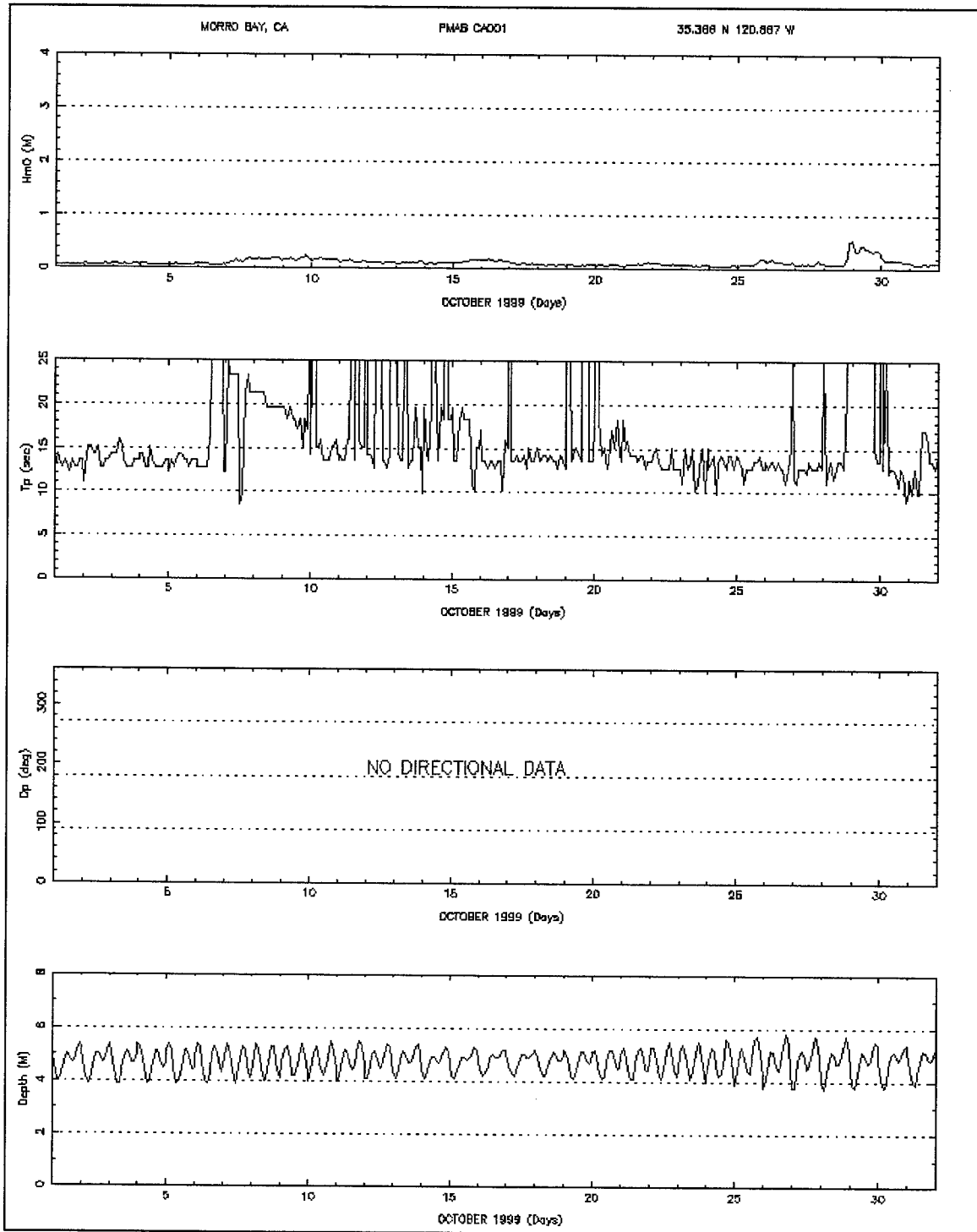


Figure 37. October 1999 monthly time series (CA001)

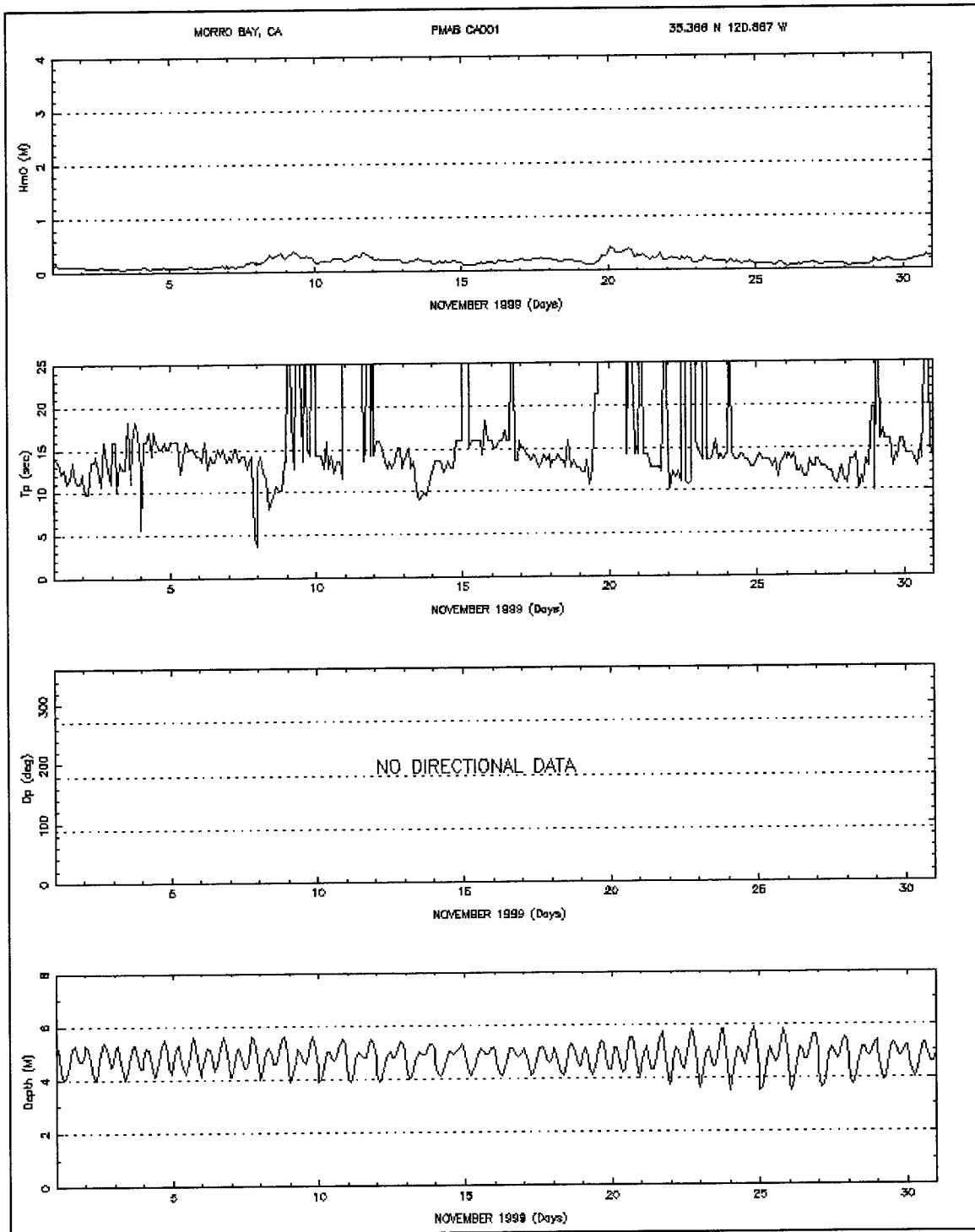


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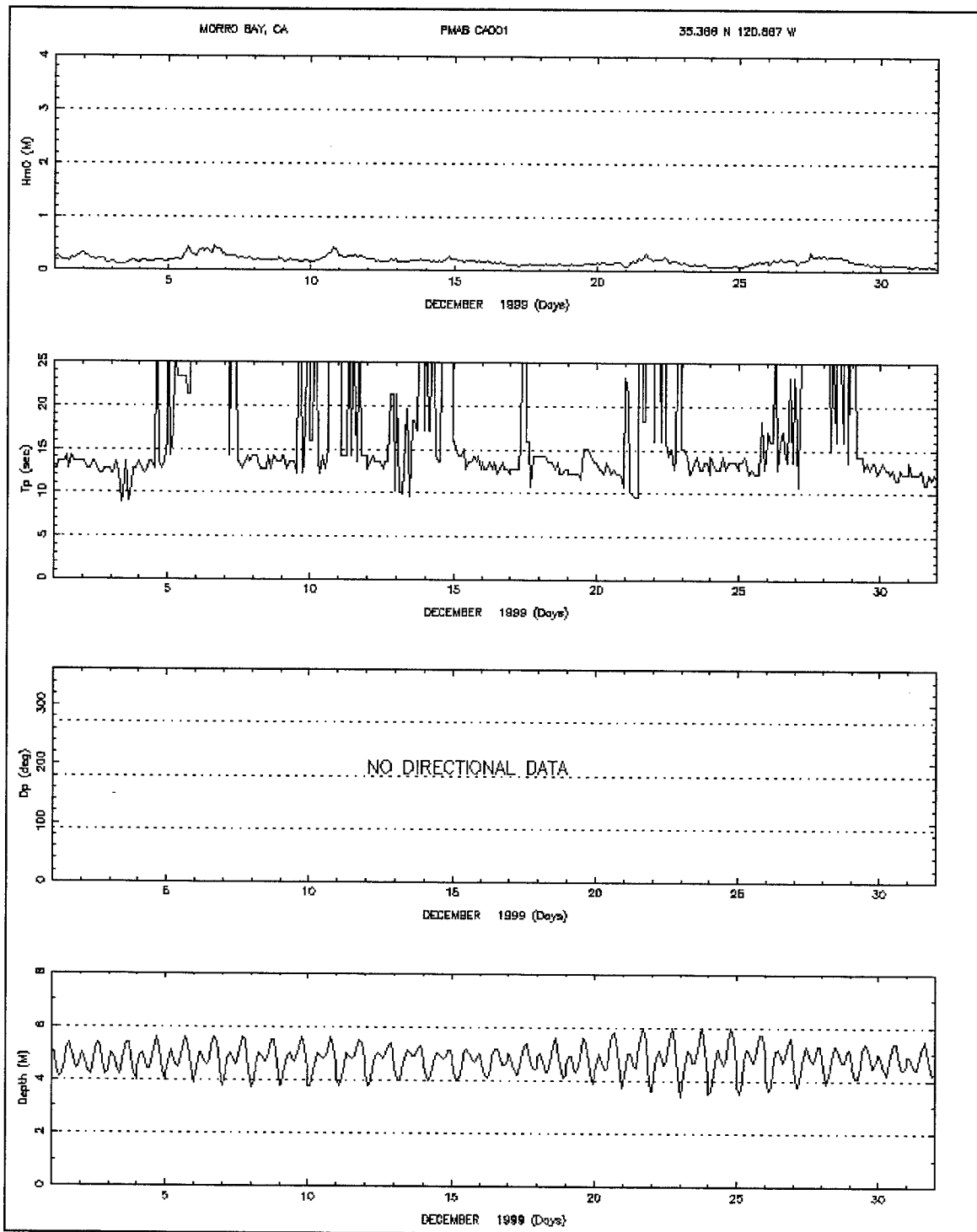


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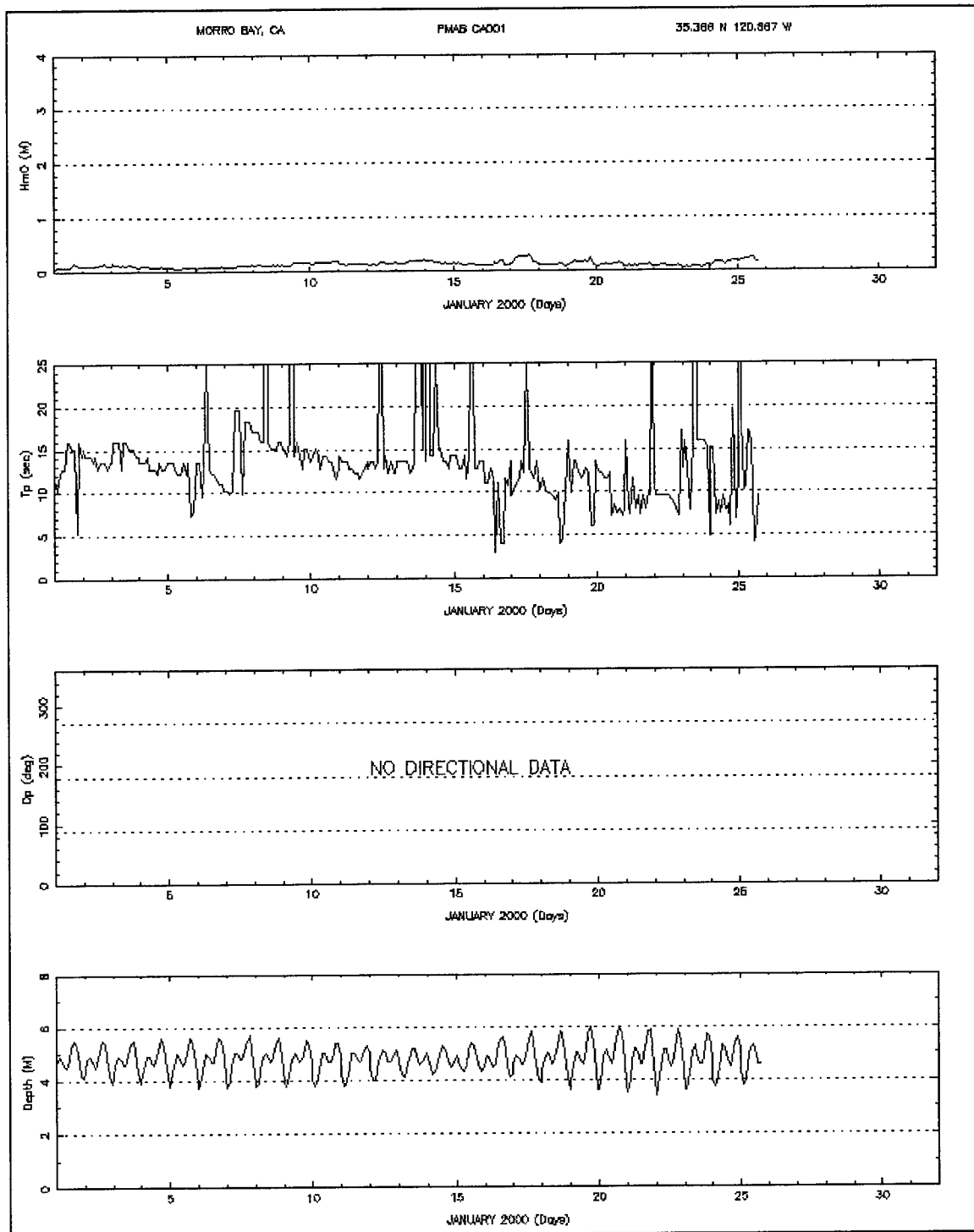


Figure 40. January 2000 monthly time series (CA001)

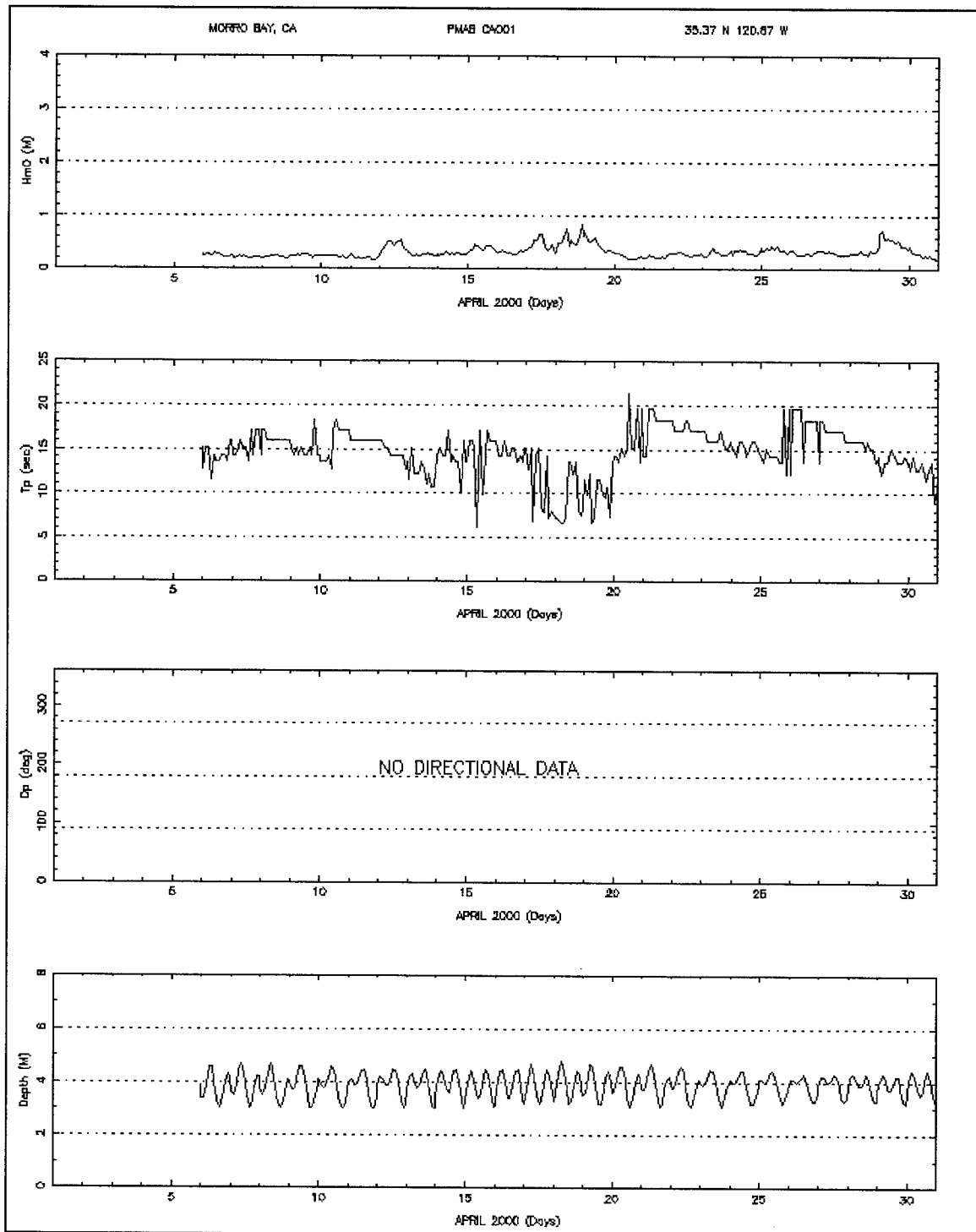


Figure 41. April 2000 monthly time series (CA001)

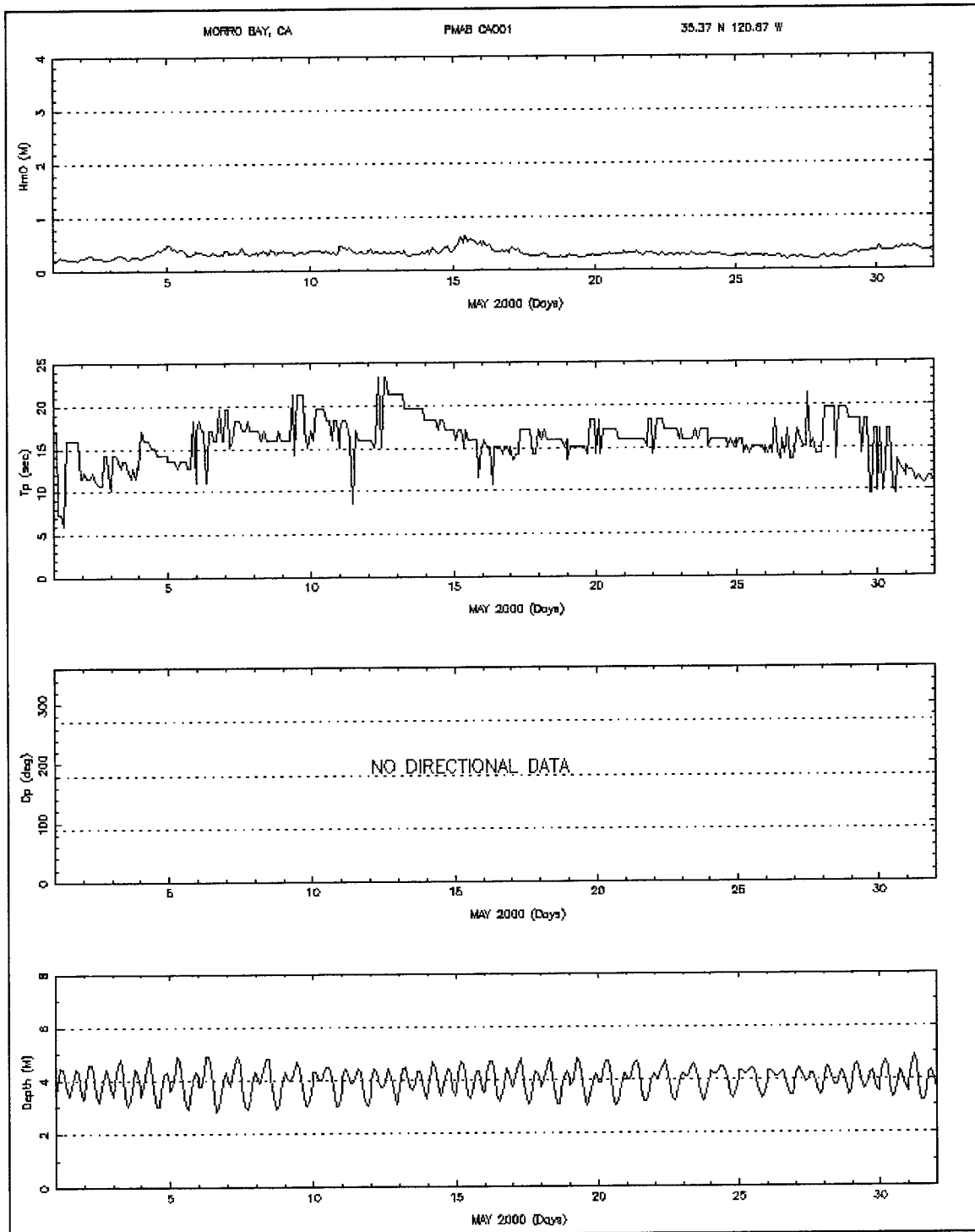


Figure 42. May 2000 monthly time series (CA001)

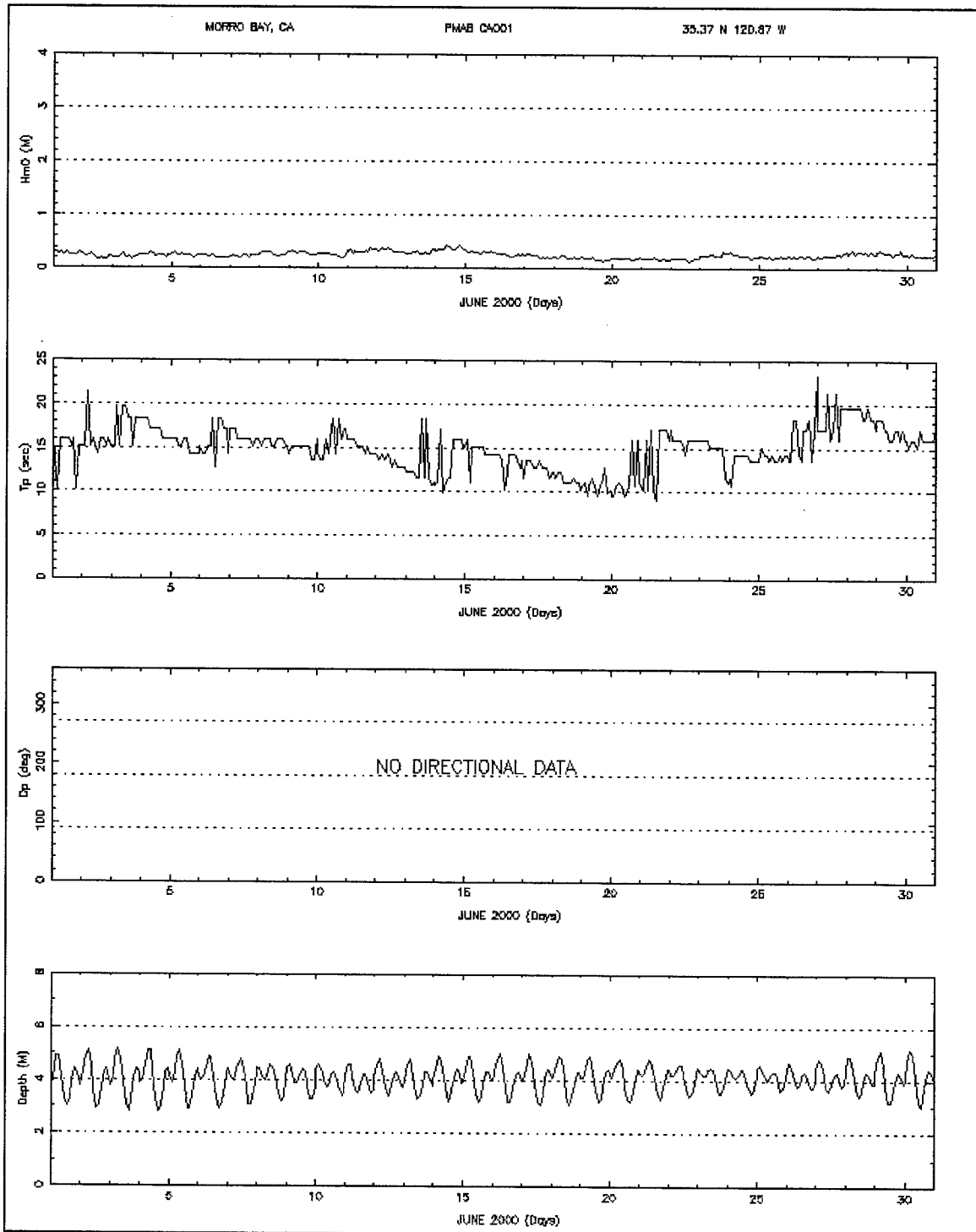


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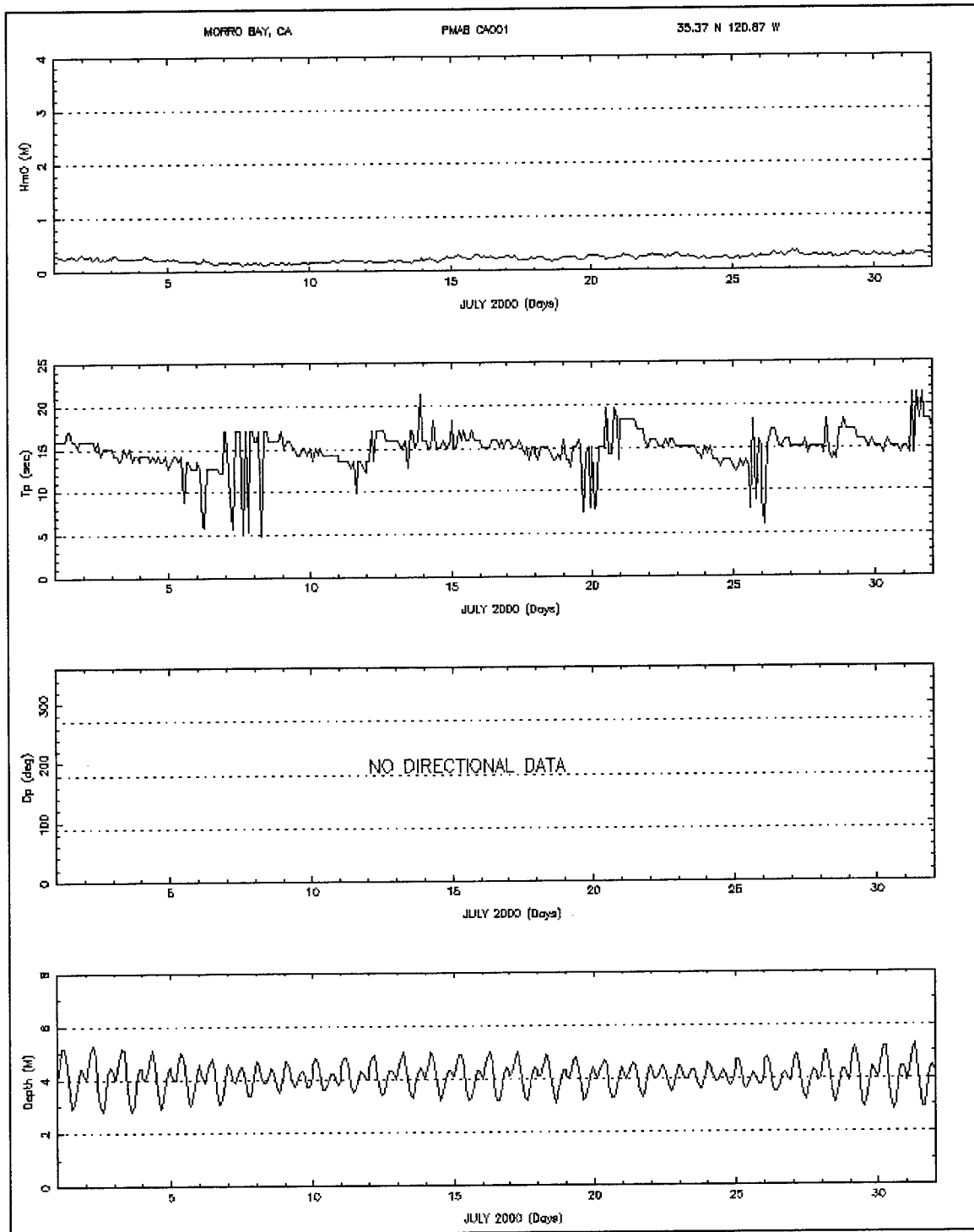


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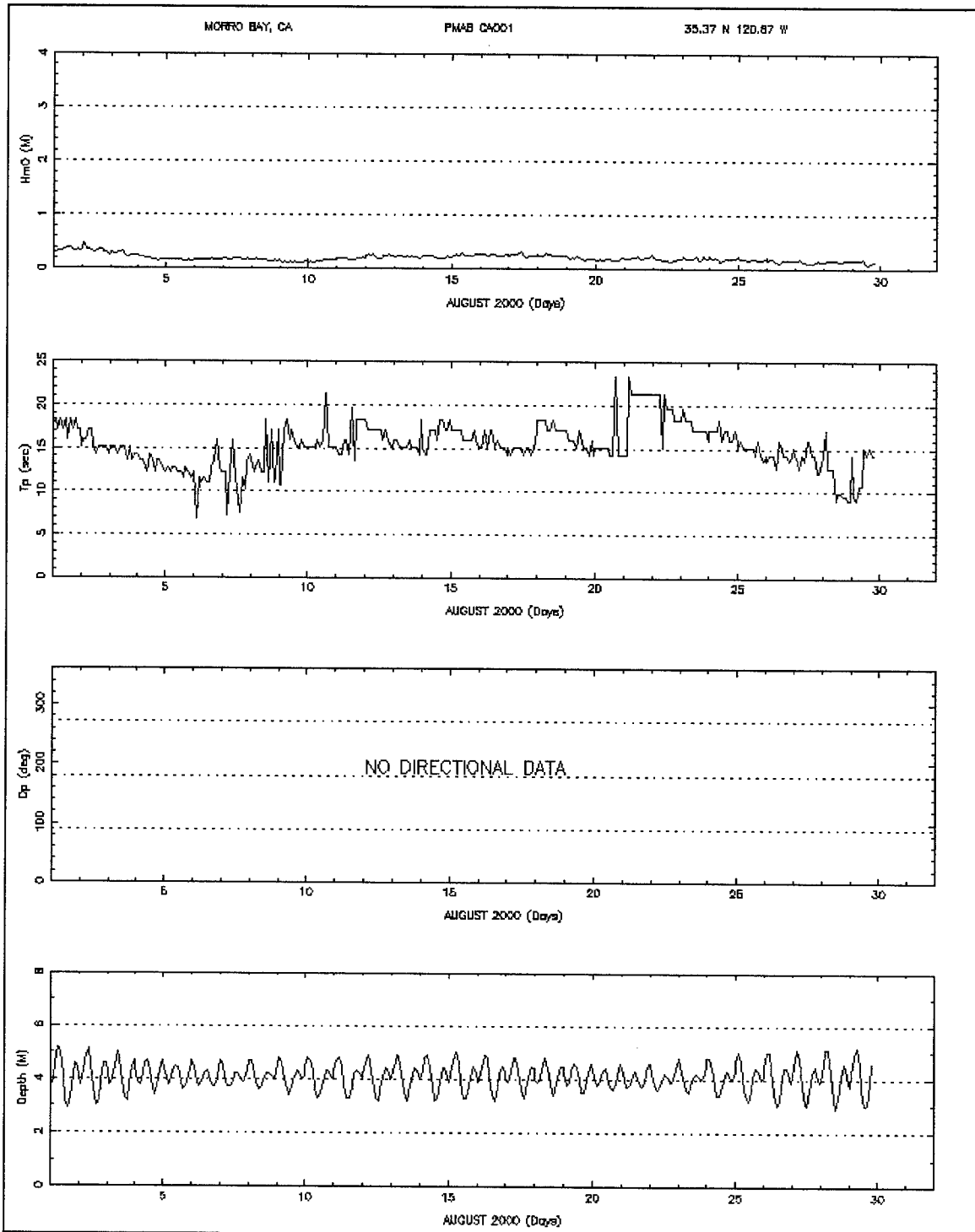


Figure 45. August 2000 monthly time series (CA001)

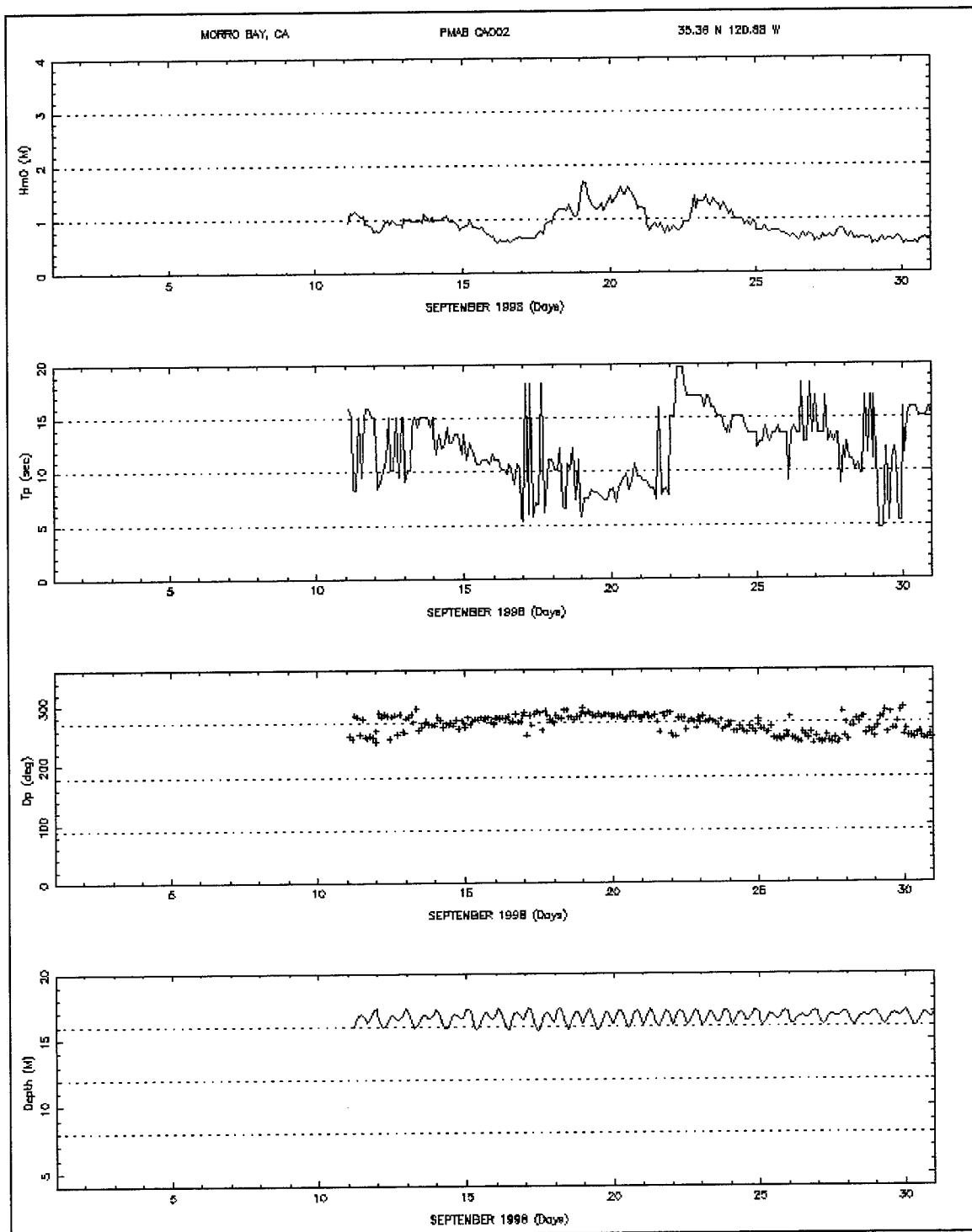


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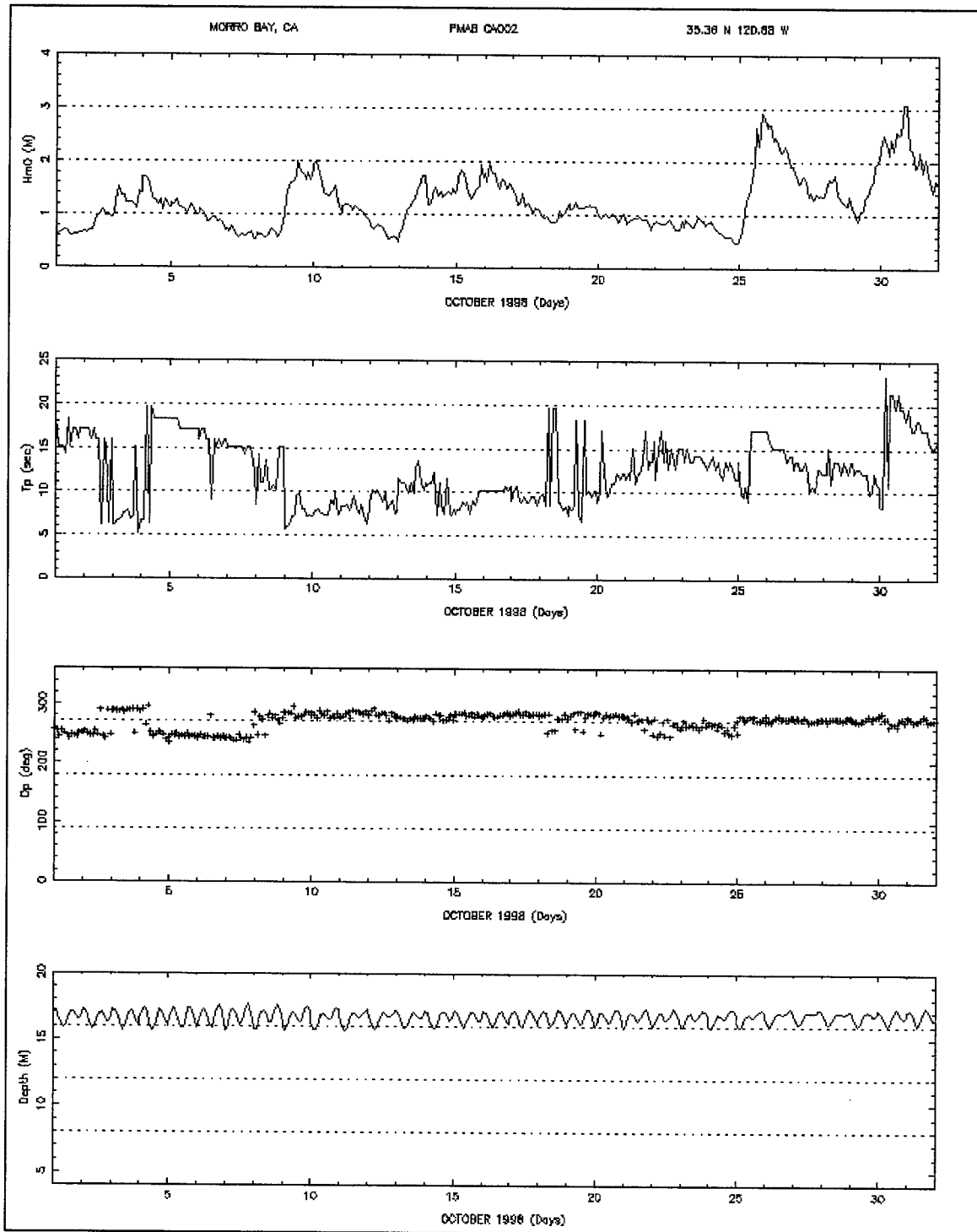


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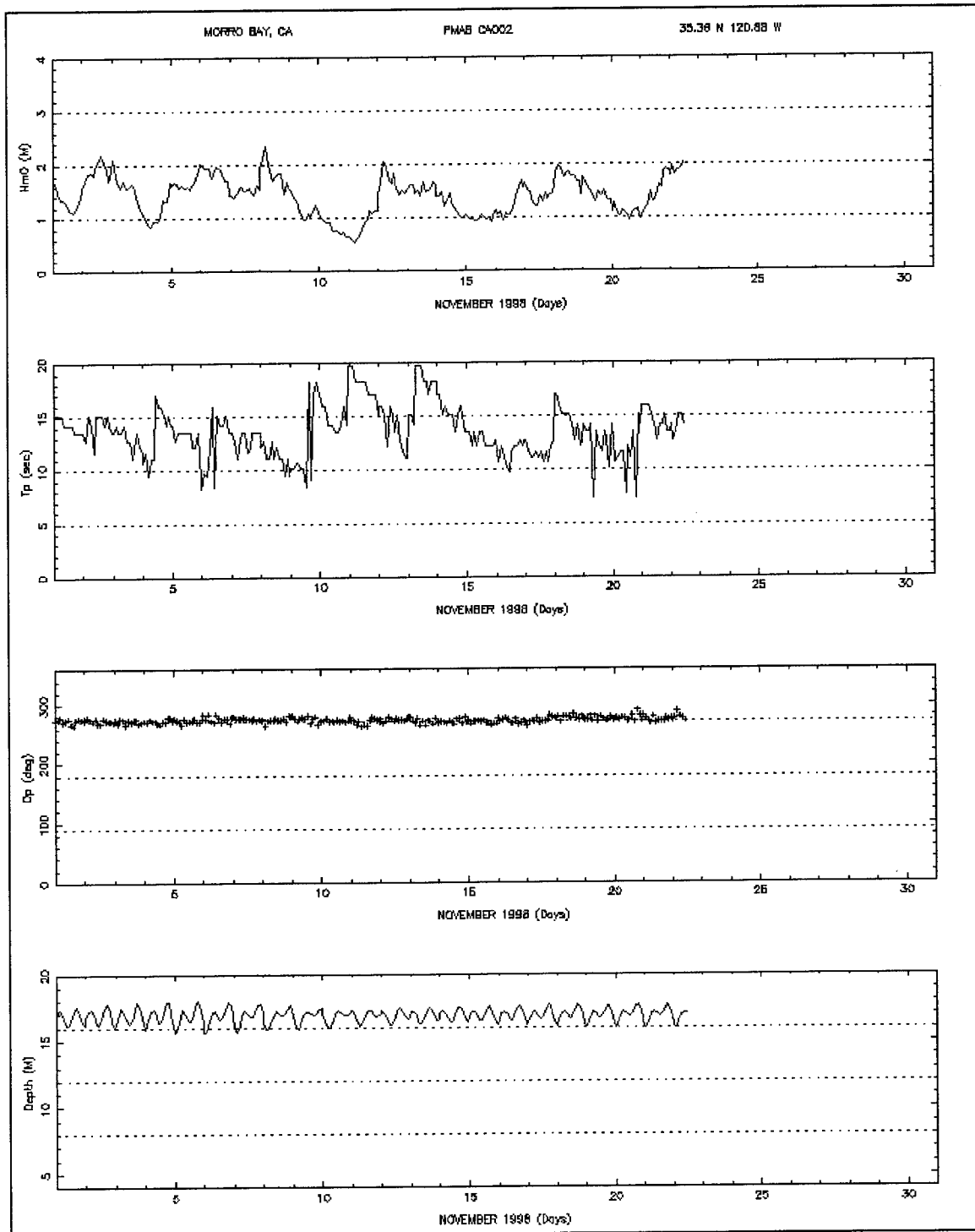


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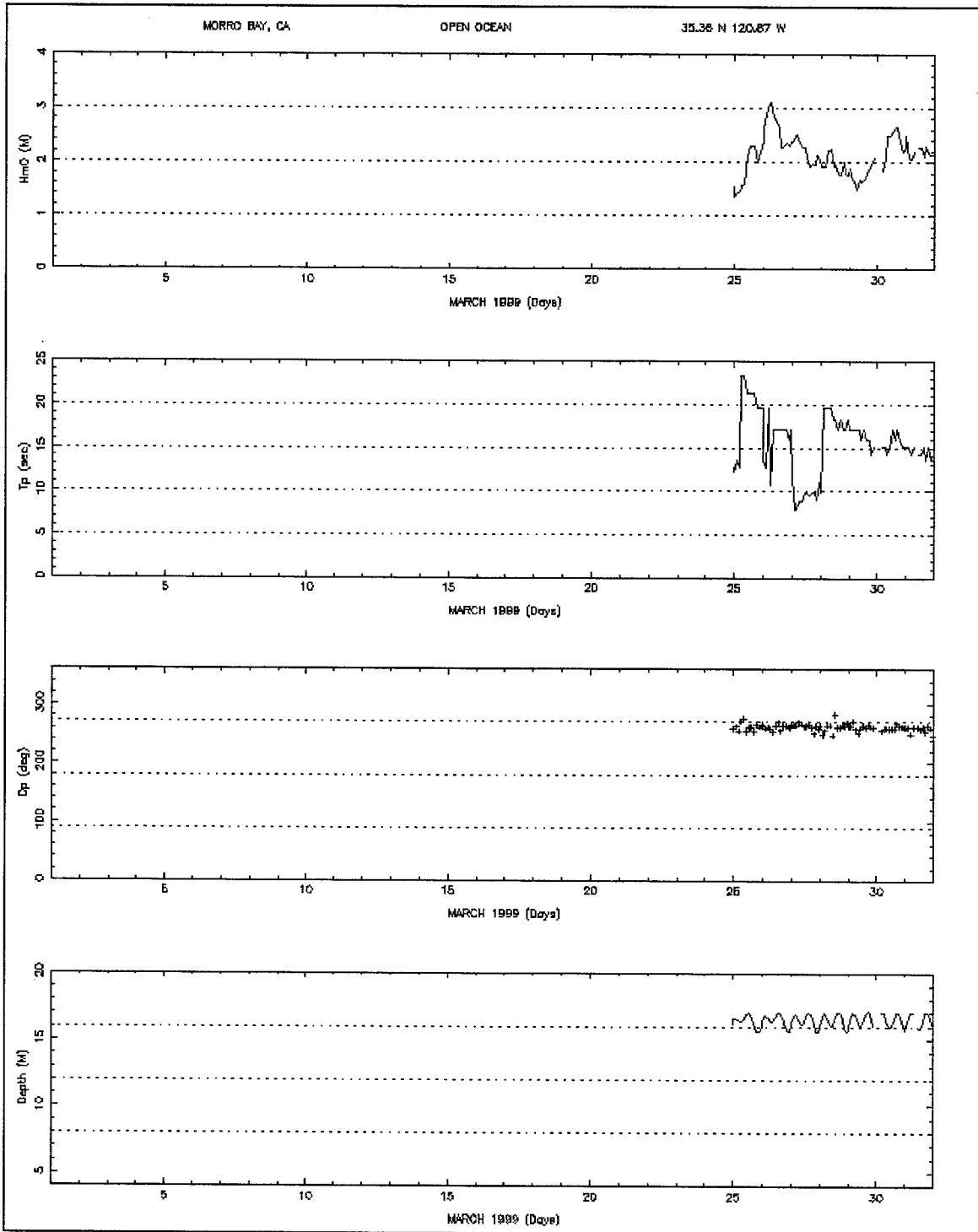


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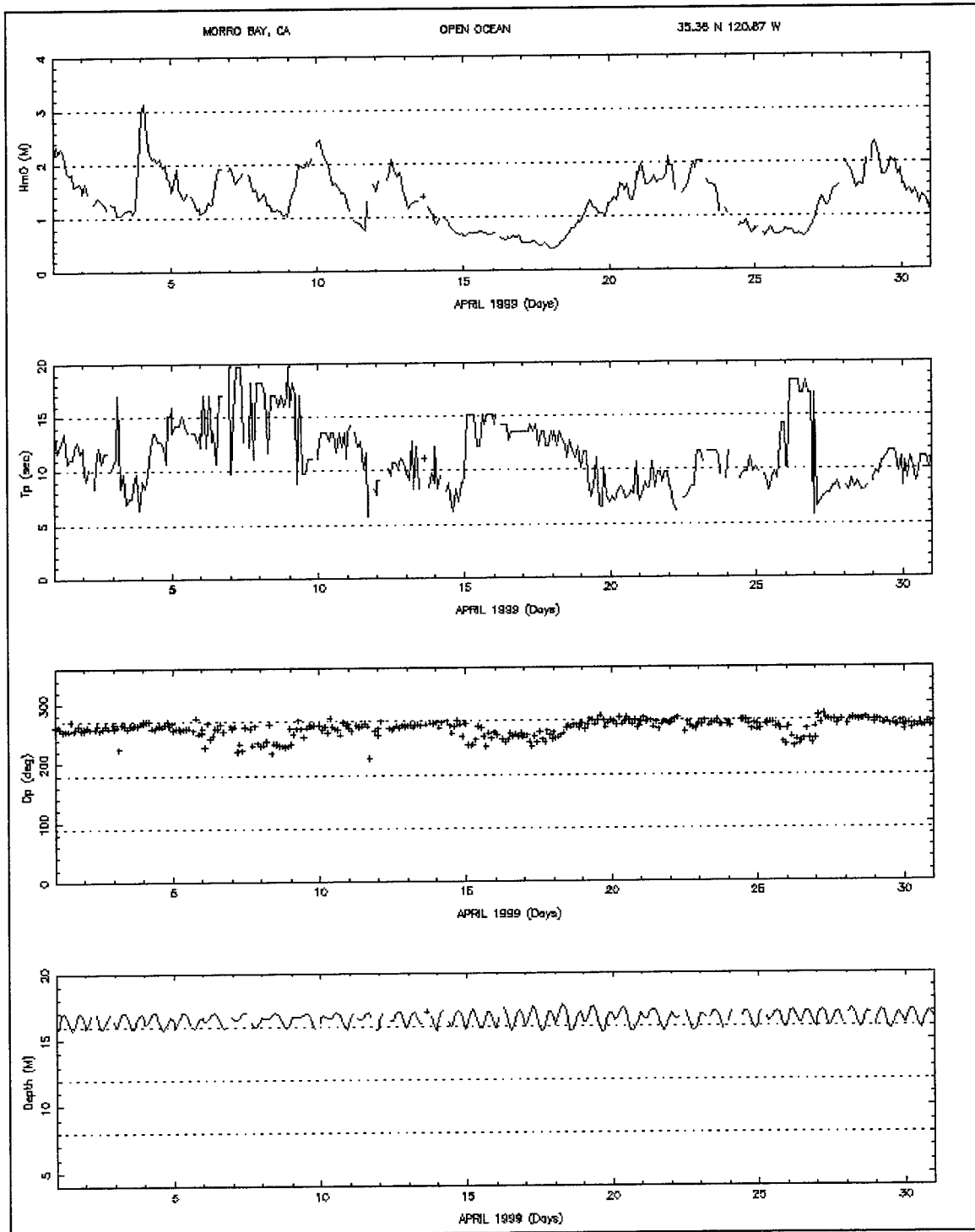


Figure 50. April 1999 monthly time series (CA002)

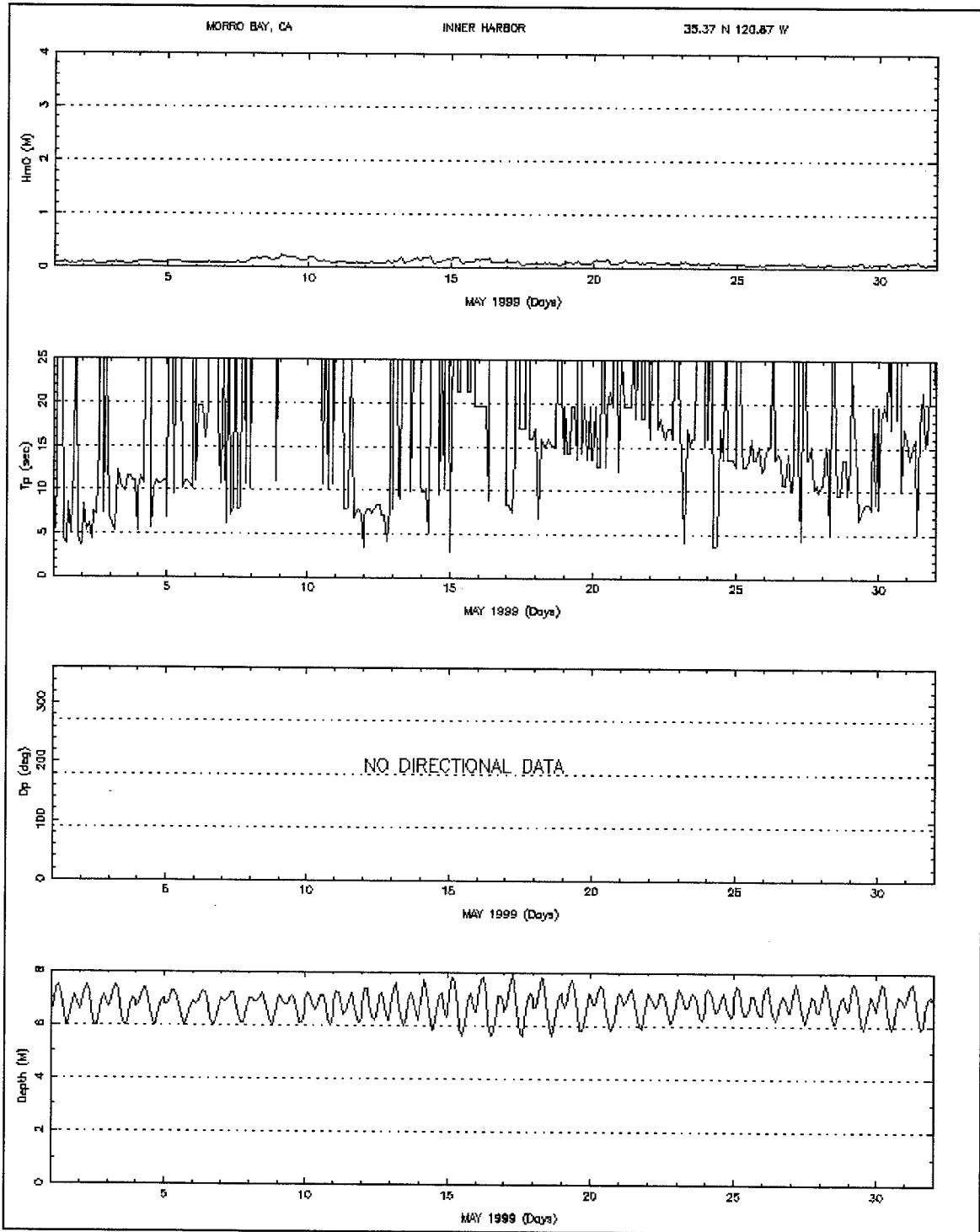


Figure 51. May 1999 monthly time series (CA002)

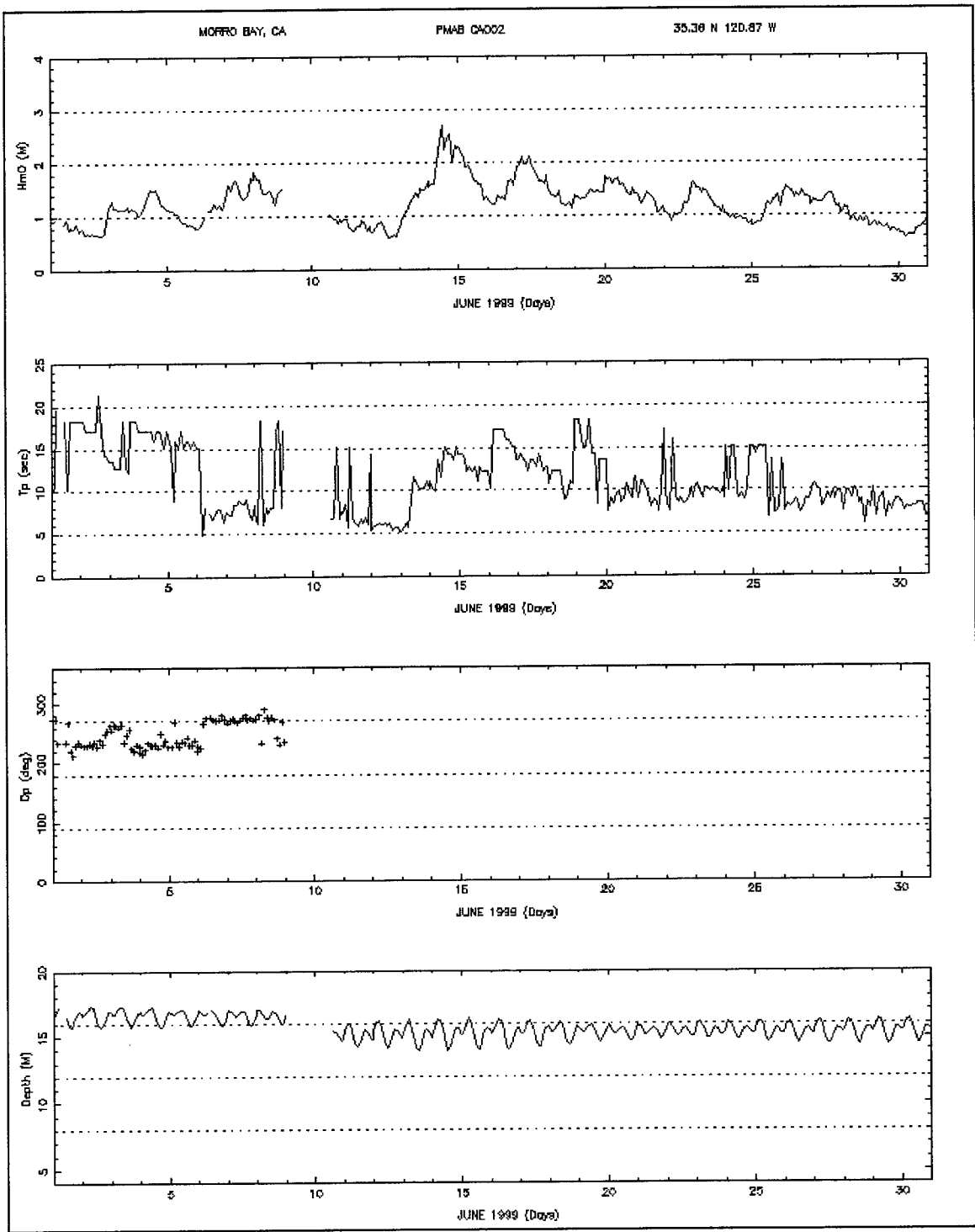


Figure 52. June 1999 monthly time series (CA002)

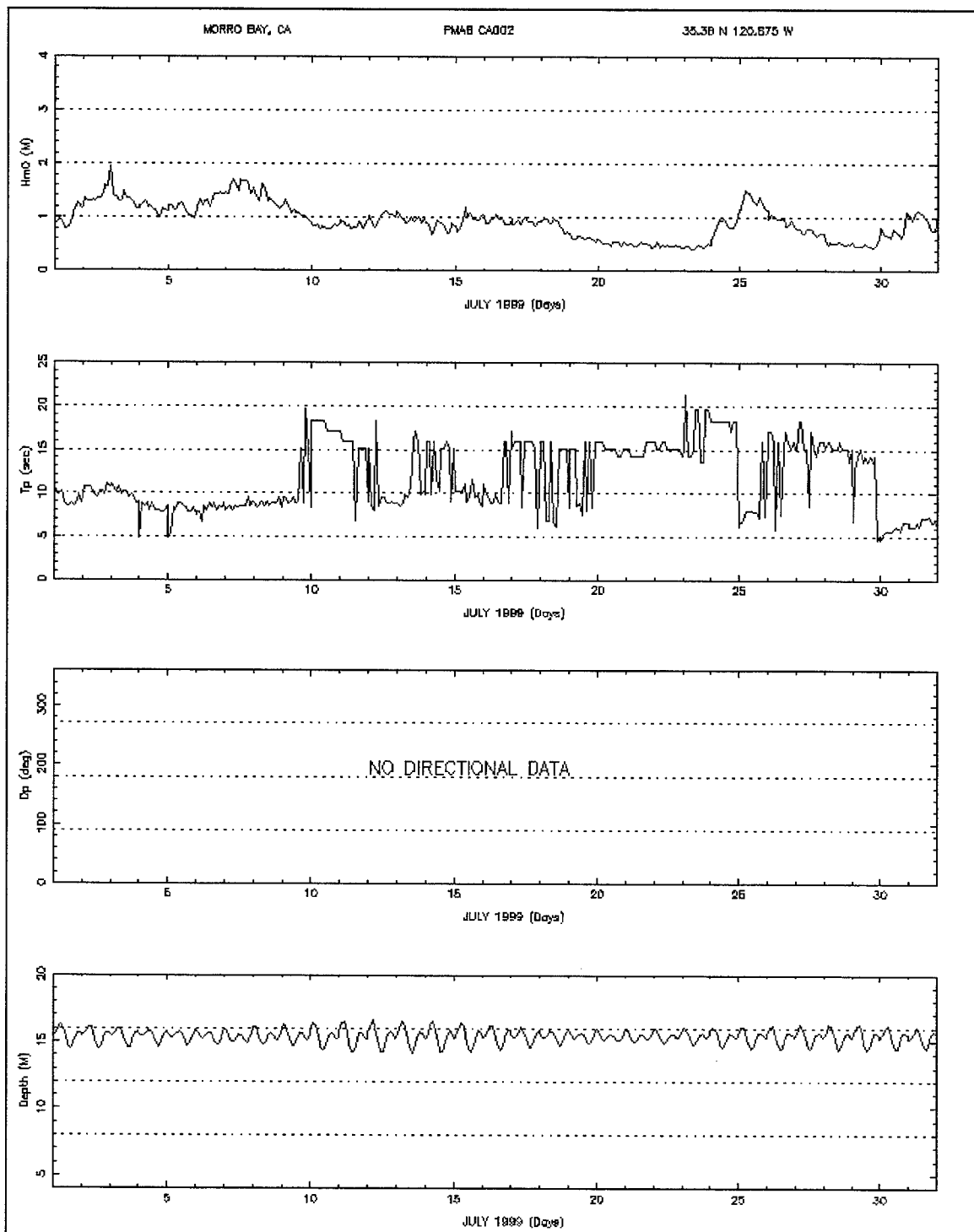


Figure 53. July 1999 monthly time series (CA002)

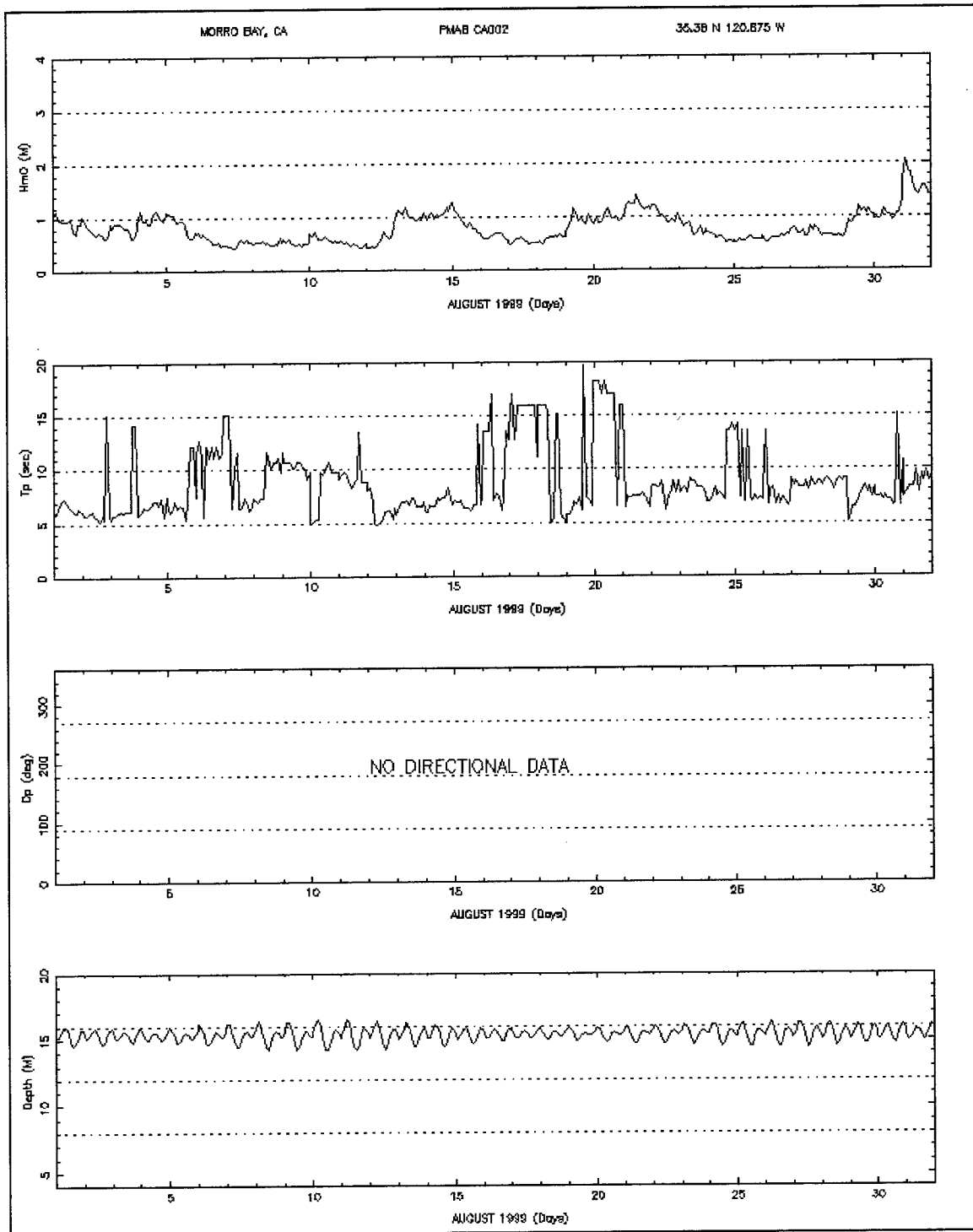


Figure 54. August 1999 monthly time series (CA002)

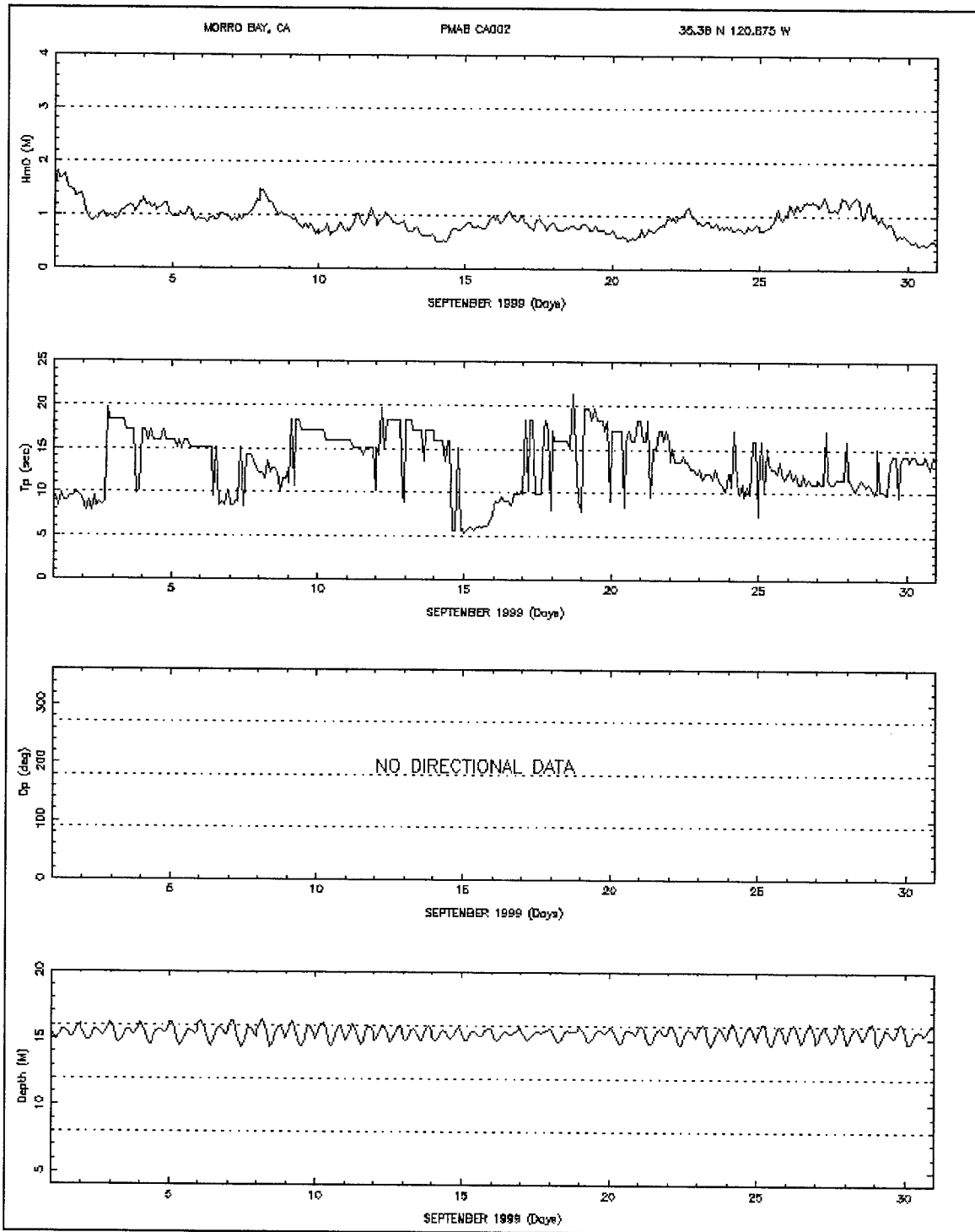


Figure 55. September 1999 monthly time series (CA002)

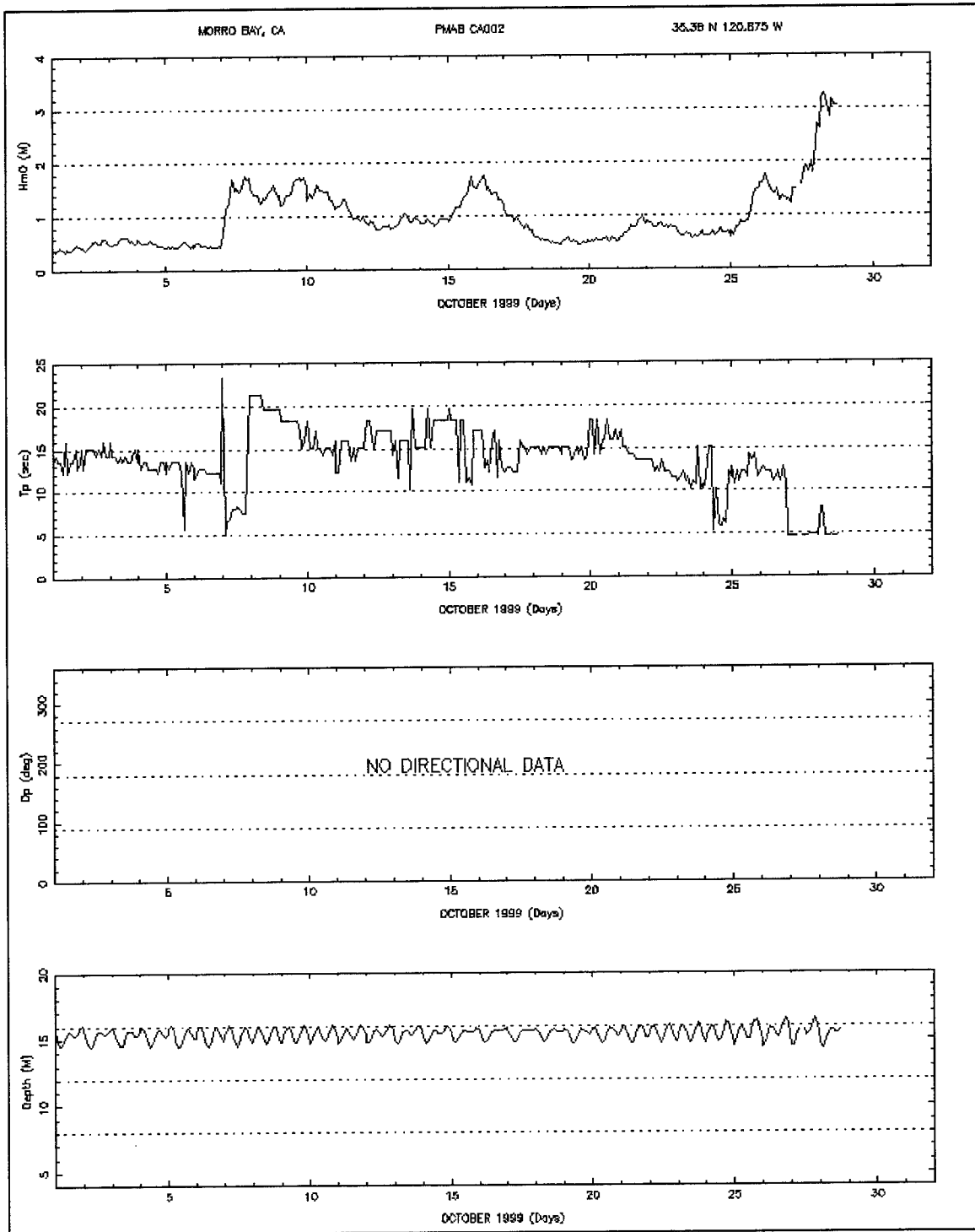


Figure 56. October 1999 monthly time series (CA002)

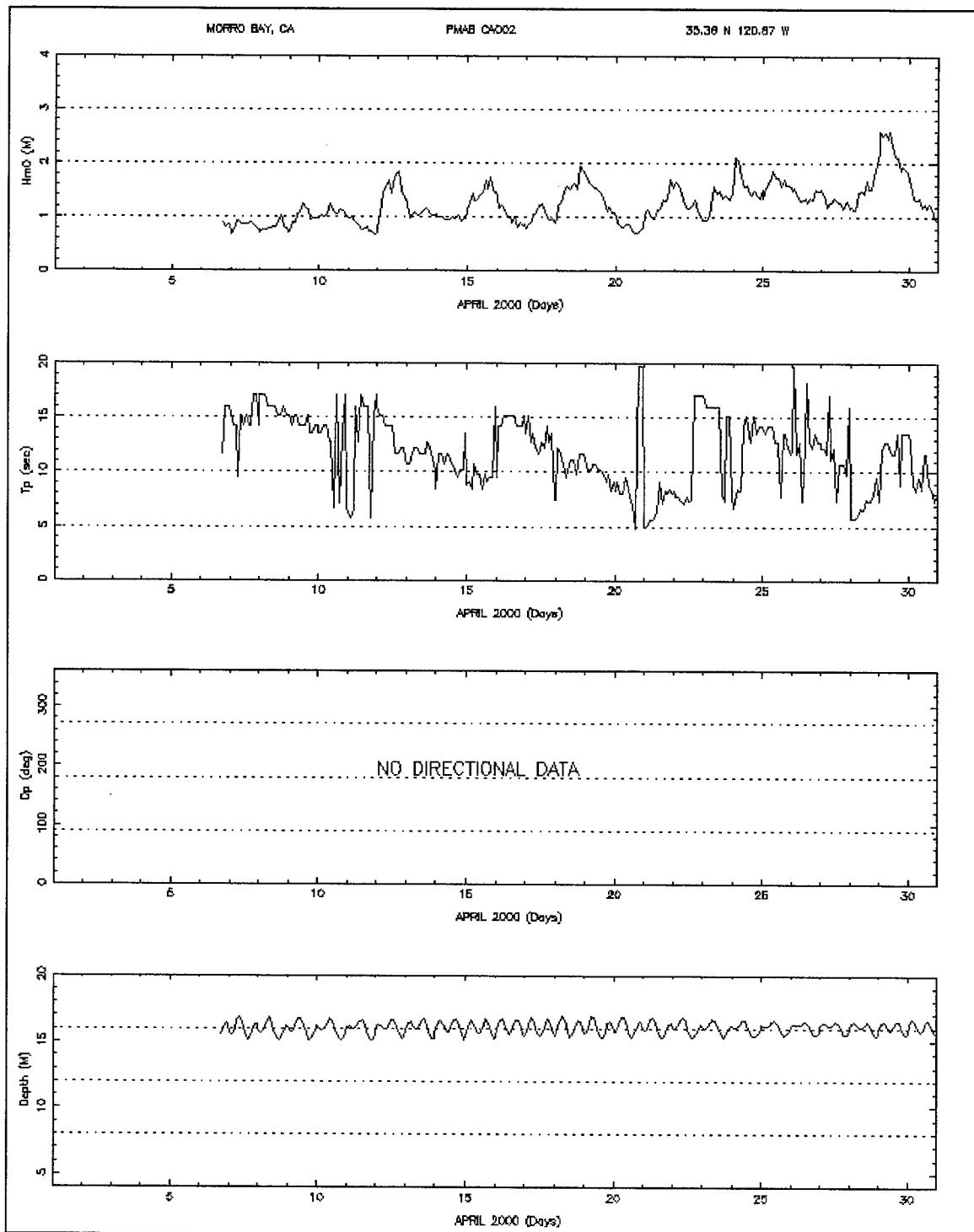


Figure 57. April 2000 monthly time series (CA002)

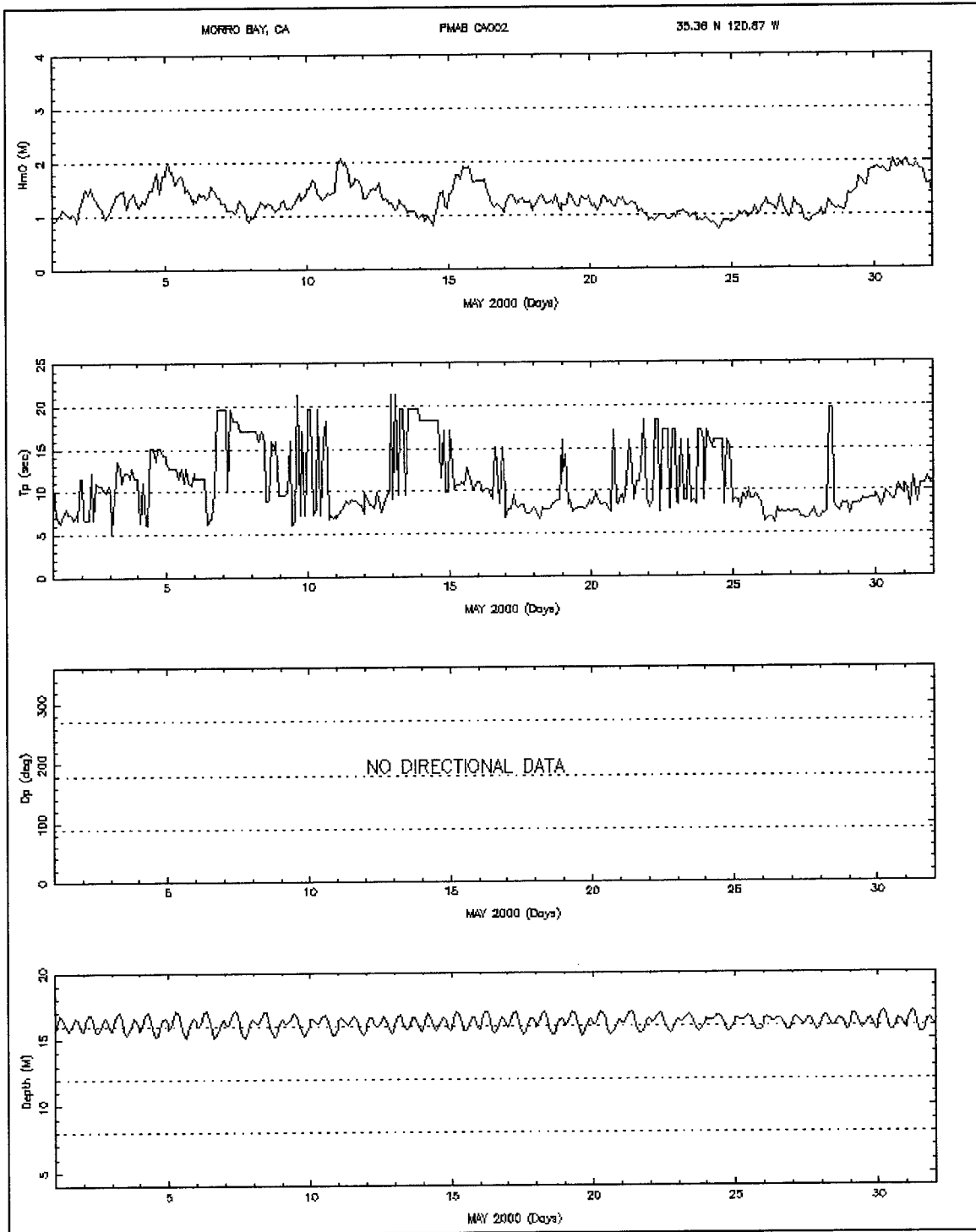


Figure 58. May 2000 monthly time series (CA002)

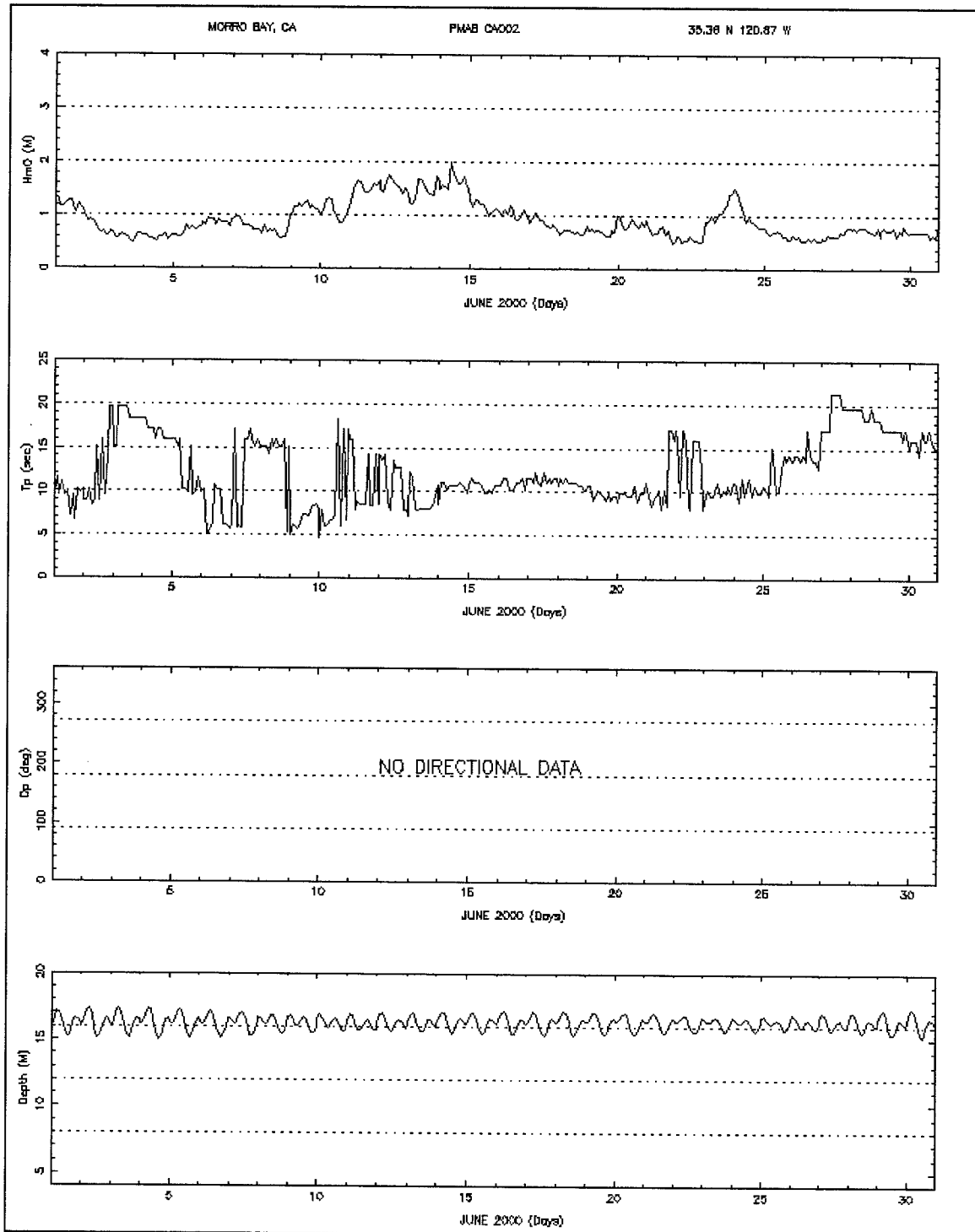


Figure 59. June 2000 monthly time series (CA002)

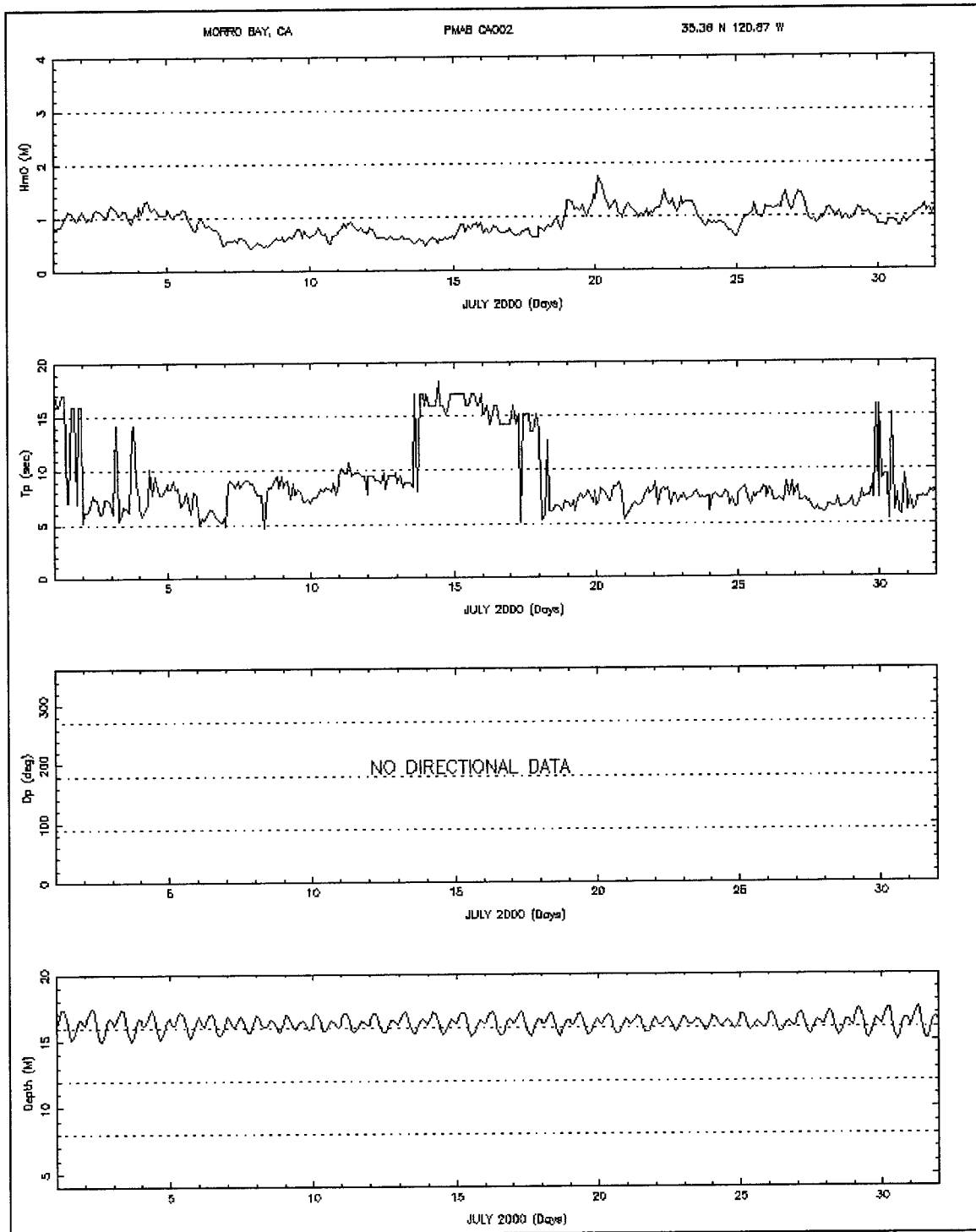


Figure 60. July 2000 monthly time series (CA002)

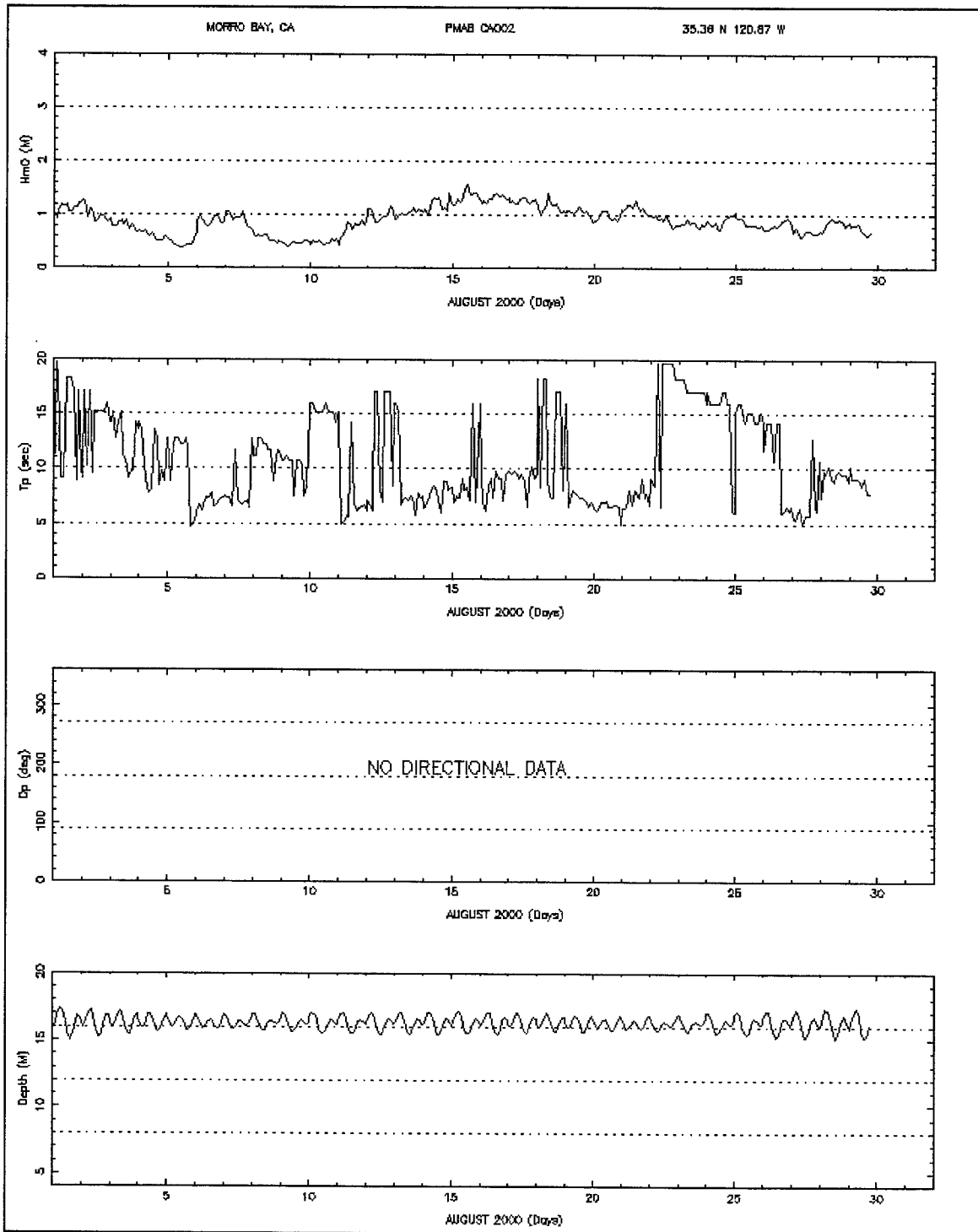


Figure 61. August 2000 monthly time series (CA002)

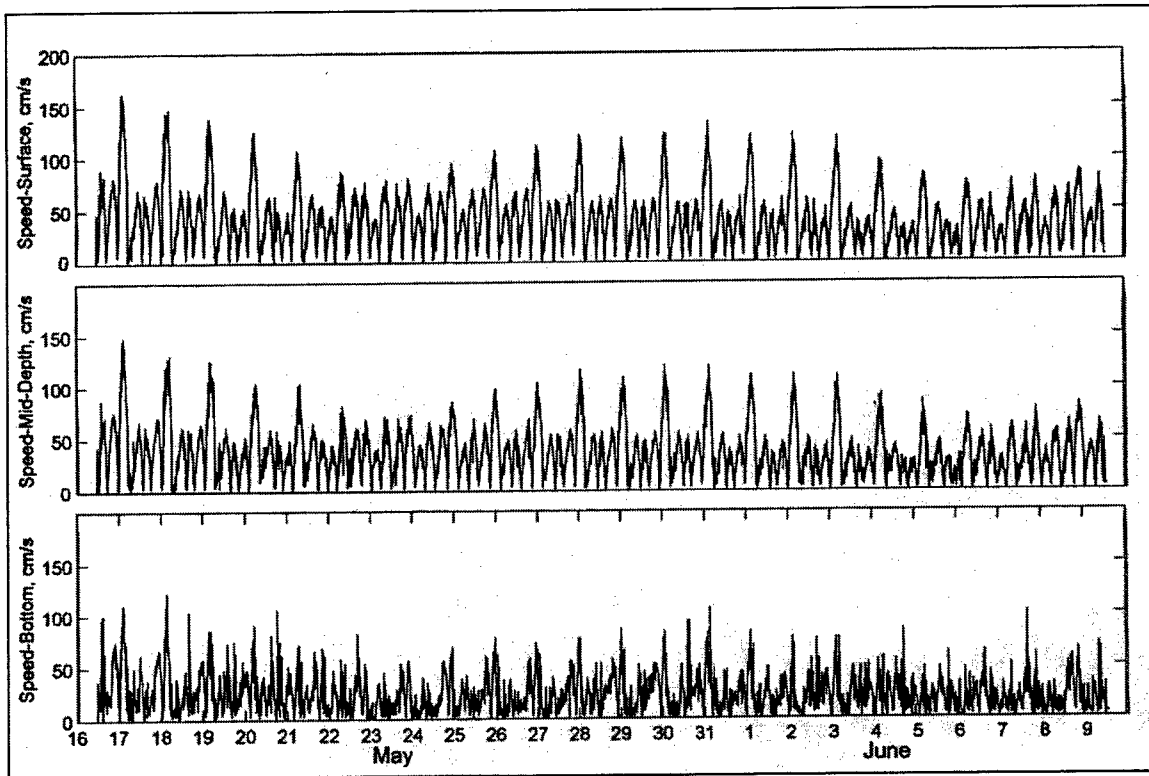


Figure 62. Morro Bay near-bottom, near-middepth, and near-surface current speeds

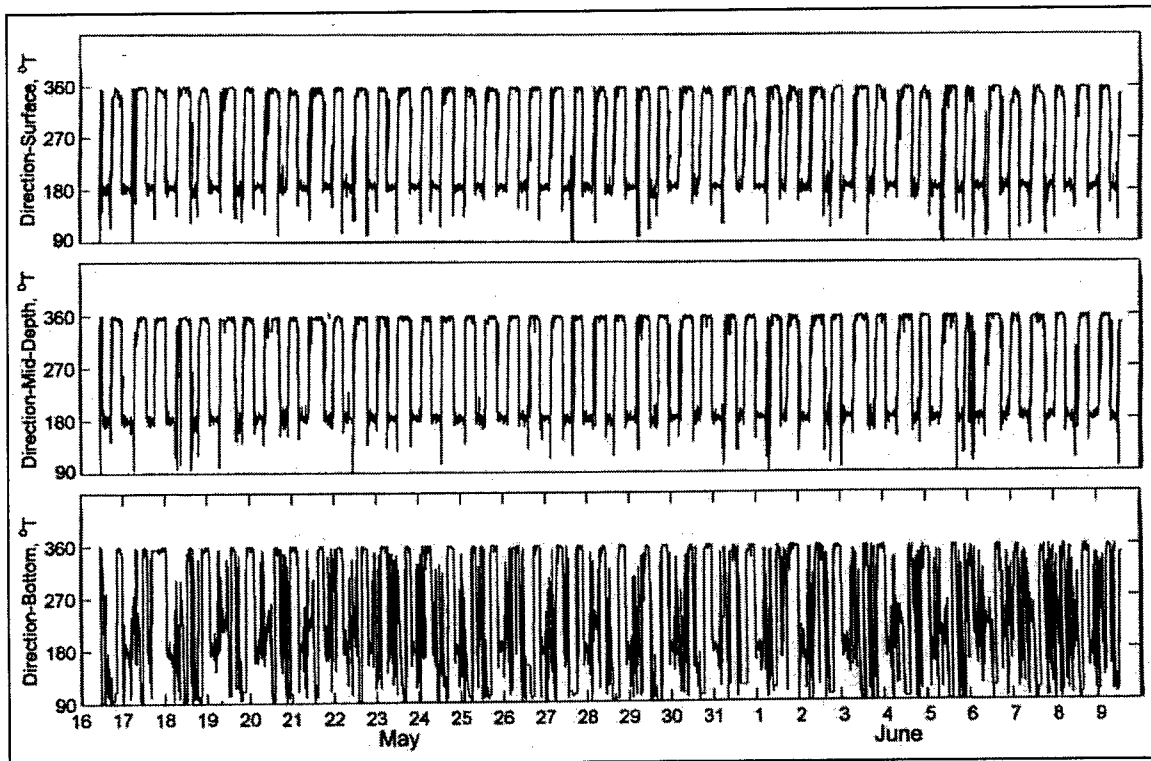


Figure 63. Morro Bay near-bottom, near-middepth, and near-surface current directions

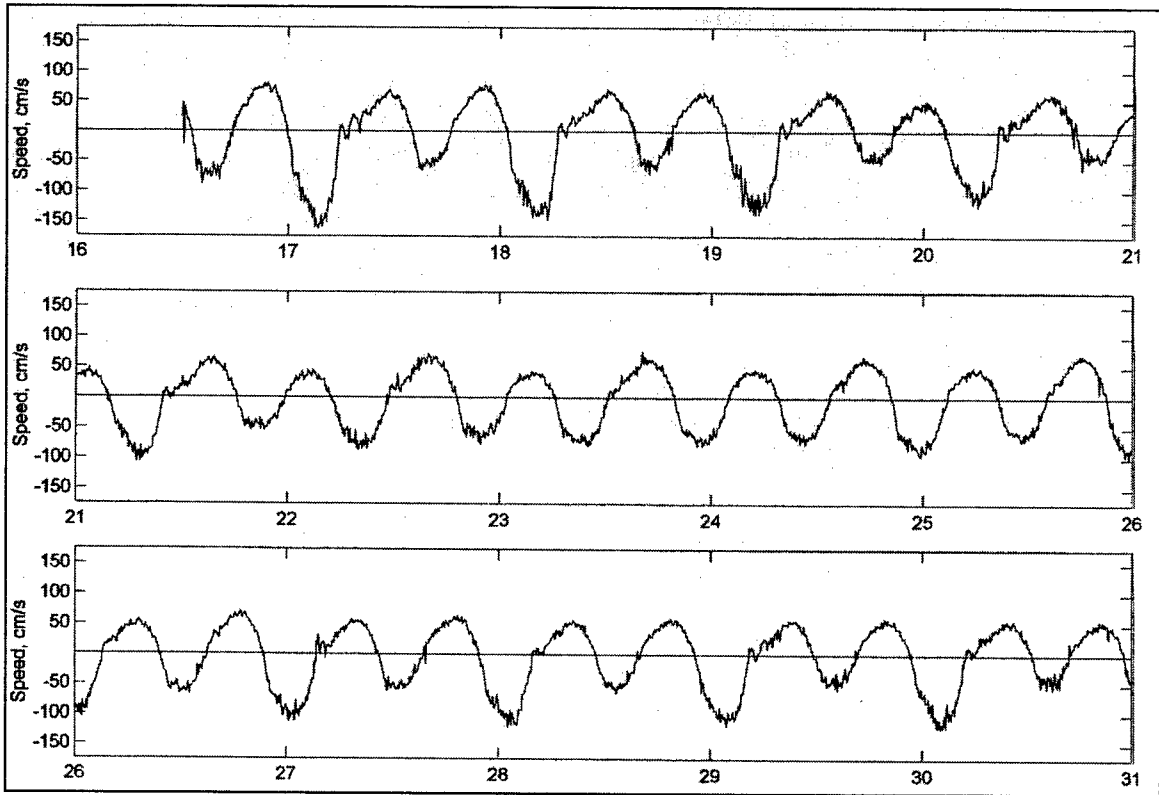


Figure 64. Ebb (-) and flood (+) near-surface currents for May 16 – 31, 1999

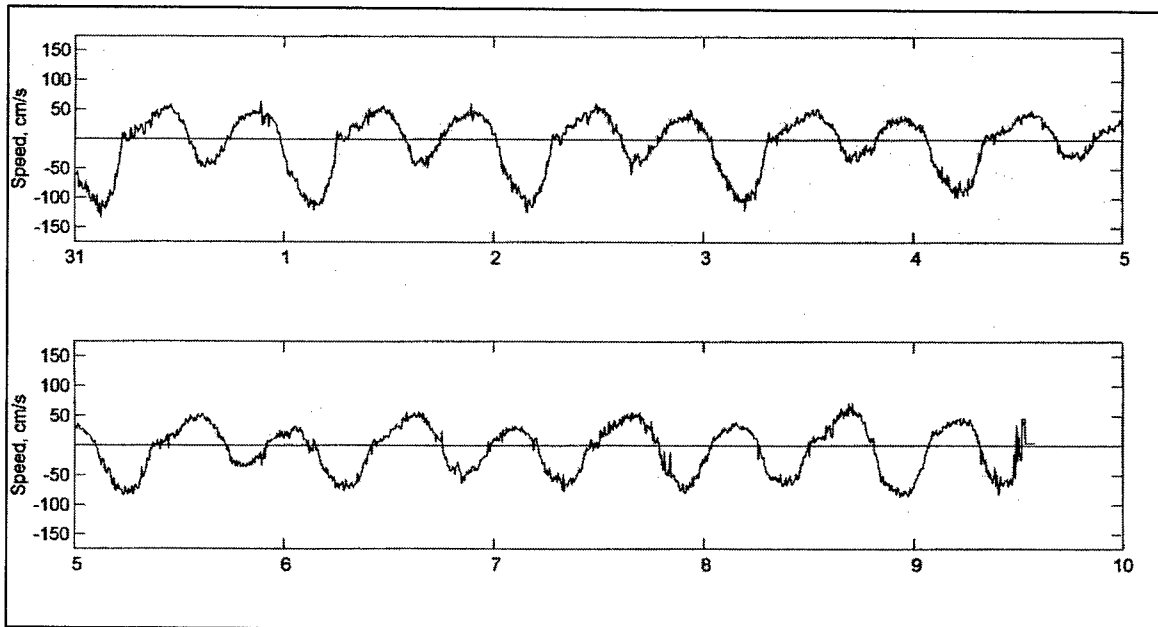


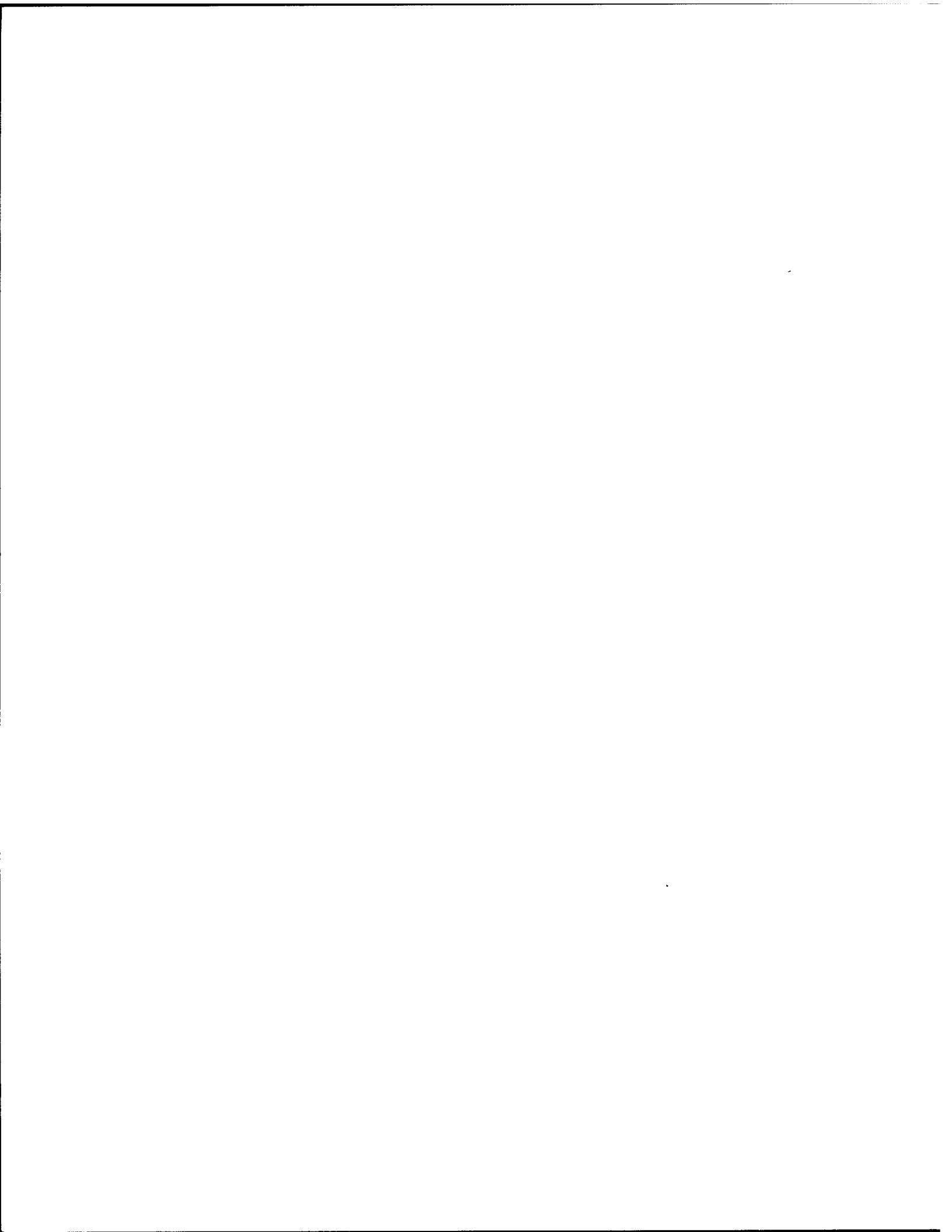
Figure 65. Ebb (-) and flood (+) near-surface currents for June 1 - 9, 1999

REPORT DOCUMENTATION PAGE

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14. ABSTRACT Morro Bay Harbor, CA, was selected for inclusion in the Monitoring Completed Navigation Project Program in 1997 and monitoring was initiated in 1998. The objective was to determine if nonstructural modifications at the harbor entrance were performing as predicted by design tools. Monitoring included the collection of wave and current data, bathymetric data, and ground and photogrammetric surveys of the south breakwater. This report presents wave and current data obtained at the site during the monitoring effort. A subsequent report will provide further analysis as well as results of the comprehensive monitoring effort.					
15. SUBJECT TERMS Broad Band Acoustic Doppler Current Profiler Current data					
Morro Bay Harbor, CA			Slope array gauge system		Waverider data
Wave data					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
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