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1970-71

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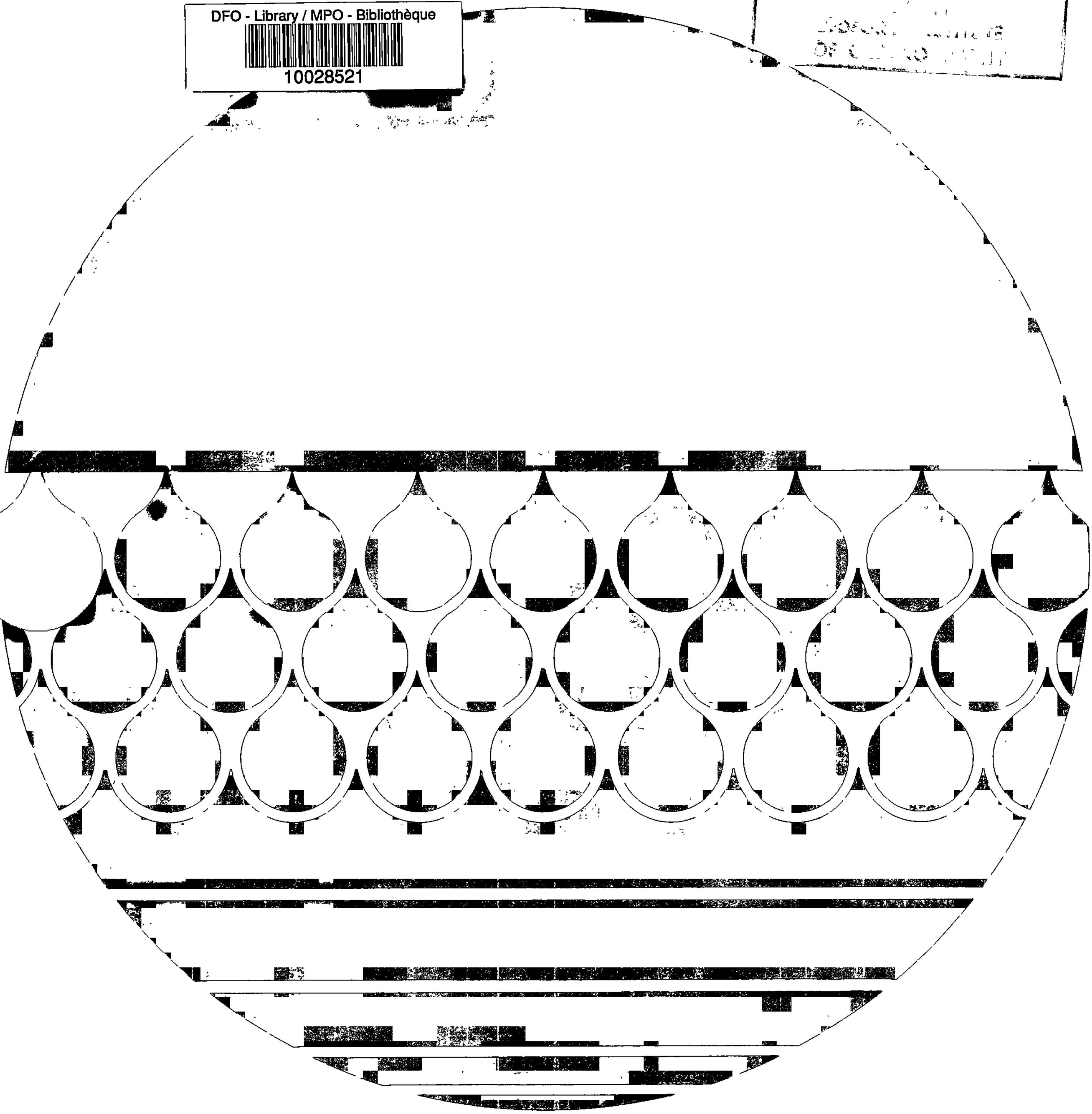
Data Series/BI-D-74-5/September 1974



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HALIFAX NARROWS: SAMPLE CURRENT METER DATA 1970-71

by

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September 1974 DATA SERIES BI-D-74-5

ABSTRACT

The highlights of the oceanographic data collected in the Halifax Narrows from May 1970 to May 1971 are presented. They indicate the major importance of the wind and the lesser effect of the river in influencing the currents. The presence of a permanent body seiche is noted. The statistics of current velocities, which may be expected, are also discussed. We use a detailed description of one set of stations (Stations 65 and 66 during September 1970) to demonstrate the wealth of information that exists in the body of data collected.

RESUME

Les plus importantes des données océanographiques, qui ont été collectées dans le Détroit d'Halifax pendant la période mai, 1970 jusqu'à mai, 1971, sont présentées. Ils indiquent l'importance majeure du vent et l'effet plus petit de la rivière en influençant les courants. On remarque la présence d'un seiche permanent. Les statistiques des vitesses des courants, qu'on peut prédire, sont discutées aussi. Nous employons une description en détail des donneés qui ont été collectées des stations 65 et 66 durant septembre de 1970 afin de démontrer la richesse de renseignements dans les données entières.

CONTENTS

1. INTRODUCTION

Halifax Harbour is an important ocean terminal on Canada's east coast for cargo vessels, passenger liners, and especially container ships. Plans for expanding container ship docking facilities have included consideration of the Fairview Cove-Negro Point and the Wright's Cove-Navy Island areas as possible sites for additional container piers. Development of either of these sites would mean increased traffic through the Narrows. For safer operations pilots and navigators will need to know the type of currents in this area.

The Halifax Narrows (Fig. 1) act like a bottleneck restricting the movement of water between the outer harbour and Bedford Basin. To the 70-metre deep basin the Narrows constitutes a sill 20 metres in depth and 300 to 400 metres wide. This feature contributes to the occasional anaerobic nature of the bottom layer of the Basin. Like most estuaries the Bedford Basin system is a huge biological factory converting nutrients from sewage into organisms (i.e. phytoplankton) which, if not flushed out to sea, use up the available oxygen. Hence movement of water through the Narrows is of interest to water quality modellers and city/harbour planners.

Rapid growth of urban and industrial areas round coastal inlets have also increased the strain on the water in these inlets to eliminate the waste materials that inevitably are dumped into the water. Harbour planners have had to re-assess the role of estuary waters as a catch-all for man's diverse refuse. One important tool is the numerical water quality model which is designed to simulate the response of the inlet to pollutant input. Ultimately we would like to drive a water quality model with observed currents.

A current meter survey was carried out in 1970-71 in the region of the Narrows (Fig. 1). Two stations on both sides of the Narrows recorded the currents at three different depths through the year. It is hoped that the statistics of this data will yield an appreciation of the range and distribution of current velocities expected.

2. CURRENT METER DATA: COLLECTION AND PRESENTATION

In May 1970 and throughout the following 12 months current meters were moored in the Narrows as shown (Fig. 2). Due to instrument failure, some of the records were considerably shorter than the 20- to 25-day average and 20% were completely blank, but the resulting body of useful data was still large (refer to Table 1). To present the flavour of the data concisely we have chosen what we consider to be interesting example records. The records, for the most part, span two stations and three depths for the period September 11, 1970, to October 5, 1970.

The data are presented in several forms: dial plots of resolved data, tidal ellipses, power spectra of data, and time series plots of both resolved and residual data. Each of these is discussed separately in the following pages.

2.1 Power Spectra (Fig. 3 to 5)

The power spectra show the variance in the velocity data over a range of frequencies and yield the average amplitude within a particular frequency band. At tidal frequency, for example, there is a large peak indicative of the power of the tides. Similarly, at higher frequencies, there are peaks revealing seiches. i.e. oscillations at natural frequencies.

The spectra shown here are mainly derived from data recorded at five-minute intervals, except for Station 66 (at 17 m depth) which recorded at ten-minute intervals. An interesting feature is present in the lower level (compare Fig. 4 and 5) which indicates large power existing in the low frequency range.

All of the spectra examined showed a large peak around 0.47 cph (a period of approximately 2.1 hours) which means that superimposed on the tidal oscillations is another wave, often of comparable power. The time series plots (Fig. 7a and 7b) of residual data at five-minute intervals shows clearly this periodicity. (Since both depths are in phase, this is believed to be a body seiche within Halifax Harbour.) The driver of this seiche may be the semi-diurnal tide itself (amplified by wind and atmospheric pressure on occassion), since the seiche frequency is almost an integer multiple of that of the tide (0.47/0.078 = 6.0). The two can, therefore, interact to produce high velocities sometimes, or low velocities at others, depending on their phase. It has also been noted that the winter velocities are generally greater than the summer ones, suggesting weather systems amplify the seiche as they move along the coast. There are some variations over depth and station though one expects the body wave to have uniform velocity. Various topological irregularities at the boundaries may cause this. Other seiches with periods of 20 and 35 minutes are evident in some spectra.

The average seiche amplitudes are given in Table 2.

2.2 Time Series Plots (Fig. 6 to 9)

There are four separate types of data constituting these 'time series plots': wind stress, river, residual currents, and resolved currents. The significance of each of these is noted below.

2.2.1 Wind Stress (Fig. 6a)

From the wind data, collected at Shearwater by the Atmospheric Environment Service during 1970-71, the appropriate (northwest or seaward and southeast or landward) components of the wind stress were calculated using:

$$\tau = \rho_a * |u|u * C_D$$

where τ is the wind stress in dynes cm^{-2}

ρ_a is the density of air ($1.2x10^{-6}$)

C_D is the drag coefficient ($1.3x10^{-6}$)

$|u|$ is the magintude of the wind velocity (cm/s)

u is the component of the wind (cm/s)

2.2.2 River (Fig. 6b)

The second parameter shown is the combination of the Sackville River discharge and Kearney Lake run-off data and are daily averaged. The influence of the river does not play a dominant role in driving currents through the Narrows.

2.2.3 Residual Currents (Fig. 7a and 7b)

These times series plots show residual current velocities (i.e. the effect of the tides has been subtracted from the original data) versus time. Two-layer residual circulation can clearly be seen, flowing seaward in the surface layers and landward in the lower layers. This two-layer flow depends very highly on the winds.

2.2.4 Resolved Currents (Fig. 8 and 9)

The resolved current time series are included to show the influence of the tidal signal in the currents observed.

2.3 Dial Plots (Fig. 10 to 14)

The dial plot summarizes the statistics of the data recorded over a 20- to 25-day period in a single location. It consists of a dial divided into twelve 30^{o} sectors. True north is towards the top of the page as indicated and the angle increases positively in a clockwise direction. Each sector contains a frequency distribution histogram of the measured speeds observed in that direction. The horizontal axis shows speeds in knots, the maximum is marked by an arrow; the vertical axis indicates the frequency as a percentage of all observations, so the height of a block is a measure of how often that speed occurs in a particular direction. When looking at the whole picture the predominant trends in current flow for the period can be seen. All identifying information is given in the centre of the plot.

Due to a strong tidal influence the majority of the data are distributed over directions close to the principle axis of the channel, with mean speeds ranging from 0.4 to 0.6 knots.

Currents flowing into the inlet show slight differences in distribution with varying depth. There is very little variation in the frequency distributions for the different months.

2.4 Extreme and Mean Currents

Figures 15 and 16 contain the extreme data point in both major directions from every 25-day record (from May 1970 to May 1971). A pilot might use these to estimate maximum currents possible, bearing in mind that these are observed extremes.

The extreme plots (fig.15 and 16) show some interesting contrasts. First, the extreme currents are generally higher in winter than in summer, although the extreme for the year occurred in August (2.2 knots landward). In general too, the landward extremes exceed the seaward extremes at all depths and both stations. (The landward wind extremes also exceed the seaward ones during the period of observation.) It can be seen that the surface layer tends to have greater maximum currents than the bottom layers. Finally, the Dartmouth side of the channel has higher extremes than the Halifax side, particularly at the surface.

At a later date it is hoped to use this data to verify a model for predicting extreme currents from sparse or intermittant data (Loucks, Lawrence, Ingraham, and Flemming, 1973).

Monthly (25 days) mean currents are displayed in Figures 17 and 18 using the same time scale. Note that the overall means are an order of magnitude smaller than the extremes. Several isolated points on the graphs indicate that the record was considerably shorter than the 20- to 25-day average length.

The monthly mean current plots (Fig. 17 and 18) show no apparent difference between summer and winter. There is a slight distinction between stations; the mean currents on the Dartmouth side are somewhat faster in their chosen direction than the ones on the Halifax side. Comparison of means at different depths shows the two-layered flow trend - seaward at the surface and landward below.

2.5 The Tides

The influence of the tides is illustrated via two approaches: the tidal ellipse and polar scatter plots. Each of these is discussed below.

2.5.1 The Tidal Ellipses (Fig. 19)

The harmonic constants required to plot the ellipse and to subtract tidal influence from the resolved data were obtained from harmonic analysis of 15-day sections of current meter data.

Nine tidal components were used on each location and the six strongest are presented in the composite plots: M2, S2, N2, M4, K1, MS4. The ellipse plots show concisely the tidal velocities in all directions over one cycle.

All the ellipses are very narrow and have their maximum close to the direction of the channel.

2.5.2. Polar Scatter Plots

There is a great deal of variation with respect to season, depth, and station in the phases and amplitudes of the components. The two predominant tidal components, M2 and S2, are shown in Figures 20 to 27 as example cases. The points plotted are vector averages of the results of two 15-day harmonic analysis.

3. SUMMARY

The results of a detailed currents meter survey carried out in May 1970 to May 1971 are presented here in the form of graphs and plots which will be useful to harbour planners, navigators and water quality modellers.

It is found that currents in the Halifax Narrows are mainly tidal and tend to flow in the directions close to those of the channel axis. (The surface currents are highly dependent on the winds present.) The average daily residua; speeds are approximately 0.5 knots, with a slightly higher average on the north (Dartmouth) side of the channel. Inbound observed currents also tend to have slightly higher extreme and average values than the outbound ones.

Extreme currents heading inward tend to be higher than these and can reach 2 knots in winter. The measuredextreme for the year 1970-1971 was in August (2.2 knots at 280^{o} inward).

From power spectra plots there is evidence of seiches in Bedford Basin and Halifax Harbour. One seiche of period 2.1 hours (corresponding to the resonant frequency of Basin and Harbour together) can contribute as much as 0.3 knots to the observed velocity, and interacts either constructively or destructively with the tide.

4. REFERENCE

LOUCKS, R.H., D.J. LAWRENCE, D.INGRAHAM, and B. FLEMMING. 1973. A Technique for Estimating Extreme Ocean Current Vectors. Bedford Institute of Oceanography, BI-R-73-5, 7 pp.

TABLE 1. Current Meter Performance Record

Station	Depth (m)	1970 May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	1971 Jan.	Feb.	Mar.	Apr.	May
65	3													
	8													
	15													
66	3													
	8													
	17													

———— good record

— — — — partly good

++++++++++ useable with caution

+ + + + + partly useable with caution

TABLE 2. Seiche Velocities (knots) 2.1 Hour Period

Station	Depth (m)	Summer average	Winter average
65	3	0.129	0.268
	8	0.132	0.163
	15	0.157	
66	3	0.084	
	8	0.119	
	17	0.124	

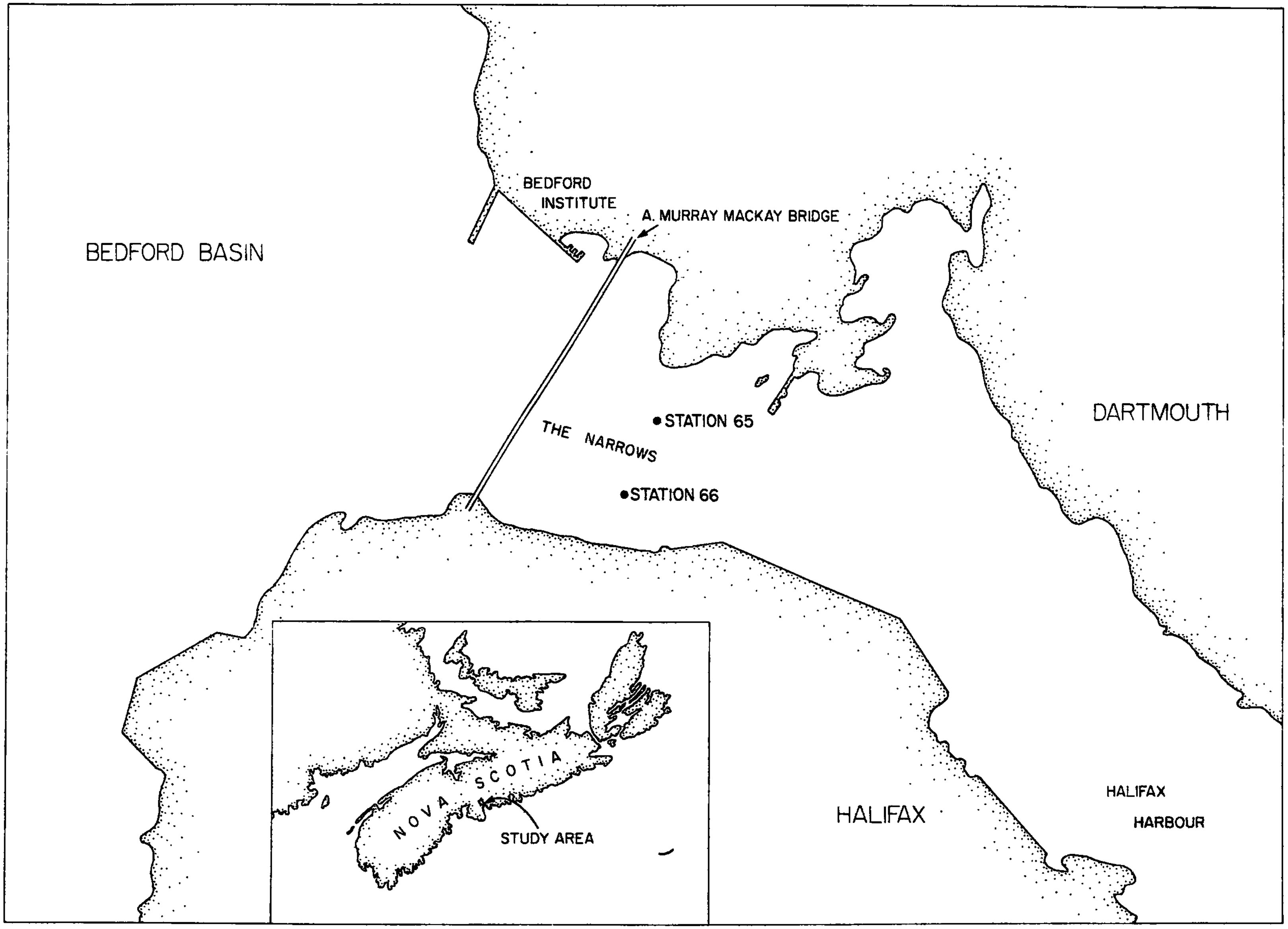


FIGURE 1. Plan of the Halifax Narrows showing the position of the two current meter stations used from May 1970 to May 1971.

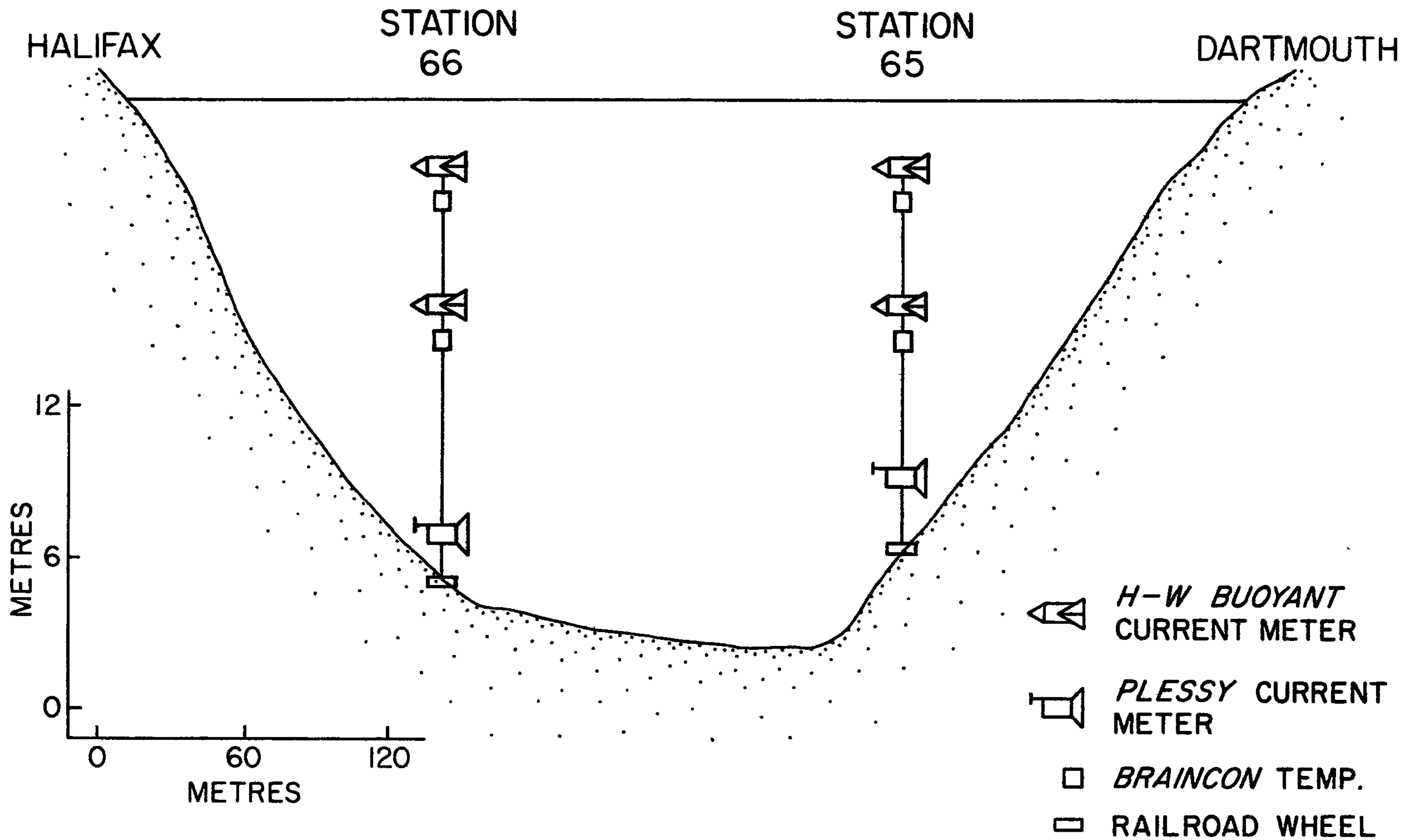


FIGURE 2. A cross-channel view of the mooring arrangement used to gather the data.

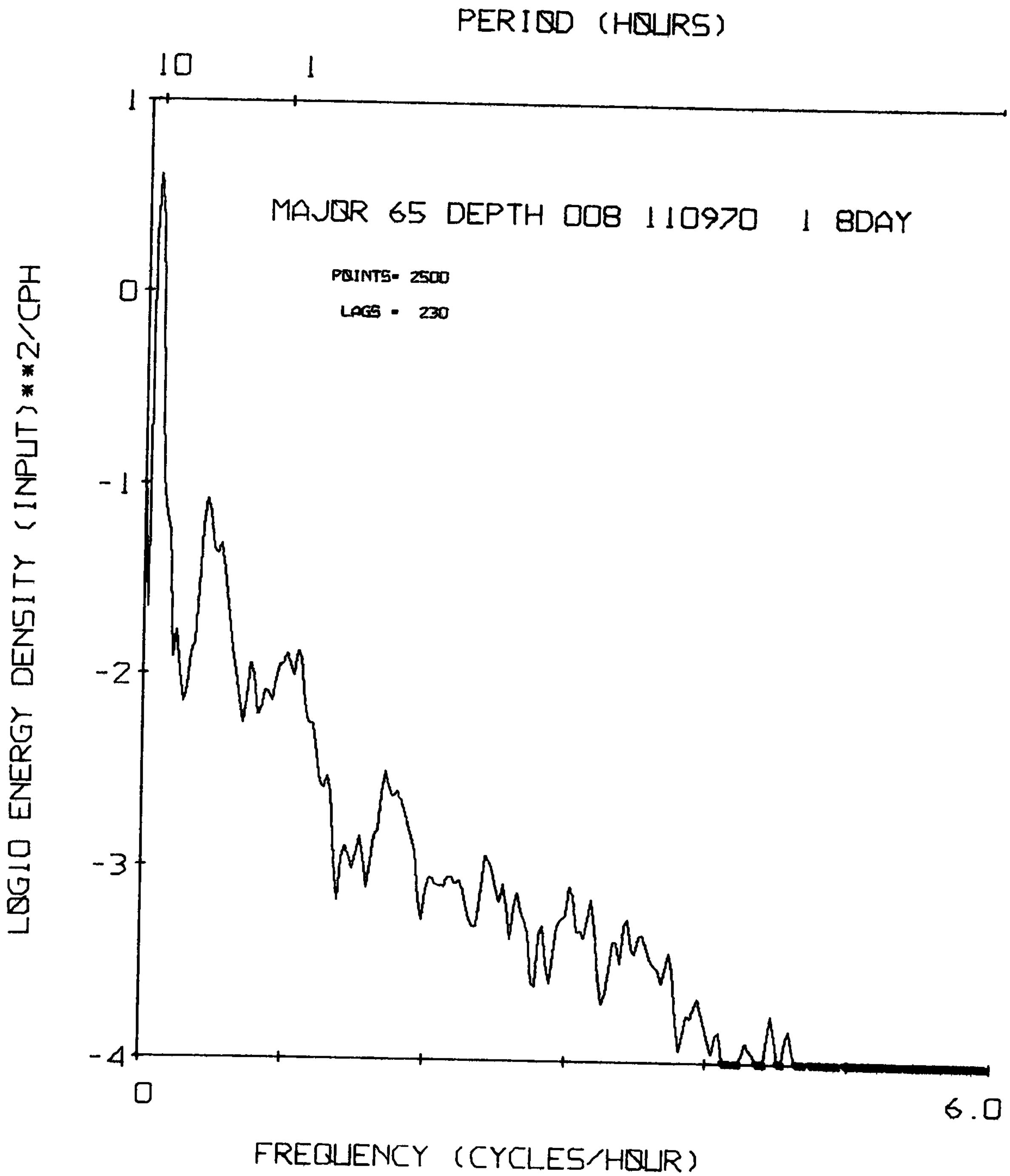


FIGURE 3. Power spectrum of resolved data for Station 65 at 8 m depth.

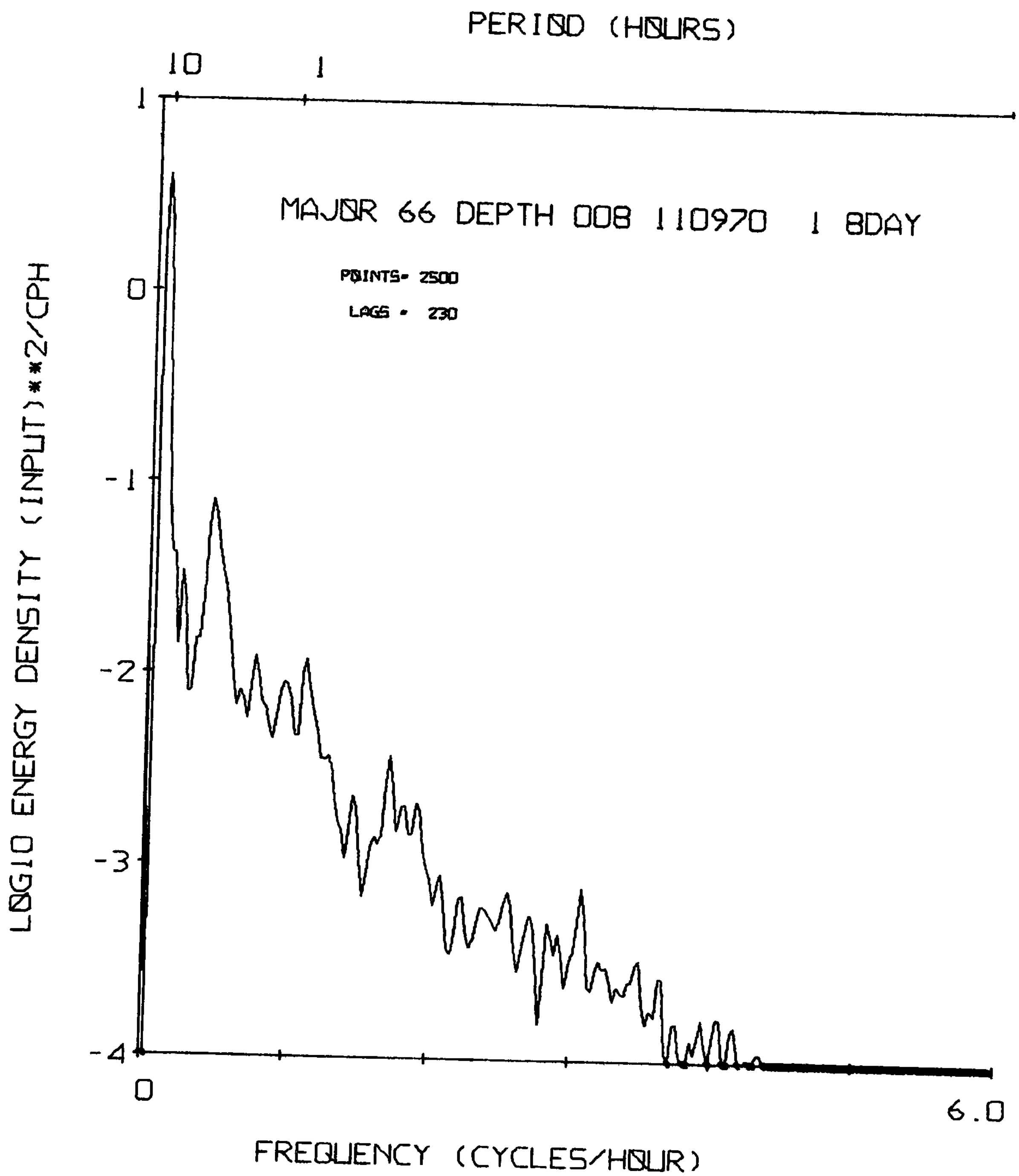


FIGURE 4. Power spectrum of resolved data for Station 66 at 8 m depth.

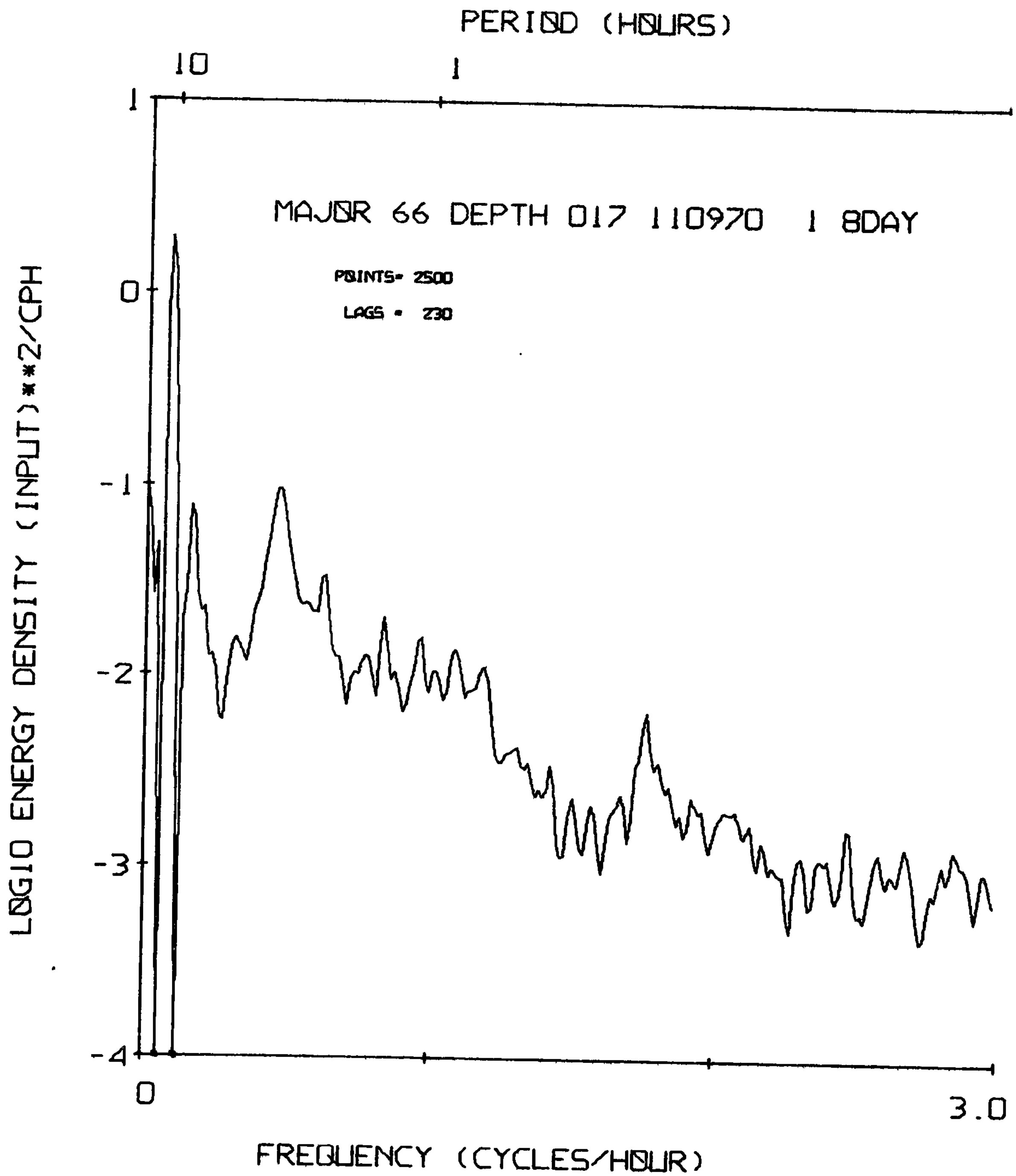


FIGURE 5. Power spectrum of resolved data for Station 66 at 17 m depth.

6a.

6b.

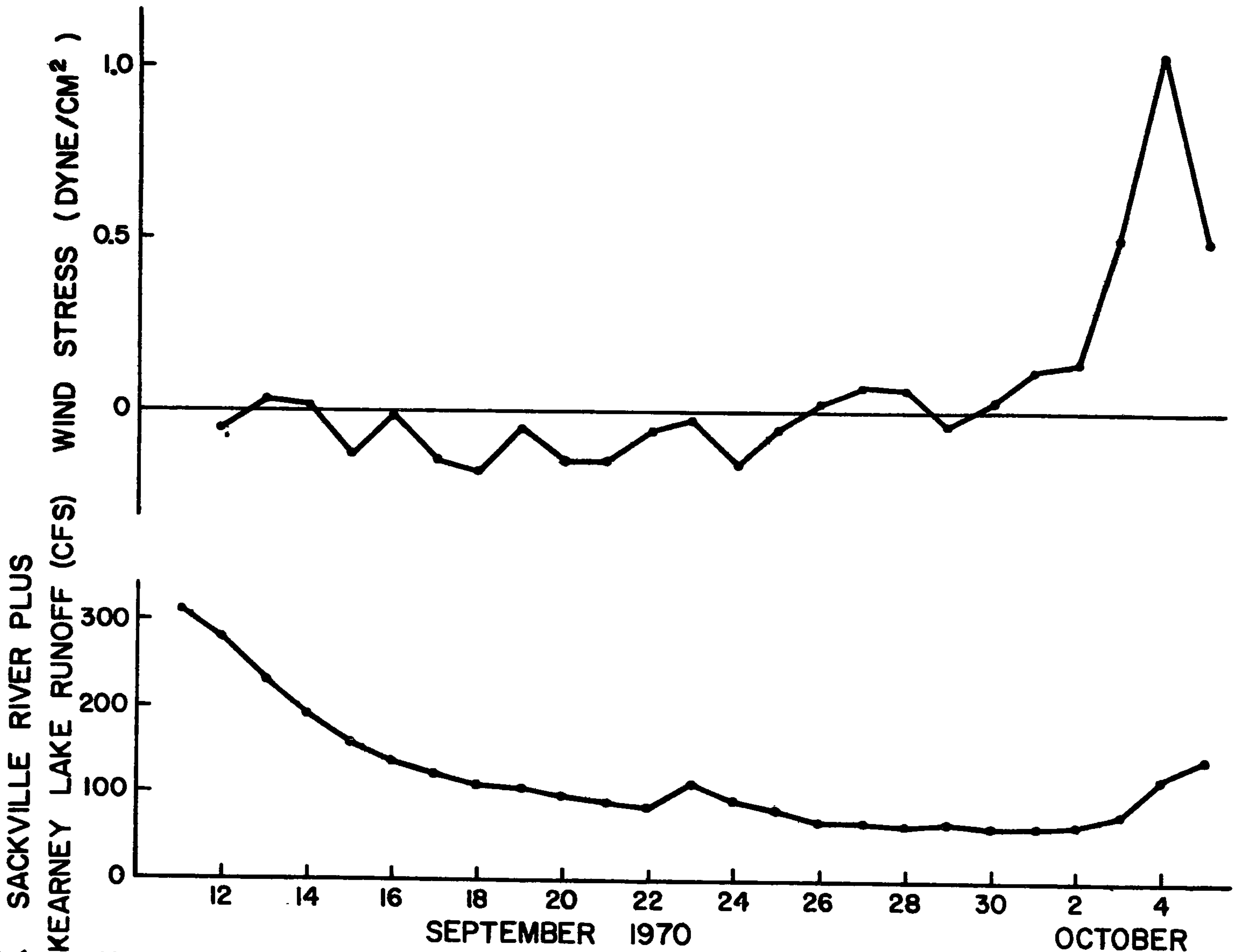
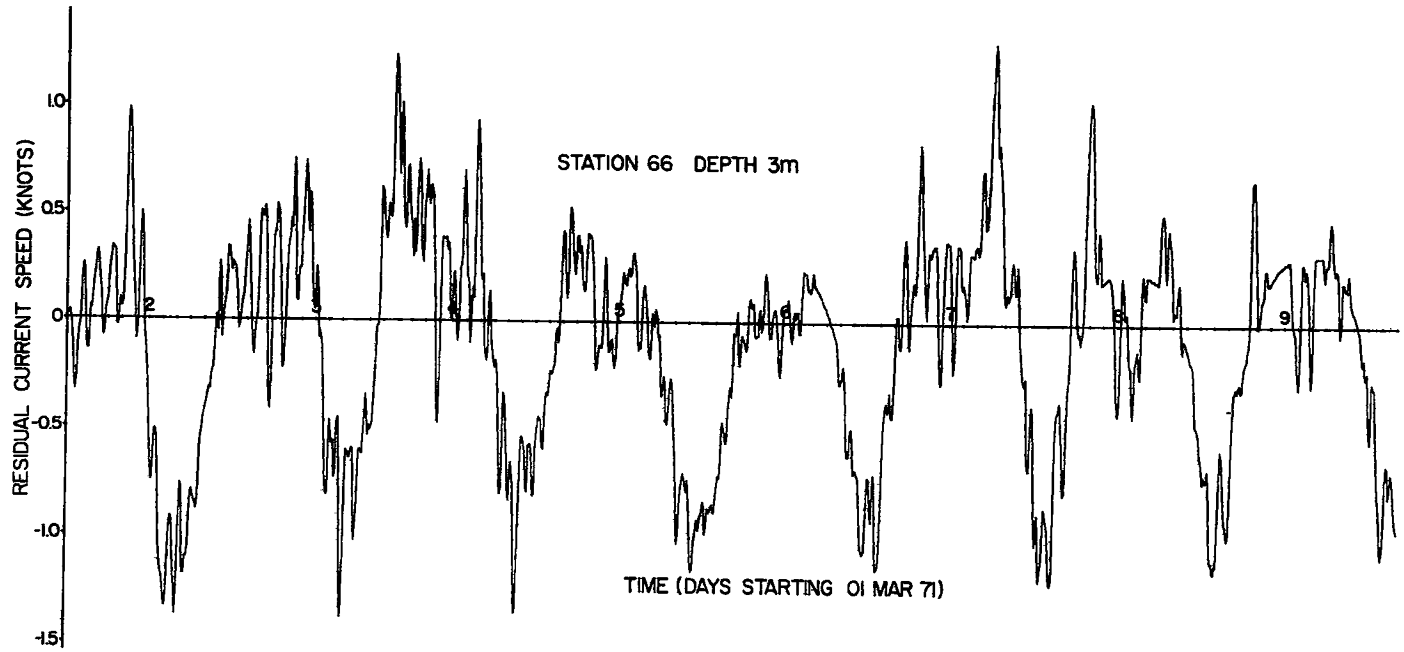


FIGURE 6a. Daily averaged northwest-southeast components of the wind stress (dynes/cm)(from wind data collected at Shearwater) versus time (days).

6b. Daily averaged Sackville River plus Kearney Lake run-off (cfs) versus time (days).

7a.



7b.

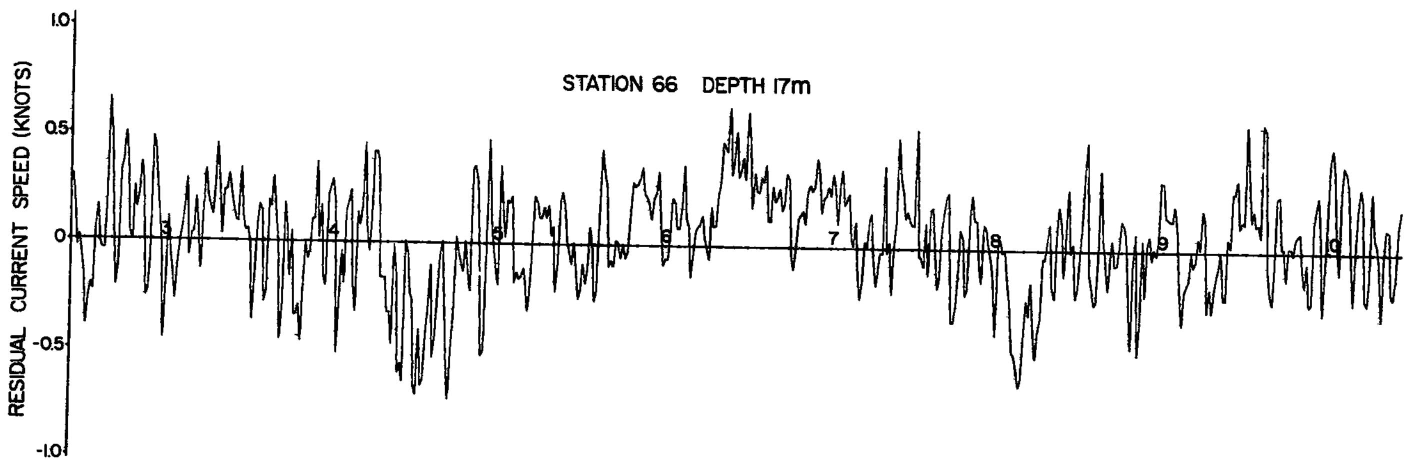
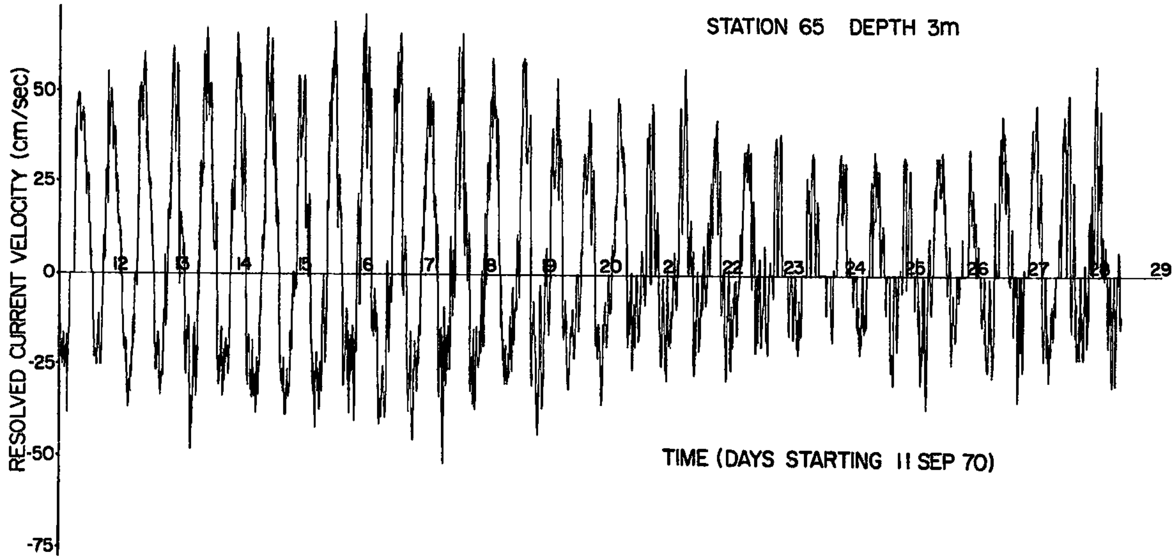


FIGURE 7a. Time series plot of residual data from Station 66 at 3 m depth.
7b. Time seriés plot of residual data from Station 66 at 17 m depth.
(Compare - seiche is in phase for both depths.)

8a.



8b.

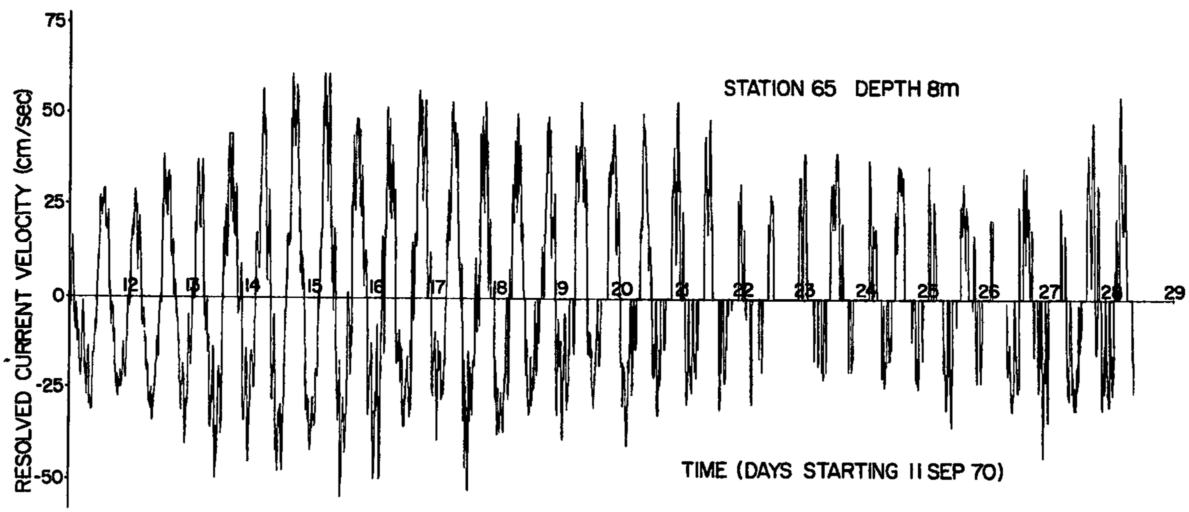


FIGURE 8a. Time series plot of resolved data for Station 65 at 3 m depth.
8b. Time series plot of resolved data for Station 65 at 8 m depth.

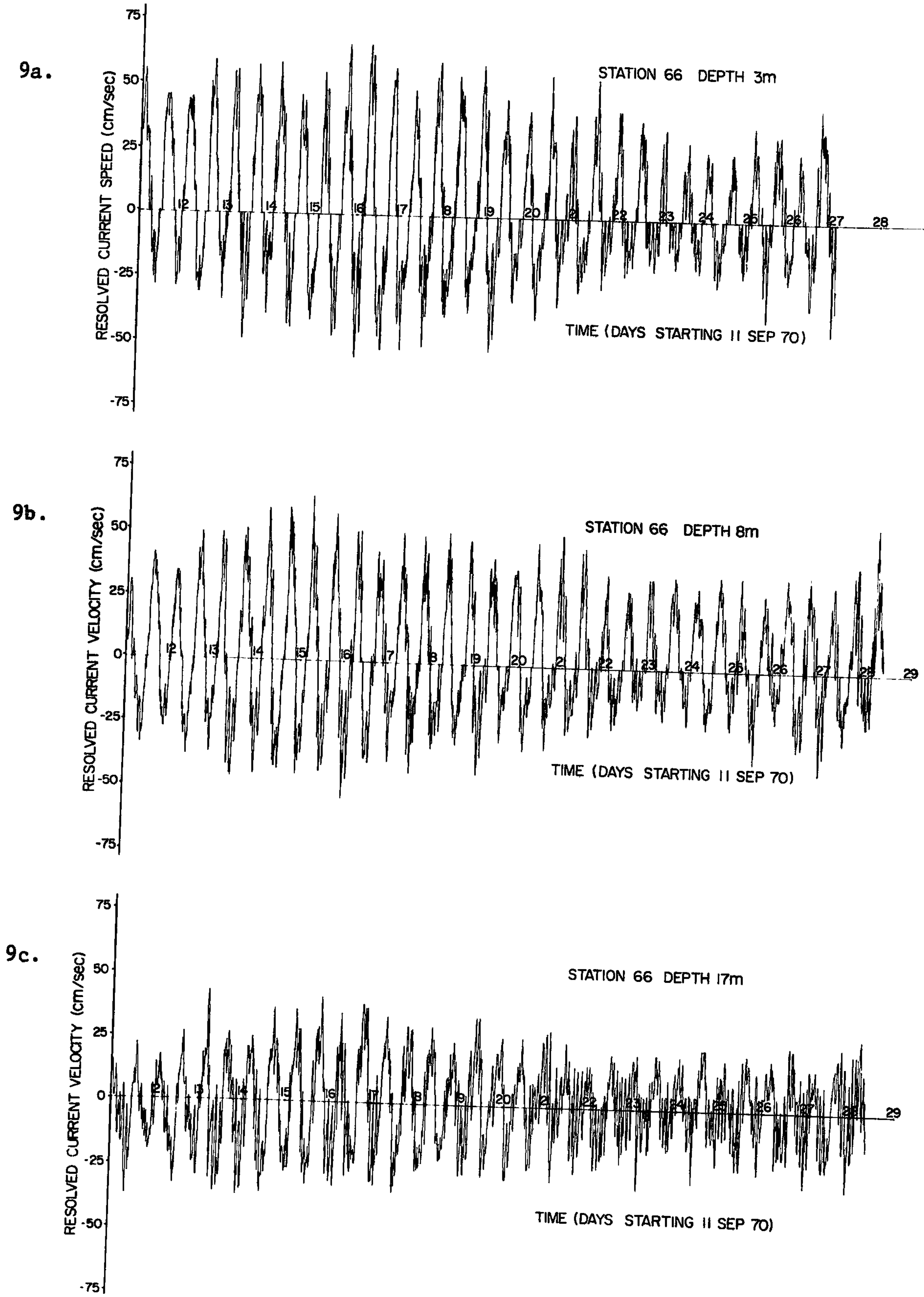


FIGURE 9. Time series plot of resolved data for Station 66 at 3 m depth, 8 m depth, and 17 m depth.

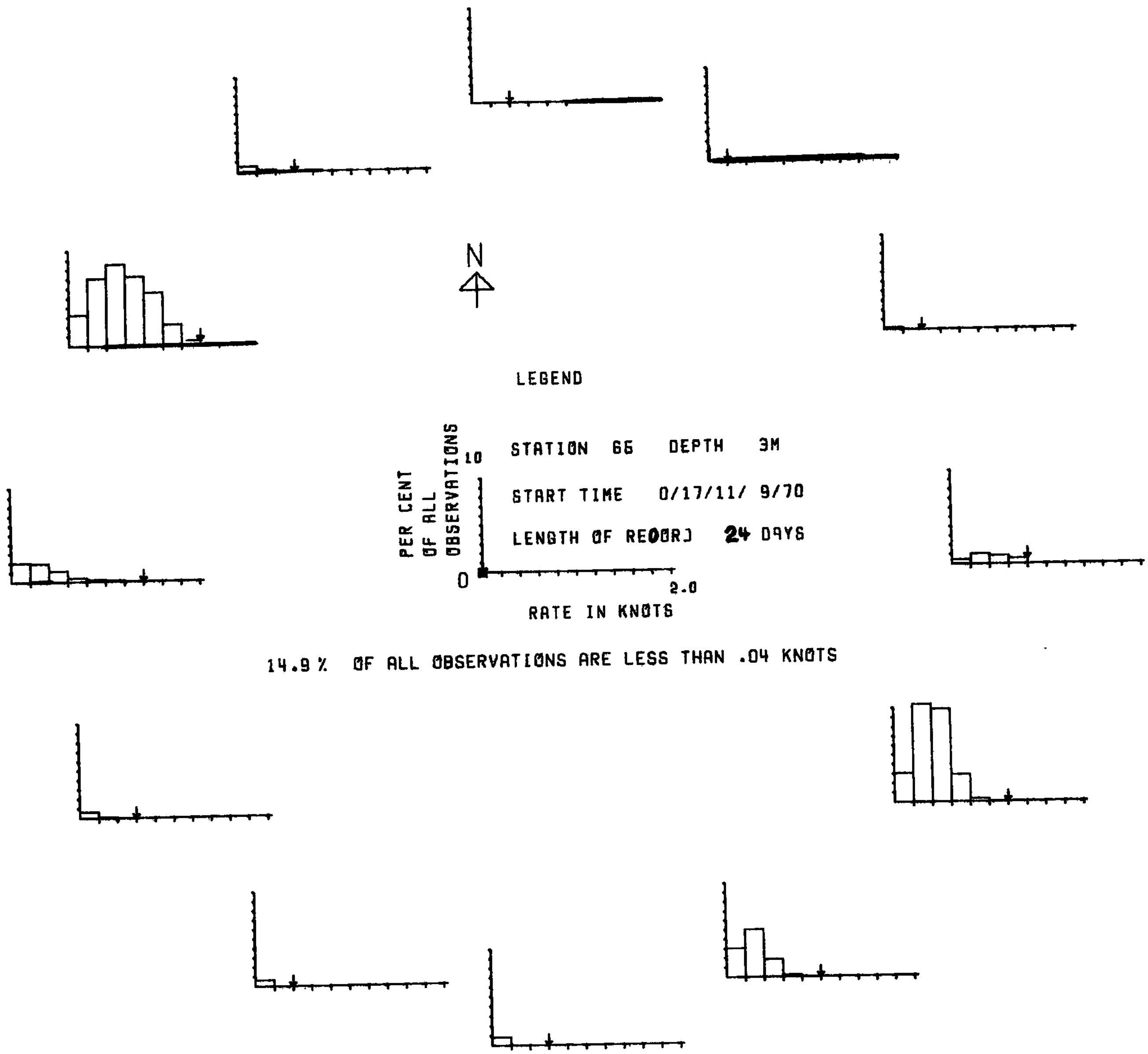


FIGURE 10. Dial plot of resolved data for Station 65 at 3 m depth.

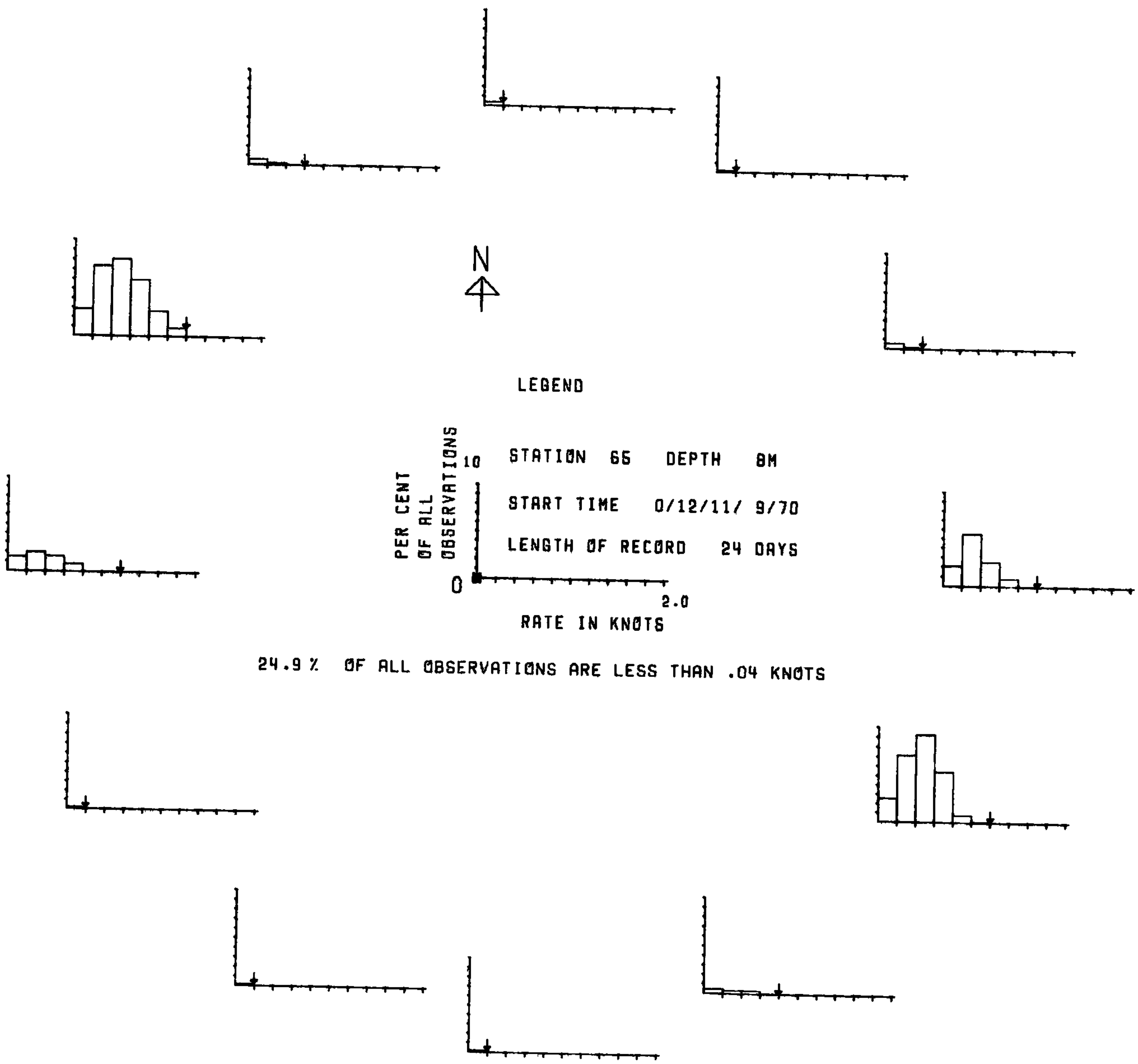


FIGURE 11. Dial plot of resolved data for Station 65 at 8 m depth.

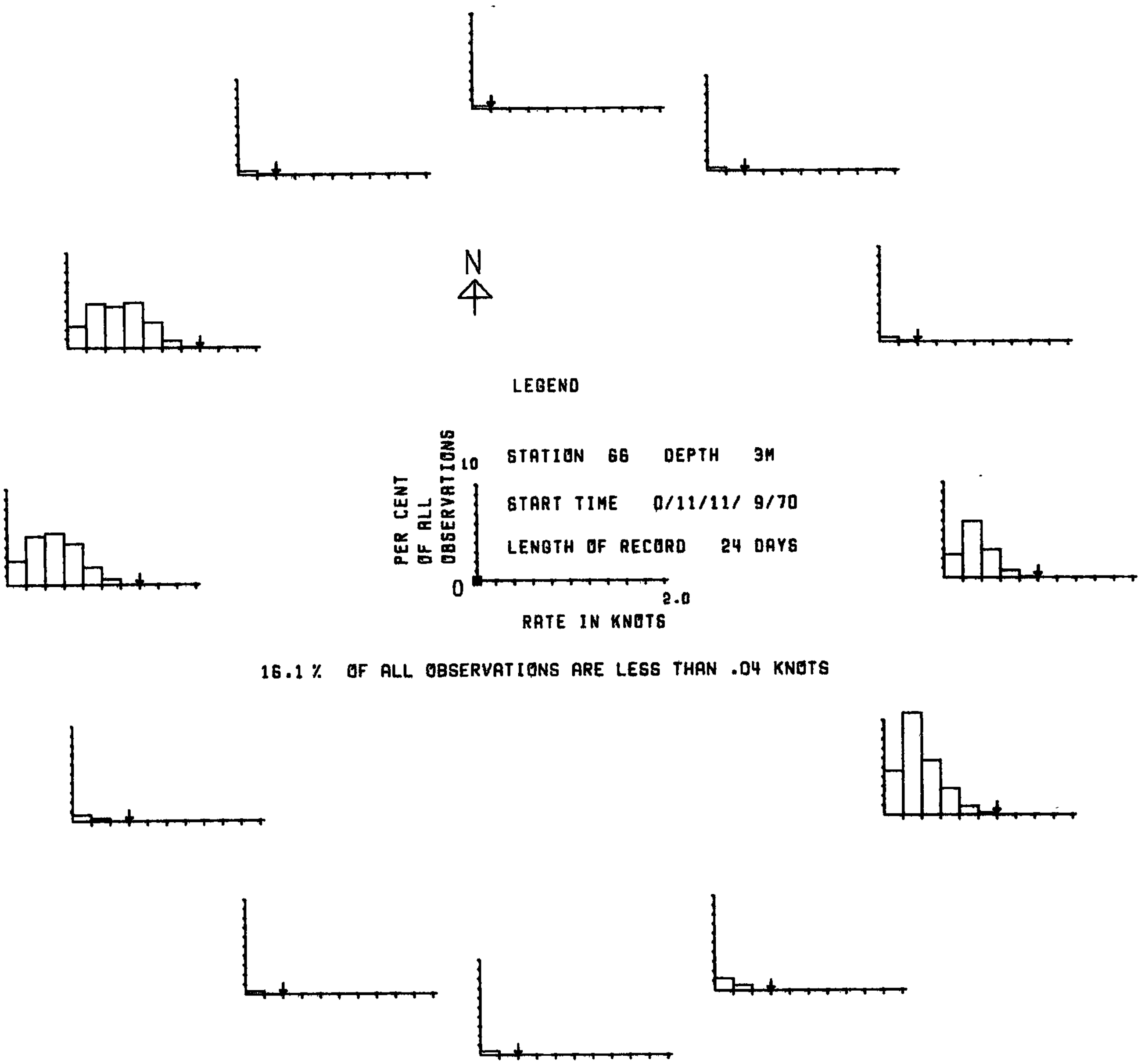


FIGURE 12. Dial plot of resolved data for Station 66 at 3 m depth.

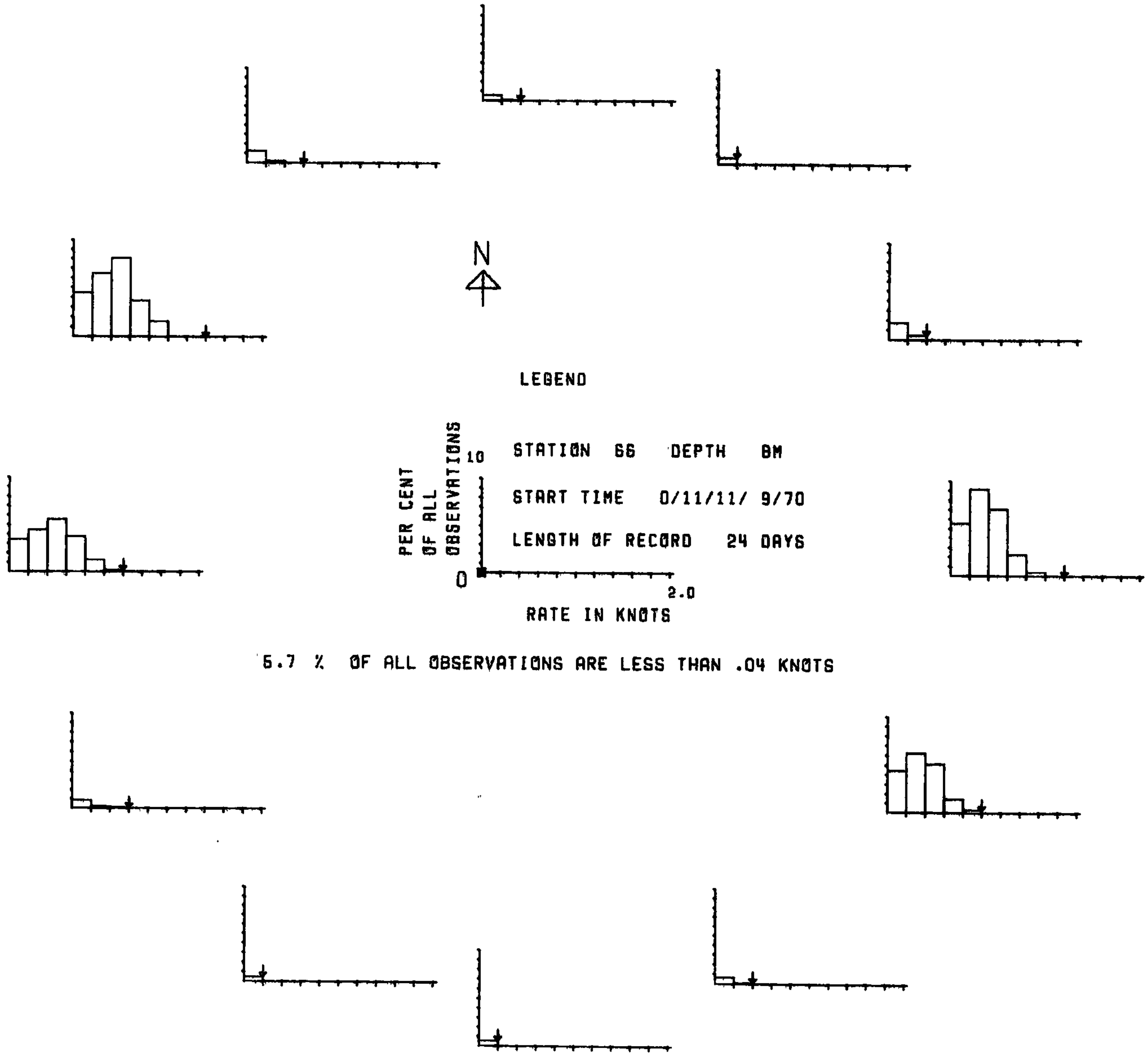


FIGURE 13. Dial plot of resolved data for Station 66 at 8 m depth.

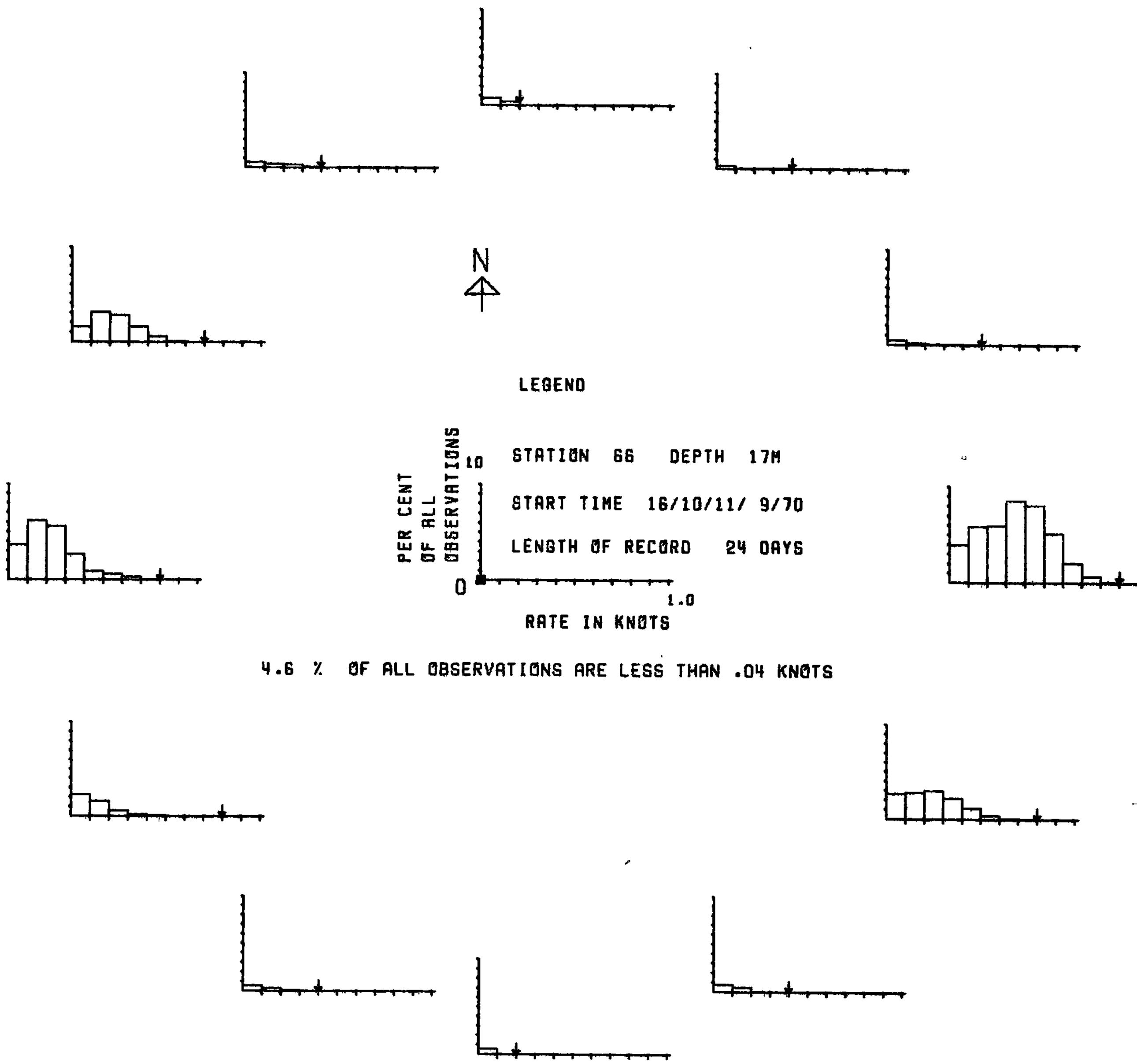


FIGURE 14. Dial plot of resolved data for Station 66 at 17 m depth.

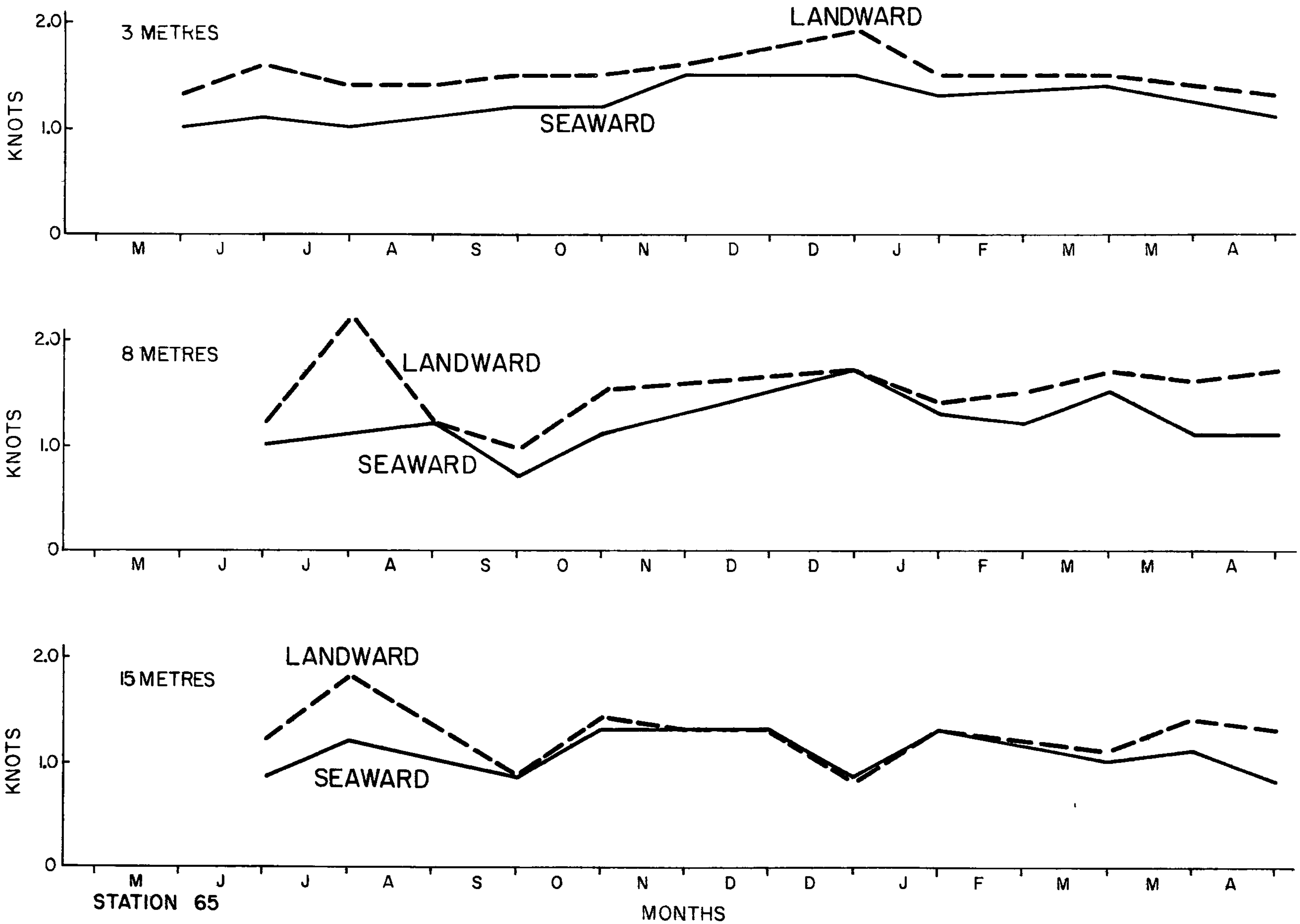


FIGURE 15. Extreme current points for the year May 1970 to May 1971, Station 65.

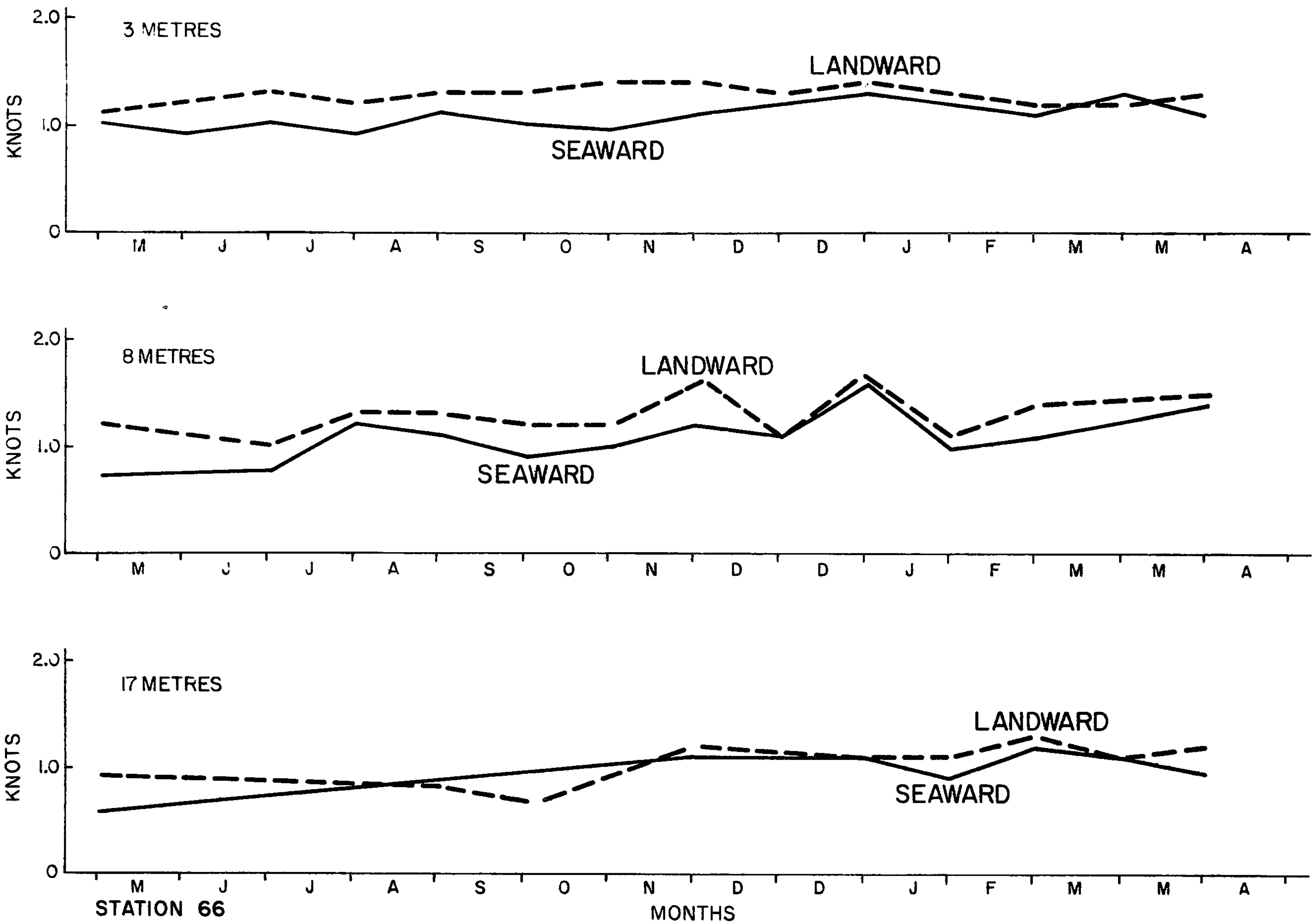


FIGURE 16. Extreme current points for the year May 1970 to May 1971, Station 66.

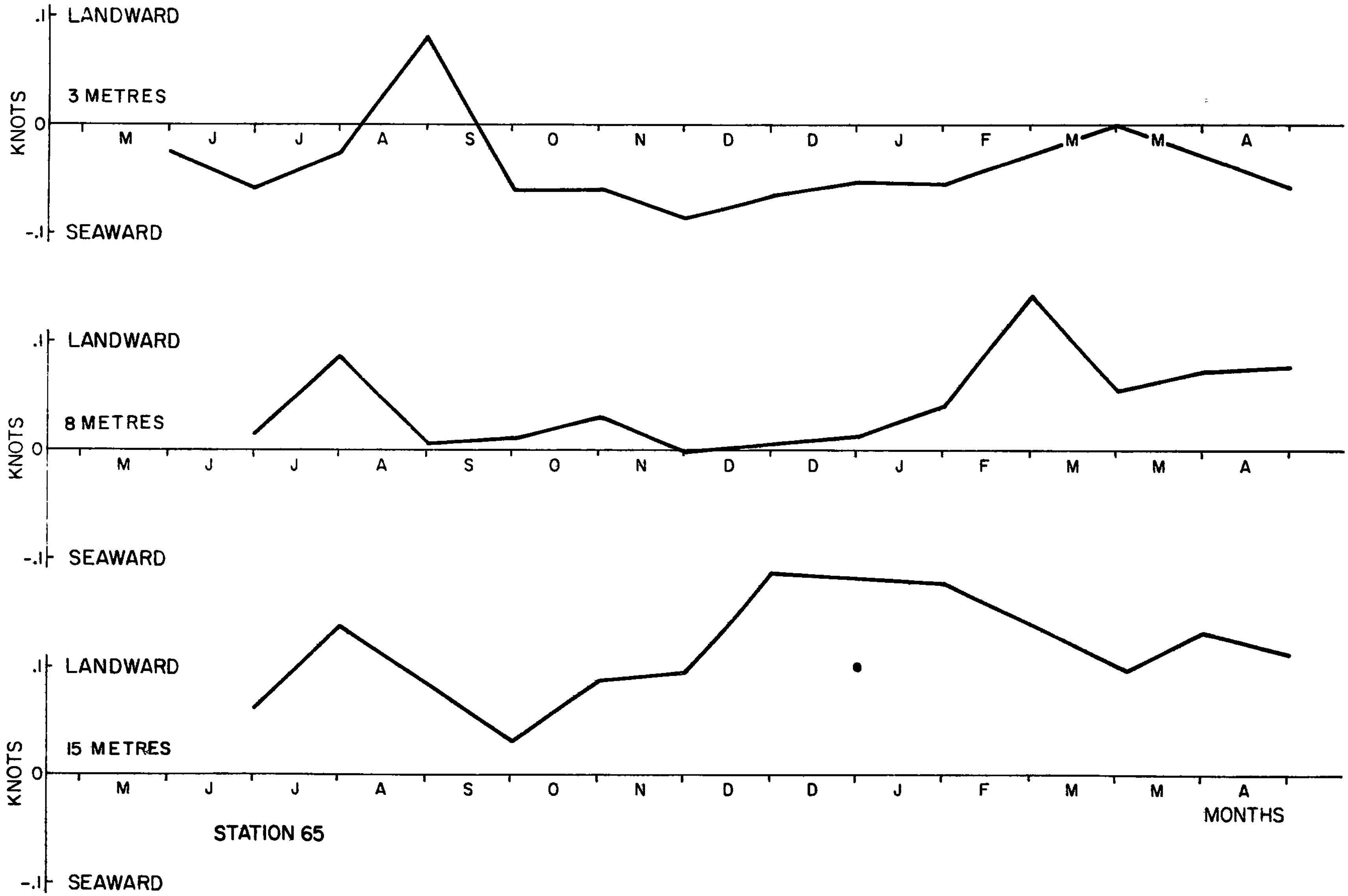


FIGURE 17. Monthlv mean currents for the year May 1970 to Mav 1971, Station 65.

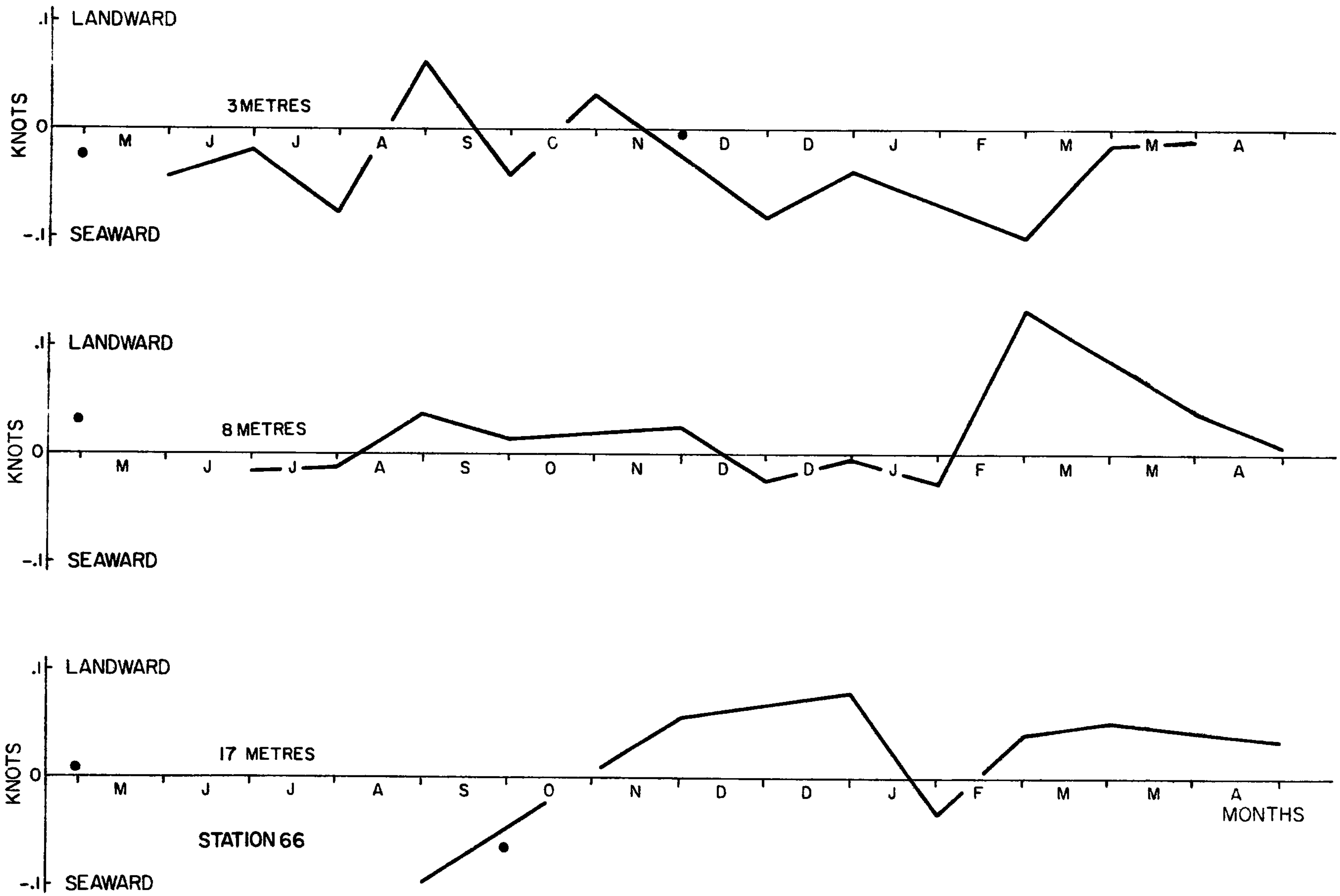


FIGURE 18. Monthly mean currents for the year May 1970 to May 1971, Station 66.

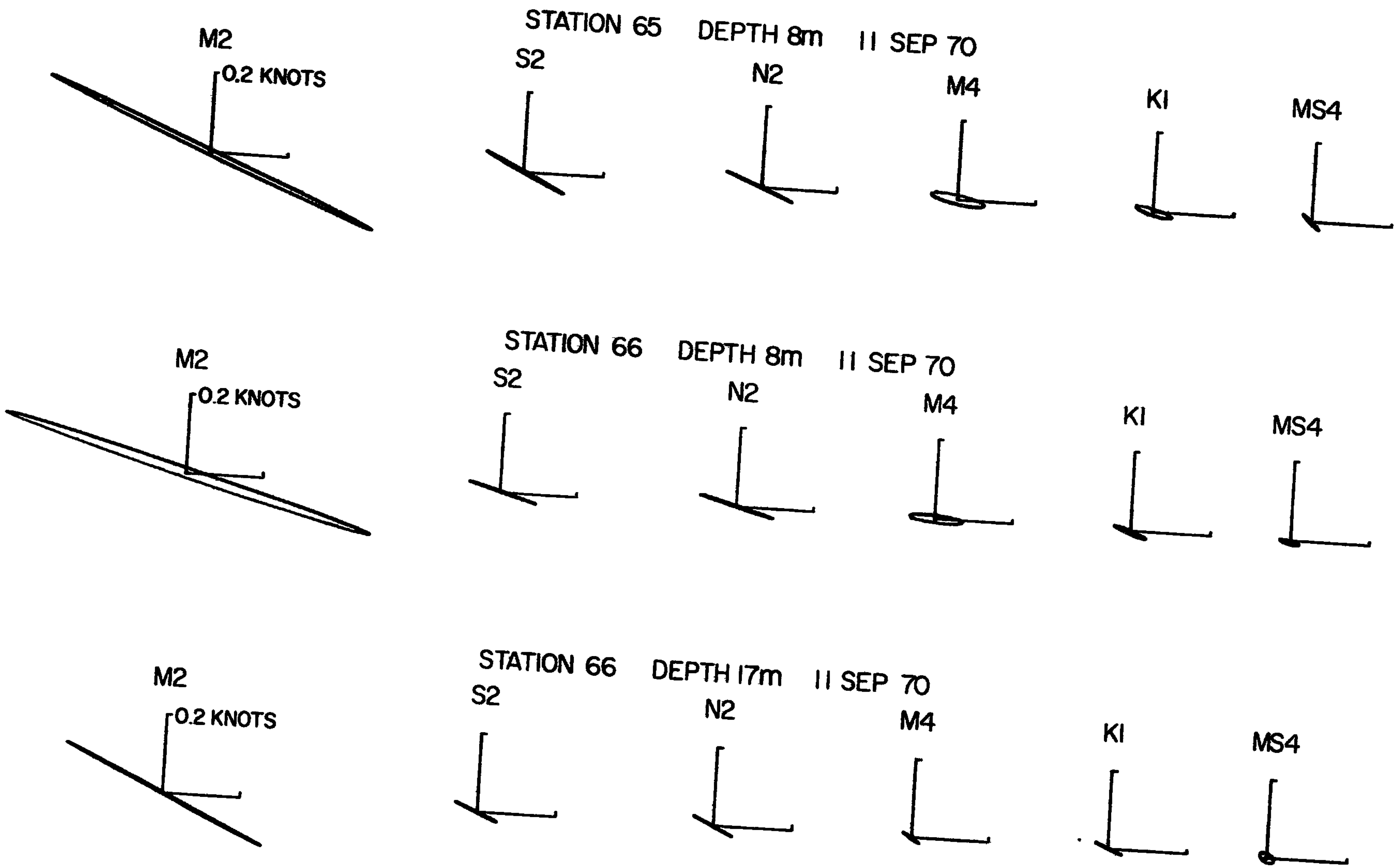


FIGURE 19a, b, & c. Principal tidal component ellipses.

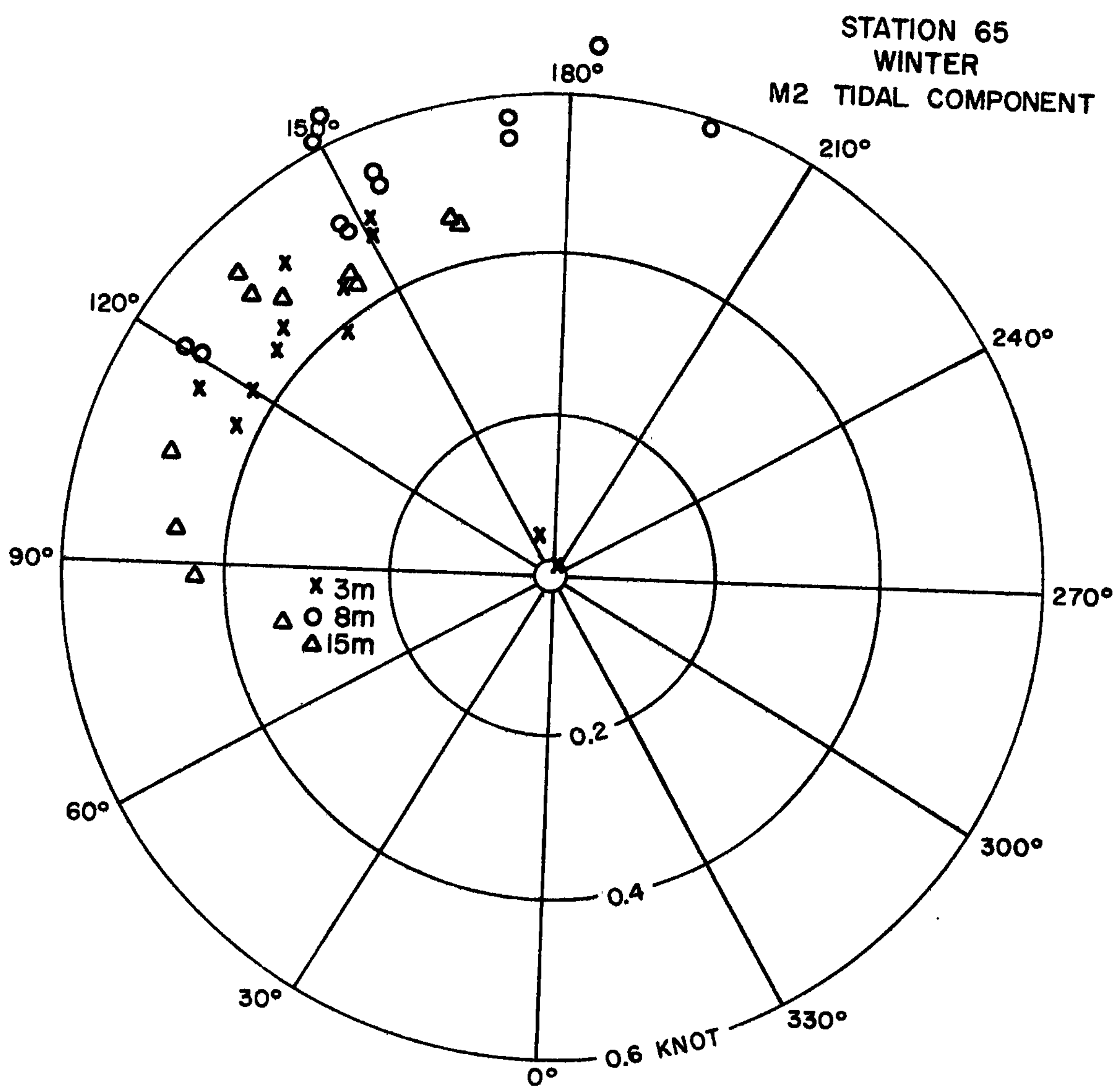


FIGURE 20. Polar scatter plot for the winter M2 tidal component at Station 65,

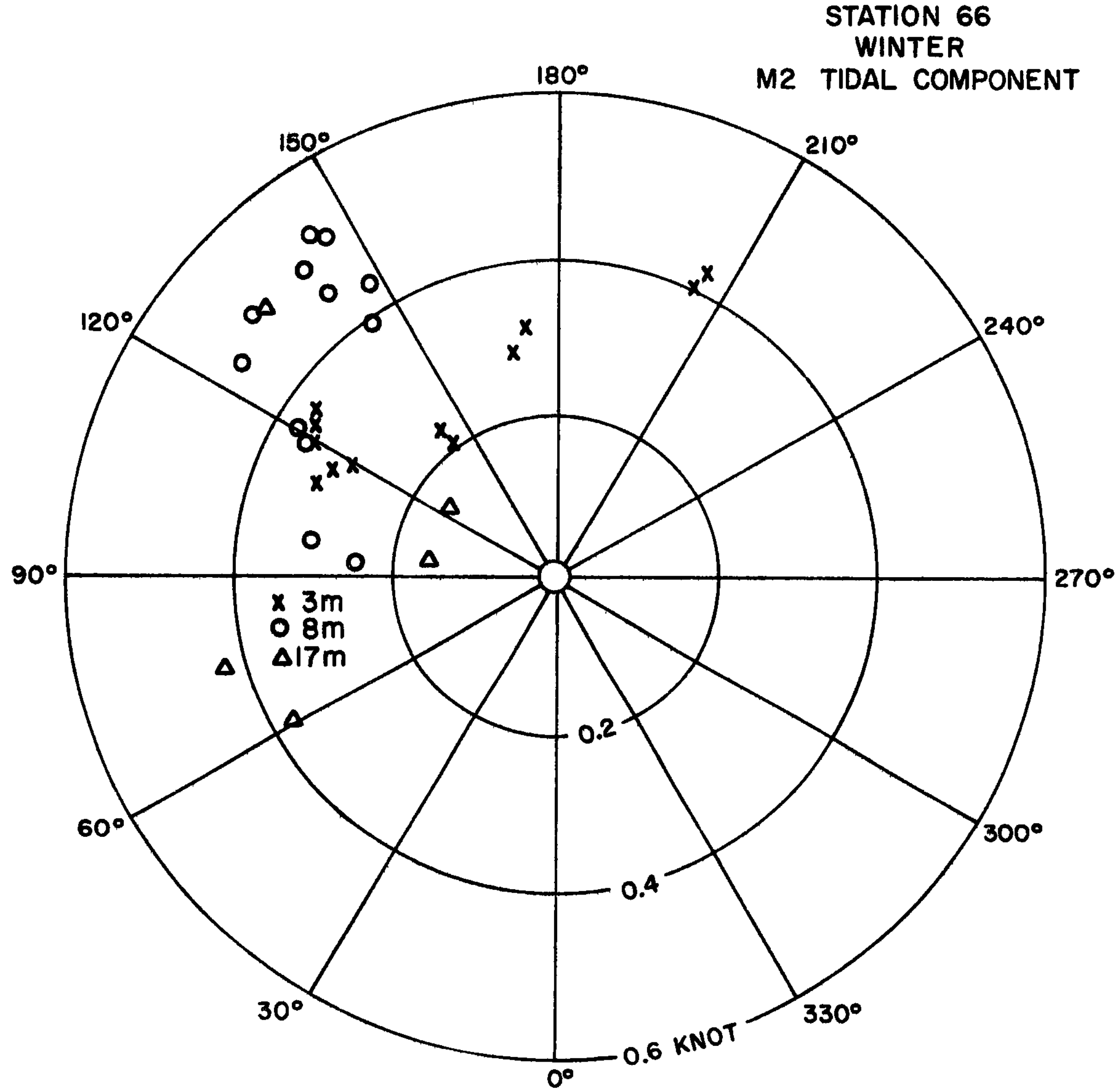


FIGURE 21. Polar scatter plot of the winter M2 tidal component at Station 66.

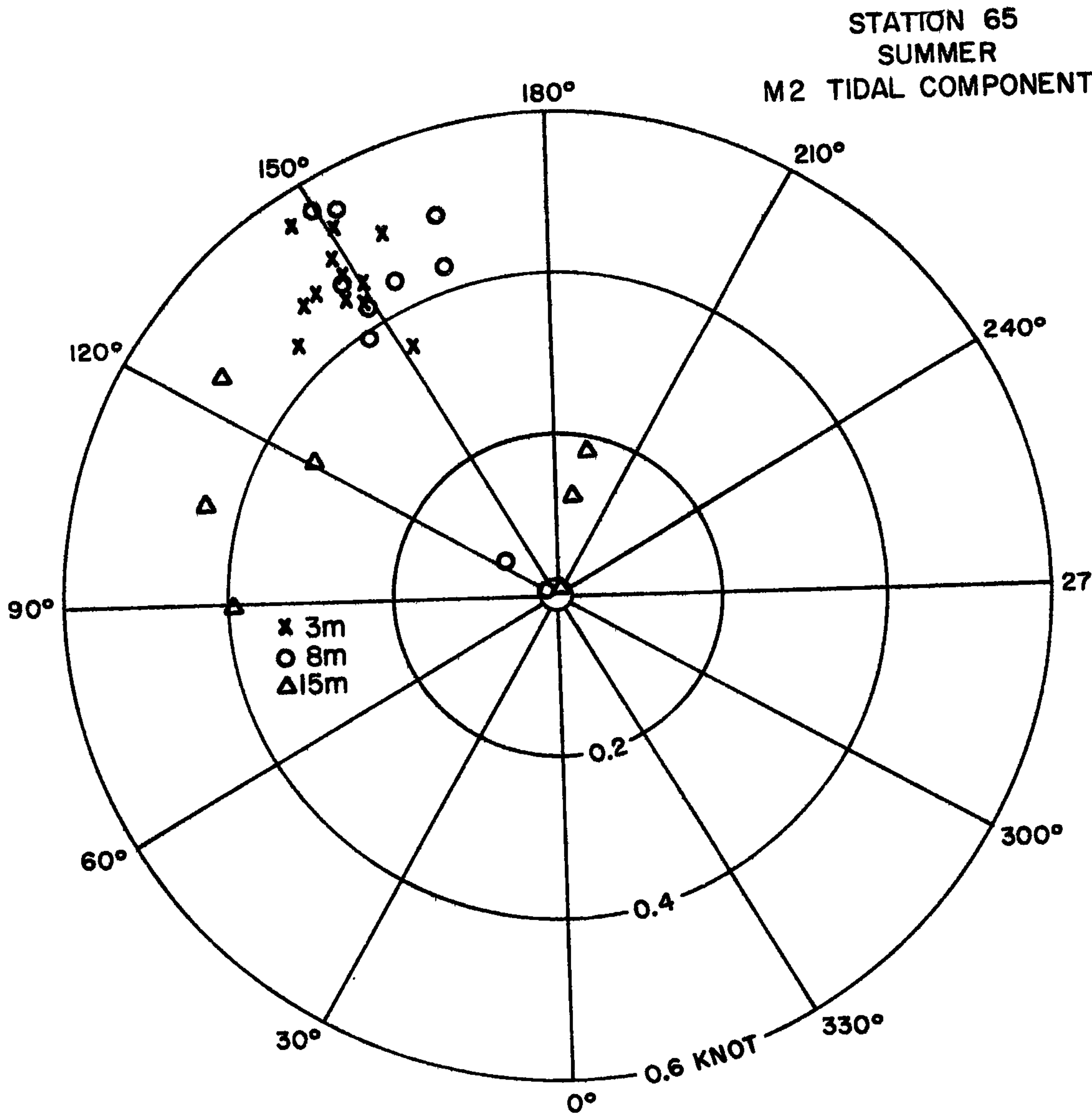


FIGURE 22. Polar scatter plot of the summer M2 tidal component at Station 65.

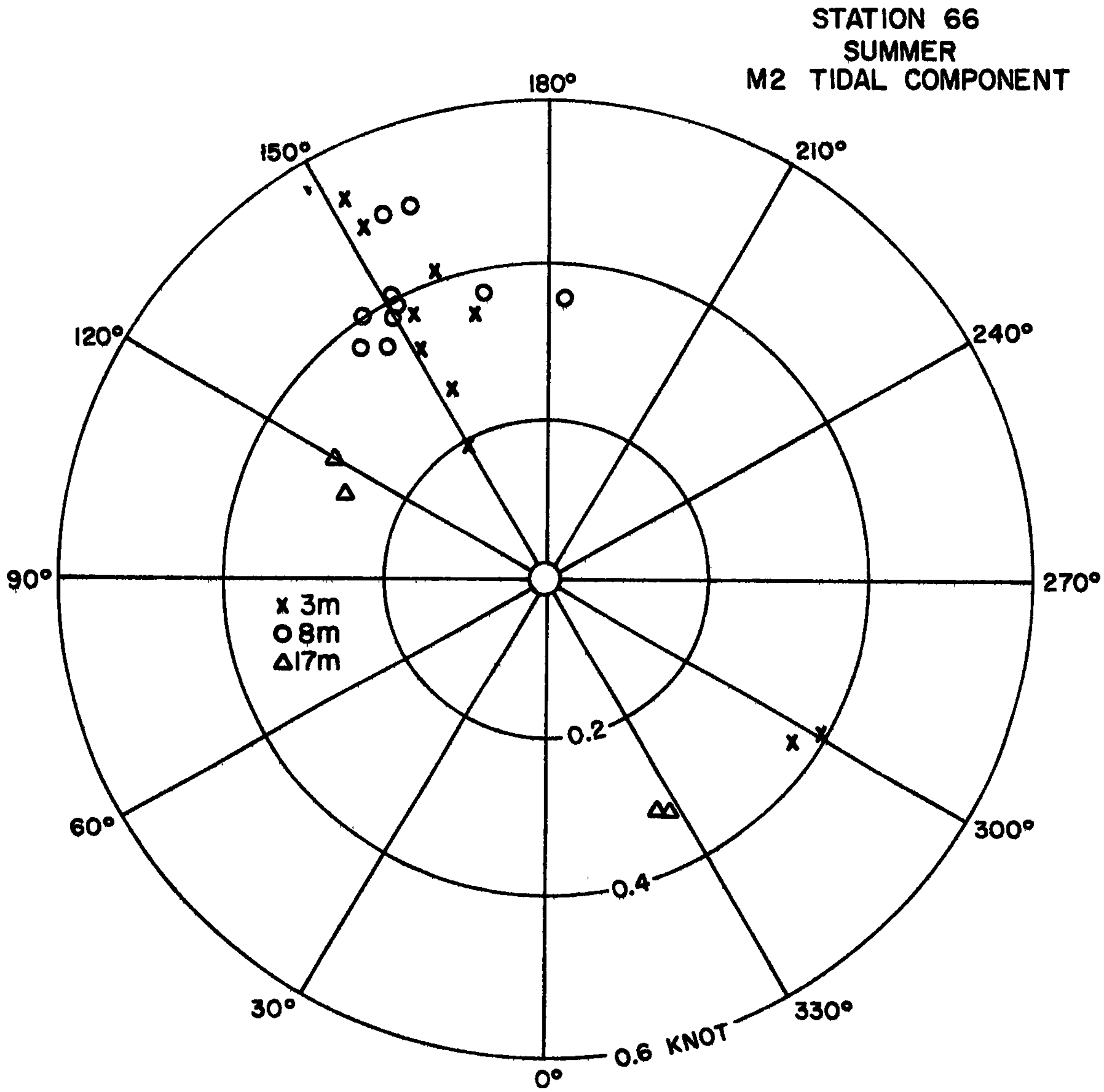


FIGURE 23. Polar scatter plot of the summer M2 tidal component at Station 66.

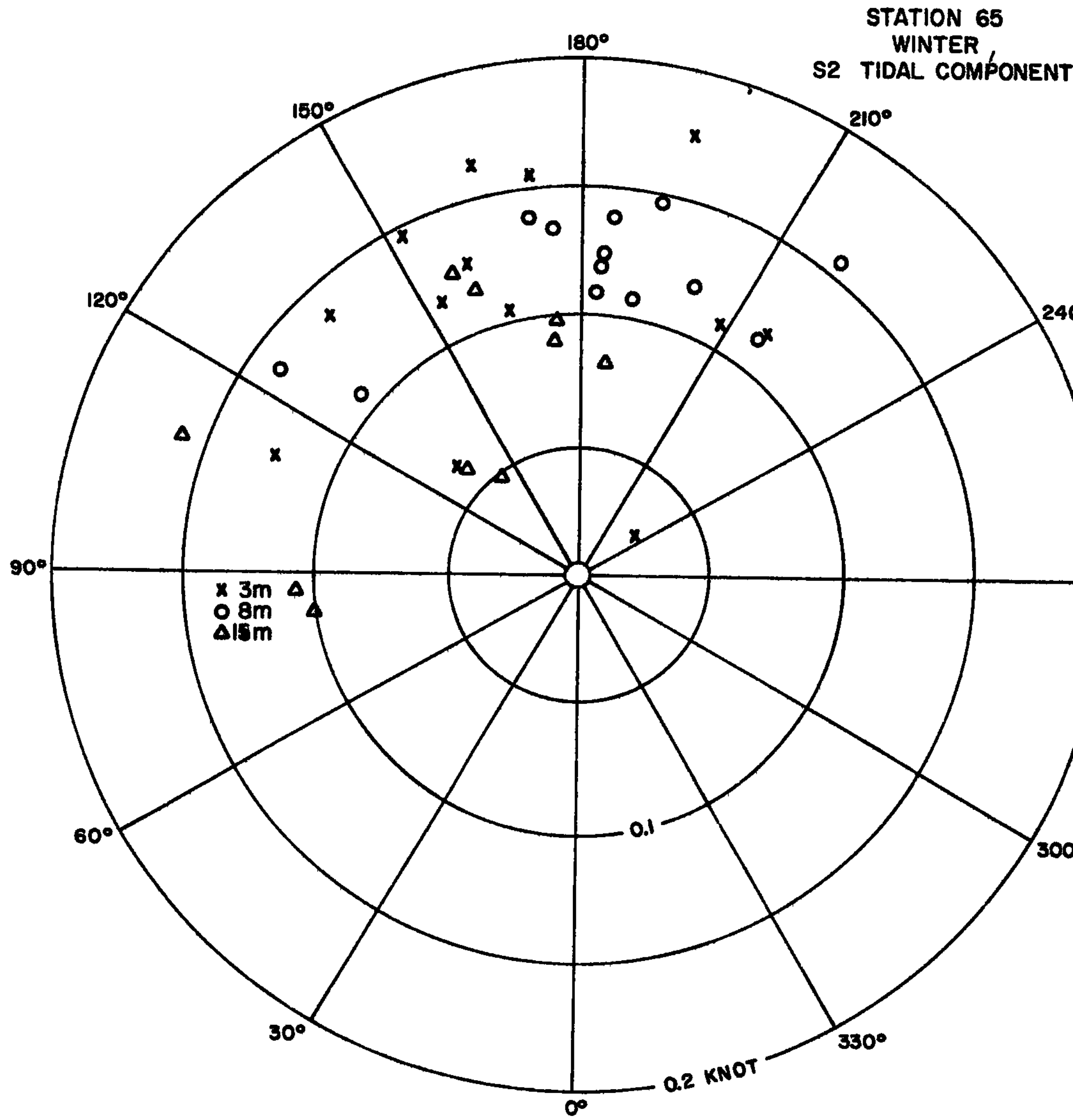


FIGURE 24. Polar scatter plot of the winter S2 tidal component at Station 65.

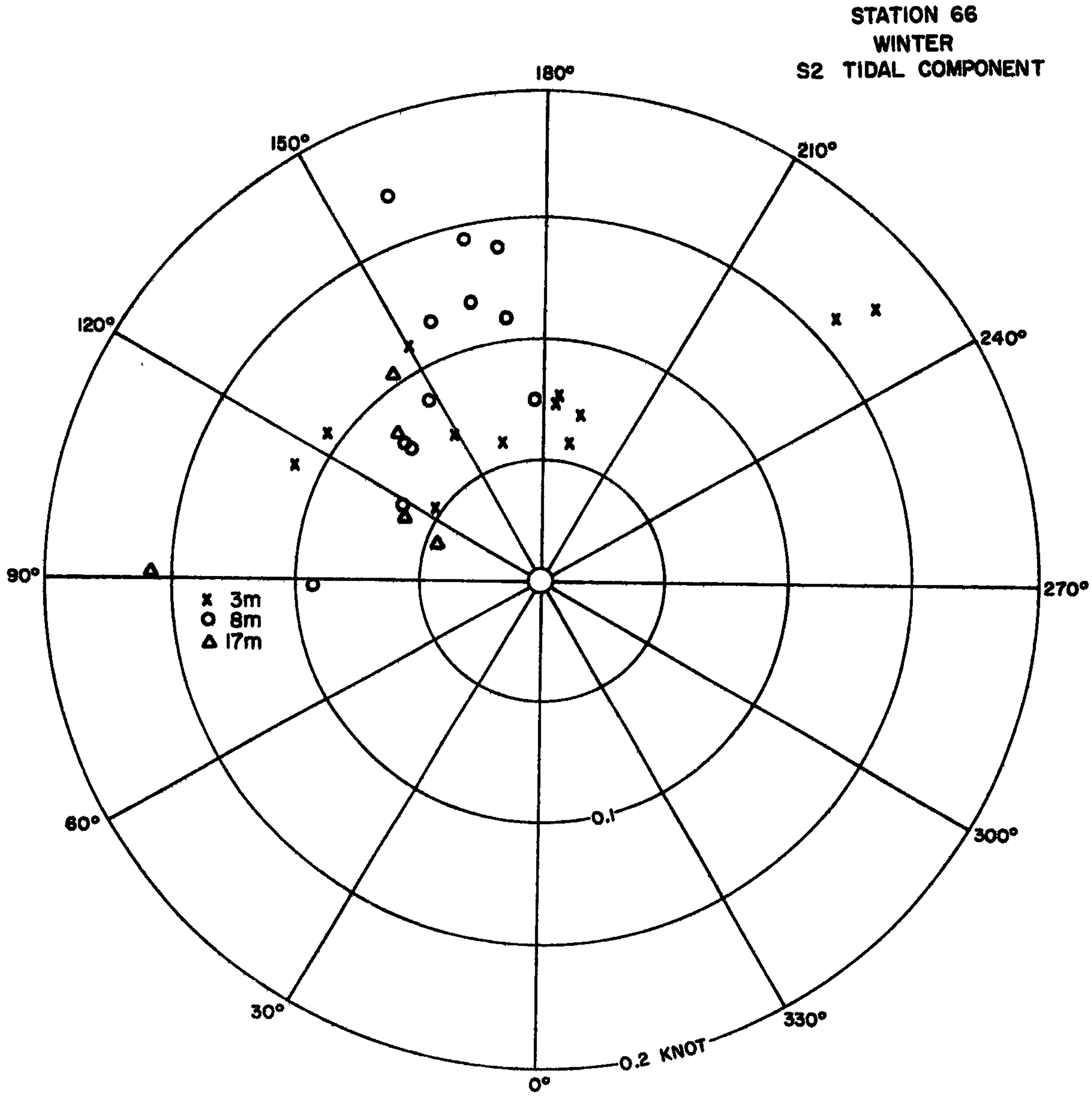


FIGURE 25. Polar scatter plot of the winter S2 tidal component at Station 66.

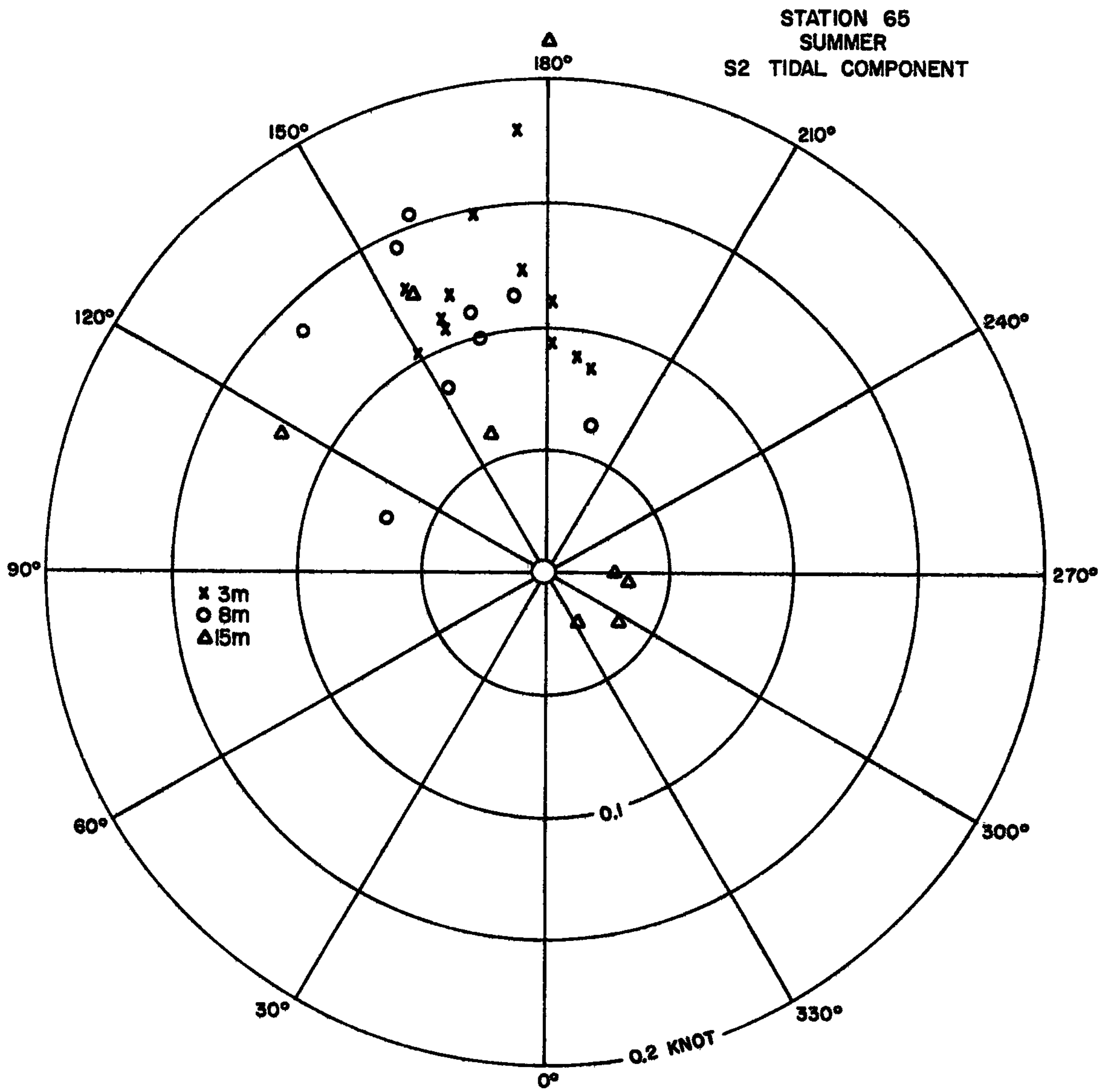


FIGURE 26. Polar scatter plot of the summer S2 tidal component at Station 65.

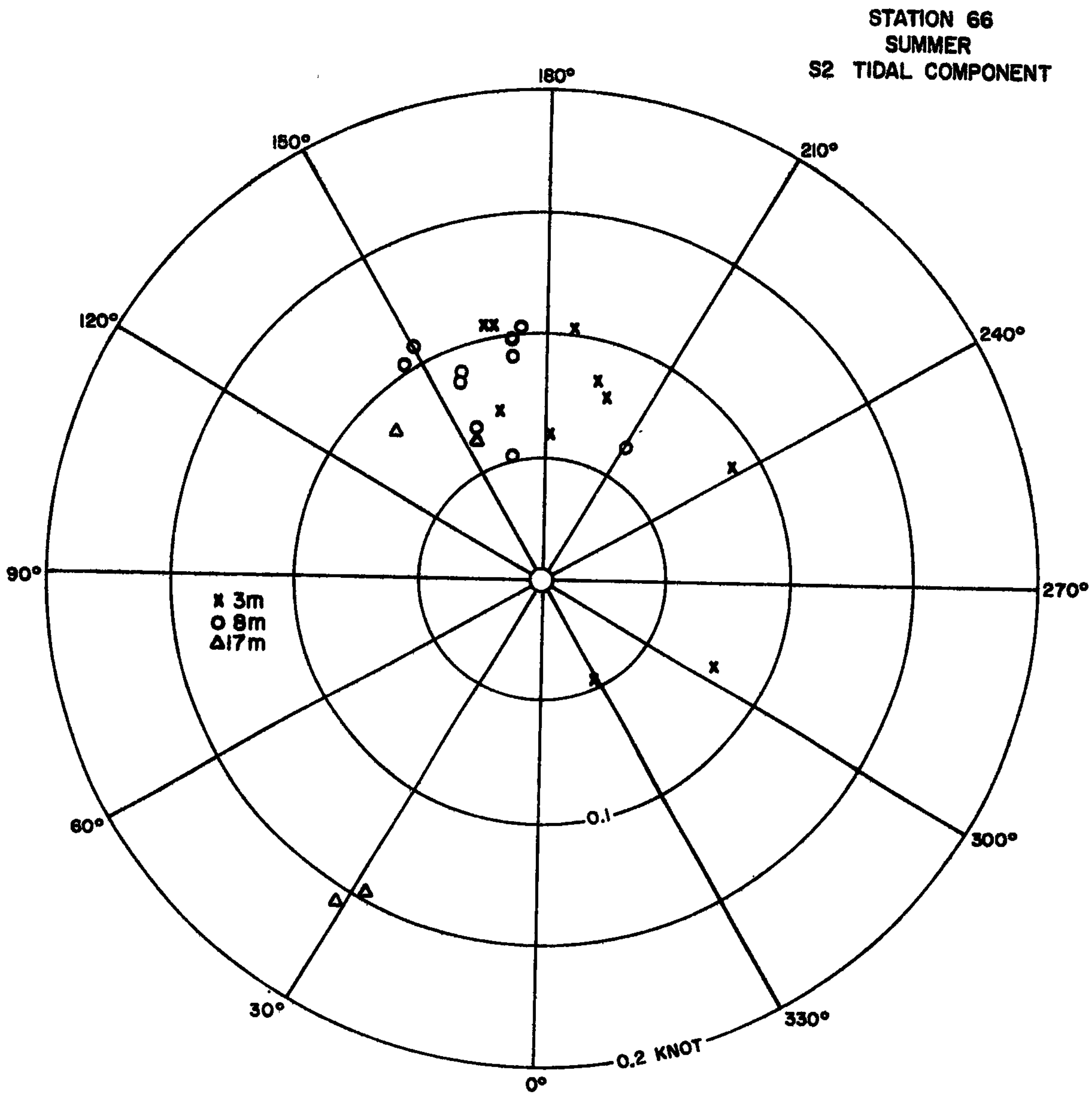


FIGURE 27. Polar scatter plot of the summer S2 tidal component at Station 66.