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# Current Meter Observations in Massachusetts Bay

DAVID HALPERN

BOULDER, COLO.

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# CURRENT METER OBSERVATIONS IN MASSACHUSETTS BAY

David Halpern

Summaries of current meter measurements recorded in Massachusetts Bay during the summer of 1967 are presented in computer-generated output as histograms, basic statistics, periodograms, progressive vector diagrams and east-north component plots.

## 1. INTRODUCTION

During the summer of 1967 a surface float, with 3 current meters suspended beneath it, was moored at 3 different locations in Massachusetts Bay (Figure 1). The measurement periods, the instrument depths, the water depths and the mooring line scopes at each site are given in Table 1.

The surface float consisted of a toroid and a tripod tower with 2 platforms. Since the total weight of the mooring cable was insufficient to stabilize the buoy, which had a net buoyancy of 2600 kg, nine 22-kg weights were attached to the bottom of the toroid. The surface float was moored with a single 7.93-mm galvanized aircraft cable. Each current meter (Geodyne Model 102 film recording current meter (Richardson et al., 1963)) was free to swivel about the mooring line axis.

Each instrument measured a 50-second average of speed and direction each minute. The time series of the 50-second averaged speed values obtained from the instruments positioned at Station T and all the speed

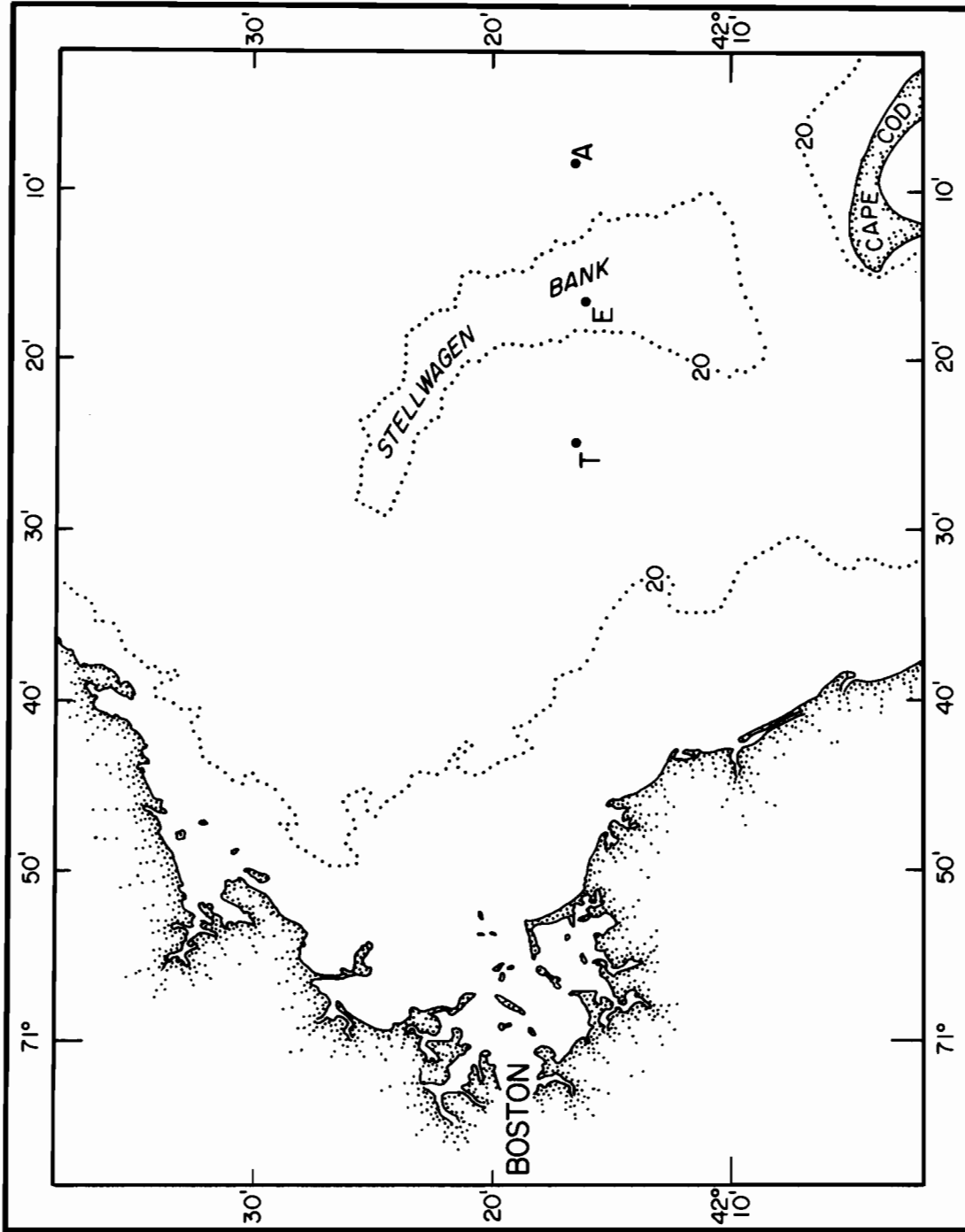


Figure 1. Location of stations T, E and A in Massachusetts Bay. Dotted lines are 20-fathom bottom contours.

Table 1. Description of the current meter measurements. The time origins of all the data were destroyed by film exposure. Depths in meters.

Date	Location	Station	Water depth	Scope	Current meter number	Current meter depth
July 13-17	42°16.5'N 70°24.9'W	T	82	1.05	H879	10.6
					H880	25.8
					H881	45.6
July 24-28	42°16.2'N 70°16.6'W	E	29	1.07	H880	7.6
					H879	15.2
					H881	22.8
August 22-25	42°16.6'N 70°08.5'W	A	61	1.05	H881	10.6
					H880	25.8
					H879	45.6

and direction histograms have been given elsewhere (Halpern, 1969). We have included the histograms in this report for "completeness" of the data summary.

## 2. DATA REDUCTION

Speed was determined over a 50-second interval by counting the number of switch closures produced by 16 small magnets mounted on the Savonius rotor. The next measurement occurred 10 seconds later. The time series of speed was edited for zero values and for erroneously high values; approximately 1% of the series was replaced by linearly interpolated values.

During the 50-second sampling period the current direction was measured by the simultaneous recording of 20 instrument-vane orientations, which give the direction of the current relative to the instrument, and 20 magnetic compass readings, which give the orientation of the instrument relative to magnetic north. The current direction associated with the 50-second averaged speed was equal to the difference between the vector average of each set of 20 measurements. Current direction is defined as the direction in which the water is flowing.

The basic data consists of two time series, one of 50-second averages of speeds and one of 50-second averages of directions. Directions are referred to true north.



### 3. DATA PRESENTATION

There is a two-page data summary of the measurements obtained from each current meter. The location and depth of the instrument, the number of observations and the observation period are given on the first page. Some of this information has been repeated on each of the four plots found on the second page to aid the researcher interested in comparing the same type of plot from different instruments.

#### 3.1 Histogram

The basic data was plotted as histograms of speed and of direction. The speeds were sorted into groups of 1.5 cm/sec and the directions were arranged in 6° sets. The speeds seen on the histograms are higher than those occurring in the other plots due to the presence of high-frequency phenomena such as internal waves (Halpern, 1971a) and mooring motion and because the Savonius rotor is an omnidirectional sensor. Direction histograms were plotted on a linear scale to eliminate the distortion inherent in a polar plot. Zero degrees refers to true north.

#### 3.2 Statistics

The basic data consists of  $N$  observations of speed and direction, i.e.,  $(S_i, \theta_i)$ ,  $i = 1, 2, 3, \dots, N$ . We define the north (+v) - south (-v) and east (+u) - west (-u) components of horizontal velocity by  $u_i = S_i \cdot \text{SIN } \theta_i$  and  $v_i = S_i \cdot \text{COS } \theta_i$ .

The following statistics were computed for  $S_i$ ,  $u_i$ , and  $v_i$ . (Here the dummy variable  $x_i$  is used.)

$$\text{Mean, } \bar{x} = \frac{1}{N} \sum_{i=1}^N x_i$$

$$\text{Variance, } \sigma^2 = \frac{1}{N} \sum_{i=1}^N (x_i - \bar{x})^2$$

$$\text{Standard deviation, } \sigma = \sqrt{\sigma^2}$$

$$\text{Skewness} = \frac{\frac{1}{N} \sum_{i=1}^N x_i^3 - \frac{3}{N} \bar{x} \sum_{i=1}^N x_i^2 + 2\bar{x}^3}{\sigma^3}$$

$$\text{Kurtosis} = \frac{\frac{1}{N} \sum_{i=1}^N x_i^4 - \frac{4}{N} \bar{x} \sum_{i=1}^N x_i^3 - \frac{6}{N} \bar{x}^2 \sum_{i=1}^N x_i^2 + 3\bar{x}^4}{\sigma^4}$$

### 3.3 East and North vs. Time

These diagrams, which accentuate inertial and tidal period oscillations, were generated from the  $u_i$  and  $v_i$  series by computing the arithmetic mean of non-overlapping groups of 60 points, e.g.,  $U_1 = \frac{1}{60} \sum_{i=1}^{60} u_i$ ,  $U_2 = \frac{1}{60} \sum_{i=61}^{120} u_i$  and similarly for  $V$ . The  $U_m$  and  $V_m$  data sets were the 1-hour vector averaged east and north component series.

### 3.4 Progressive Vector Diagram

The 1-hour averaged east (X) and north (Y) displacements (in kilometers) were given by  $X_m = U_m \cdot 36 \cdot 10^{-3}$  and  $Y_m = V_m \cdot 36 \cdot 10^{-3}$ . The progressive vector diagram (Sverdrup et al., 1942), which represents the path taken by a water particle if it is assumed that the observed motion is characteristic of a considerably extended water mass, was generated by successive additions of the end points of the position vectors ( $X_m, Y_m$ ). The progressive vector diagram, which accentuates very low frequency events (e.g., mean flow), is not the horizontal projection of a water particle trajectory with time. The spatial scale of the diagram corresponds to the displacement which would occur if the motion over the entire area (i.e., the extent of the displacement diagram) were the same as that observed at the location of the current meter.

The plot begins with an asterisk surrounded by a circle. Every twelfth hour is marked on the curve by an asterisk.

### 3.5 East and North Periodograms

By use of a fast Fourier transform algorithm, raw periodograms (Bingham et al., 1967), defined so that the integral over positive frequencies is equal to twice the total variance, were computed for the 1-hour vector averaged  $U_m$  and  $V_m$  series. (We note that generally a periodogram ordinate is not a consistent spectral estimate of a random process.) The data length (90 hours) was too short to form spectral estimates.

#### 4. CONCLUSION

It is important to note that (1) the data presentation given in this report is biased towards a description of phenomena associated with periods greater than about 6 hours, (2) during the summer months the circulation in Massachusetts Bay contains both external and internal tidal motions (Halpern, 1971b), and (3) 7-minute period fluctuations having 50-second averaged speeds of about 50 cm/sec have been measured in Massachusetts Bay.

An analysis of this current meter data will be discussed in a later paper.

#### 5. ACKNOWLEDGEMENTS

I thank Norman Brenner (Massachusetts Institute of Technology) for the subroutine to compute the fast Fourier transform and Linda Olund (University of Washington) for preparing the CURRENT PLOT computer program. Assistance by Pat Laird (Pacific Oceanographic Laboratory) and Kurt Schneblee (National Ocean Survey) is gratefully acknowledged.

The current meter measurements were one segment of an experimental program conducted in the Department of Meteorology, Massachusetts Institute of Technology and supported by the Office of Naval Research under contract Nonr 1841 (74). This report was prepared at the Pacific Oceanographic Laboratory.

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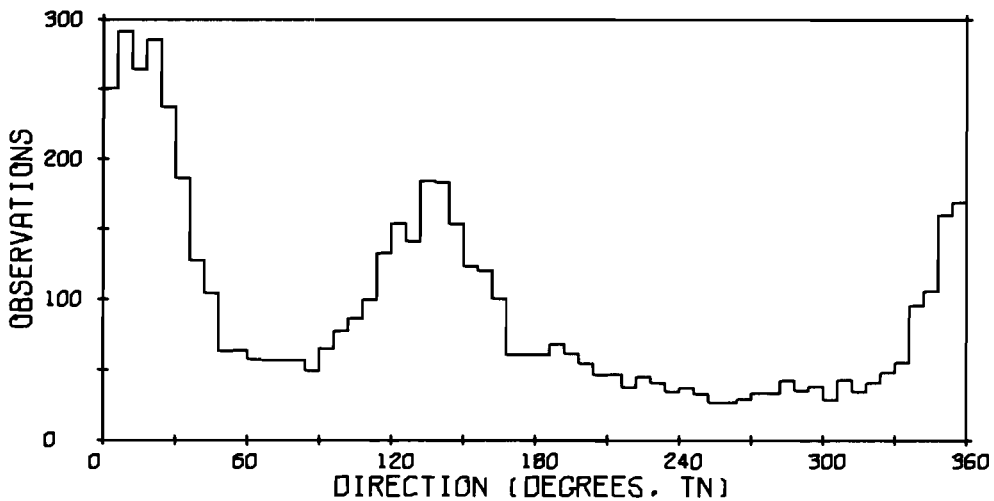
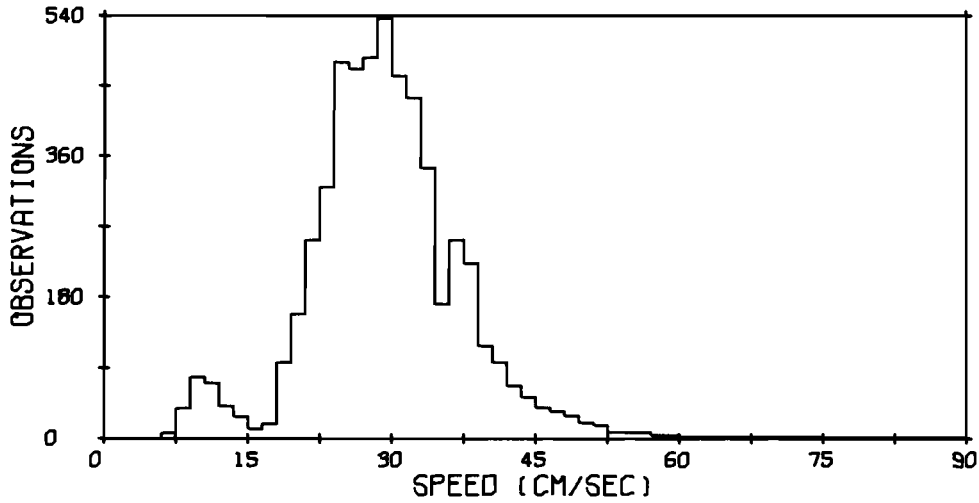
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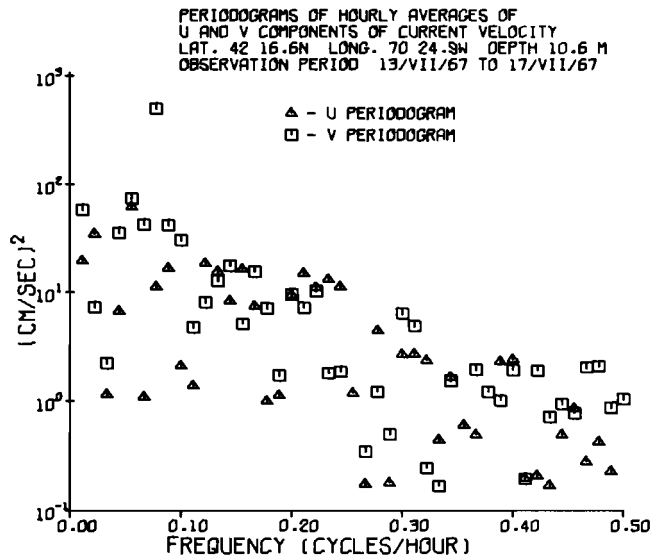
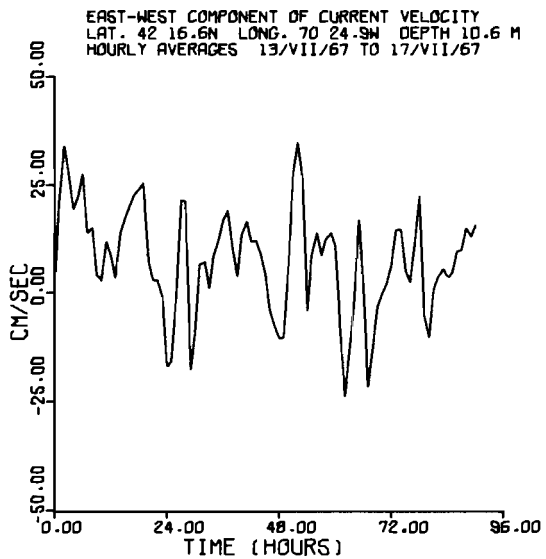
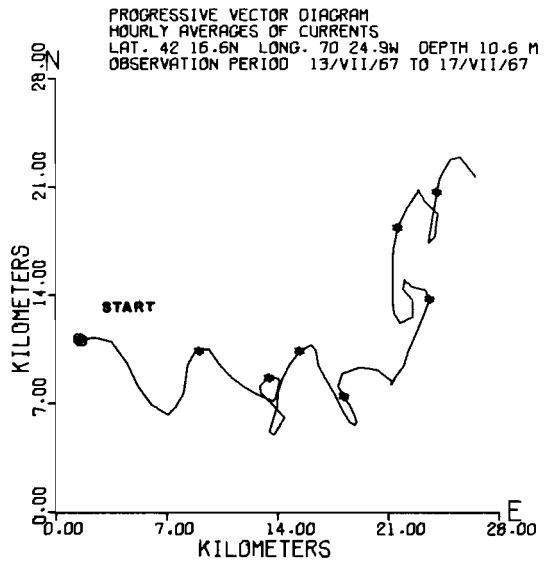
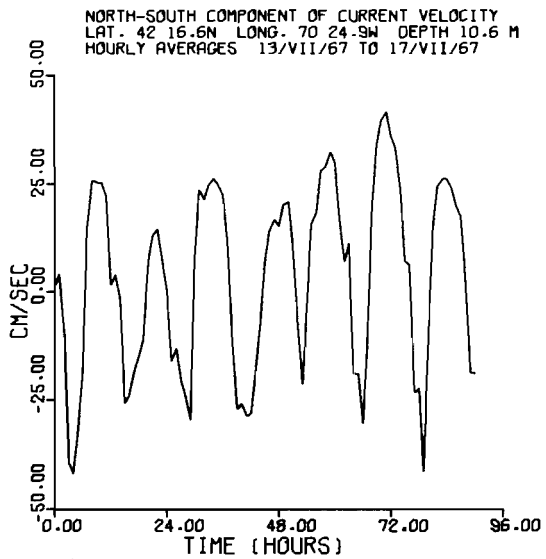
**Depth: 10.6 meters**

STATISTICS OF CURRENTS    LAT. 42 16.6N    LONG. 70 24.9W  
 DEPTH 10.6 METERS    NUMBER OF OBSERVATIONS = 5500  
 OBSERVATION PERIOD 13/VII/67 TO 17/VII/67

	MEAN CM/SEC	VARIANCE (CM/SEC) <sup>2</sup>	ST-DEV CM/SEC	SKEW	KURT	MAX CM/SEC	MIN CM/SEC
S	29.32	62.96	7.94	-.228	4.64	71.51	4.63
U	7.54	276.26	16.62	-.437	2.65	46.96	-55.04
V	2.98	580.63	24.10	-.317	1.85	48.64	-71.12

S = SPEED  
 U = EAST-WEST COMPONENT OF VELOCITY. EAST = POSITIVE U  
 V = NORTH-SOUTH COMPONENT OF VELOCITY. NORTH = POSITIVE V





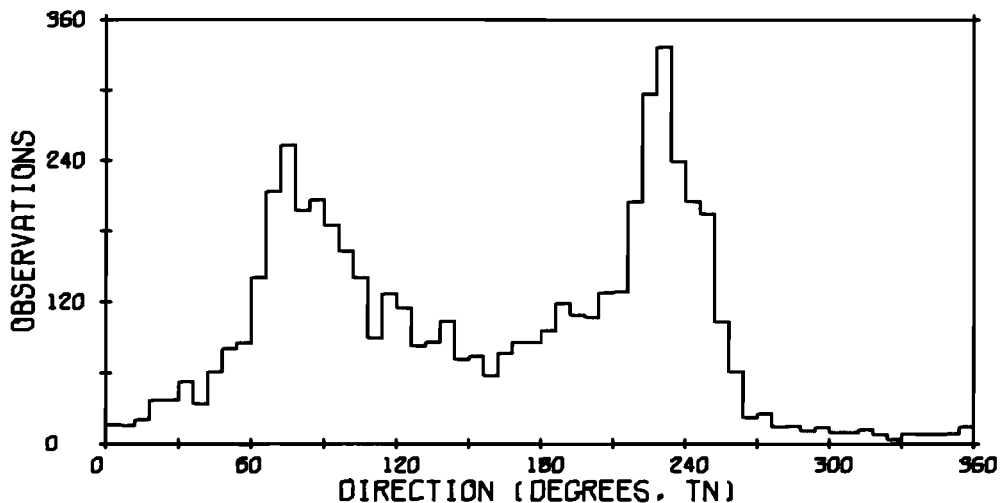
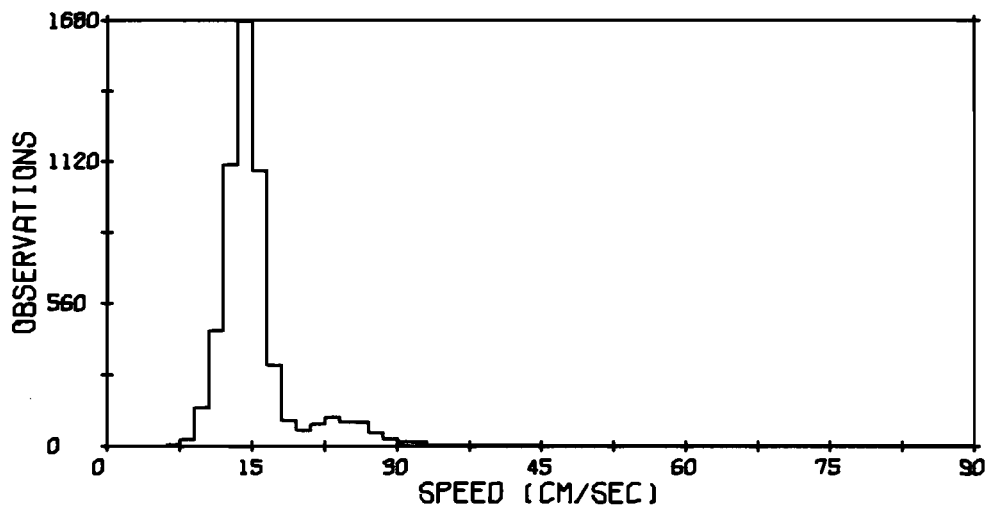


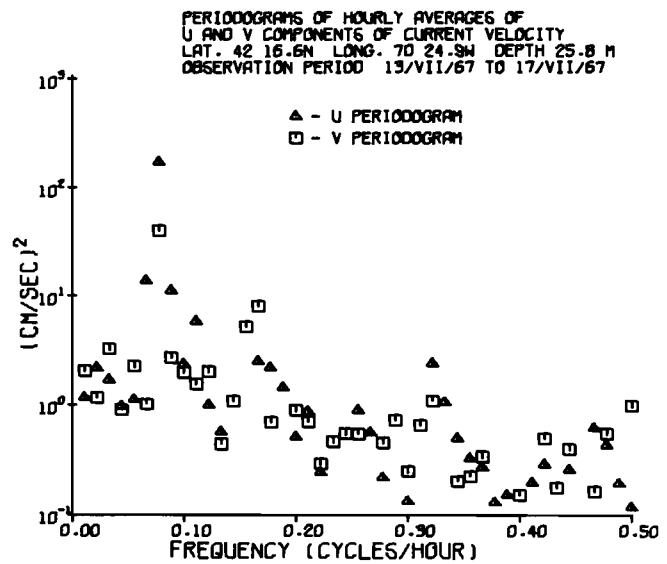
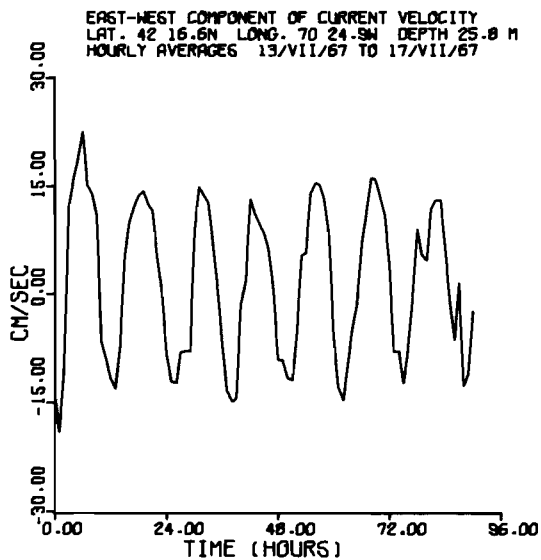
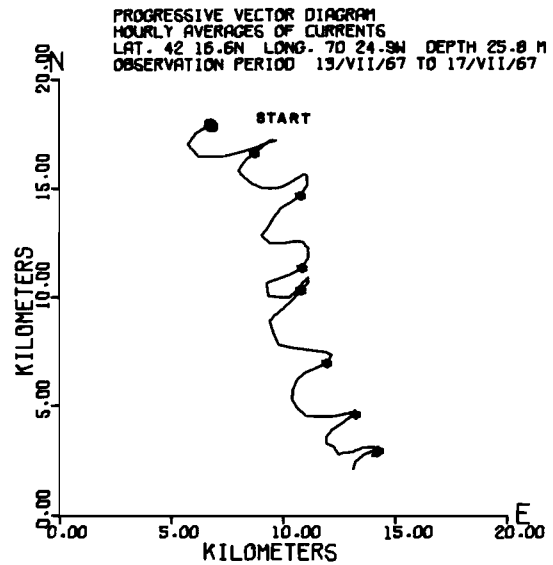
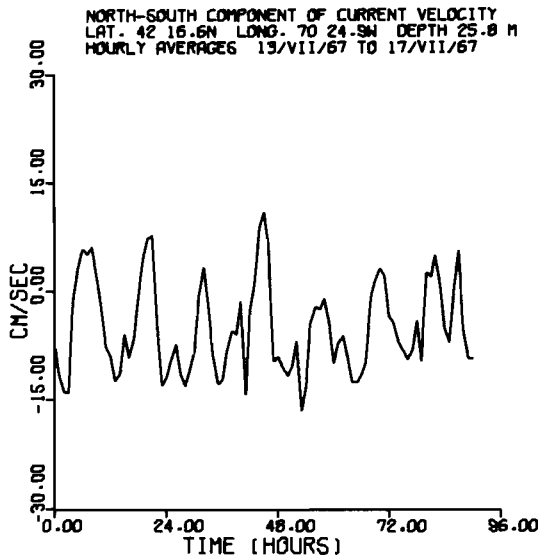
**Location:** Station T  
**Depth:** 25.8 meters

STATISTICS OF CURRENTS    LAT. 42 16.6N    LONG. 70 24.9W  
 DEPTH 25.8 METERS    NUMBER OF OBSERVATIONS = 5500  
 OBSERVATION PERIOD 13/VII/67 TO 17/VII/67

	MEAN CM/SEC	VARIANCE (CM/SEC) <sup>2</sup>	ST-DEV CM/SEC	SKEW	KURT	MAX CM/SEC	MIN CM/SEC
S	15.34	16.66	4.08	2.521	13.87	60.70	6.17
U	1.69	149.88	12.24	-.086	1.76	40.12	-31.49
V	-4.97	74.53	8.63	.139	3.43	28.29	-60.70

S = SPEED  
 U = EAST-WEST COMPONENT OF VELOCITY, EAST = POSITIVE U  
 V = NORTH-SOUTH COMPONENT OF VELOCITY, NORTH = POSITIVE V





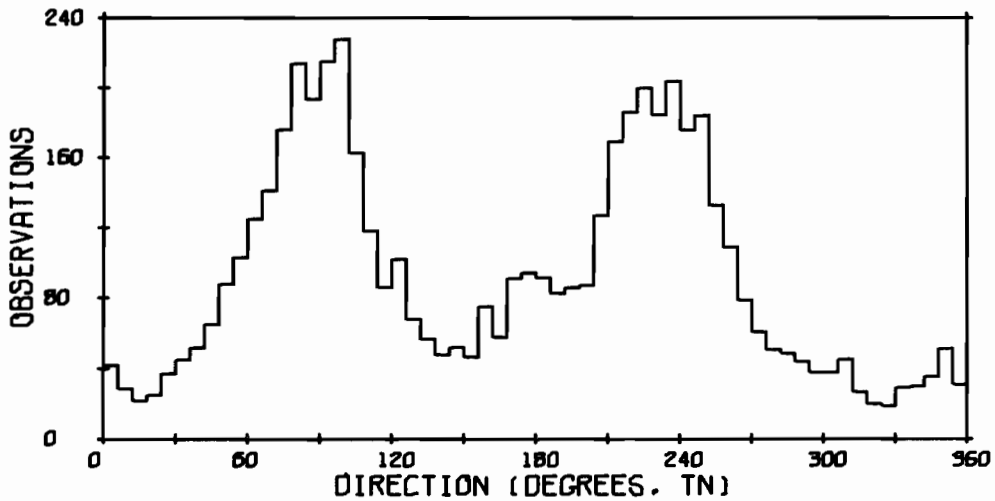
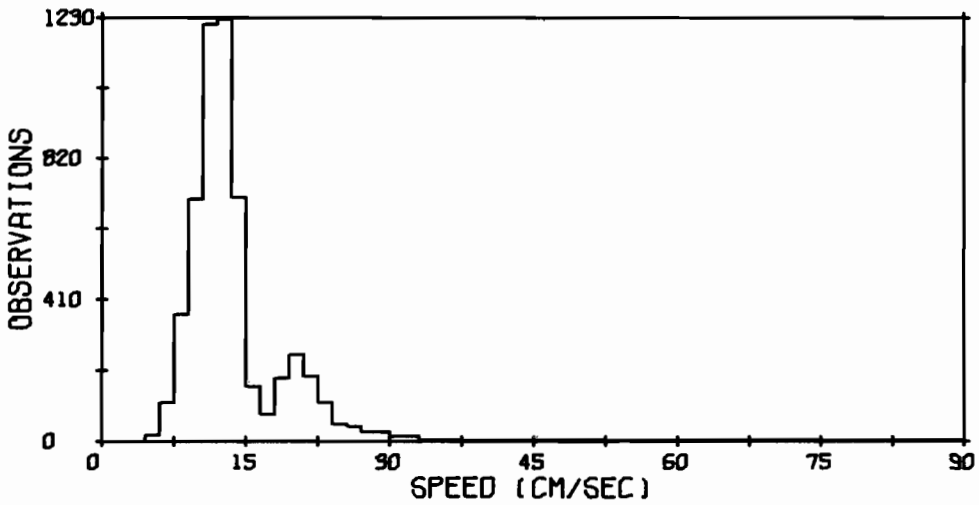
Location: Station T

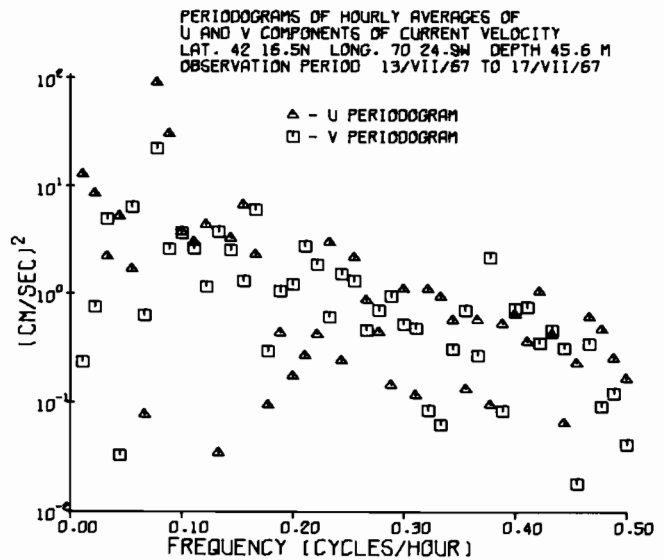
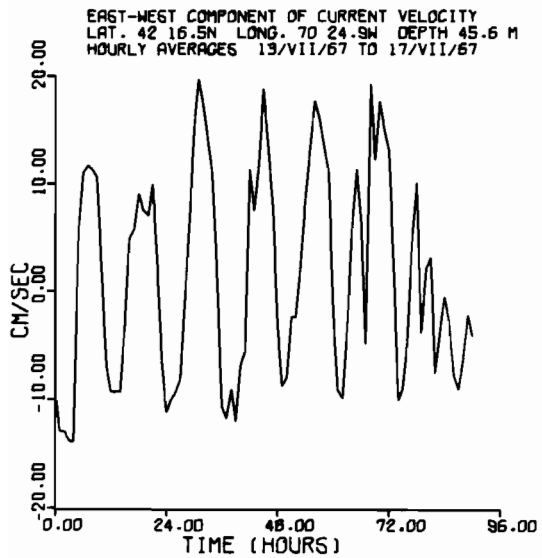
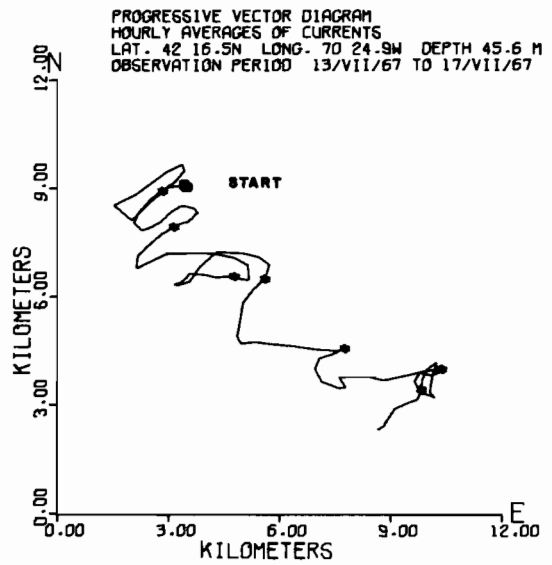
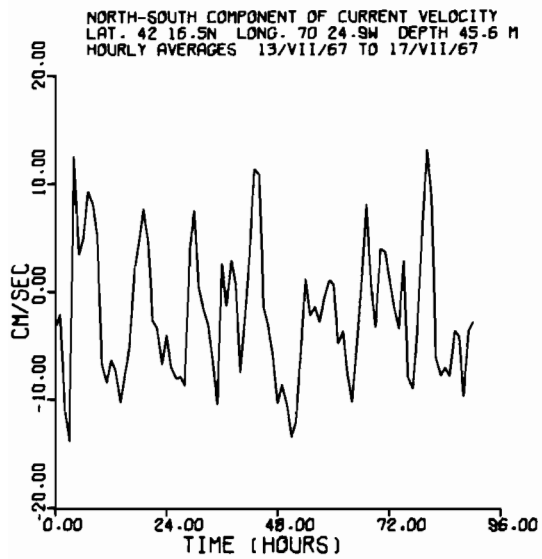
Depth: 45.6 meters

STATISTICS OF CURRENTS    LAT. 42 16.5N    LONG. 70 24.9W  
 DEPTH 45.6 METERS    NUMBER OF OBSERVATIONS = 5500  
 OBSERVATION PERIOD 13/VII/67 TO 17/VII/67

	MEAN CM/SEC	VARIANCE (CM/SEC) <sup>2</sup>	ST-DEV CM/SEC	SKEW	KURT	MAX CM/SEC	MIN CM/SEC
S	13.50	20.48	4.53	1.551	6.47	45.79	1.03
U	1.47	126.80	11.26	-.041	1.99	97.24	-94.47
V	-2.08	69.56	8.34	-.718	3.99	42.74	-31.65

S = SPEED  
 U = EAST-WEST COMPONENT OF VELOCITY, EAST = POSITIVE U  
 V = NORTH-SOUTH COMPONENT OF VELOCITY, NORTH = POSITIVE V



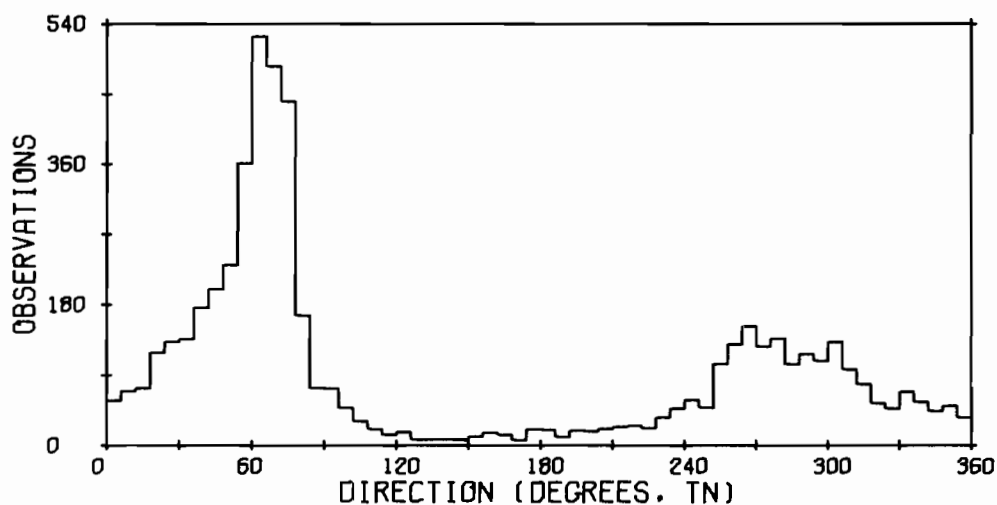
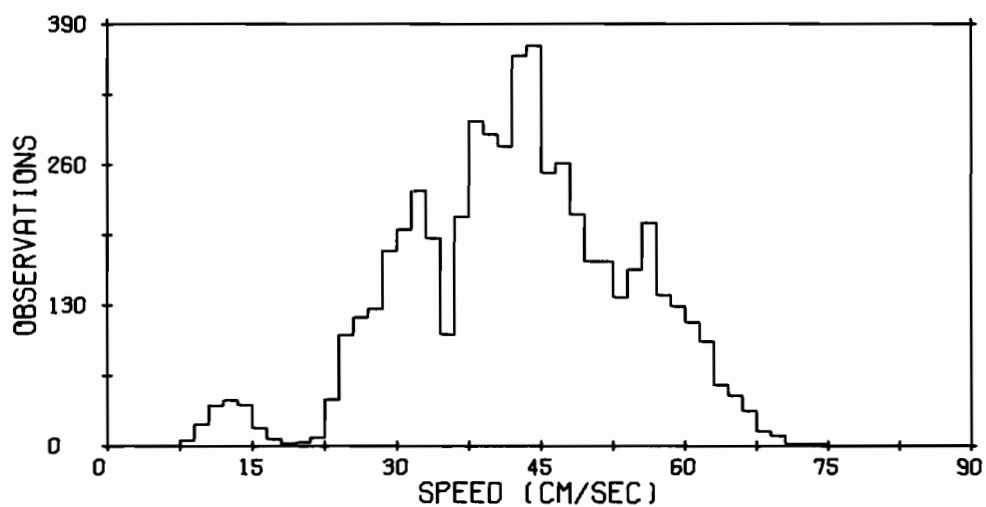


Location: Station E  
Depth: 7.6 meters

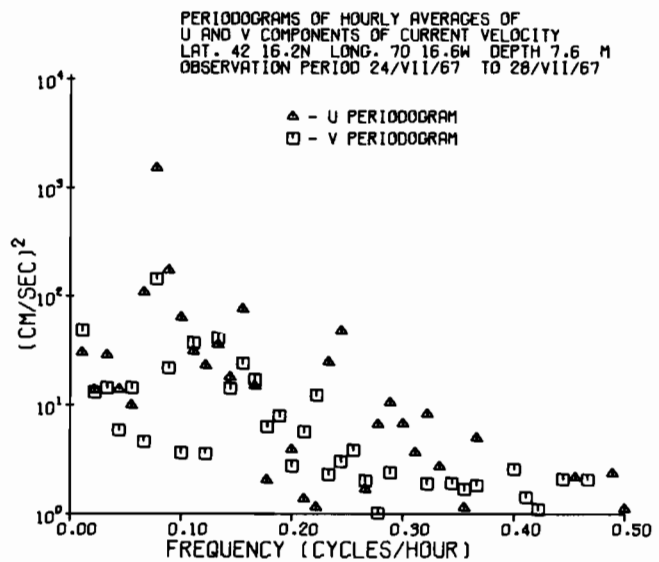
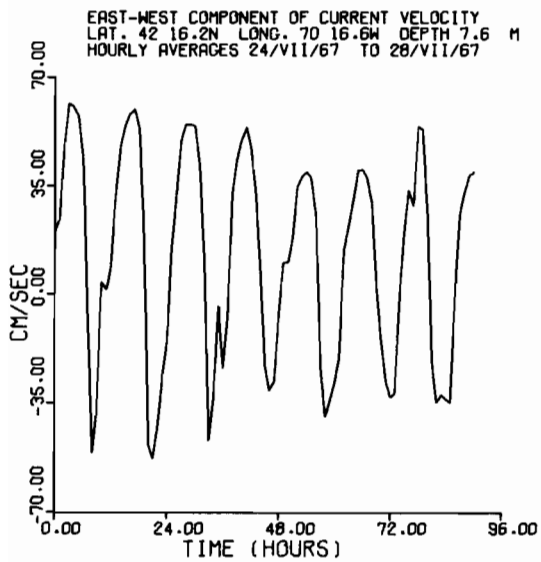
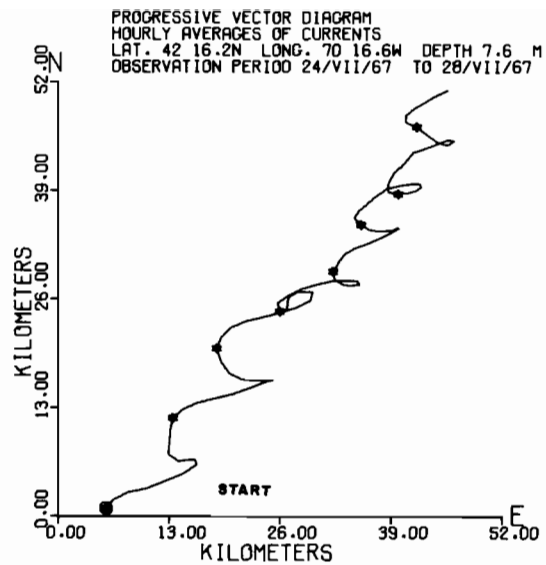
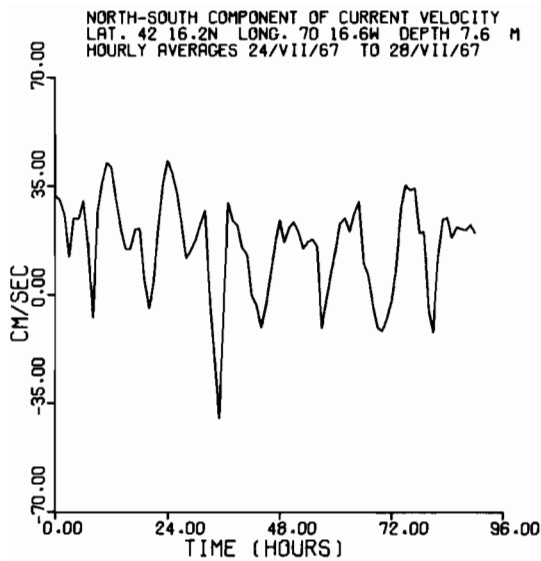
STATISTICS OF CURRENTS    LAT. 42 16.2N    LONG. 70 16.6W  
 DEPTH 7.6 METERS    NUMBER OF OBSERVATIONS = 5500  
 OBSERVATION PERIOD 24/VII/67 TO 28/VII/67

	MEAN CM/SEC	VARIANCE (CM/SEC) <sup>2</sup>	ST-DEV CM/SEC	SKEW	KURT	MAX CM/SEC	MIN CM/SEC
S	42.59	132.74	11.52	-.214	2.96	73.56	7.72
U	12.65	1243.33	35.26	-.362	1.72	70.97	-65.21
V	15.69	297.61	17.25	-.815	3.86	53.84	-47.84

S = SPEED  
 U = EAST-WEST COMPONENT OF VELOCITY, EAST = POSITIVE U  
 V = NORTH-SOUTH COMPONENT OF VELOCITY, NORTH = POSITIVE V







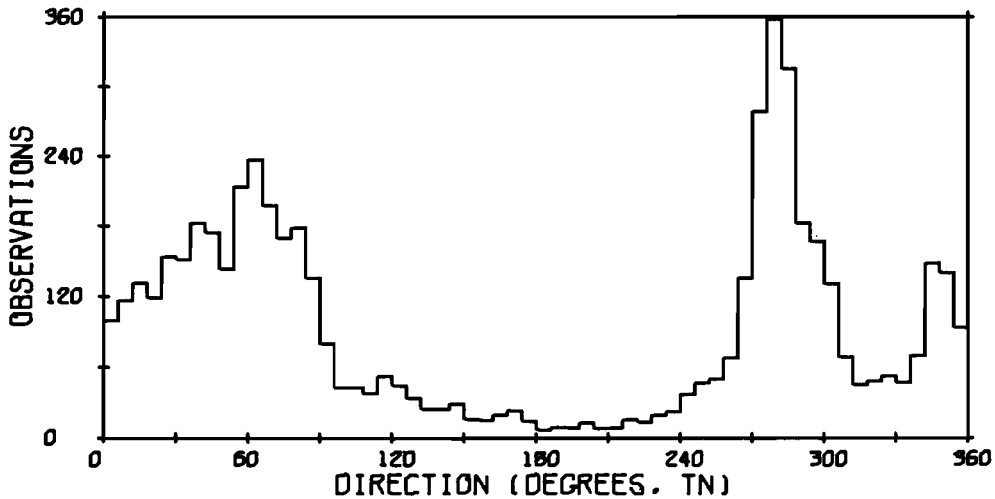
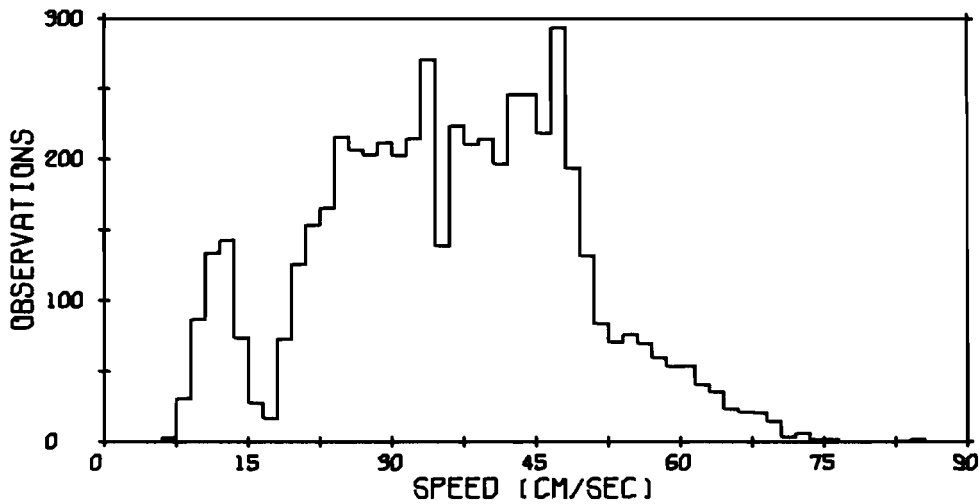
**Location: Station E**

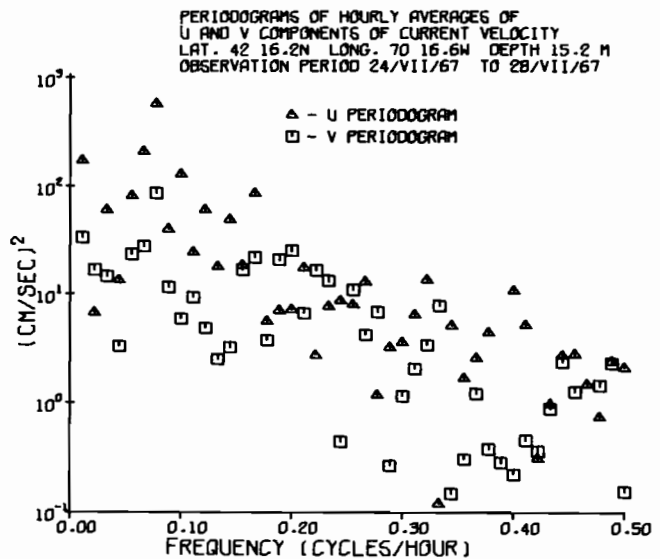
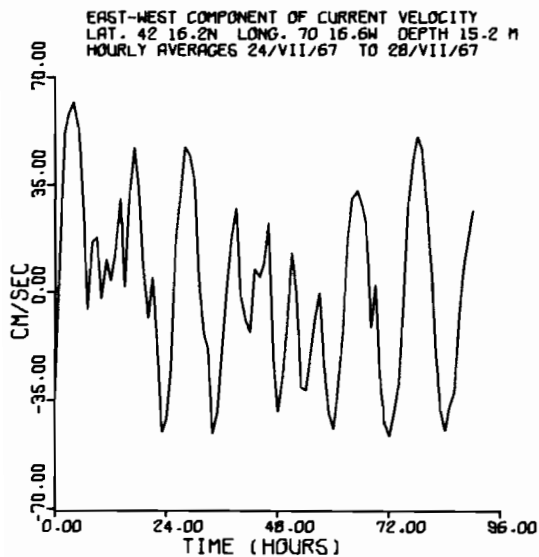
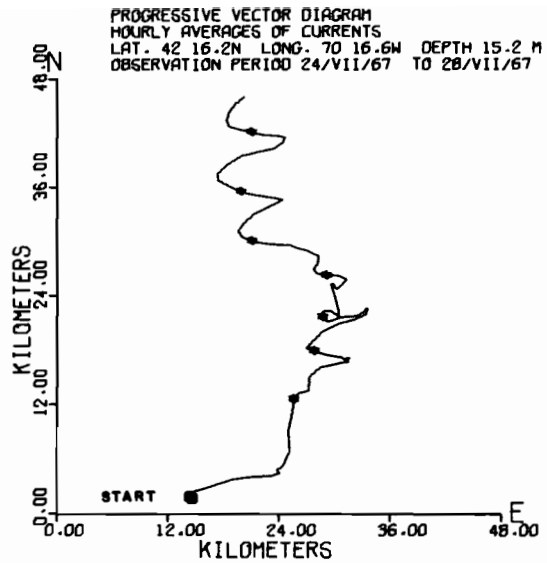
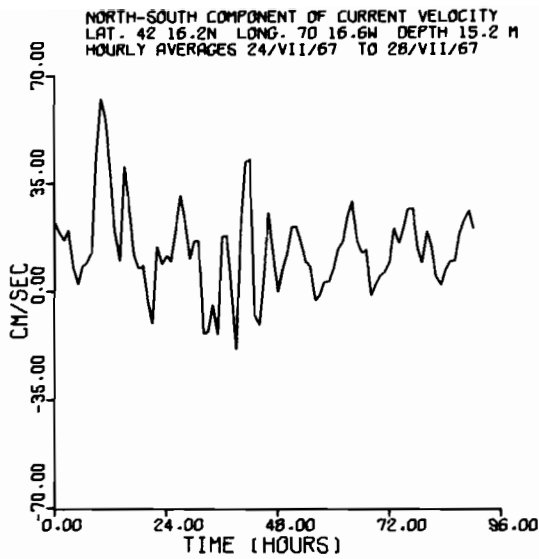
**Depth: 15.2 meters**

STATISTICS OF CURRENTS    LAT. 42 16.2N    LONG. 70 16.6W  
 DEPTH 15.2 METERS    NUMBER OF OBSERVATIONS = 5500  
 OBSERVATION PERIOD 24/VII/67 TO 28/VII/67

	MEAN CM/SEC	VARIANCE (CM/SEC) <sup>2</sup>	ST-DEV CM/SEC	SKEW	KURT	MAX CM/SEC	MIN CM/SEC
S	36.05	178.69	13.37	.050	2.62	84.88	7.20
U	1.61	976.78	31.25	-.087	1.87	72.87	-54.01
V	13.80	308.88	17.58	-.249	3.70	84.25	-48.40

S = SPEED  
 U = EAST-WEST COMPONENT OF VELOCITY. EAST = POSITIVE U  
 V = NORTH-SOUTH COMPONENT OF VELOCITY. NORTH = POSITIVE V





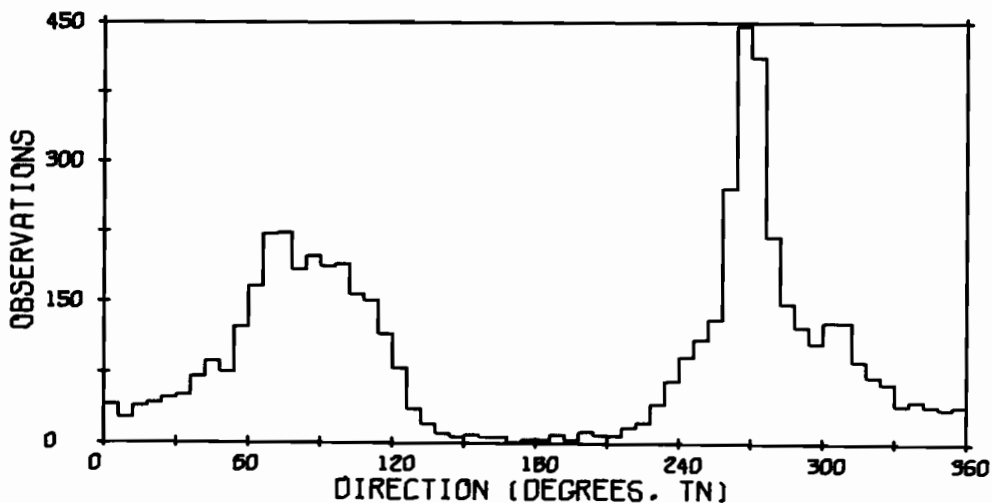
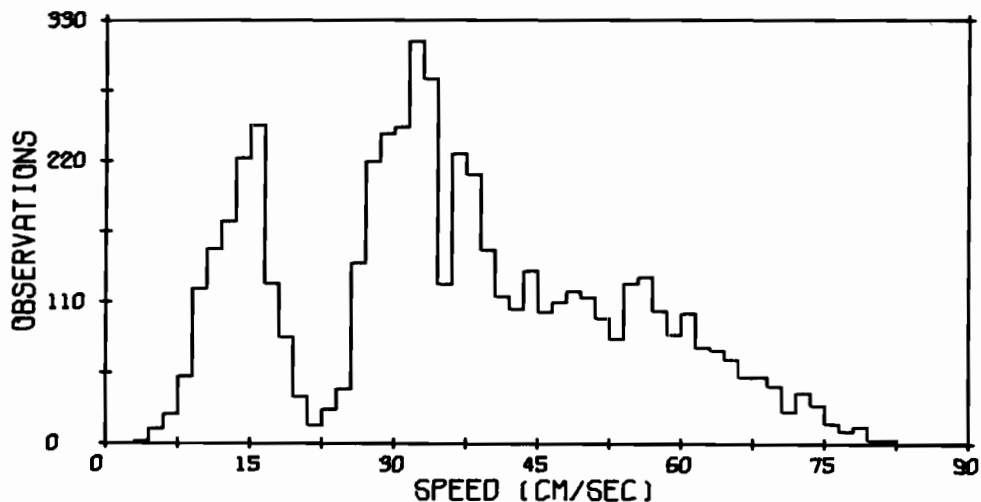
**Location:** Station E

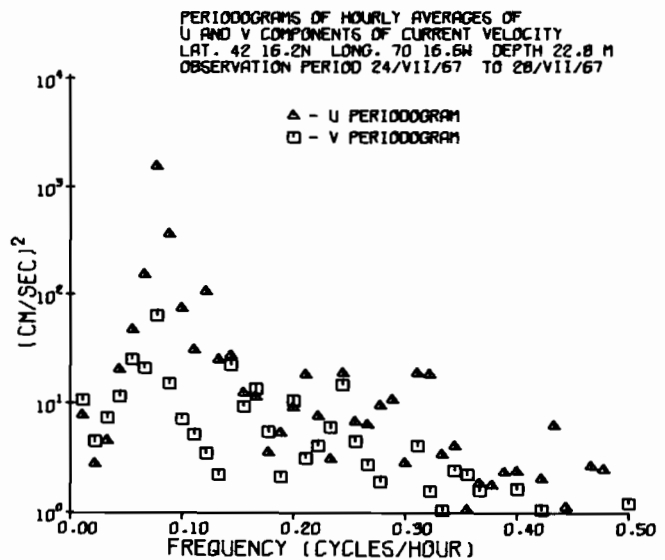
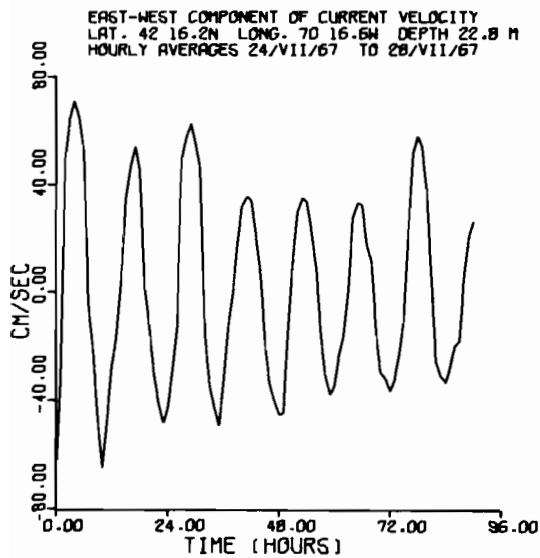
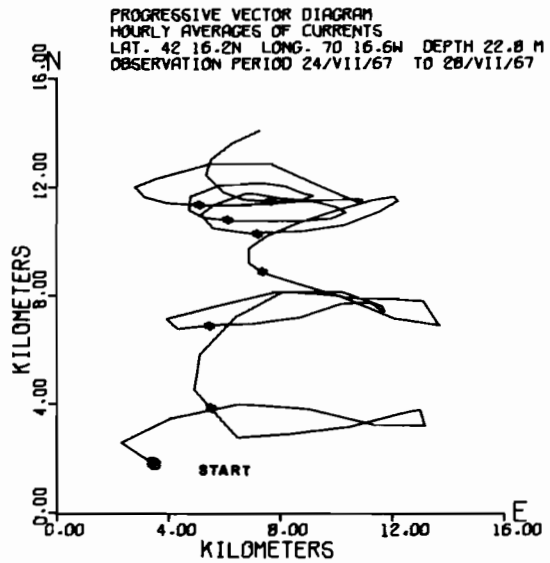
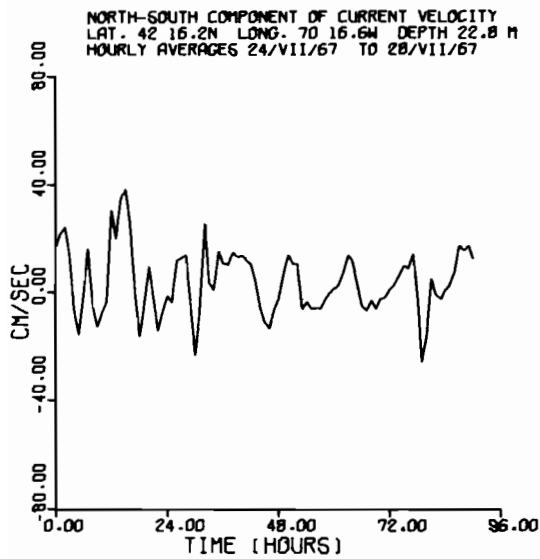
**Depth:** 22.8 meters

STATISTICS OF CURRENTS LAT. 42 16.2N LONG. 70 16.6W  
 DEPTH 22.8 METERS NUMBER OF OBSERVATIONS = 5500  
 OBSERVATION PERIOD 24/VII/67 TO 28/VII/67

	MEAN	VARIANCE	ST-DEV	SKEW	KURT	MAX	MIN
	CM/SEC	(CM/SEC) <sup>2</sup>	CM/SEC			CM/SEC	CM/SEC
S	36.49	200.63	16.99	-.262	2.30	81.28	2.57
U	-.61	1369.87	37.01	-.187	1.86	78.92	-78.70
V	3.89	294.69	15.92	.319	4.03	60.18	-55.00

S = SPEED  
 U = EAST-WEST COMPONENT OF VELOCITY. EAST = POSITIVE U  
 V = NORTH-SOUTH COMPONENT OF VELOCITY. NORTH = POSITIVE V





**Location: Station A**

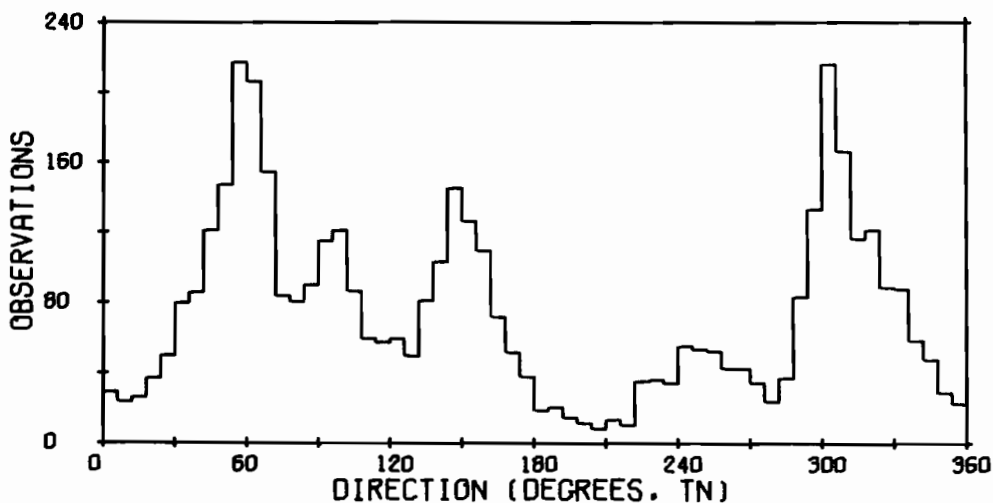
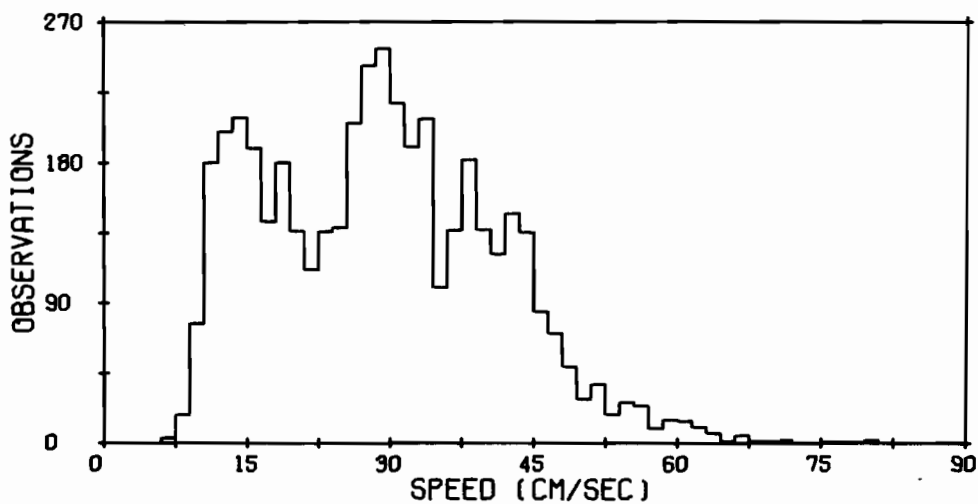
**Depth: 10.6 meters**

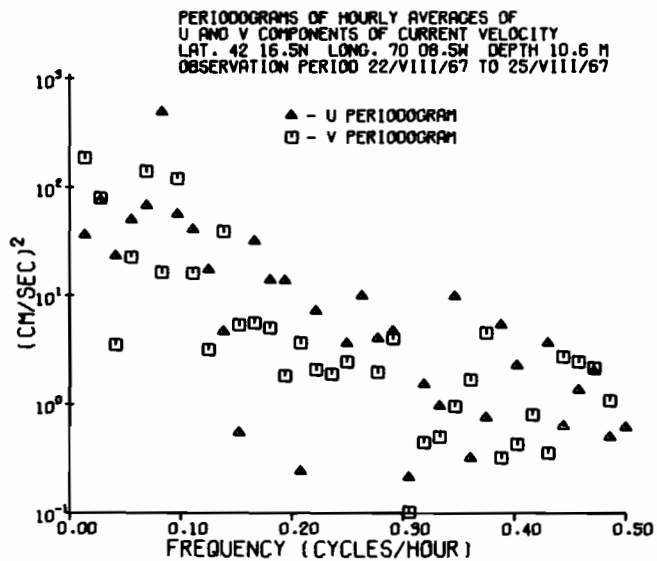
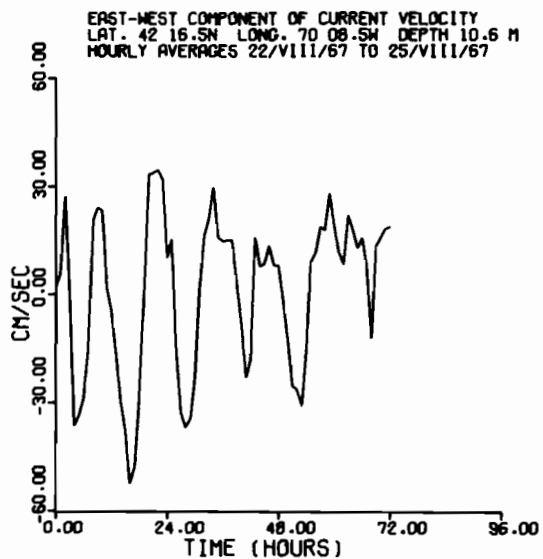
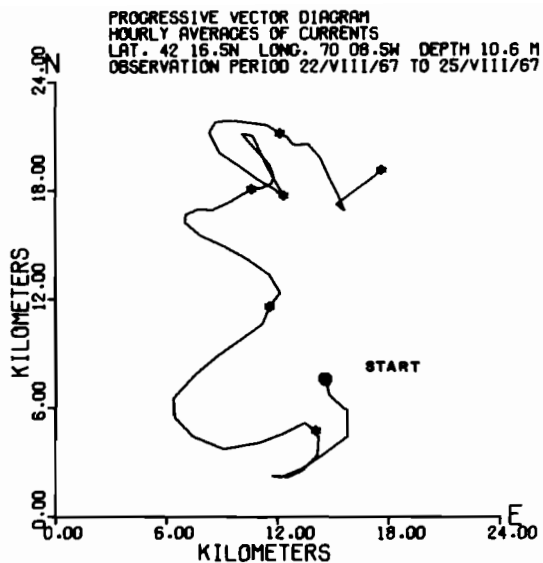
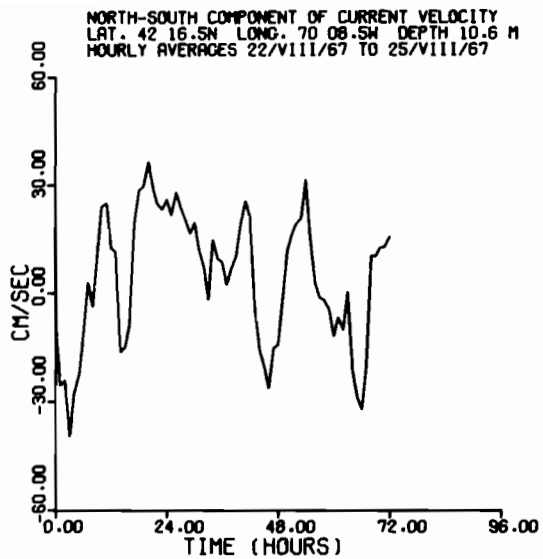


STATISTICS OF CURRENTS    LAT. 42 16.5N    LONG. 70 08.5W  
 DEPTH 10.6 METERS    NUMBER OF OBSERVATIONS = 4400  
 OBSERVATION PERIOD 22/VIII/67 TO 25/VIII/67

	MEAN CM/SEC	VARIANCE (CM/SEC) <sup>2</sup>	ST-DEV CM/SEC	SKEW	KURT	MAX CM/SEC	MIN CM/SEC
S	29.01	145.63	12.07	.426	2.87	87.45	6.69
U	1.27	578.06	24.04	-.498	2.26	56.87	-72.27
V	4.30	389.33	19.73	-.372	2.51	65.35	-62.91

S = SPEED  
 U = EAST-WEST COMPONENT OF VELOCITY, EAST = POSITIVE U  
 V = NORTH-SOUTH COMPONENT OF VELOCITY, NORTH = POSITIVE V



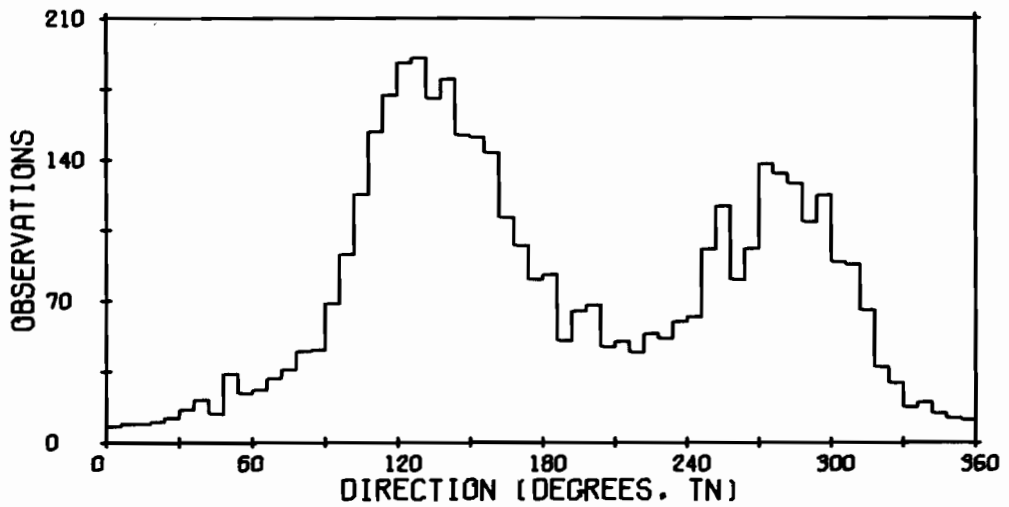
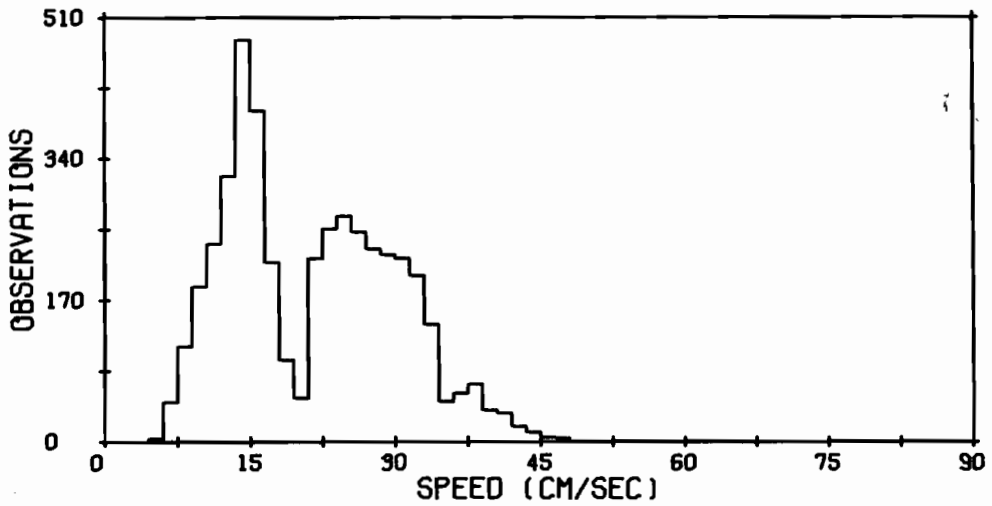


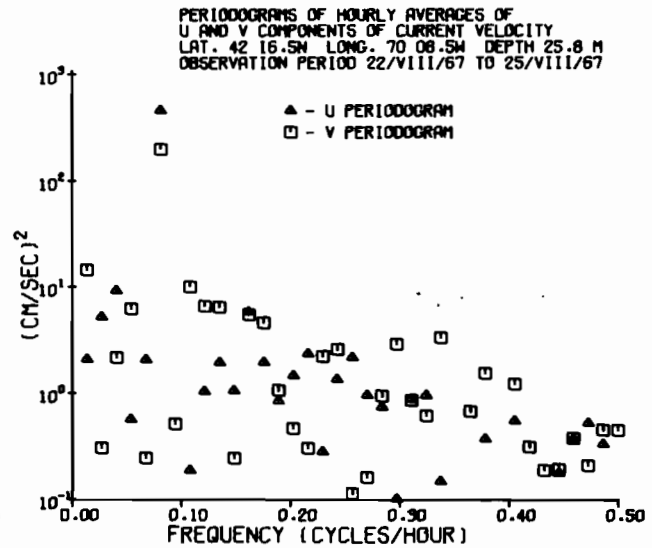
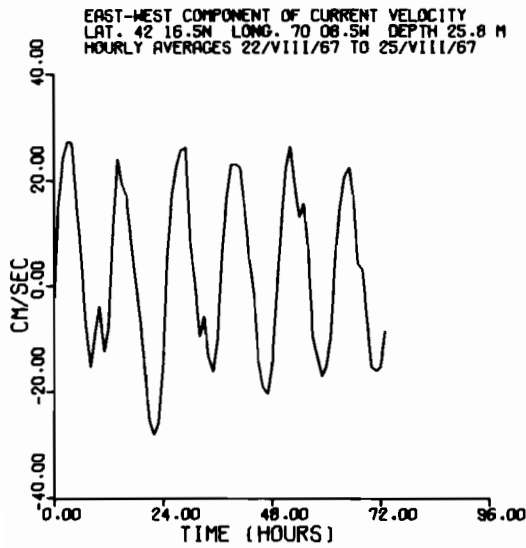
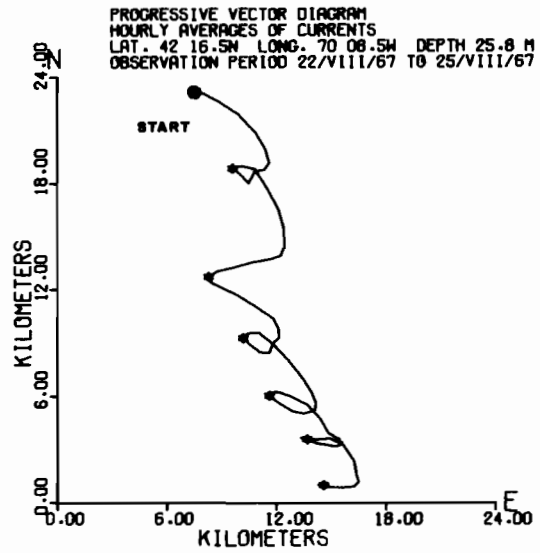
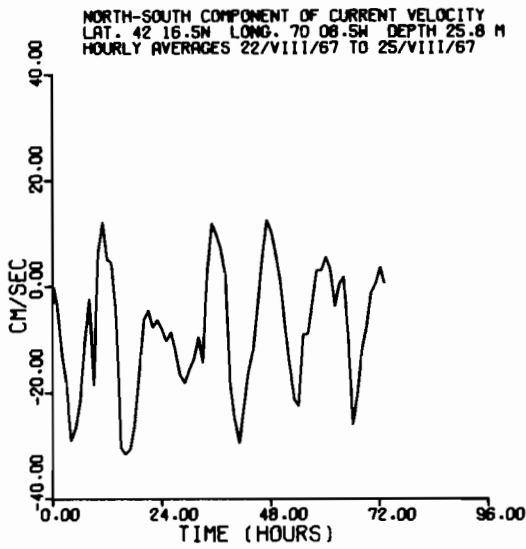
**Location:** Station A  
**Depth:** 25.8 meters

STATISTICS OF CURRENTS    LAT. 42 16.5N    LONG. 70 08.5W  
 DEPTH 25.8 METERS    NUMBER OF OBSERVATIONS = 4450  
 OBSERVATION PERIOD 22/VIII/67 TO 25/VIII/67

	MEAN CM/SEC	VARIANCE (CM/SEC) <sup>2</sup>	ST-DEV CM/SEC	SKEW	KURT	MAX CM/SEC	MIN CM/SEC
S	21.50	73.91	8.60	.361	2.20	47.84	5.66
U	2.53	287.49	16.96	-.034	1.76	44.65	-33.95
V	-8.30	173.35	13.17	.020	2.45	37.67	-40.93

S = SPEED  
 U = EAST-WEST COMPONENT OF VELOCITY. EAST = POSITIVE U  
 V = NORTH-SOUTH COMPONENT OF VELOCITY. NORTH = POSITIVE V





**Location:** Station A

**Depth:** 45.6 meters

STATISTICS OF CURRENTS    LAT. 42 16.5N    LONG. 70 08.5W  
 DEPTH 45.6 METERS    NUMBER OF OBSERVATIONS = 4450  
 OBSERVATION PERIOD 22/VIII/67 TO 25/VIII/67

	MEAN CM/SEC	VARIANCE (CM/SEC) <sup>2</sup>	ST-DEV CM/SEC	SKEW	KURT	MAX CM/SEC	MIN CM/SEC
S	17.84	83.51	9.14	1.233	7.24	102.37	3.09
U	3.67	329.12	18.14	.209	2.05	73.28	-66.62
V	-2.21	54.24	7.37	.509	15.70	100.49	-42.70

S = SPEED  
 U = EAST-WEST COMPONENT OF VELOCITY, EAST = POSITIVE U  
 V = NORTH-SOUTH COMPONENT OF VELOCITY, NORTH = POSITIVE V

