Woods Hole Oceanographic Institution

A Compilation of Conductance Data and Associated Mooring Action Data from Mooring SO2, Volume XII (1976 Data)

by

S. Tarbell, R. Payne and R. Walden

September 1977

TECHNICAL REPORT

Prepared for the Applied Physics Laboratory of the Johns Hopkins University under Contract 600651.

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DATA AND ASSOCIATED MOORING ACTION DATA
FROM MOORING 592, VOLUME XIV (1976 DATA)

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S. Tarbell, R. Payne
and R. Walden

WOODS HOLE OCEANOGRAPHIC INSTITUTION
Woods Hole, Massachusetts 02543

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6006851.

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Valentine Worthington, Chairman
Department of Physical Oceanography

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ABSTRACT

Summaries of moored current meter data from one mooring set and retrieved in 1976 near St. Croix by the Woods Hole Oceanographic Institution are presented. The averaged current data are presented as statistics, spectral diagrams, plots of vector and scalar quantities versus time. Horizontal and vertical mooring motion data are also presented.
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PREFACE

This volume is the fourteenth of a series of Data Reports presenting moored current meter and associated data collected by the W.H.O.I. Buoy Group.


Volume fourteen discusses measurements of the motion of a particular mooring and presents the current meter data from that mooring.

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<td>15</td>
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* In press

1966 measurements
1967 measurements
1968 measurements
1970 Array data
1973 IWEX Array
1969 data (early)
1969 data (late)
1973 MODE Array
1970 measurements
Mooring 592, 1976
Saint Croix
1971 measurements
ACKNOWLEDGMENTS

Planning, staging, executing and processing the data for this experiment involved numbers of people and organizations. The W.H.O.I. Mooring Engineering group consisting of R. G. Walden, C. W. Collins, Jr., P. R. Clay and P. O'Malley designed, prepared, set and retrieved the mooring. J. R. Poirier and C. W. Collins, Jr. prepared the current meters. R. A. La Rochelle prepared the acoustic release. Help in the preparation of the mooring from the W.H.O.I. operations group under the supervision of R. D. Simoneau is gratefully acknowledged. The W.H.O.I. data processing group (D. Chausse, M. Raymer, S. Tarbell and A. Whitlatch) under the supervision of R. E. Payne processed all current meter data and prepared displays for this report. Staff scientists including W. J. Schmitz, Jr., M. G. Briscoe, and N. P. Fofonoff provided guidance and support to the experiment.

Dr. Wenstrand of APL was most helpful in the experiment design and planning. Acoustic release deck command gear was loaned by NADC (D. Closser) and MAS, Christensted (R. Mosey) who also provided other helpful services. Special mention is made of Lt. J. Hollister, an observer from NAVOCÉANO whose sharp eyes averted a near-disaster during deployment by spotting an unwelded link of chain in the backup recovery system as it was about to go over the side. The Atlantic Fleet Weapons Training Facility services, under the direction of R. Kirkpatrick, were excellent. Special thanks are due the captains and crews of the deployment vessel USNS LYNCH and the YFU/ASP recovery vessel.

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Introduction, Section 1, Mooring Motion

A contract was entered into with The Johns Hopkins University, Applied Physics Laboratory, February 1976, to deploy and retrieve an instrumented intermediate mooring for the Principal Scientist, Dr. David Wenstrand, at the Atlantic Fleet Weapons Training Facility, Frederiksted, St. Croix, U.S. Virgin Islands. The mooring design, preparation, launch and recovery was under the supervision of Robert G. Walden (W.H.O.I.). The current meters and acoustic release were prepared at W.H.O.I. The current meter data were processed under the direction of Dr. Richard E. Payne (W.H.O.I.).

Description of Experiment

The objective of the experiment was to obtain time series of current speed and direction and temperature at five depths over a period of one month and for two months at a sixth depth. The required mooring location was in the vicinity of hydrophone 3 at the St. Croix Atlantic Fleet Weapons Training Facility in approximately 1000 meters water depth. The Training Facility includes an acoustic tracking range which will be referred to in this report as "the range" or "the tracking range". Five vector averaging current meters (VACMs) were employed with a sampling rate of once per 56.2 seconds to provide adequate information on diurnal, semi-diurnal and inertial tidal motions as well as other effects. Originally specified current meter depths were 70, 120, 170, 220 and 270 meters from the surface. The spacing between instruments was required to be accurate to ±5 meters. The static depth of the top current meter was specified to be within ±15 meters of 70 meters. The depth of the top current meter was subsequently re-specified to be "no deeper than 100 meters". The sixth current meter was added to the mooring to obtain near-bottom currents for the Naval Facility Engineering Command. The sampling rate of this VACM was half the others (once per 112.5 seconds) allowing its record to be twice as long (two months) as the others. An acoustic pinger was attached near the top of the mooring to obtain tracking data for the determination of mooring motion for 72 hours after launch.

The deployment vessel (USNS LYNCH) was equipped with a hull-mounted acoustic pinger which was tracked by tracking range personnel who provided appropriate track and speed information to the vessel by radio according to a prearranged plan. This tracking service was used for both the preliminary bathymetric survey and the actual mooring deployment. The acoustic
tracking provided by the range was accurate to a meter or so. This accurate position data was imperative to prevent the anchor from damaging the many cables and hydrophones on the bottom. The operation plan is enclosed as Appendix 1. Coordinates given refer to range coordinates in meters from a datum point.

**Description of the Mooring**

The mooring was patterned after a standard W.H.O.I. intermediate mooring. Figure 1 shows a schematic representation of the mooring. Starting at the top of the mooring the following components were installed. A radio/light float using three seventeen inch glass spheres was used as an aid in mooring recovery. Flotation throughout the mooring consisted of 17" glass spheres in hardhats attached to chain. Chain was also used to connect instruments together when the separation was small. The pinger was supplied by the range and was mounted in a special stainless steel bracket for insertion into the mooring. It was designed to operate continuously on a frequency of 75 kHz for 72 hours. VACMs were inserted at 90, 140, 190, 240, 290 and 928 meters depth beneath the radio float. 3/16" U. S. Steel 3 × 19 torque-balanced wire rope was used throughout the mooring. Thirteen glass spheres were attached above the anchor release to permit a back-up recovery capability in the event that any portion of the mooring parted. An AMF acoustic anchor release Model 322 with a transponder and a disabling feature was employed. A ten meter section of 3/4" nylon line was inserted between the release and the anchor to absorb transients during anchor launch. Five railroad wheels were chained together to provide 3000 pounds (weight in water) for the anchor.

The mooring was designed using the NOYFB computer program (Moller, 1976). Our best estimate of expected currents obtained from various sources were used as program inputs.

**Description of Results**

The mooring was launched February 20, 1976 and was retrieved April 27, 1976. The anchor location, 17° 43.8'N, 64° 56.53'W, was within 100 meters of the proposed position in water 972 meters deep. The depth of the radio float after settling out was determined to be 71.4 meters by steaming over it and observing its depth on the precision fathometer. The tracking range determination of the pinger depth was 98 meters giving a radio float depth of 74.2 meters, in good agreement with the fathometer-determined depth. The depth of the top VACM at this time was 96 meters.
(3) Ball Radio Float with Radio and Light
2 M-1/2" Chain

(16) 17" Balls
VACM
2 M-3/8" Chain
Pinger
33 M-3/16" Wire
(11) 17" Balls
VACM
42 M-3/16" Wire
(5) 17" Balls
VACM
42 M-3/16" Wire
(5) 17" Balls
VACM
42 M-3/16" Wire
(5) 17" Balls
VACM
438 M-3/16" Wire
150 M-3/16" Wire
50 M-3/16" Wire (Adjustable Shots)
(13) 17" Balls Backup Recovery
VACM
2 M-3/8" Chain
AMF Release with Isolation Link
3 M-1/2" Chain
10 M-3/4" Nylon
3 M-1/2" Chain
Anchor (Railroad Wheels) 3000 Lb Wet

Sta. #592

Termination Code

1 (2) 1/2" Shackles and (1) 1/2" Master Link
2 (3) 1/2" Shackles and (2) 1/2" Master Links
3 5/8" Shackles

Figure 1. St. Croix mooring
Figure 2. a) A stick plot displacements of pinger from mean position
b) North displacement from range
c) East displacement from range
d) Depth variation
Figure 3. A plot of the horizontal movement of the pinger
The range tracked the pinger on the mooring for 72 hours. Figure 2a is a stick plot of the displacement of the pinger from the mean position. The length of each "stick" is proportionate to the displacement of the pinger from its mean position. Its direction indicates the displacement direction. X and Y coordinates for this same time period are also shown in Figure 2b and 2c. Figure 2d shows pinger depth variations over this time span. Figure 3 is a plan view plot of the horizontal movement of the pinger for the first 72 hours. The plotted pinger data is from 1-hour subsampled data series. The numbers on the plot represent hours after launch.

The DSRV ALVIN inspected and photographed the mooring a few days after launch. They reported that the rotor of the bottom current meter was "cocked" in its housing. Upon retrieval the instrument was inspected and found to have a broken rotor pivot bearing. This damage appears to have occurred at launch.
Introduction, Section 2, Current Data

Unlike the preceding volumes this report presents data from a single mooring (Number 592) set by the Buoy Group in February 1976. The purpose and result of the experiment have been discussed in Section 1. This section presents the current meter data from that mooring. There were seven instruments on the mooring line: 6 VACMs and one pinger. The following table lists the instruments and related information.

Table 1

<table>
<thead>
<tr>
<th>Data Name</th>
<th>Instrument Type</th>
<th>Recording Interval (sec)</th>
<th>Depth (m)</th>
<th>Data Length (Days)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>5921</td>
<td>VACM</td>
<td>56.25</td>
<td>95</td>
<td>32</td>
<td>Good data</td>
</tr>
<tr>
<td>5922</td>
<td>Pinger</td>
<td>-</td>
<td>97</td>
<td>3</td>
<td>Tracked by the range</td>
</tr>
<tr>
<td>5923</td>
<td>VACM</td>
<td>56.25</td>
<td>144</td>
<td>32</td>
<td>Good data</td>
</tr>
<tr>
<td>5924</td>
<td>VACM</td>
<td>56.25</td>
<td>193</td>
<td>32</td>
<td>Good data</td>
</tr>
<tr>
<td>5925</td>
<td>VACM</td>
<td>56.25</td>
<td>243</td>
<td>32</td>
<td>Good data</td>
</tr>
<tr>
<td>5926</td>
<td>VACM</td>
<td>56.25</td>
<td>292</td>
<td>0</td>
<td>No data on tape</td>
</tr>
<tr>
<td>5927</td>
<td>VACM</td>
<td>112.50</td>
<td>950</td>
<td>64</td>
<td>No rotor information</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pivot broken at launch</td>
</tr>
</tbody>
</table>

Water depth 972 m

Vector Averaging Current Meter

The Vector Averaging Current Meter (VACM) gathers compass and vane information and computes E and N components each time a pair of rotor magnets pass the sensing diode. These components are summed through the entire recording interval. There are 16 magnets on the rotor so one complete revolution causes eight compute and accumulate cycles. Temperatures are measured by a thermistor whose resistance is converted to frequency and summed over the recording interval. The VACM uses a quartz crystal which oscillates at a frequency of 74.5654 Khz to provide clocking pulses to the instrument. The accuracy of the crystal clock is ±1 second per day. Time is indicated by placing a clock count value in each data cycle.
Data Processing

The VACM data, recorded on 4 track 1/4" magnetic tape cassettes, were first transcribed onto a computer compatible magnetic tape, then converted to the Maltais format (Maltais, 1969). Data from the top four VACMs were very clean and needed no editing. Data from the lowest VACM had no rotor information. Its only recoverable data were the last compass and vane values from each recording interval and temperature. All five records have had gaps in the time series filled with interpolated values. The maximum number of interpolated points occurred in record 5923 in which 30 data cycles were interpolated in a series 47,824 data cycles long.

Data Presentation

All the data from the four good VACMs plus the partial information from the bottom VACM are displayed in this section following the descriptions for each type of plot. Presentations are as follows:

1. Statistical information
2. Progressive vector diagrams
3. u vs. v scatter plots
4. Spectral diagrams and computer print out
5. Variable vs. time plots. Variables plotted are u, v (north and east current components), direction, speed (both derived from u, v), temperature, instantaneous compass and vane, and bearing (compass + vane)
6. Selected segments of variable vs. time plots with expanded time scales.

Statistics (STATS)

Standard statistical parameters are calculated for data in the time-range given at the bottom of the table. If there are \( n \) speed and direction values in a sample, and we define \( E_i = S_i \sin \theta_i, \ N_i = S_i \cos \theta_i \), then for \( A = E, N, \text{ and } S \),

\[
\text{mean, } \bar{A} = \frac{1}{n} \sum_{i=1}^{n} A_i
\]

\[
\text{variance, } \sigma^2_A = \frac{1}{n} \sum_{i=1}^{n} A_i^2 - \bar{A}^2
\]
standard error of the mean = \frac{\sigma_A}{\sqrt{n}}

standard deviation = \sigma_A

skewness = \frac{1}{\sigma_A^3} \left[ \frac{1}{n} \sum_{i=1}^{n} A_i^3 - \frac{3\overline{A}}{n} \sum_{i=1}^{n} A_i^2 + 2\overline{A}^3 \right]

kurtosis = \frac{1}{\sigma_A^4} \left[ \frac{1}{n} \sum_{i=1}^{n} A_i^4 - \frac{4\overline{A}}{n} \sum_{i=1}^{n} A_i^3 + \frac{6\overline{A}^2}{n} \sum_{i=1}^{n} A_i - 3\overline{A}^4 \right]

The program also calculates "East and North" statistics,

covariance, \quad M = \frac{1}{n} \sum_{i=1}^{n} (E_i \times N_i) - \overline{E} \overline{N}

standard deviation of covariance, \quad \sigma_m = \frac{1}{n} \sum_{i=1}^{n} (E_i N_i)^2 - \overline{E} \overline{N}^2

standard error of covariance = \frac{\sigma_m}{\sqrt{n}}

correlation coefficient, \quad M' = \frac{M}{\sigma_E \sigma_N}

The program also calculates parameters related to vector quantities:
the scalar amplitude of the vector mean, \quad V_m = \sqrt{E^2 + N^2}; vector variance, \quad V_v = \frac{1}{2} (\sigma_E^2 + \sigma_N^2); standard deviation = V_v.
DATA: 5927A112+5

**************
VARIABLE: TEMPERATURE
UNITS: DEGREES C.
**************
MEAN: 5.585
STD. ERR.: 450E-3
VARIANCE: 101E-1
STD. DEV.: 100
KURTOSIS: 3.192
SKEWNESS: 907E-1
MINIMUM: 5.200
MAXIMUM: 5.917

**************
SAMPLE SIZE: 49569 POINTS

* SPANNING RANGE
  * FROM 76- II 020  13+00.68
  * TA 76- IV 025  08+00.68
* DURATION 64.5% DAYS
Progressive Vector Diagram (PROVEC)

The EAST and NORTH progressive displacements are computed from two hour vector averages. The plot begins with an asterisk (*) on 76-02-20 19.00.28. All following day boundaries are indicated with a plus (+). This type of plot accentuates very low frequency events at the expense of higher frequency oscillations which may be hidden by a large amplitude low-frequency current.
Scatter Plots

The 1 hour averaged $u$ and $v$ components are plotted against each other to display the vector coordinates. This type of plot shows general data trends and velocity extrema.
Spectra and Cross-Spectra

Program TIMSAN (TIME Series ANalysis) is used to calculate all spectral quantities; the Fast Fourier Transform routine of Singleton (1969) is the basic algorithm.

The autospectra shown are from records which have been broken into 9 segments of 5000 points each; additionally, the East, North, and Temperature autospectra are cosine windowed (Hanning) and 50% overlapped. Spectral estimates are obtained by ensemble-averaging across the segments.

Each autospectrum has a lowest-frequency estimate of $64/5000 = 0.0128$ cph, and a Nyquist frequency of 32 cph. The spectra are frequency-band averaged to further increase stability, at the expense of frequency resolution. The averaging algorithm is:

- first forty points - average 1 frequency
- next thirty points - average 2 frequencies
- next thirty points - average 5 frequencies
- next 400 points - average 10 frequencies
- next 300 points - average 20 frequencies
- next 300 points - average 50 frequencies
- next 4000 points - average 100 frequencies.

Since each spectrum contains only 2500 estimates before band averaging, the plotted results display only 136 points, the first 40 of which are based on one frequency band each, the last 14 of which are based on 100 frequency bands each.

The spectra are "one-sided", i.e., the area under the spectrum, for positive frequencies only, equals the variance of the original data. The variance loss due to the cosine window is accounted for by multiplying each spectral estimate by 8/3.

Table 2 is a matrix of Page Numbers for each depth-variable pair; "CW" is the clockwise rotary spectrum, "CCW" the counter-clockwise rotary spectrum, "Total" the spectrum of horizontal kinetic energy, i.e., the sum of CW and CCW (c.f., Gonella, 1972).
Table 2
Page Numbers for Auto-Spectra

<table>
<thead>
<tr>
<th></th>
<th>East</th>
<th>North</th>
<th>Temperature</th>
<th>CW</th>
<th>CCW</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>95 m</td>
<td>21</td>
<td>29</td>
<td>37</td>
<td>49</td>
<td>51</td>
<td>47</td>
</tr>
<tr>
<td>144 m</td>
<td>23</td>
<td>31</td>
<td>39</td>
<td>55</td>
<td>57</td>
<td>53</td>
</tr>
<tr>
<td>193 m</td>
<td>25</td>
<td>33</td>
<td>41</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>243 m</td>
<td>27</td>
<td>35</td>
<td>43</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>950 m</td>
<td></td>
<td></td>
<td>45</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Confidence limits for the autospectra depend upon whether the data segments were windowed and overlapped or not, and on how much frequency-band averaging has occurred. Table 3 gives the 95% confidence limits; the number in parenthesis following the confidence limit is the number of equivalent degrees of freedom in the estimate.

Table 3
95% Confidence Limits for Autospectra Estimates

<table>
<thead>
<tr>
<th>Frequency Band (cph)</th>
<th>East, North Temperature (windowed, overlapped)</th>
<th>CW, CCW, Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0128 - 0.512</td>
<td>0.66 - 1.71 (34.4)</td>
<td>0.57 - 2.19 (18)</td>
</tr>
<tr>
<td>0.5248 - 0.8960</td>
<td>0.69 - 1.58 (46.2)</td>
<td>0.66 - 1.69 (36)</td>
</tr>
<tr>
<td>0.9088 - 1.280</td>
<td>0.76 - 1.37 (91.7)</td>
<td>0.76 - 1.37 (90)</td>
</tr>
<tr>
<td>1.2928 - 6.400</td>
<td>0.82 - 1.25 (171.5)</td>
<td>0.82 - 1.24 (180)</td>
</tr>
<tr>
<td>6.4128 - 10.240</td>
<td>0.86 - 1.17 (332.3)</td>
<td>0.87 - 1.16 (360)</td>
</tr>
<tr>
<td>10.2528 - 14.080</td>
<td>0.91 - 1.10 (815.6)</td>
<td>0.91 - 1.10 (900)</td>
</tr>
<tr>
<td>14.0928 - 32.000</td>
<td>0.93 - 1.07 (1624.5)</td>
<td>0.94 - 1.07 (1800)</td>
</tr>
</tbody>
</table>

Cross-spectra are shown only for the upper pair of instruments (95 m and 144 m). Table 4 shows which variable pair is given on which page. The cross-spectra are plotted as coherence (modulus of the complex cross-spectrum) and phase (arctangent of the ratio of quadrature spectrum to co-spectrum). The same logarithmic frequency-band averaging scheme...
as used for autospectra has been used on the cross-spectra prior to cal-
culating coherence and phase. In addition, each cross-spectrum has been
calculated twice: once with the same resolution and averaging as for the
autospectra, and once with data segments of only 640 points which gives
more segments to average over and hence increased statistical reliability,
at the expense of low-frequency resolution.

Table 4

<table>
<thead>
<tr>
<th>Page Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>for Cross-Spectra</td>
</tr>
<tr>
<td>(95 m vs 144 m)</td>
</tr>
<tr>
<td>East-East</td>
</tr>
<tr>
<td>North-North</td>
</tr>
<tr>
<td>Temperature-Temperature</td>
</tr>
</tbody>
</table>

The 95% confidence levels for the hypothesis of zero true coherence
(i.e., the level below which 95% of the estimates would fall if the two
records were truely incoherent) are given in Table 5.

Table 5

| 95% Confidence Levels |
| on Zero True Coherence Hypothesis |

<table>
<thead>
<tr>
<th>No. of Points in Data Segment</th>
<th>Frequency Band (cph)</th>
<th>95% Confidence Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>5000</td>
<td>0.0128 - 0.512</td>
<td>0.411</td>
</tr>
<tr>
<td></td>
<td>0.5248 - 0.8960</td>
<td>0.356</td>
</tr>
<tr>
<td></td>
<td>0.9088 - 1.280</td>
<td>0.254</td>
</tr>
<tr>
<td></td>
<td>1.2928 - 6.400</td>
<td>0.186</td>
</tr>
<tr>
<td></td>
<td>6.4128 - 10.240</td>
<td>0.134</td>
</tr>
<tr>
<td></td>
<td>10.2528 - 14.080</td>
<td>0.086</td>
</tr>
<tr>
<td></td>
<td>14.0928 - 32.00</td>
<td>0.061</td>
</tr>
<tr>
<td>640</td>
<td>0.10 - 4.00</td>
<td>0.146</td>
</tr>
<tr>
<td></td>
<td>4.10 - 7.00</td>
<td>0.126</td>
</tr>
<tr>
<td></td>
<td>7.10 - 10.00</td>
<td>0.089</td>
</tr>
<tr>
<td></td>
<td>10.10 - 32.00</td>
<td>0.065</td>
</tr>
</tbody>
</table>
It would be inappropriate to accept as meaningful any phase estimate corresponding to a coherence estimate falling below the 95% confidence level. For those few acceptable phase estimates, 95% confidence limits may be estimated as

$$\pm \Delta \phi = \arcsin \left( t \sqrt{1 - \frac{\gamma^2}{\nu}} \right)$$

where $t_\nu = 1.96 + 2.38/\nu + 2.64/\nu^2 + 2.56/\nu^3$, $\gamma$ is the acceptable coherence estimate, and $\nu$ is the equivalent number of degrees of freedom for the estimate. For the higher-resolution, lower-stability cross-spectra (upper part of each figure), the $\nu$ value is given in Table 3 for the windowed, overlapped case. For the lower-resolution, higher-stability cross-spectra, the $\nu$ value is 8.15 times larger, for each frequency band. Note that for $\nu > 23$, i.e., all the estimates given here, $t_\nu = 1.96$ to better than 5%. For example, in the lower part of the Temperature-Temperature coherence (page 63) at cph is 0.25, which implies it is acceptable non-zero. The phase confidence limits are thus $22^\circ$ which means that the phase at 0.3 cph is statistically indistinguishable from zero.

A set of cross-spectral quantities is provided, page 64, but they are not plotted. These are the rotary (i.e., vector) coherences between the 95 m and 144 m current measurements; only the results up to 4 cph are given. For completeness computer output is also included from the 95 m and 144 m (pages 70, 76 respectively) rotary autospectral results: of particular interest are the quantities such as rotary coefficient, ellipse orientation and stability, and mean ellipse orientation.
PERIOD, HRS.
10 1 0.1

AUTO SPECTRUM
5921856.25 EAST
95 METERS
76-II-20 TO 76-III-22
18 PIECES WITH 2500 ESTIMATES
PER PIECE, AVERAGED OVER
1 ADJACENT FREQUENCY BANDS

KINETIC ENERGY DENSITY
CM²/SEC²

FREQUENCY, CYCLES/HRS.
0.1 1 10

10⁶ 10⁵ 10⁴

10³ 10² 10¹

10⁰ 10⁻¹
PERIOD, HRS.

10  1  0.1

AUTO SPECTRUM
5923B56.25 EAST
144 METERS
76-II-20 TO 76-III-22
18 PIECES WITH 2500 ESTIMATES
PER PIECE. AVERAGED OVER
1 ADJACENT FREQUENCY BANDS
Auto Spectrum
5924856.25 East
193 Meters
76-II-20 to 76-III-22
18 Pieces with 2500 Estimates Per Piece. Averaged over 1 Adjacent Frequency Bands
PERIOD, HRS.

10^3

10^2

10^1

10^0

KINETIC ENERGY DENSITY

10^{-1}

10^{-2}

10^{-3}

FREQUENCY, CYCLES/HRS.

AUTO SPECTRUM
5925A56.25 EAST
243 METERS
76-II-20 TO 76-III-22
18 PIECES WITH 2500 ESTIMATES PER PIECE. AVERAGED OVER 1 ADJACENT FREQUENCY BANDS
AUTO SPECTRUM
5921856.25 NORTH
95 METERS
76-II-20 TO 76-III-22
18 PIECES WITH 2500 ESTIMATES
PER PIECE. AVERAGED OVER
1 ADJACENT FREQUENCY BANDS
PERIOD, HRS.

AUTO SPECTRUM
5923B56.25 NORTH
144 METERS
76-II-20 TO 76-III-22
18 PIECES WITH 2500 ESTIMATES
PER PIECE. AVERAGED OVER
1 ADJACENT FREQUENCY BANDS

KINETIC ENERGY DENSITY

CM^2/SEC^2
C/T.U.

10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}

FREQUENCY, CYCLES/HRS.
AUTOSPECTRUM
5924B56.25 NORTH
193 METERS
76-II-20 TO 76-III-22
18 PIECES WITH 2500 ESTIMATES
PER PIECE. AVERAGED OVER
1 ADJACENT FREQUENCY BANDS

Period, Hrs.
0 1 0.1

Kinetic Energy Density
$	ext{cm}^2/\text{sec}^2$

Frequency, Cycles/Hrs.
0.1 1 10
A
t
O
T
S
P
E
C
T
R
U
M
5
9
2
5
A
5
6
.
2
5
N
O
R
T
H
2
4
3
M
E
T
E
R
S
7
6
-II
-2
0
T
O
7
6
-I
I
-2
2
1
8
P
I
E
C
E
S
W
I
T
H
2
5
0
0
E
S
T
I
M
A
T
E
S
P
E
R
P
I
E
C
E
.  
A
V
E
R
A
G
E
D
O
V
E
R
1
A
D
J
A
C
E
N
T
F
R
E
Q
U
E
N
C
Y
B
A
N
D
S
KINE
T
I
C
E
N
E
R
G
I
C
E
Y
E
N
E
R
G
Y
D
E
N
S
I
T
Y
C
M
2/
S
E
C
2
C/T.U.
10^4
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
FREQUENCY, CYCLES/HRS.
10
1
0.1
10
1
0.1
PERIOD, HRS.
AUTO SPECTRUM
5925A56.25 NORTH
243 METERS
76-II-20 TO 76-III-22
18 PIECES WITH 2500 ESTIMATES
PER PIECE. AVERAGED OVER
1 ADJACENT FREQUENCY BANDS
ENERGY DENSITY (MILLIDEGREES$^2$) / C/T.U.

AUTO SPECTRUM
5924.856.25 TEMPERATURE
193 METERS
76-II-20 TO 76-III-22
18 PIECES WITH 2500 ESTIMATES
PER PIECE. AVERAGED OVER
1 ADJACENT FREQUENCY BANDS
ENERGY DENSITY (MILLIDEGREES)² / C/T.U.

AUTO SPECTRUM 5925A56.25 TEMPERATURE 243 METERS 76-II-20 TO 76-III-22 18 PIECES WITH 2500 ESTIMATES PER PIECE. AVERAGED OVER 1 ADJACENT FREQUENCY BANDS
ENERGY DENSITY \( \left( \text{millidegrees} \right)^2 \) C/T.U.

AUTO SPECTRUM

5927A112.5 TEMPERATURE
950 METERS
76-II-20 TO 76-IV-22
18 PIECES WITH 2500 ESTIMATES
PER PIECE, AVERAGED OVER
1 ADJACENT FREQUENCY BANDS
TOTAL SPECTRUM
5921B56.25 EAST
5921B56.25 NORTH
95 METERS
76-II-20 TO 76-III-21
9 PIECES WITH 2500 ESTIMATES PER PIECE. AVERAGED OVER 1 ADJACENT FREQUENCY BANDS
CLOCKWISE SPECTRUM
5921B56.25 EAST
5921B56.25 NORTH
95 METERS
76-II-20 TO 76-III-21
9 PIECES WITH 2500 ESTIMATES
PER PIECE. AVERAGED OVER
1 ADJACENT FREQUENCY BANDS

KINETIC ENERGY DENSITY

CM^2/SEC^2
C/UNIT.

PERIOD, HRS.

10^3
10^2
10^1
10^0
10^-1
10^-2
10^-3
10^-4

FREQUENCY, CYCLES/HRS.

0.1
1
10
ANTI-CLOCKWISE SPECTRUM
5921856.25 EAST
5921856.25 NORTH
95 METERS
76-II-20 TO 76-III-21
9 PIECES WITH 2500 ESTIMATES
PER PIECE. AVERAGED OVER
1 ADJACENT FREQUENCY BANDS
PERIOD, HRS.

TOTAL SPECTRUM
5923B56.25 EAST
5923B56.25 NORTH
144 METERS
76-II-20 TO 76-III-21
9 PIECES WITH 2500 ESTIMATES
PER PIECE. AVERAGED OVER
1 ADJACENT FREQUENCY BANDS

KINETIC ENERGY DENSITY
CM²/SEC² C/T.U.

FREQUENCY, CYCLES/HRS.
CLOCKWISE SPECTRUM
5923B56.25 EAST
5923B56.25 NORTH
144 METERS
76-II-20 TO 76-III-21
9 PIECES WITH 2500 ESTIMATES
PER PIECE. AVERAGED OVER
1 ADJACENT FREQUENCY BANDS
ANTI-CLOCKWISE SPECTRUM
5923B56.25 EAST
5923B56.25 NORTH
144 METERS
76-II-20 TO 76-III-21
9 PIECES WITH 2500 ESTIMATES
PER PIECE. AVERAGED OVER
1 ADJACENT FREQUENCY BANDS
CROSS-SPECTRUM
5921856.25 EAST
5923856.25 EAST
76-11-20 TO 76-11-22
18 PIECES WITH 2500 ESTIMATES
PER PIECE. AVERAGED OVER
1 ADJACENT FREQUENCY BANDS

CROSS-SPECTRUM
5921856.25 EAST
5923856.25 EAST
76-11-20 TO 76-11-22
148 PIECES WITH 320 ESTIMATES
PER PIECE. AVERAGED OVER
1 ADJACENT FREQUENCY BANDS

PHASE

COHERENCE

FREQUENCY, CYCLES/HR.
CROSS-SPECTRUM
5921856.25 NORTH
5923856.25 NORTH
76-II-20 TO 76-III-22
18 PIECES WITH 2500 ESTIMATES
PER PIECE. AVERAGED OVER
1 ADJACENT FREQUENCY BANDS

FREQUENCY, CYCLES/HR.

COHERENCE
0.0
0.5
1.0

PHASE
-180
-90
0
90
180

CROSS-SPECTRUM
5921856.25 NORTH
5923856.25 NORTH
76-II-20 TO 76-III-22
148 PIECES WITH 320 ESTIMATES
PER PIECE. AVERAGED OVER
1 ADJACENT FREQUENCY BANDS

FREQUENCY, CYCLES/HR.

COHERENCE
0.0
0.5
1.0

PHASE
-180
-90
0
90
180
Cross-spectrum
5921856.25 temperature
5923856.25 temperature
75-II-20 to 75-III-22
18 pieces with 2500 estimates
per piece. Averaged over
1 adjacent frequency bands

Cross-spectrum
5921856.25 temperature
5923856.25 temperature
76-II-20 to 76-III-22
148 pieces with 320 estimates
per piece. Averaged over
1 adjacent frequency bands
SPECTRUM OF SERIES WITH 45000 POINTS DIVIDED INTO 9 PIECES WITH 5000 POINTS IN EACH PIECE.
2500 ESTIMATES AVERAGED OVER 1 ADJACENT FREQUENCY BANDS TO GIVE 2500 AVERAGED ESTIMATES.
SPECTRUM UNITS: (MMS)^2/SEC
UNITS OF TIME (T,W) ARE HOURS
ORIENTATIONS ARE CLOCKWISE FROM NORTH

<table>
<thead>
<tr>
<th>ESTIMATE NUMBER</th>
<th>FREQUENCY CYCLES/T.W.</th>
<th>CLOCKWISE SPECTRUM</th>
<th>ANTI-CLOCKWISE SPECTRUM</th>
<th>TOTAL SPECTRUM COEFFICIENT</th>
<th>ROTARY SPECTRUM COEFFICIENT</th>
<th>ELLIPSE ORIENTATION</th>
<th>ELLIPSE STABILITY</th>
<th>MEAN ORIENTATION</th>
<th>PERIOD CYCLE</th>
<th>ESTIMATE NUMBER</th>
</tr>
</thead>
</table>
Variable vs. Time Plots

The current and temperature data are plotted in a variety of ways. Included are both averaged and filtered data. A one hour average refers to a series with one point per hour, that point being the vector average of the basic series over that hour for speed, or the scalar average for temperature. To obtain the Gaussian filtered series, the one hour averaged series was passed through a Gaussian filter with a half width of one day and the resulting series subsampled at one per day.

The plots are:

p. 83 - Record 5921 plotted as a one hour averaged series and as a Gaussian filtered series. The length of a "stick" is proportional to speed, its direction corresponds to geographic direction (magnetic deviation has been applied). The direction of north is indicated.

pp. 84-93 - Line plots of the one hour averaged version of all variables for all the records.

p. 94 - A composite stick plot of the Gaussian filtered velocities.

p. 95 - A day-by-day composite of the Gaussian filtered vectors with the "sticks" arranged by depth.

p. 96 - A composite line plot of the one hour averaged north components.

p. 97 - A composite line plot of the one hour averaged east components.

p. 98 - A composite line plot of the one hour averaged speeds.

p. 99 - A composite of the Gaussian filtered temperatures.

pp. 100-117 - Expanded scalar line plots of east, north and temperature for selected segments of basic series.
Figure 4. Stick plots of the 1 hour Gaussian filtered data and the 1 hour averaged data for 5921.
Daily averages from four current meters plotted by depth
1) 5921  3) 5923  4) 5924  5) 5925
References

Gonella, J., 1972

Maltais, J. A., 1969

Moller, D. A., 1976
A computer program for the design and static analysis of single-point subsurface mooring systems: NOYFB. W.H.O.I. Ref. 76-59 (unpublished manuscript).

Singleton, R. C., 1969
Appendix 1

OPERATIONS PLAN

1. OBJECTIVE

The objective of the experiment is to install a sub-surface mooring near Hydrophone Array 3 which will contain 5 vector averaging current meters at depths below the surface of 100, 150, 200, 250 and 300 meters. An additional meter will be located 22 meters off the bottom. The sampling rates chosen and the experiment duration should provide excellent information on current speed and direction at these six depths in this range location. Diurnal, semi-diurnal and inertial tidal motions will be indicated as well as other major lunar effects. Data from the top five meters is required by APL, while the data from the bottom meter will be of particular interest to the range. An acoustic pinger at the top of the mooring will be tracked during the first 48 hours of the experiment to provide data on mooring motion. It is estimated that the mooring will be installed for 2 months and will be retrieved using the YFU from Roosevelt Roads.

2. PERSONNEL AND FACILITIES

The USNS LYNCH will be used to deploy the mooring. It is anticipated that 6 hours will be required to complete the survey and installation. The installation will probably be 20 February 1976. Woods Hole Oceanographic Institution (W.H.O.I.) personnel will conduct a bathymetric survey and install the mooring. W.H.O.I. personnel are:

Robert G. Walden - Principal Investigator
Clayton W. Collins, Jr. - Electronics Engineer
Peter Clay - Ocean Engineer
Patrick O'Malley - Technician

Range tracking facilities will be required.

a) LYNCH

The vessel will be loaded by W.H.O.I. personnel prior to the deployment date. LYNCH personnel will be required to operate the crane to hoist aboard a payout winch and other material. A welder will be required to tack-weld the payout winch and cleats to the deck.

In order to set this mooring at an accurate depth, a preliminary bathymetric survey will be required. The precision depth sounder will be checked against well established hydrophone array depths at array locations 1 and 3 prior to the survey.
Appendix 1 (cont.)

Radar and acoustic tracking information will be supplied to the ship every five minutes. This data will also be required at the bathymetry station on the LYNCH. A tracking pinger will be required on the LYNCH for range tracking of the vessel. An additional pinger will be required for attachment to the mooring.

b) AFWTF

Laboratory space at the Range tracking station for the preparation of six current meters and two acoustic releases is requested. Additional space outside is requested for uncrating, measuring wire rope lengths and assembly of mooring components. Space is also requested for storage of packing crates until the experiment's completion. At that time the recovered mooring components will be recreted by W.H.O.I. personnel for return shipment.

The range truck is requested for transportation of the mooring components and handling gear from the air freight warehouse at St. Croix airport, and to deliver this equipment to the U.S.N.S. LYNCH in Frederiksted on or about 19 February 1976. After recovery of the mooring (approximately April 20, 1976) the truck is again requested to transport gear to and from the YFU at the Frederiksted dock.

To recover the mooring in April, a YFU out of Roosevelt Roads will be required. It is requested that a cherry picker crane and Pengo winch be installed for this purpose. We request that W.H.O.I. personnel (names previously given) be picked up at Frederiksted on the date to be established. After recovery of the mooring it is requested that the YFU again dock at Frederiksted at which time W.H.O.I. personnel will put aboard packing crates and other gear left at the tracking station. The equipment should then be transported to Roosevelt Roads where W.H.O.I. personnel will assist in crating and shipping operations for shipment to Woods Hole, Mass.

During the mooring installation phase the range should provide both acoustic and radar tracking. Range coordinate data is requested for each five minutes during the survey phase of the operation. The USNS LYNCH will be equipped with a pinger for tracking purposes. An additional pinger will be attached near the top of the mooring. The mooring installation phase is estimated at 6 hours. Continued tracking of the mooring line pinger is desired for 48 hours.
Appendix 1 (cont.)

3. OPERATION SCENARIO

The ship's track should be monitored by range acoustic and radar tracking. The range will pass to the ship North and East range coordinates every five minutes. Appropriate course corrections should be applied to maintain track. Bathymetry data will be made continuously during the operation with five minute position times noted on the record.

a) Depart Frederiksted

b) Proceed to Array 1 and stop

Coordinates N 53386
    E 29079

Check depth

Depth to bottom should be:

    2350 + 30 = 2380 ft.
    = 397 fath.
    = 726 meters

Note depth sounder discrepancy

c) Proceed to Array 3 and stop

Coordinates N 46668
    E 32440

Check depth

Depth to bottom should be:

    3003 + 3 = 3033 ft.
    = 505 fath.
    = 925 meters

Note depth sounder discrepancy

d) Determine depth sounder correction

e) Proceed on course to make good 307°T approximately 3600 ft. to

Point Alpha

Coordinates N 34600
    E 43750

f) Turn to course to make good 078°T approximately 6350 ft. to

Point Baker

Coordinates N 35900
    E 50000

g) Turn to heading to make good 245°T approximately 12000 ft. at a

speed of 2 knots to Point Charlie

Coordinates N 30900
    E 39300
Appendix 1 (cont.)

h) Continue on course at best reasonable speed approximately 15000 ft. to Point Delta
   Coordinates  N 24750
   E 25850

i) The vessel should then heave-to while the acoustic releases are lowered and tested. The vessel can then take up a course to make good a reciprocal along the same track. (065°T) Establish speed of two knots.

j) During this transit the mooring will be paid out on the surface behind the vessel. The anchor will be held aboard until the drop site at Point Easy.
   Coordinates  N 34000
   E 45800

k) After anchor launch, the mooring will be in place in approximately 8 minutes. It is estimated that the final mooring position, Point Foxtrot, will be at
   Coordinates  N 33650
   E 45000

l) The range should obtain X, Y, and Z coordinate data on the mooring line pinger each minute after anchor launch for approximately 15 minutes. X, Y, and Z coordinates of this pinger are desired by the ship at the end of this fifteen minute "settle-out" period.

m) The vessel should heave-to after anchor launch in order to track the release transponder until the anchor bottoms. Coordinate data of the vessel each minute is also requested for this 15 minute period.

n) The vessel will then proceed to pass over the mooring to obtain an independent depth by the fathometer of the top radio float.

o) Secure operations.
A COMPILATION OF MOORED CURRENT METER DATA AND ASSOCIATED
MOORING ACTION DATA FROM MOORING 592, VOLUME XIV (1976 DATA)

S. Tarbell, R. Payne and R. Walden

Woods Hole Oceanographic Institution
Woods Hole, MA 02543

Applied Physics Laboratory of the Johns Hopkins University

Summaries of moored current meter data from one mooring set and retrieved in
1976 near St. Croix by the Woods Hole Oceanographic Institution are presented.
The averaged current data are presented as statistics, spectral diagrams, plots
of vector and scalar quantities versus time. Horizontal and vertical mooring motion
data are also presented.

1. Mooring Motion
2. Current Data
3. St. Croix Mooring

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

18. Availability Statement

UNCLASSIFIED

19. Security Class (This Report)

UNCLASSIFIED

21. No. of Pages

122

20. Security Class (This Page)

UNCLASSIFIED

22. Price
A Compilation of Moored Current Meter Data and Associated Mooring Action Data from Mooring 592, Volume XVII, (1976 Data)

Woods Hole Oceanographic Institution

Moored Current Motions

1. Mooring Motion
2. Current Data
3. St. Croix Mooring

I. Tarbell, S.
II. Payne, R.
III. Walden, R.
IV. 600651

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