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1080  
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no.14

NOAA Technical Memorandum OMPA-14



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CURRENT METER DATA PROCESSING  
AND QUALITY CONTROL METHODS

Donald A. Ortman

Boulder, Colorado  
January 1982

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NATIONAL OCEANIC AND  
ATMOSPHERIC ADMINISTRATION

Office of Marine  
Pollution Assessment

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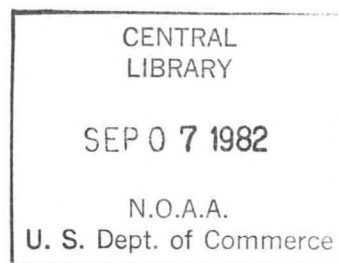
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January 1982



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# CURRENT METER DATA PROCESSING AND QUALITY CONTROL METHODS

Donald A. Ortman

ABSTRACT. A description of fixed point current meter data processing is described from the initial data acquisition to the final data product. Much of the early discussion is unique to the series of Aanderaa recording instruments although the techniques of editing and joining of time series are generally applicable to any velocity time series. The stages of data processing are: conversion of instrument units to scientific units; editing strategies; and joining and filtering strategies.

## 1. INTRODUCTION

The purpose of this memorandum is to outline the strategies used for the processing of current meter (CM) data. We will be concerned primarily with processing of Aanderaa CM data following transcription of the Aanderaa CM audio tape to a nine-track or seven-track standard computer tape.

The sequence of processing steps leading to a final data product (library tape) of archive quality will be outlined. The archived tape is of a level of quality where the user can be reasonably certain that what is seen in the data is real and not an artifact of processing.

The procedures described will be those developed at AOML and used with CM data collected for the MESA New York Bight Project and OTEC CM deployments in the Gulf of Mexico. Though the early stages of processing are specific to Aanderaa data, the later stages of processing can be applied to any data set of velocity time series. A schematic of the CM data processing system is in Figure 1.

## 2. AANDERAA TAPE TRANSCRIPTION

The strategies described below will be principally concerned with the stages following transcription from the Aanderaa current meter tape to a standard nine or seven-track computer tape. We include here, however, a short description of the Aanderaa tape and the transcription process so that it is clear exactly what state the data are in as they enter our CM data processing system.

The Aanderaa CM registers ten-bit binary words on 1/4-inch audio tape for each of its six parameters in the following sequence: reference number, temperature, conductivity, pressure, current direction, and current speed. One scan or interrogation of each of these six parameters is recorded at a preset sampling interval ranging from 30 seconds to one hour.



The reference number is a fixed reading and identifies the beginning of each interrogation. A thermistor is used to measure temperature and an induction-type conductivity cell is used to measure conductivity. Pressure is measured by a bourdon-tube-driven potentiometer.

Current direction is a single reading sensed by a magnetic compass at the moment of sampling, based on the orientation of the instrument as it aligns itself in the current.

Speed values are based on the number of revolutions of a rotor at the top of the Aanderaa unit during the sampling interval. Beginning with serial number 1327, the standard electronic counter records one count per four rotor turns. A continuously rotating potentiometer was used in instruments with a serial number before No. 1327. For these instruments there is a set number of rotor turns to one potentiometer turn as determined by the gearbox used, for example, with a 6000:1 gearbox there are 6000 rotor turns to one potentiometer turn (1024 counts).

The first stage in processing of these audio tapes is to transcribe them onto a digital, computer-compatible tape. In the process, the data are checked for hardware-detectable bit errors, missing bits, noise bits, encoder stability, completeness of data, and start and end times, then written out to a nine-track or seven-track tape.

A more detailed description of the Aanderaa recording current meter can be found in the RCM-4 Operating Manual. Details of the transcription process are also given by Lee and Shutts (1977).

### 3. CONVERSION

The next step after the Aanderaa tape has been transcribed onto a digital computer tape is to convert the Aanderaa counts into scientific units (cgs). Temperature is converted to degrees Celsius, direction to degrees true, pressure to decibars, and conductivity to salinity in parts per thousand.

All meters are calibrated for temperature, pressure and direction before and/or after deployment. The least-squares method is used to calculate the calibration curve for best linear fit. These calibrations of slope and bias (intercept) are used in the conversion from Aanderaa counts to scientific units:

Temperature slope ( $^{\circ}\text{C}/\text{counts}$ )  
Temperature bias ( $^{\circ}\text{C}$ )

Conductivity slope [ $(\text{mmho}/\text{cm})/\text{count}$ ]  
Conductivity bias ( $\text{mmho}/\text{cm}$ )

Depth slope ( $\text{meters}/\text{count}$ )  
Depth bias ( $\text{meters}$ )

A typical graph used to check for linearity is shown in Figure 2.

The gear reduction ratio (e.g., four rotor turns/one count) for the speed rotor of each instrument is entered into the conversion program along with the

calibration values for each instrument. The standard Aanderaa calibration regards the ratio of water speed to rotor speed as 42.24 units and is used to convert the Savonius rotor speed (rev/sec) to water speed (cm/sec).

Other references for calibration procedures are: NOIC, Instrument Fact Sheet (1974), and the technical report by Lee and Shutts (1977).

A velocity of 1.4 cm/sec is used as a threshold, and a speed of 150 cm/sec is set as a maximum limit. Limits can be higher depending on the gear reduction ratio of the instrument. Values that exceed these limits are flagged in the conversion program output listing for subsequent editing. Direction angle changes greater than 60 degrees for each time step are flagged also.

With the old-type speed potentiometer, there was a dead angle of three degrees. New counters have a dead angle of zero degrees.

There are two options for output from the conversion stage of processing. One is a tape of time series files in FESTSA format (Herman and Jacobsen, 1975). The other is a PCF element tape of raw current meter data (Aanderaa counts). Normal processing requires the output in FESTSA files only.

### 3.1 PCF Element Tape (Optional)

The PCF element tape is used in conjunction with a program called ELCHED to edit the raw data, chop beginning or end times, interpolate or delete data, or perform other manipulations as necessitated by the condition of the data. The PCF element tape of raw data counts is an option that is not usually used; in most cases minor editing of the FESTSA files is sufficient. The PCF element tape is only necessary for raw data counts that are unusually irregular, that is, counts that are permuted, missing, or transposed in such an indiscriminate manner that routine editing procedures are impractical.

ELCHED is a program used for actually going into the PCF element tape and editing the raw Aanderaa counts. When working with the element tape, the converted FESTSA output listing is also necessary to show the Aanderaa counts for all six parameters. The FESTSA listing shows all raw data counts and their corresponding converted (calibrated) values. Missing bits and otherwise erroneous counts are evident from the FESTSA listing.

In addition to checking the FESTSA listing, the FESTSA files (see section on Plots and Quality Control) are plotted and used to isolate the erroneous data points. After editing, the counts are again run through the conversion program and the resulting time series plotted to see if the editing procedures were sufficient or if further editing is required.

### 3.2 Directory Information

During the conversion stage of processing, all necessary and important directory information is included on tape for each data file. The information includes in a concise format all pertinent directory information for each CM record that a user will need for processing or analysis.



A "CM record" refers to data from all parameters of a single CM of an array. A "data file" refers to the data for a single parameter of that CM record. The format for the directory information in each file is taken from FESTSA (Herman and Jacobsen, 1975) which includes: title, variable and units, start and end times (year, Julian day, hour, minute), length of series (number of data points), timing interval (hours), latitude and longitude, water depth, and depth of the CM. All start time values are converted to hours from a reference day, which is either the start time of each series or a convenient start reference for the whole project. For example, the start reference for the New York Bight MESA CM data is January 1 (0000), 1974; all start times are computed from that reference time (hours).

Updating of the tape directory information, although not absolutely necessary until all processing is complete, is also useful at various stages of the processing, especially as start and end times are adjusted or chopped, after files are joined, or for new or additional title information.

All pertinent header-type information for each file is also recorded on a tabular log sheet for easy reference and as a processing work sheet. See Figure 3.

#### 4. PLOTS AND QUALITY CONTROL

After the conversion and calibration of the CM data, each file is plotted in order to visually check the quality of the data. Four types of plots are used as visual aids during data reduction. They are: time series plots, individual data point time series (dot plots), progressive vector diagrams (PVD), and time-versus-depth bar graphs.

In most cases the standard time series plot is adequate for quality control and editing purposes. A data set of very erratic or questionable data, however, should be plotted as individual data points to identify those points that should be deleted or edited (Figure 4). Temperature, conductivity, speed, and direction (TCSD) are plotted as a time series (Figure 5). North (V) and east (U) components of speed and direction may also be plotted at this stage; they will become a permanent part of the data record later in processing. Time series plots give information about the magnitude and direction of current flow and the maximum and minimum values for each parameter in time. Erroneous data should be obvious, such as temperature, speed or conductivity spikes, or a diminishing speed presumably because of rotor fouling (Figure 6).

The questionable data can first be checked by referring to the deployment and retrieval log sheets (Figure 7) which record all relevant mechanical repairs and maintenance, and also note the extent of fouling and corrosion that could be the cause of erroneous values. Problems such as battery failure and erratic sensor operation are also recorded on the log sheets.

A progressive vector diagram (PVD), showing the north versus east components of virtual displacement, is also plotted showing the cumulative movement of water past the CM location (Figure 8).

When checking plots for data quality, if there is a question about the data, the other parameters for the same time period are checked to see if there is a

corresponding change. For example, if there is a sudden increase in temperature, the speed or conductivity is checked to see if it has changed during the same time or closely precedes or follows the change.

Another test is to check the records of the other meters which are at various depths on the same array to see if there is a simultaneous change in their data records that corresponds to the data record for the CM in question. In addition, if there is another array within the same area, a check is made to see if any of its meters have registered a corresponding shift for the same time period. Simultaneous changes do not guarantee that the change is valid, but they do indicate that the data in question could be the result of an actual event. If the series dies out immediately or shortly after the event in question, or if the data become erratic toward the end of the record, the problem could be batteries that were running down. Low batteries are especially suspect if all parameters die out.

If all parameters change, another possibility is that the entire array was somehow moved to a different depth. This could happen if the array was deployed on an unstable slope or if the array is exposed to heavy ship traffic. Field deployment logs may make note of either of these possibilities.

## 5. TCSD CONVERSION TO VUTS

Up to this stage of the processing procedure, the parameters have been temperature, conductivity, speed, direction, and pressure. The output of the conversion may consist of any of these parameters, but since the pressure values are relatively constant, this parameter is usually omitted at this stage from further processing, especially at depths of 100 m or less, because the wire depth is then considered to be sufficiently accurate. At water depths greater than 100 m the pressure data are included for further processing.

The output of the conversion program is now run through a program called TSCD-VUTS to convert speed and direction to north (V) and east (U) components and conductivity to salinity.

This program can be used to adjust start and end times and set maximum and minimum limits for each parameter for auto-editing, as determined from the previous steps. It is also advisable at this point to update all directory information.

### 5.1 Pressure Data

The accuracy of the pressure sensors depends on the resolution and range of each sensor. Aanderaa specifications state both the accuracy and resolution to be  $\pm 1\%$  of the range.

To verify the pressure sensor values, they are compared with their CM's respective position on the array, i.e., wire depth. In some instances the pressure sensor reading of a CM may not agree with the wire length. In this case, the pressure calibration is checked. If the calibration values for the sensor in question are correct, then it must be decided whether to use the



wire lengths or the pressure readings in determining the depth of the current meter.

XBT's taken at the array location can also be very helpful when the depth of a CM is in doubt.

It is also important to be aware of whether the water depth, as recorded by the ship's fathometer, has been corrected for the speed of sound through water (H.O. SP-68). The deeper the water at the deployment site, the more critical this factor is.

## 6. JOINING STRATEGY

Two data records are considered compatible for joining when they meet the following criteria: they must be at the same depth within an acceptable tolerance that usually depends on the overall depth; have the same location within about 1 nm unless there are large depth gradients, have the same sampling interval (series with different sampling intervals can be joined by a join conditioning procedure that is described in section 6.3); and generally have a data gap no larger than six hours. These criteria are only general guidelines and should be compatible with the uses to which the data are put.

### 6.1 Bar Graph

A bar graph is a visual display that shows the depth, series length, and start and end times for each CM record (Figure 9) and aids in quality control, especially when working with a large quantity of data. This format gives an overview of all the data, and shows which data sets are compatible to be joined.

### 6.2 Join Key

In conjunction with the bar graph, a joining key is a useful aid in organizing and ordering files to be joined and for making the proper editing notes. The key shows all the data files available at each depth of a current meter array, as well as the location,  $\Delta T$ , start and end times, and join compatibility of the files (Figure 10).

Data series that are compatible in all aspects but have different  $\Delta T$ 's can still be joined by resampling the series. This is discussed in the following section.

The join key summarizes the status of the files to be joined, as evaluated from the raw data edit plots, field reports (deployment and retrieval log), bar graph, and CM tape log sheets (work sheet, Figure 3). All records are assembled on one FESTSA tape in the order of joining.

When preparing files to be joined, whether using a join key or another method for checking join compatibility, you may find that the latitude or longitude may be slightly different. A minute variation is probably not worth worrying about, but does warrant referring back to the deployment log. If the depth or latitude and longitude are slightly different, check the preliminary



plots of the files to be joined by comparing them to see if the parameters are consistent and compatible.

The acceptable time gap is determined by the type of analyses expected to be performed on the data. If you are interested in high-frequency events, then you want to have as small a gap as possible. In cases where you are interested in low-frequency events or when the series are very long, a larger gap is less critical. Generally, our maximum allowable time gap has been set at six hours. There are three options for filling the data gap between two files: linear interpolation, total mean, and fill with zeros. Whichever option is used for joining, it is very important to maintain the phase with an error no greater than 15 minutes.

If any of the series are not compatible for joining, it is better not to join them, but rather preserve them as distinct series.

### 6.3 Join Conditioning

Two series cannot be directly joined if their sampling intervals are different, i.e., if series-one has a  $\Delta T$  of 20 minutes and series two has a  $\Delta T$  of 30 minutes. Join conditioning is a subroutine that prepares these two series for joining by resampling the first part of series-2 at the sampling rate of series-one. These values are then used to lengthen the last part of the first series so that the two series overlap. In this way, after filtering, the end time of the first series will be equal to or slightly greater than the second series start time, thus allowing the two series to be joined.

## 7. FILTERING

When all the CM data with uniform sampling intervals have been processed through the stages of calibration, editing, and all possible series have been joined, the series are then filtered with a three-hour, low-pass filter and resampled hourly. The start time of each series is adjusted to the nearest day, and all series plotted as a check on data quality.

There is a different sequence of filtering and joining for CM series that do not have uniform sampling intervals. The series with different sampling intervals that have met the criteria for joining and have been join conditioned are first filtered with the three-hour, low-pass filter, resampled hourly, and then joined.

## 8. SUMMARY

In summary, the processing of current meter data requires the conversion of raw Aanderaa counts to scientific units onto a digital computer tape. Calibration values are applied at the time of conversion from the raw counts to scientific units. The data then are edited, start and end times adjusted, and, as means of quality control, each parameter plotted as a time series. Conductivity is converted to salinity, and speed and direction to north and east components. Compatible data sets are joined, and all records are filtered with a three-hour, low-pass filter. The resulting series are at

hourly intervals. The final product is a CM data library tape that is as free from errors as possible and that contains all the information necessary for further analyses.

#### ACKNOWLEDGMENTS

Appreciation is extended to Dennis Mayer and Mike Minton for developing the strategies and procedures for the processing of current meter data and for generating much of the computer software used in that data reduction.

## REFERENCES

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- U.S. Naval Oceanographic Office, 1966: Handbook of oceanographic tables, SP-68, p. 324-363.





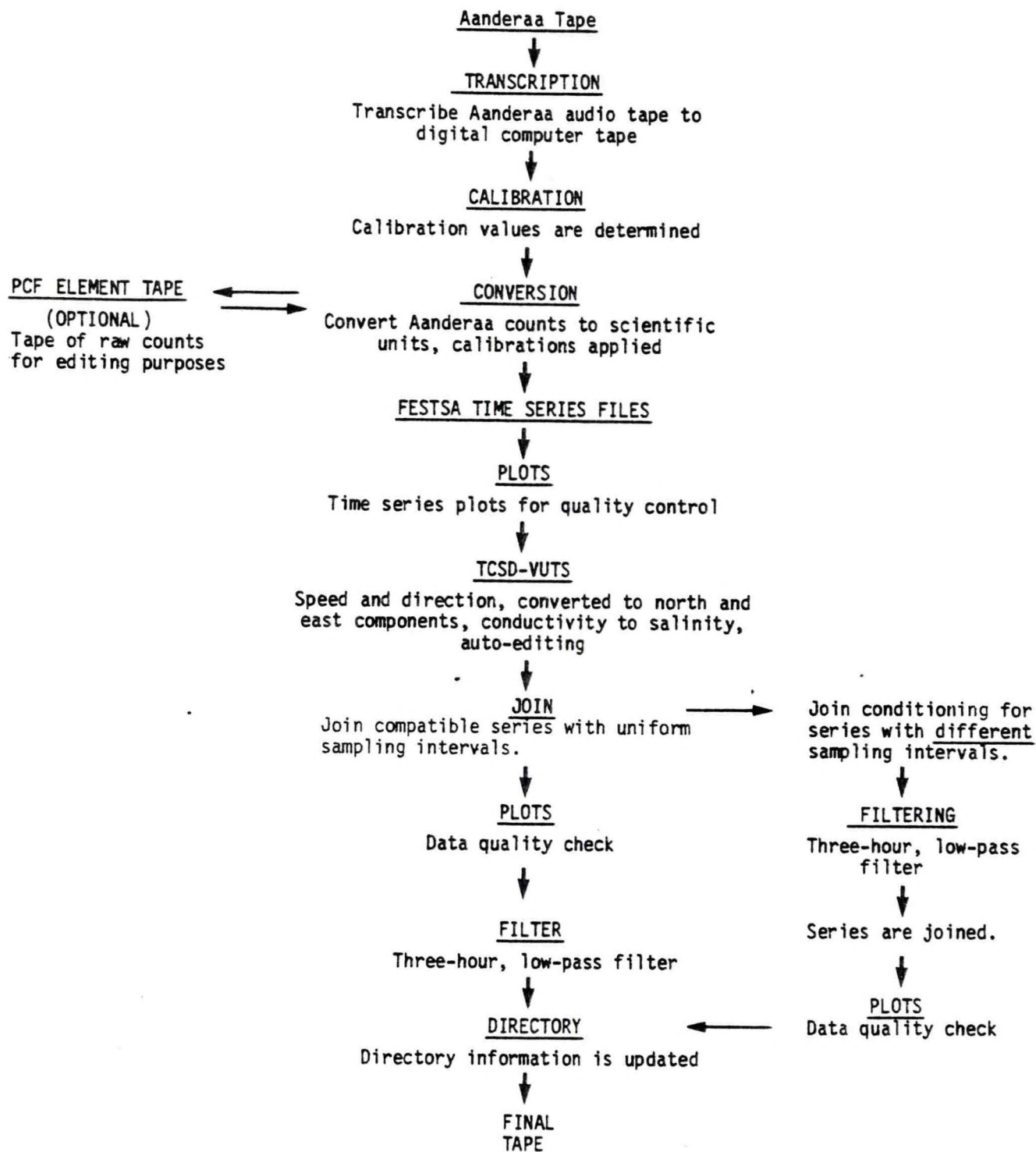


Figure 1. Flow chart of current meter processing system.

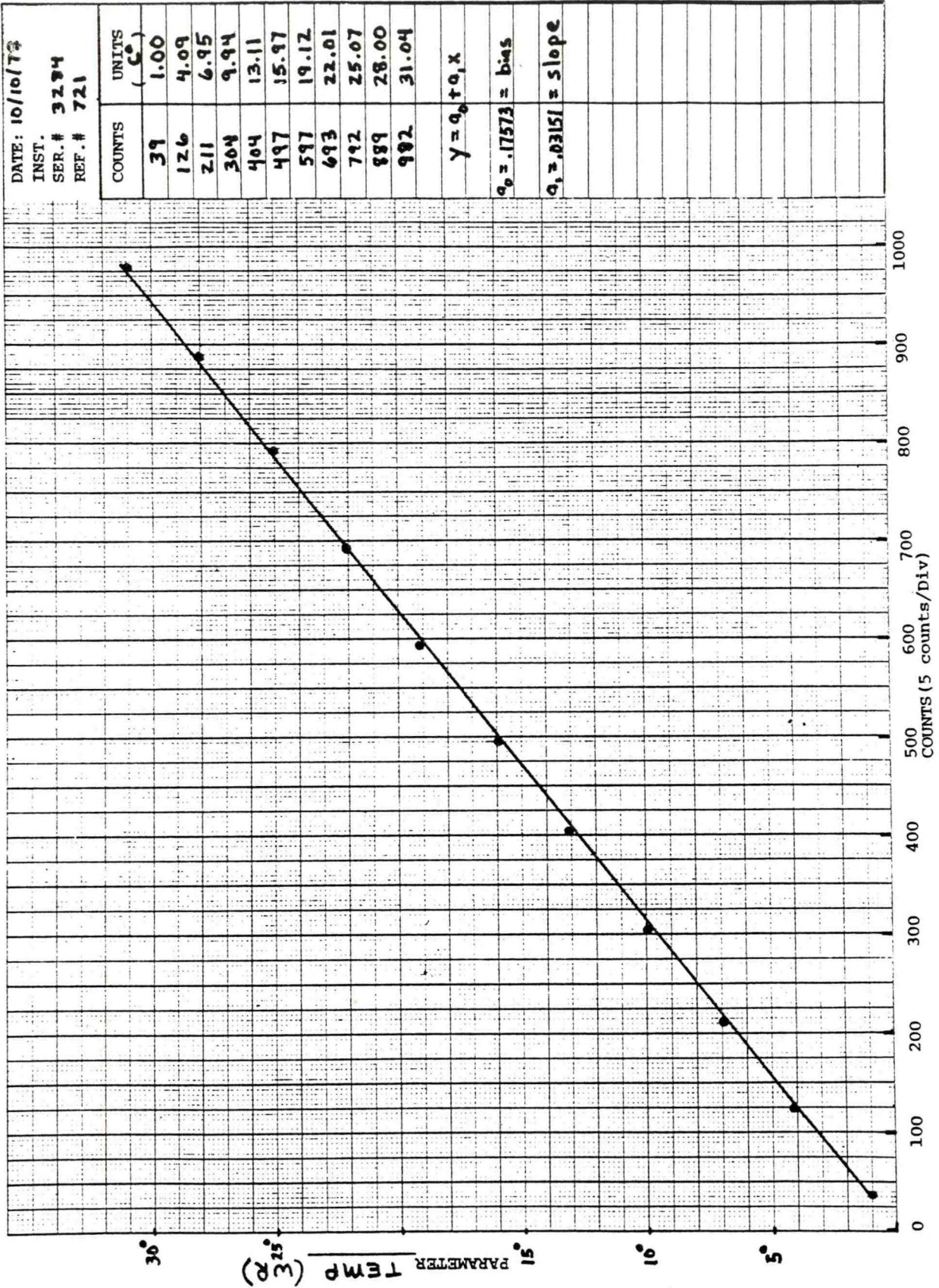


Figure 2. Calibration graph.



# WORK SHEET

Notes	Record Number	Meter	Water Depth	Distance from Bottom	Start Time	End Time	Series Length	T	L	$\lambda$
	1	NJ2AB	36 m	5 m	72(2142)	114(2042)	3022	20 min	39°13.5'	73°51.3'
	2	N31S	20 m	17 m	71(1800)	112(1600)	1965	30 min	40°18.1'	73°54.5'
	3	N31A	20 m	5 m	71(1802)	112(1602)	1965	30 min	40°18.1'	73°54.5'
	4	N32S	57 m	54 m	71(2000)	112(1830)	1966	30 min	40°18.4'	73°47.5'
Check Speeds	5	N32A	57 m	25 m	71(2002)	112(1832)	1966	30 min	40°18.4'	73°47.5'
	6	N32B	57 m	5 m	71(2004)	112(1834)	1966	30 min	40°18.4'	73°47.5'
	7	N41S	23 m	20 m	72(1330)	113(1300)	1968	30 min	40°04.5'	73°58.0'
	8	N41A	23 m	5 m	72(1332)	113(1302)	1968	30 min	40°04.5'	73°58.0'
	9	N42S	31 m	28 m	71(2230)	112(2200)	1968	30 min	40°04.5'	73°46.5'
Temp. spikes at end	10	N42A	31 m	5 m	71(2232)	112(2202)	1968	30 min	40°04.5'	73°46.5'

FOR EACH RECORD THERE ARE FOUR FESTSA FILES (TEMPERATURE, CONDUCTIVITY, SPEED, DIRECTION)

Figure 3. Processing work sheet.

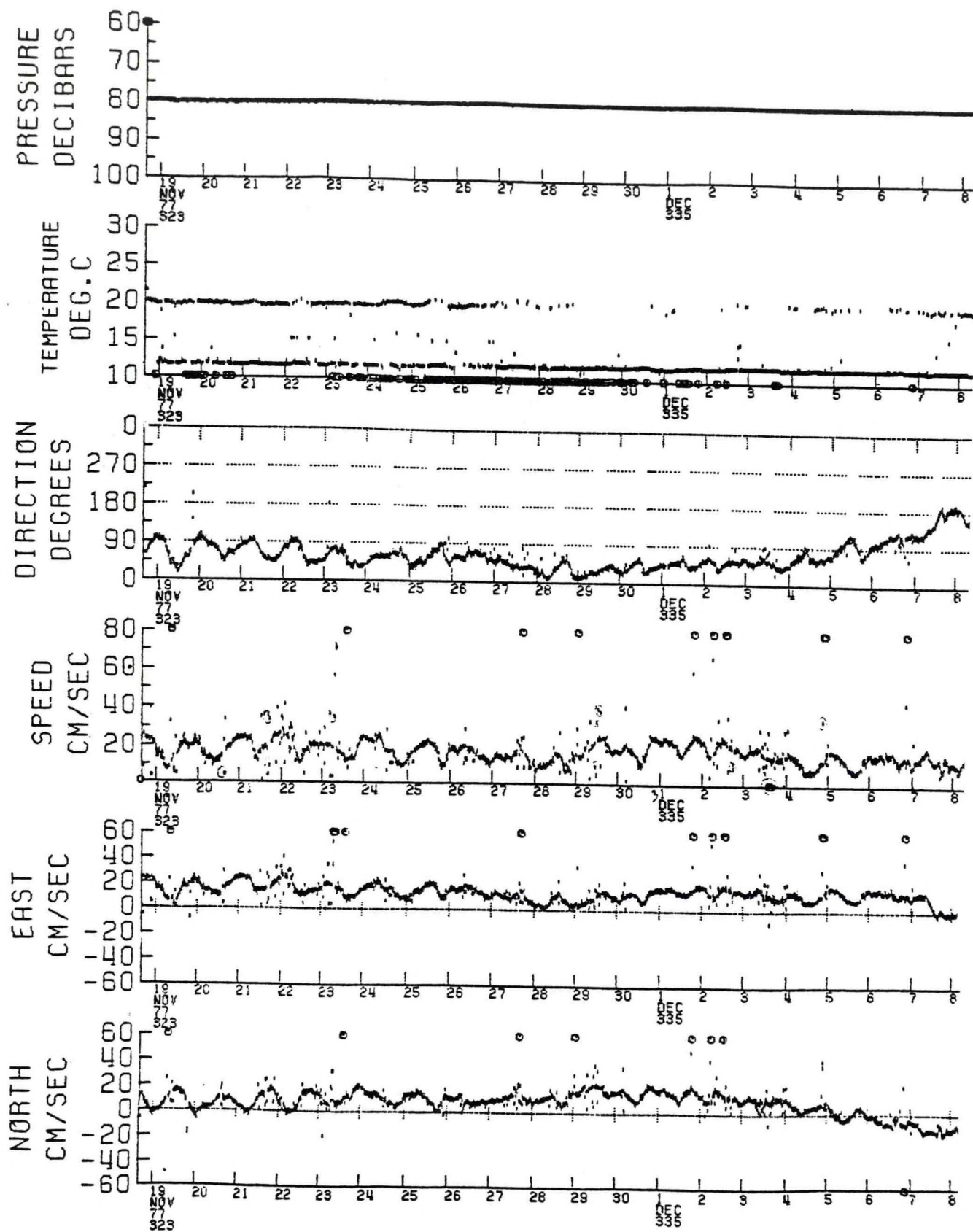


Figure 4. Time series dot plot ( $^{\circ}$  indicates data out of bounds).

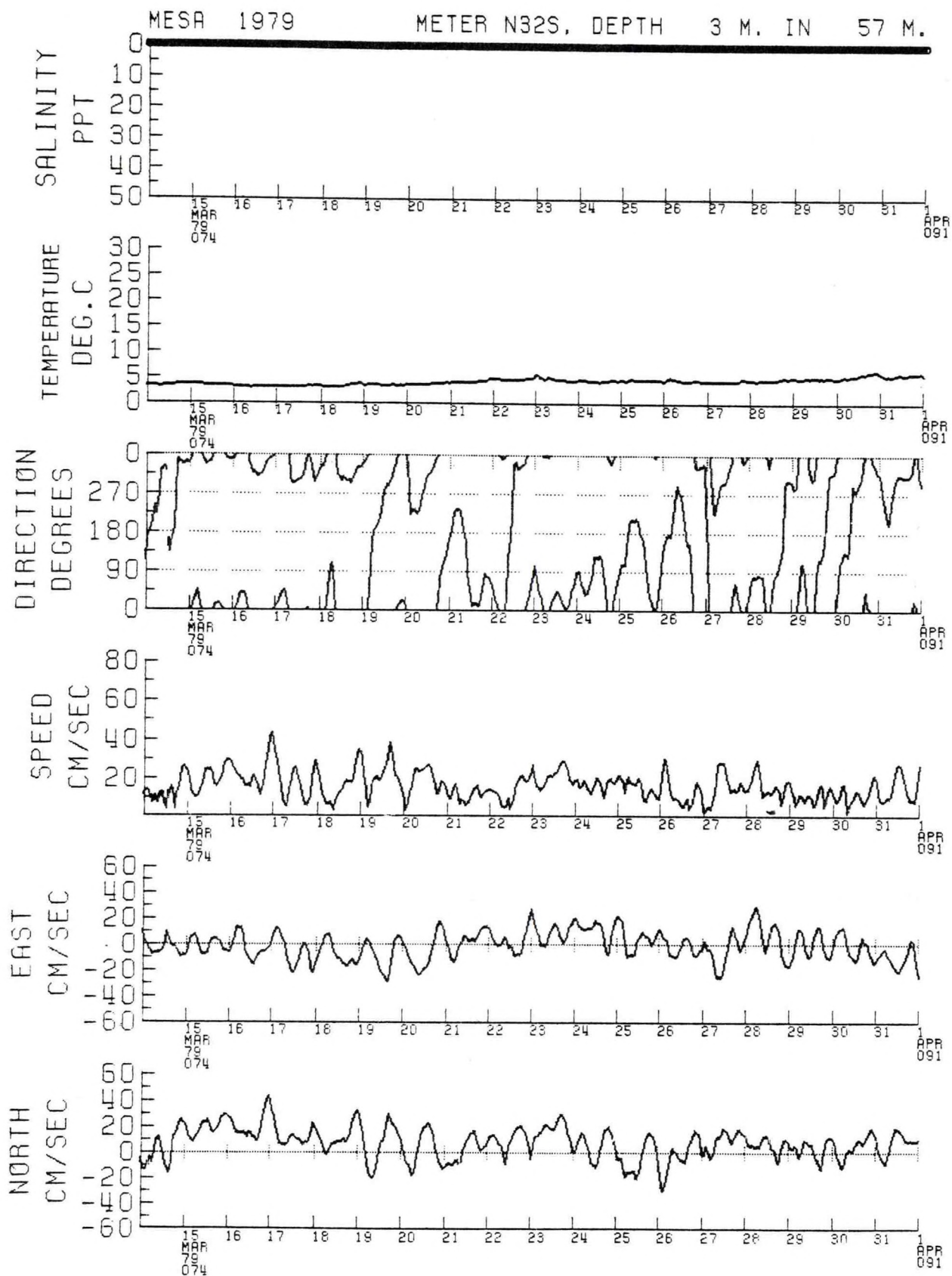
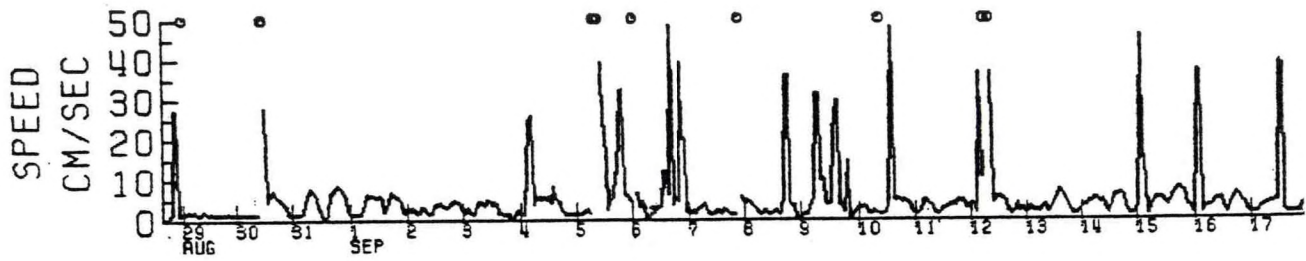


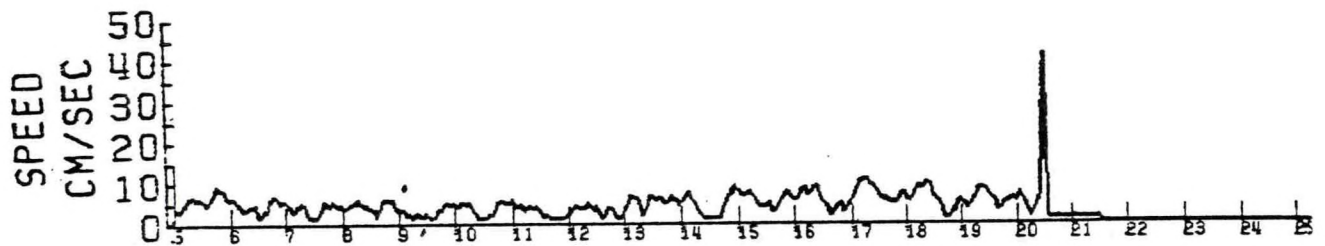
Figure 5. Time series plots.



### SPEED SPIKES



### SPEEDS DIE OUT AFTER DAY 20



### TEMP SPIKES



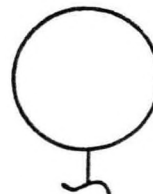
°Indicates data out of bounds

Figure 6. Plots showing erroneous data (° indicates data out of bounds).

Deploy { SHIP: Va. Key  
 PARTY CHIEF Roddy  
 Retrieval { SHIP: Va. Key  
 PARTY CHIEF Bushnell

MOORING LABEL: OTEC-3 TAMPA  
 Deployed 2, 11, 80, JD 42 Array Away 0244 GMT  
 mo. day yr.  
 Retrieved 6, 13, 80, JD 165

	PLANNED	ACTUAL
WATER DEPTH(M)	1000	1007
<u>L</u>	<u>27° 39.5</u>	<u>27° 39.6 N</u>
<u>λ</u>	<u>85° 31.0</u>	<u>85° 31.22 W</u>



CONDITION OF  
METER AFTER  
RETRIEVAL

## START UP TIMES

SER# 3285 MODEL RCM 5 REF# 469  
 CLOCK SET GMT Jan, 30, 80, JD 30 DEPTH(M) 507  
 1ST CYCLE 1209.00 ± DISTANCE  
 2ND CYCLE 1229.00 FROM BOTTOM(M) 500  
 3RD CYCLE 1249.00 ROTOR RATIO 4:1  
 IN WATER 0001 2 → 2-11-80 CLOCK SET AT (Δt) 20 MIN



tape ran out  
 ≈ 10 to 15 ft.  
 unwound &  
 lying in bottom  
 of pressure case

## SHUT DOWN TIMES

JD = 167  
 6-15-80 → OUT OF WATER 2042 GMT  
 1748.20 1ST CYCLE GMT 6, 13, 80 JD 165  
 1808.20 2ND CYCLE mo. day yr.  
 1828.20 3RD CYCLE

## START UP TIMES

SER# 3482 MODEL RCM 5 REF# 191  
 CLOCK SET GMT Jan, 30, 80, JD 30 DEPTH(M) 907  
 1ST CYCLE 1209.00 ± DISTANCE  
 2ND CYCLE 1229.00 FROM BOTTOM(M) 100  
 3RD CYCLE 1249.00 ROTOR RATIO 4:1  
 IN WATER 0033 2 → 2-11-80 CLOCK SET AT (Δt) 20 MIN



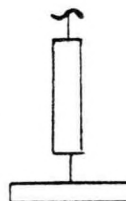
good - tape  
 still left

## SHUT DOWN TIMES

JD = 167  
 6-15-80 → OUT OF WATER 2120 GMT  
 1806.50 1ST CYCLE GMT 6, 13, 80 JD 165  
 1826.50 2ND CYCLE  
 1846.50 3RD CYCLE

AMF SER#  
 REC CHAN  
 XPONDER  
 REL COMM  
 TIME IN  
 WATER

mod. 325  
 AMF SER# 1607  
 REC CHAN 1  
 XPONDER 11 KMZ  
 REL COMM 1  
 TIME IN  
 WATER 0150 ±  
 → 2-11-80



OK - top  
 collar zinc  
 eaten away

Figure 7. Deployment/retrieval log sheet.

PROGRESSIVE VECTOR DIAGRAM  
N32S

3 M. IN 57 M.

SYMBOLS EVERY 10 DAYS

BEGINNING 1979 MAR13 (072), 2359Z

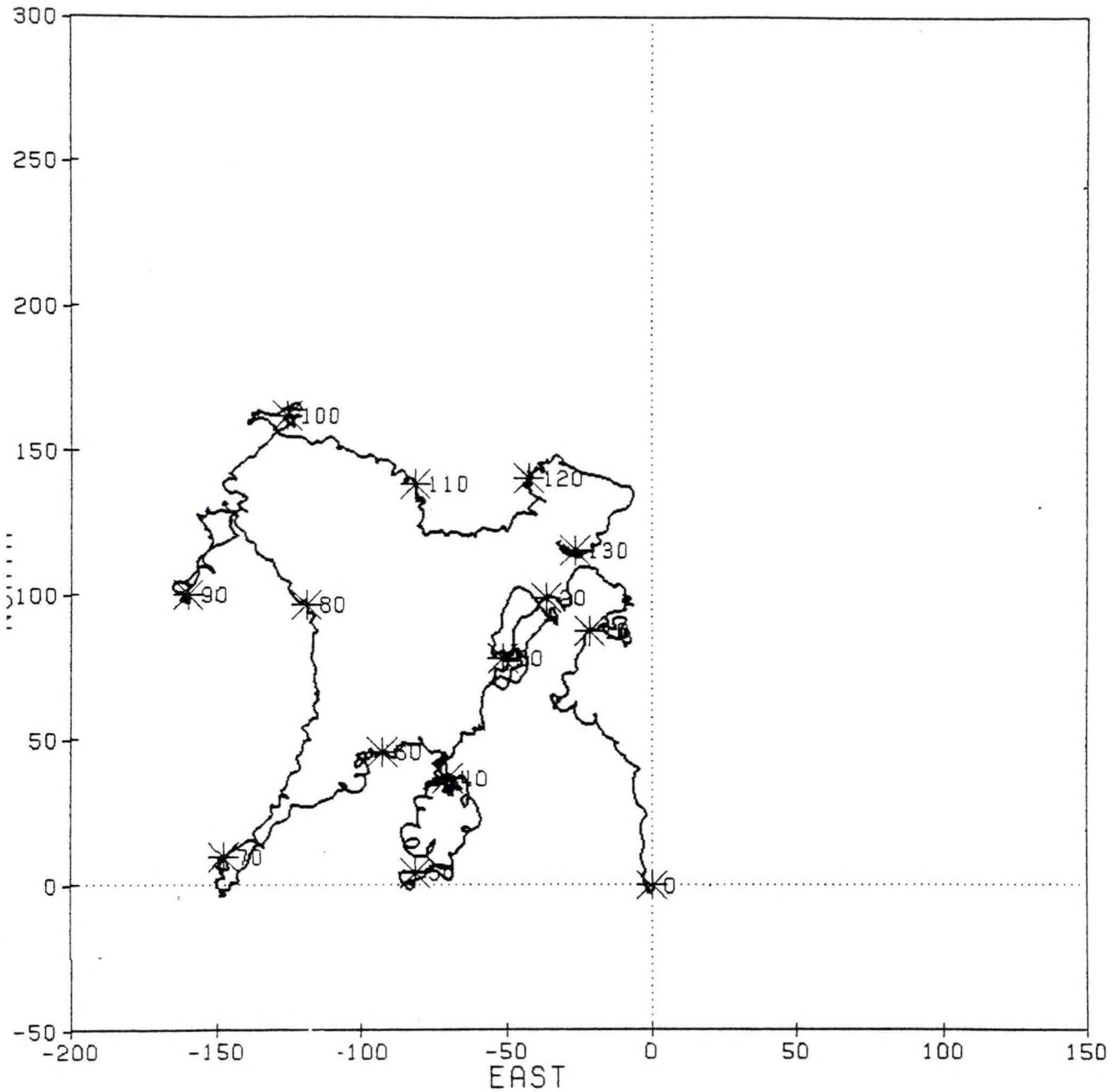
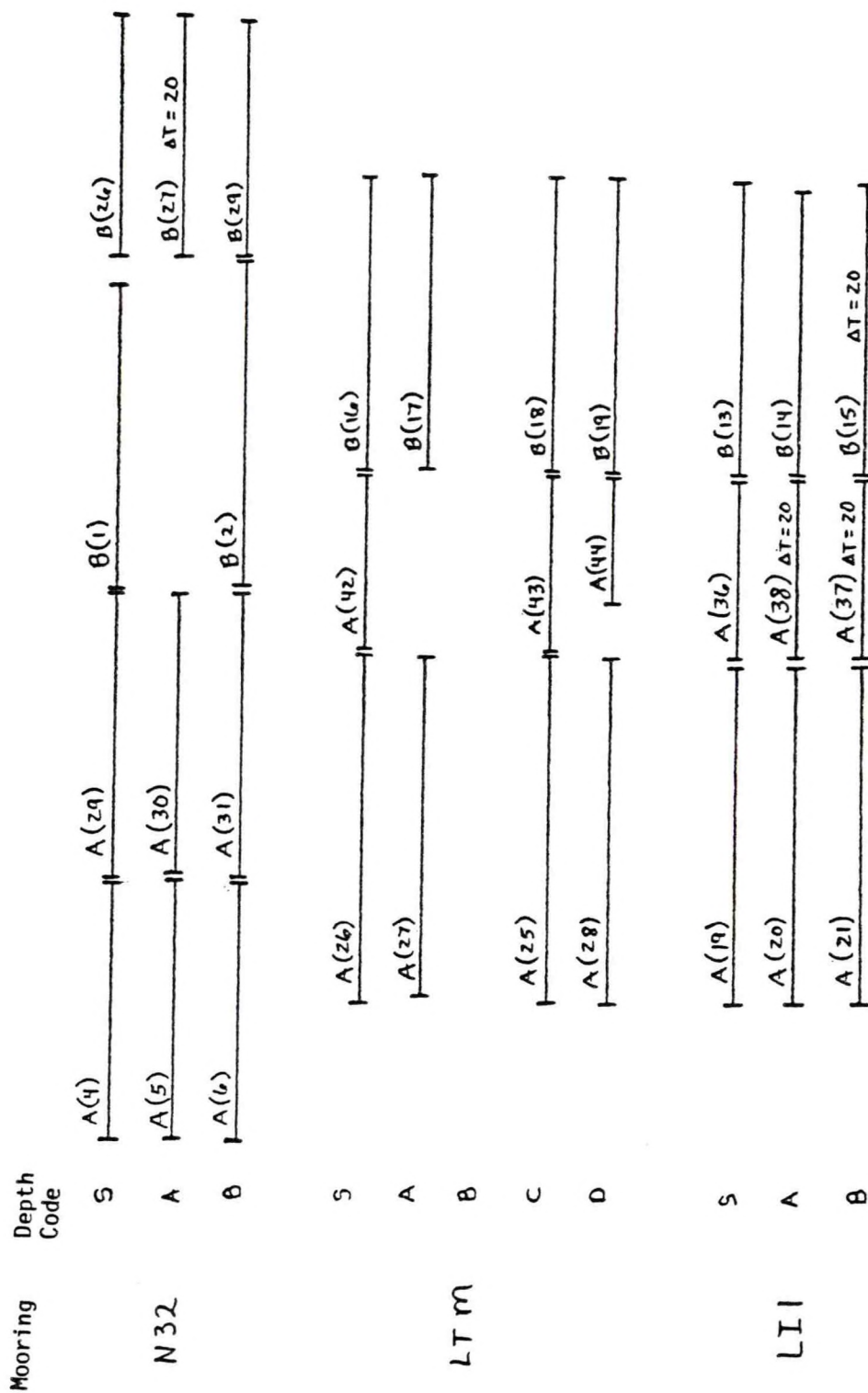


Figure 8. Progressive vector diagram (scale in km).



# BAR GRAPH

$\Delta T = 30$  min  
unless indicated  
otherwise



JULIAN DAYS 1979

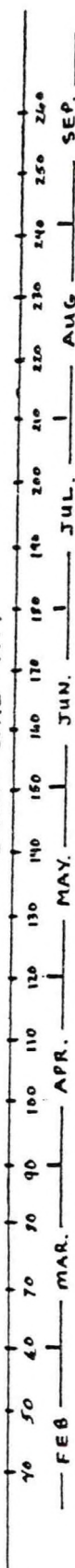


Figure 9. Bar graph.

# JOIN KEY

A = Tape # P15001  
 B = Tape # P15002  
 (#) = File number  
 x indicates incompatibility

N32S

ΔT	A(4) 30 min. 54	A(29) 30 54	B(1) 30 54	B(26) 30 54
Depth	40°18.4'	40°18.4'	40°18.4'	40°18.4'
Latitude	73°47.5'	73°47.5'	73°47.5'	73°47.5'
Longitude	71(2000Z)	113(0100)	160(0000)	213(2200)
Start	112(1900Z)	159(1800)	209(0100)	252(1700)
End				

Time gap too large.

N32A

ΔT	A(5) 30 25	A(30) 30 25	B(27) 20 25
Depth	40°18.4'	40°18.4'	40°18.4'
Latitude	73°47.5'	73°47.5'	73°47.5'
Longitude	71(2000Z)	113(0000)	213(2200)
Start	112(1900Z)	159(1800)	252(1700)
End			

Different ΔT's.

Time gap too large.

N32B

ΔT	A(6) 30 5	A(31) 30 5	B(2) 30 5	B(29) 30 5
Depth	40°18.4'	40°18.4'	40°18.4'	40°18.4'
Latitude	73°47.5'	73°47.5'	73°47.5'	73°47.5'
Longitude	71(2000)	113(0000)	160(2300)	213(0000)
Start	112(1900)	159(1800)	212(1900)	252(1700)
End				

No temp B(29).  
 File is not used.

LTMS

ΔT	A(26) 30 46	A(42) 30 46	B(16) 30 46
Depth	40°06.9'	40°06.9'	40°06.9'
Latitude	72°56.5'	72°56.5'	72°57.0'
Longitude	94(0000)	150(1700)	179(0800)
Start	150(1100)	179(0200)	227(1500)
End			

B(16) has speed spikes near end.

Figure 10. Join key.