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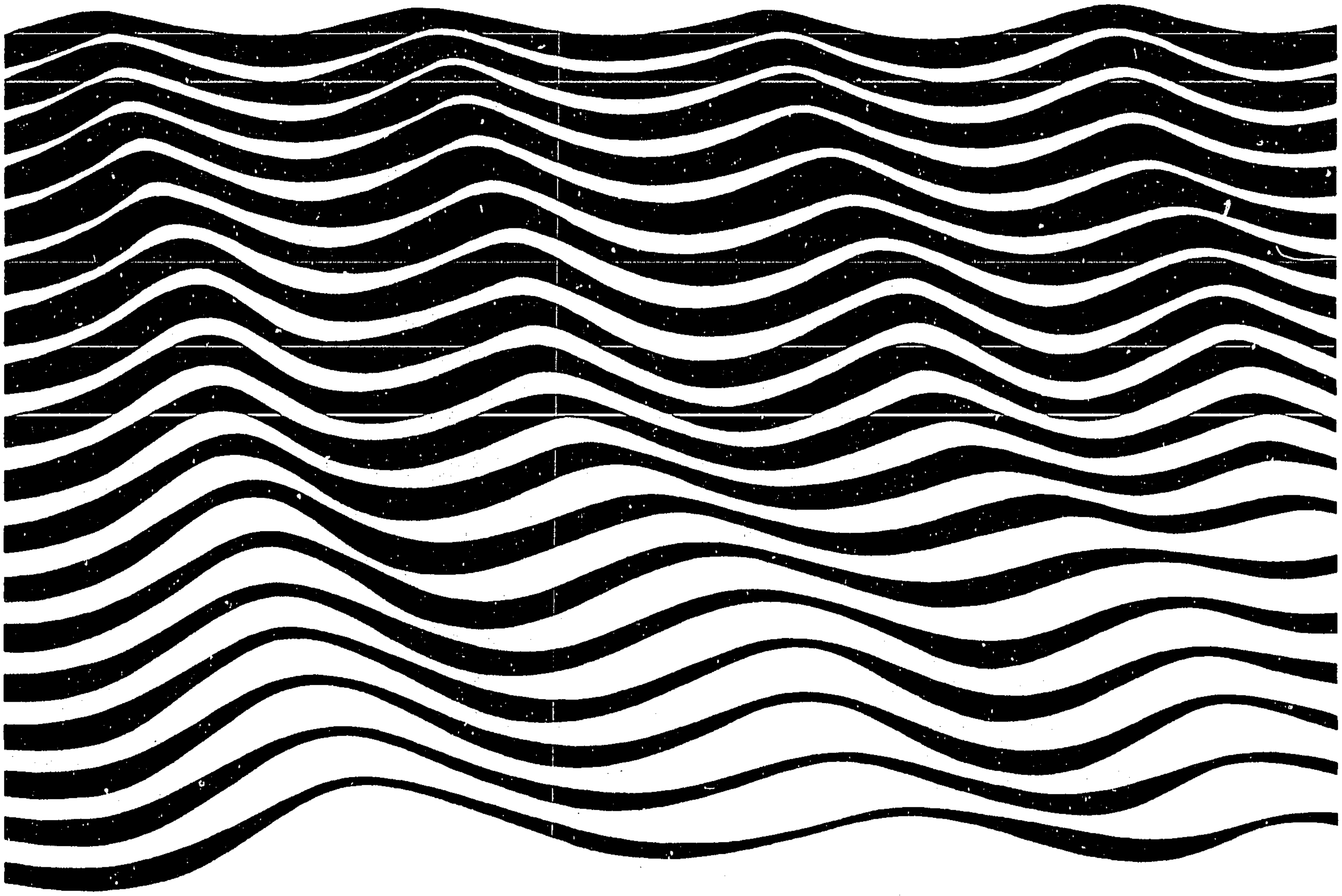

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No.		Year	SCOR WG
9	Report on intercalibration measurements, Leningrad, 24-28 May 1966 and Copenhagen, September 1966; organized by ICES	1969	–
13	Technical report of sea trials conducted by the working group on photosynthetic radiant energy, Gulf of California, May 1968; sponsored by SCOR, IAPSO, Unesco	1969	WG 15
15	Monitoring life in the ocean; sponsored by SCOR, ACMRR, Unesco, IBP/PM	1973	WG 29
16	Sixth report of the joint panel on oceanographic tables and standards, Kiel, 24-26 January 1973; sponsored by Unesco, ICES, SCOR, IAPSO	1974	WG 10
17	An intercomparison of some current meters,report on an experiment of Research Vessel Akademic Kurchatov, March-April 1970, by the working group on Current Velocity Measurements; sponsored by SCOR, IAPSO, Unesco	1974	WG 21
18	A review of methods used for quantitative phytoplankton studies; sponsored by SCOR, Unesco	1974	WG 33
19	Marine Science Teaching at the University Level. Report of the Unesco Workshop on University Curricula – *Also published in French and Spanish*	1974	—
20	Ichthyoplankton. Report of the CICAR. Ichthyoplankton Workshop *Also published in Spanish*	1975	–
21	An intercomparison of open sea tidal pressure sensors. Report of SCOR Working Group 27: "Tides of the open sea"	1975	WG 27
22	European sub-regional co-operation in oceanography. Report of a working group sponsored by the Unesco Scientific Co-operation Bureau for Europe and the Division of Marine Sciences	1975	—
23	An intercomparison of some current meters, III. Report on an experiment carried out from the Research Vessel Atlantis II, August-September, 1972, by the Working Group on Continuous Velocity Measurements: sponsored by SCOR, IAPSO and Unesco	1975	WG 21

Unesco technical papers in marine science 23

An intercomparison of some current meters, III

Report on an experiment carried out from the Research Vessel Atlantis II, August-September, 1972 by the Working Group on Continuous Current Velocity Measurements

sponsored by SCOR, IAPSO and Unesco

Final report of Working Group 21

Unesco 1975

PREFACE

This series, the Unesco Technical Papers in Marine Science, is produced by the Unesco Division of Marine Sciences as a means of informing the scientific community of recent developments in oceanographic research and marine science affairs.

Many of the texts published within the series result from research activities of the Scientific Committee on Oceanic Research (SCOR) and are submitted to Unesco for printing following final approval by SCOR of the relevant working group report.

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The Working Group is indebted to the sponsoring international organizations, SCOR, IAPSO, and UNESCO, for initiating the work and contributing essential funds in support of this experiment,

to the Woods Hole Oceanographic Institution and the U.S. Office of Naval Research for generous support in field operations and shore facilities,

to W. J. Gould for many contributions in every phase of this experiment and to S. P. Hayes for data processing and analysis.

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1. Introduction

Working Group 21 on Continuous Velocity Measurements was established by SCOR in 1966 with the following terms of reference: To design and propose means for carrying out an intercomparison at sea of the principal current measuring systems now employed for the continuous recording of current velocity on moored stations.

Two previous intercomparison experiments have been performed and the results have been reported (SCOR W/G 21, 1969; SCOR W/G 21, 1974)*. In this report these experiments will be referred to as SCOR-1 and SCOR-2. The second experiment involved six types of current meters: Alexaev, Bergen, Braincon, Geodyne, LSK and Plessey. Among the results of the experiment were an apparent discrepancy in the incremental speed response of the Geodyne and the Alexaev instruments. Also the high frequency energy density measured by the LSK meter was significantly lower than that measured by the other instruments.

In order to resolve these discrepancies a third current meter intercomparison experiment was performed from the R/V Atlantis II of the Woods Hole Oceanographic Institution at Site D (39° 10'N, 70° 00'W) between August 24 and September 4, 1972. This intercomparison involved four types of current meters: Alexaev (USSR), Geodyne Model 850 (USA), LSK (GDR), VACM (USA). Two types of mooring were employed. One had surface buoyancy provided by a filled 2.44 meter diameter toroid. The other had subsurface buoyancy provided by glass balls. The mooring serial numbers were 463 (surface) and 464 (subsurface). The undisturbed horizontal distance between the moorings was 400 m. The layout of the moorings is shown in Figure 1. All instruments were mounted in their standard operating configuration (i.e., mounted in the mooring line for all except the Alexaev meter which was suspended from a bracket clamped to the wire). The moorings became tangled during a storm, but separated again. Some of the instruments were damaged, particularly those with protruding parts (Alexaev and LSK).

2. Description of the Instruments

The Alexaev, Geodyne Model 850, and LSK instruments have been used in the previous intercomparison experiments; a description of these instruments was included in the reports of SCOR-1 and SCOR-2. In the present experiment the recording rates of the meters were set as follows: Alexaev every 15 min., LSK recorded speed every 10 min. and direction every 5 min., Geodyne every 3.75 min. Since the VACM was not included in the earlier experiments, a brief description of its characteristics is presented here.

2.1 Vector Averaging Current Meter (VACM)

These instruments were manufactured by AMF Electrical Products Development Division. The instrument is housed in a 19 cm diameter cylindrical case about 2 m long. At the lower end are a Savonius rotor of 16 cm diameter turning on a vertical axis and a

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* See References p. 42.

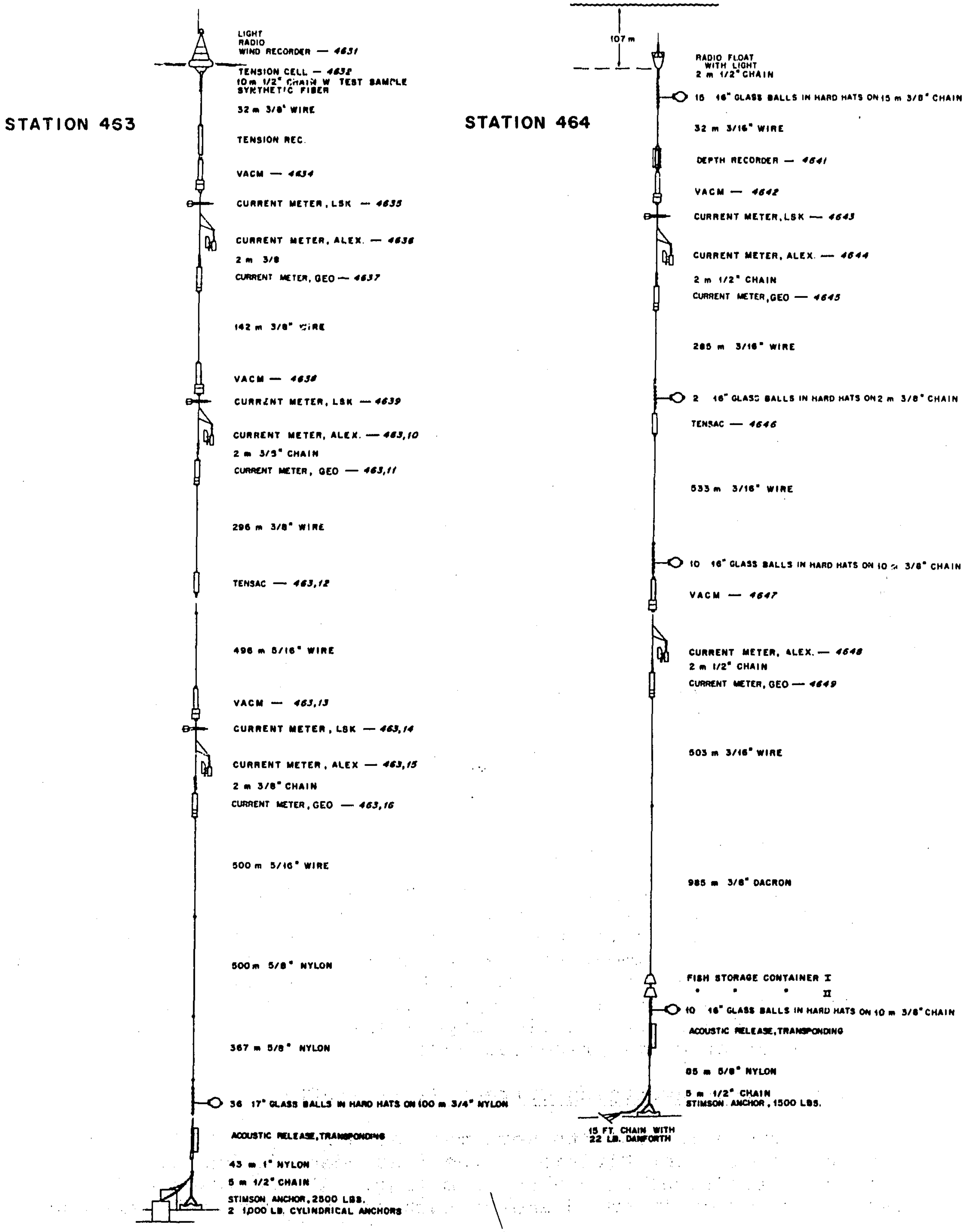

Figure 1.

Layout of the moorings. Mooring 463 has surface flotation; mooring 464 is a subsurface mooring.

vane also turning on a vertical axis. Both sensors are similar in principle to those on the Geodyne Model 850.

The sampling procedure for the VACM differs from all of the other meters. Measurements of current direction are converted internally into north and east components. There are eight calculations of the components for each revolution. Thus the north and east direction vectors are summed proportional to the rotor rate. The direction measurement is accomplished through combining the vane and compass orientations. The vane heading is sensed by a vane follower through magnetic coupling. Both compass and vane are encoded in seven level-binary so that 360° corresponds to 128 divisions and the resolution is about 2.8 degrees.

The instrument records seven pieces of information on digital magnetic tape at a preselected interval. (In this experiment the recording interval was 56.25 sec.) The data recorded are the east sum (E), the north sum (N), the total rotor count (R), one compass heading, one vane heading, temperature, and a time word. The east sum is defined as

$$E = \frac{1}{2} \sum_{i=1}^{R} (1 + \cos \theta_i)$$

where θ_i is the current orientation defined by the compass and the vane. Similarly the north sum is defined as

$$N = \frac{1}{2} \sum_{i=1}^{R} (1 + \sin \theta_i)$$

In processing the recorded data the vector components of the current are calculated from the recorded sums using the calibration formula:

$$\text{East} = \frac{2E-R}{R} (a\omega+b)$$

$$\text{North} = \frac{2N-R}{R} (a\omega+b)$$

$$\omega = \frac{R}{8T}$$

where:

ω = rotor rotation rate in revolutions per second

E,N,R = the values in the VACM east, north, and rotor registers

T = sample time in seconds

$a = 36.1$ $b = 2.0$ $\omega < .915$

$a = 32.6$ $b = 5.2$ $\omega > .915$

The speed is then found from the components:

$$\text{Speed} = \sqrt{(\text{East})^2 + (\text{North})^2}$$

3. Narrative of ATLANTIS II Cruise 69

The R/V Atlantis II left Woods Hole on 22 August 1972 and reached Site D (39° 10'N, 70° 00'W) the next day. The moorings were to be set anchor first. The setting of the surface mooring began first and problems were encountered with the anchors being too heavy for the nylon in the lower end of the mooring. Two anchors were lost before the mooring was successfully set by first streaming the lower glass balls and the release astern of the ship, then pushing the anchor over. The rest of the laying of the surface mooring went smoothly. The subsurface mooring was set the next day (24 August 1972). The intention had been to set the two moorings 1 km apart; however, a check on positions after the moorings were in place showed them to be only 400 m apart. The water depth was about 2650 m.

The Atlantis II then returned to Woods Hole to pick up replacement anchors for the ones lost. These were needed for further mooring work unrelated to this experiment.

During the course of the experiment a set of nine hydrographic stations was occupied, one station close to the moorings and the others at distances of 10 km and 20 km north, south, east, and west of the mid-point. Temperature, salinity, and Brunt Väisälä profiles for the station near the moorings are shown in Figure 2.

The hydrographic work was interrupted by a tropical storm which affected the area between 1 September and 3 September, 1972. The Atlantis II retreated to safety off Martha's Vineyard to wait out the storm.

On returning to the experimental area the subsurface mooring was immediately retrieved. It showed signs of damage to the instruments and the wire at 200 m. The surface mooring was then retrieved. Here, also, there was instrument damage noted. The indications are that sometime during the course of the experiment the two moorings may have tangled.

The Atlantis II returned to Woods Hole on 5 September 1972. K. A. Chekotillo and A. Suslyaev from the Institute of Oceanology, Moscow, U.S.S.R. and W. J. Gould from the National Institute of Oceanography, Wormley, U. K. were aboard R/V Atlantis II along with many personnel of the Woods Hole Oceanographic Institution.

4. Instrument Performance and Data Preparation

As mentioned in the preceding section, severe damage to several of the instruments was noted upon retrieval of the moorings. Table 1 summarizes the performance of the instruments and the damage sustained. To review, the numbering system used in the table is as

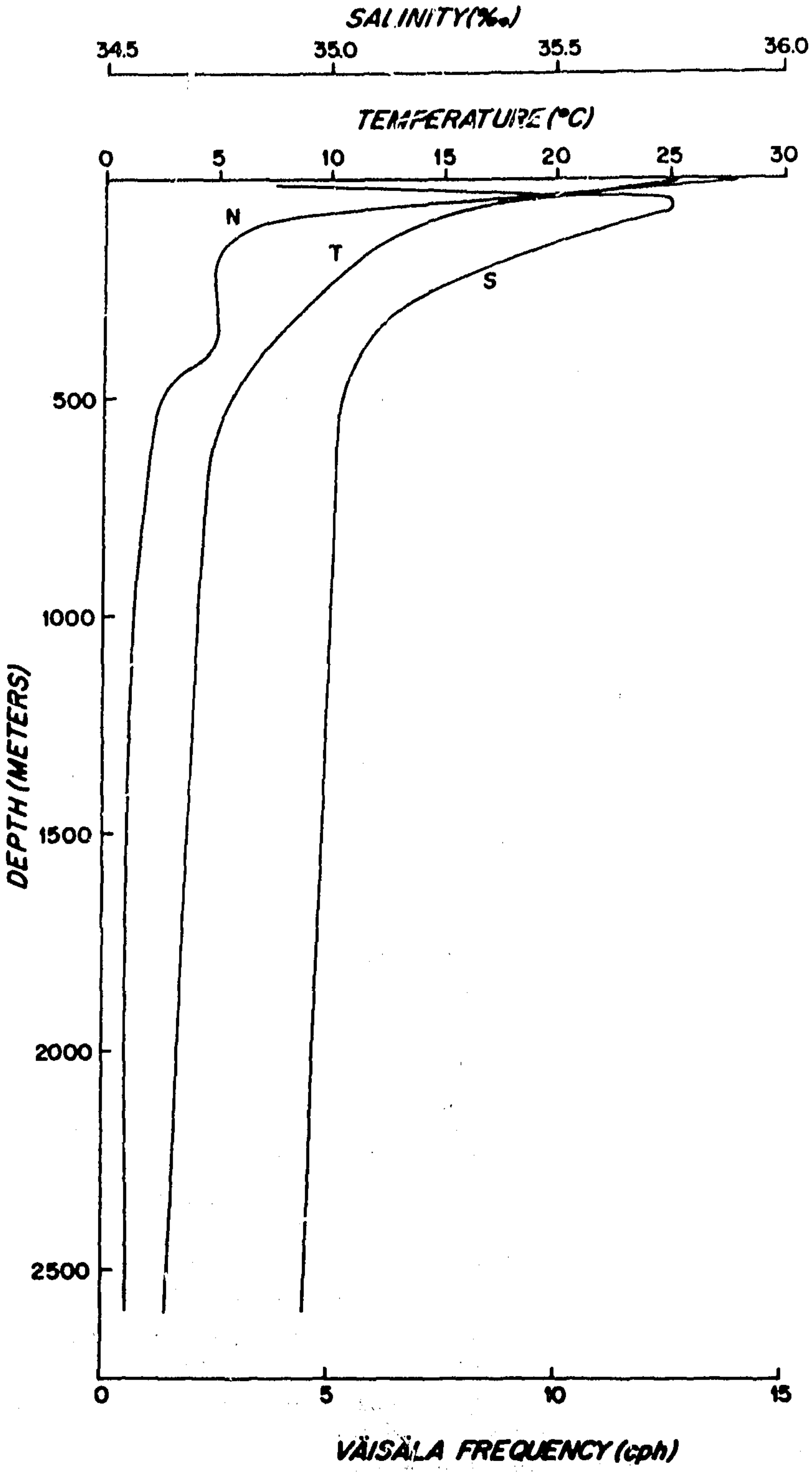

Figure 2.

Representative profiles of temperature (T), salinity (S), and Brunt-Väisälä frequency (N) taken at the mooring site.

Table 1

		Depth (m)	Surface buoy (463)
4631	(W)	0	Record very noisy but readable.
4632	(T)	2	Telemetering tensiometer.
4633	(T)	45	Recording tensiometer. Good record.
4634	(V)	47	No damage. Good record.
4635	(L)	48	Propeller and vane missing. Recorded for whole period of mooring.
4636	(A)	49	Fins missing from current meter and damage to rotor cage. Record bad from 2215Z 2-IX; Stops 2315Z 2-IX.
4637	(G)	53	Damage to paint. Good record.
4638	(V)	197	Rotor out of bearings 0600Z 4-IX. Vane missing from 2200Z 2-IX otherwise good.
4639	(L)	198	Meter had slipped down the wire. Propeller missing and damage to vane. Recorded for whole period.
463,10	(A)	199	Fins missing. Damage to suspension and rotor and rotor cage. Records stop 2215Z 2-IX. Otherwise good.
463,11	(G)	203	Damage to paint. Good record.
463,12	(TA)	501	TENSAC flooded. No record.
463,13	(V)	999	No damage. Good record.
463,14	(L)	1000	Propeller and vane missing. Recorded for whole period.
463,15	(A)	1001	Severe damage to fins. Stop 0330Z 29-VIII. Otherwise good.
463,16	(G)	1005	No damage. Good record.
			Subsurface buoy (464)
4641	(D)	159	Good record. Settled at 155 m.
4642	(V)	161	Paint chafed off pressure case. Good record.
4643	(L)	163	Current meter had moved up the wire. Evidence of damage. Good record. Piece of wire jacket found in clamp.
4644	(A)	164	Damage to rotor cage. Record stops 0300Z 3-IX. Otherwise good.
4645	(G)	168	Rotor missing 0630Z 4-IX. Damage to rotor cage. Good record.
4646	(TA)	457	Good record.
4647	(V)	1002	No damage. Good record.
4648	(A)	1003	No damage. Good record.
4649	(G)	1007	No damage. Good record.

Code

(W) Wind recorder
(T) Tension recorder
(V) Vector averaging

(D) Depth recorder
(L) LSK current meter
(A) Alexaev current meter

(G) Geodyne type 850 current meter
(TA) Tension and accelerometer

follows: the first three digits refer to the mooring (463 or 464). The last digit refers to the instrument position counting down from the top of the mooring.

The discrepancy in the depth of the instruments at the nominal 200 m level of the subsurface mooring was traced to an error in wire lengths supplied by the manufacturer.

The records from all of the instruments were processed by the procedures normally applied by the "home laboratory" of each participant. An outline of the preliminary processing is given below.

4.1 Alexaev

The speed and direction values were read from the printed paper tape at Woods Hole. The listings were punched on data cards and transcribed onto magnetic tapes. Listings of the tapes were checked for accuracy. This work was supervised by K. A. Chekotillo.

4.2 Geodyne Model 850

The Geodyne data were first translated at Woods Hole from the instrument tape cartridge onto a 7-track computer magnetic tape. This was transcribed onto a 9-track computer tape in the standard W.H.O.I. tape format (Maltais, 1969). A few obviously erroneous points were edited. This followed the standard procedure used at Woods Hole. The time series was averaged to 15 minute intervals.

4.3 LSK

The LSK samples were taken every 5 minutes for direction and every 10 minutes for propeller count. The waxed paper tape is driven by rotating the take-up spool at a constant speed, so that the paper advance changes from 91 mm/day to 125 mm/day. The inscribed paper records were digitized at the Institut für Meereskunde, G.D.R. The raw series values were smoothed to obtain 15 minute average values.

Punched paper tapes and listings of the 15 minute series were sent to Woods Hole. The data were transcribed there onto 9-track magnetic tape. A few data points were edited from the series.

4.4 VACM

Data from the internal 4-track digital tape records were transcribed at Woods Hole into the standard W.H.O.I. 9-track format. The time series were scanned for obviously bad values and a few points were edited. The time series were averaged to give 15 minute sample intervals.

The standard data series for all instruments were a 15-minute and a 1 hour time series.

At each stage of the processing the records from each instrument were scanned for evidence which indicated when and if the moorings had tangled. The most direct evidence came from the depth recorder at 200 m (nominal) on the subsurface mooring. This recorder settled out at 155 m and remained at this depth until about 2300 GMT, September 3. It then began to sink deeper, reaching a maximum depth of 205 m at about 0530 GMT, September 4. At this point, there is a sharp change in the trace and the depth returns to 165 m. The relevant portion of the record is shown in Fig. 3. The period of about 8 hours when the depth was changing is thought to be the time when the moorings were tangled. Coincident faults on the Alexaev meters in the surface mooring at 50 m and 200 m suggest some disturbance as early as 2215 GMT, September 2; but it is not clear whether the moorings were in contact then. In all subsequent analyses additional evidence for the tangling was sought. In most cases no dramatic effects were found. However, in plotting the vector variance of the data bursts in the 1000 meter subsurface Geodyne Model 850 record (see section 5.7), it was found that there was a spike in the variance early on September 4. This spike exceeds the mean level by 2 orders of magnitude and no comparable spikes were seen elsewhere in the record.

These data indicate that for a period of about 8 hours the two moorings were probably in contact. Since this is a rather short period and since all meters at a given level on the same mooring were subject to the same distortions, the affected portions of the records were not truncated.

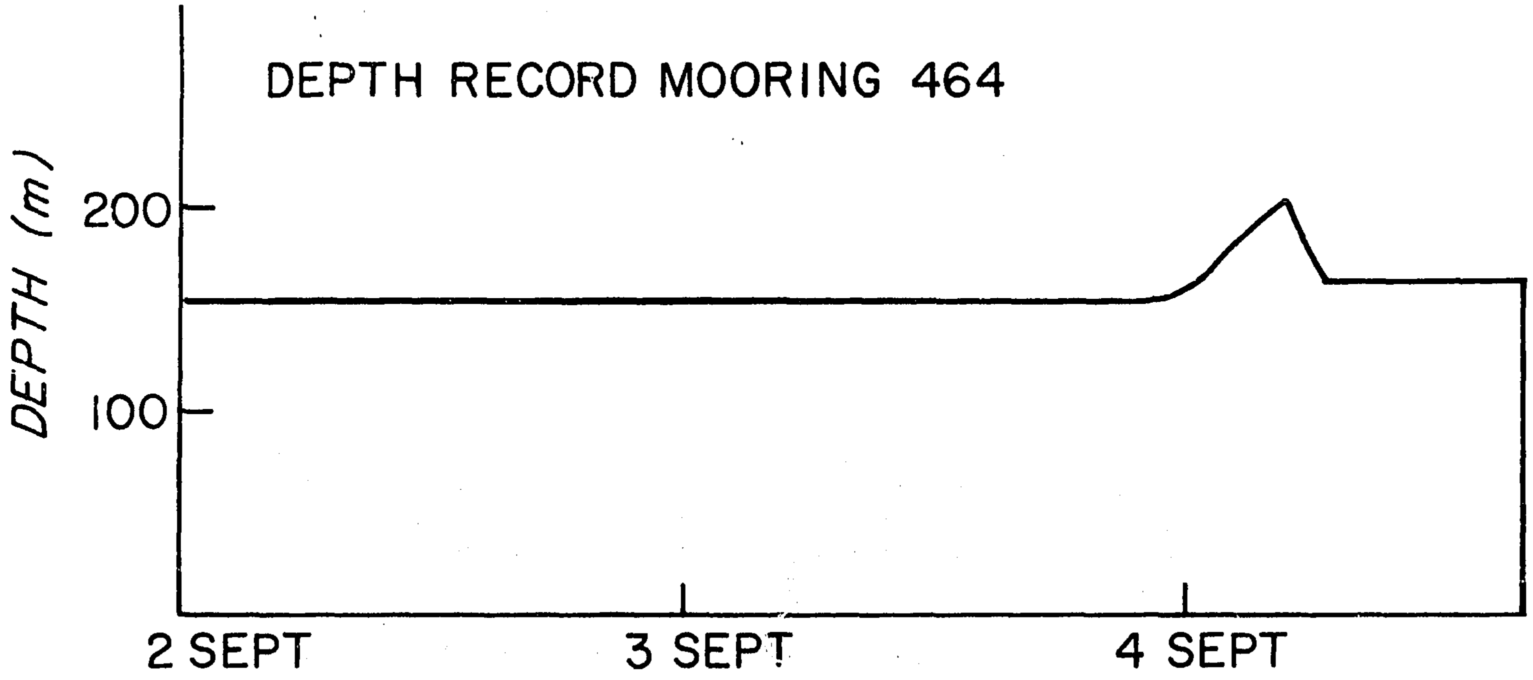

Figure 3. A portion of the depth record from instrument number 4641.

5. Instrument Comparisons

Following the preliminary processing of all records into a standard format, further analysis was carried out at the Woods Hole Oceanographic Institution. The set of standard plots and computations which were made will be discussed here with their results.

In order to compare all instruments over a uniform time interval, the records have been truncated to obtain a record between

Start time 0000 GMT August 25, 1973

Stop time 1600 GMT September 4, 1973

This interval contains 1024 15-minute samples which is convenient for spectral analysis. Records which are shorter than the standard interval due to instrument malfunctions are noted in presenting subsequent results.

The analysis presented here will begin with a description of the speed and direction time series since these show the overall character of the records. The results then proceed from the net properties of the data to the time variable properties of increasingly shorter scales.

5.1 Time Series of Speed and Direction

The 15-minute average time series of speed and direction are presented in Figures 4-6. Figure 4 (50 m, surface buoy) shows quite good agreement in both variables up to 1330 GMT on August 28. After this time the records become confused and later the Alexaev speed record shows steadily increasing values. The Alexaev meter stopped at 2315 GMT on September 2. The LSK meter also shows a tendency towards higher speed readings, and the direction does not show the fluctuations seen in the other records. This change in the quality of the records corresponds to an increase in surface wind speed (see Figure 17).

At 200 m on the surface mooring (Figure 5A) there is good agreement in the direction records throughout the period, but the speed traces are different. The Alexaev and VACM records are short for the reasons noted in Table 1. After 0000 GMT on August 26 there is a sharp increase in the speed values measured by the Geodyne, VACM and LSK meters. The speed values remain above the instrument threshold until early on September 2. The Alexaev record, on the other hand, shows large fluctuations of speed with several periods of near zero current. The records from the 200 m level on the subsurface buoy (Figure 5B) agree well in speed values. Even minor features of the time series are seen by all instruments. Also the direction records for the Alexaev, Geodyne, and VACM are in agreement. The LSK record differed markedly in direction for about 24 hours during 30-31 August and had several zero speed values not shown by the other instruments. This may have been due to slight damage causing a balance error, so that the instrument did not align itself correctly in a weak current. Since all the Alexaev and LSK instruments on the surface mooring were more or less damaged, we cannot be sure to what extent the differences in behavior were due to early slight damage or were characteristic of instrument design.

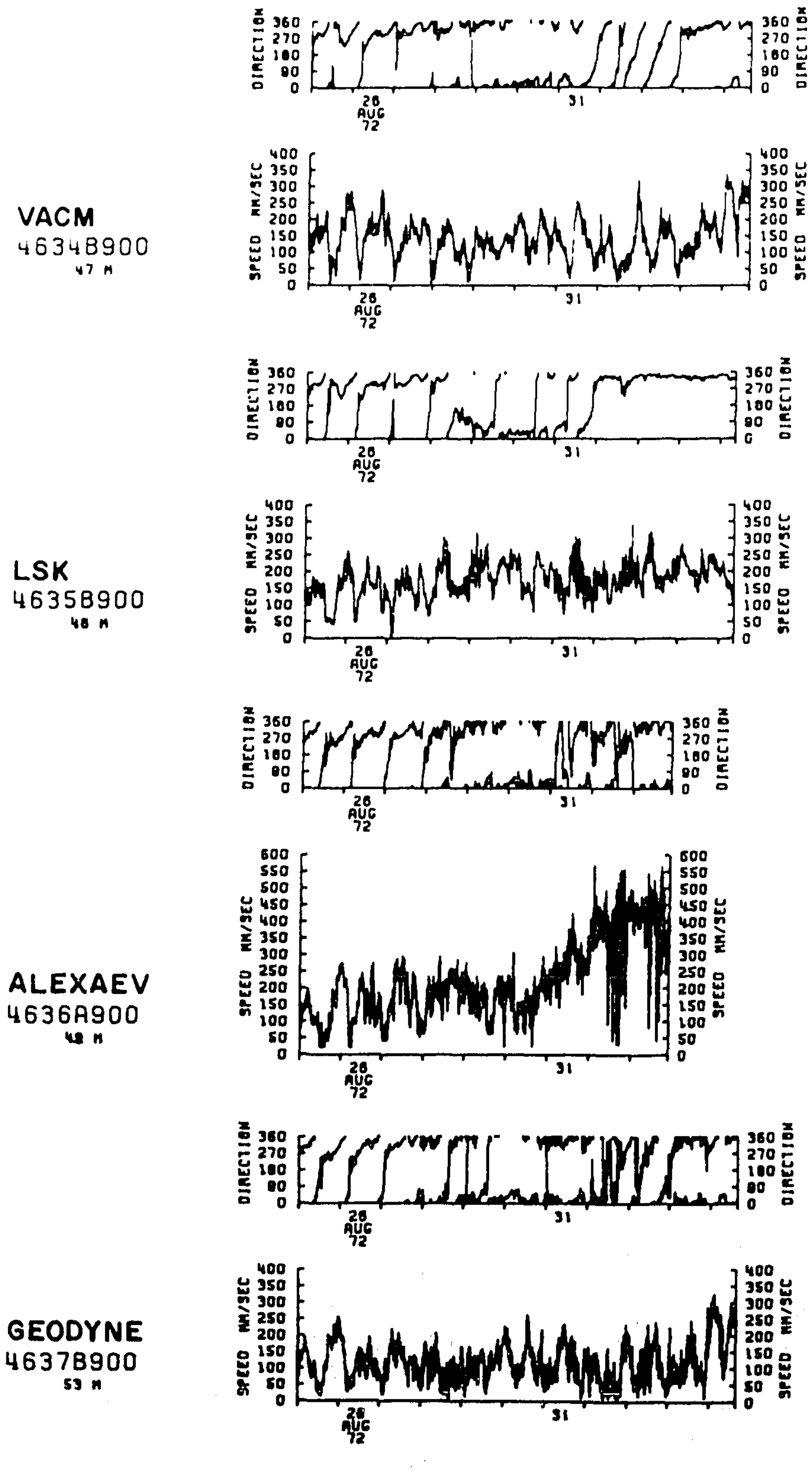

Figure 4.

Speed and direction time series for the instruments at the 50 m level. All were on the surface mooring.

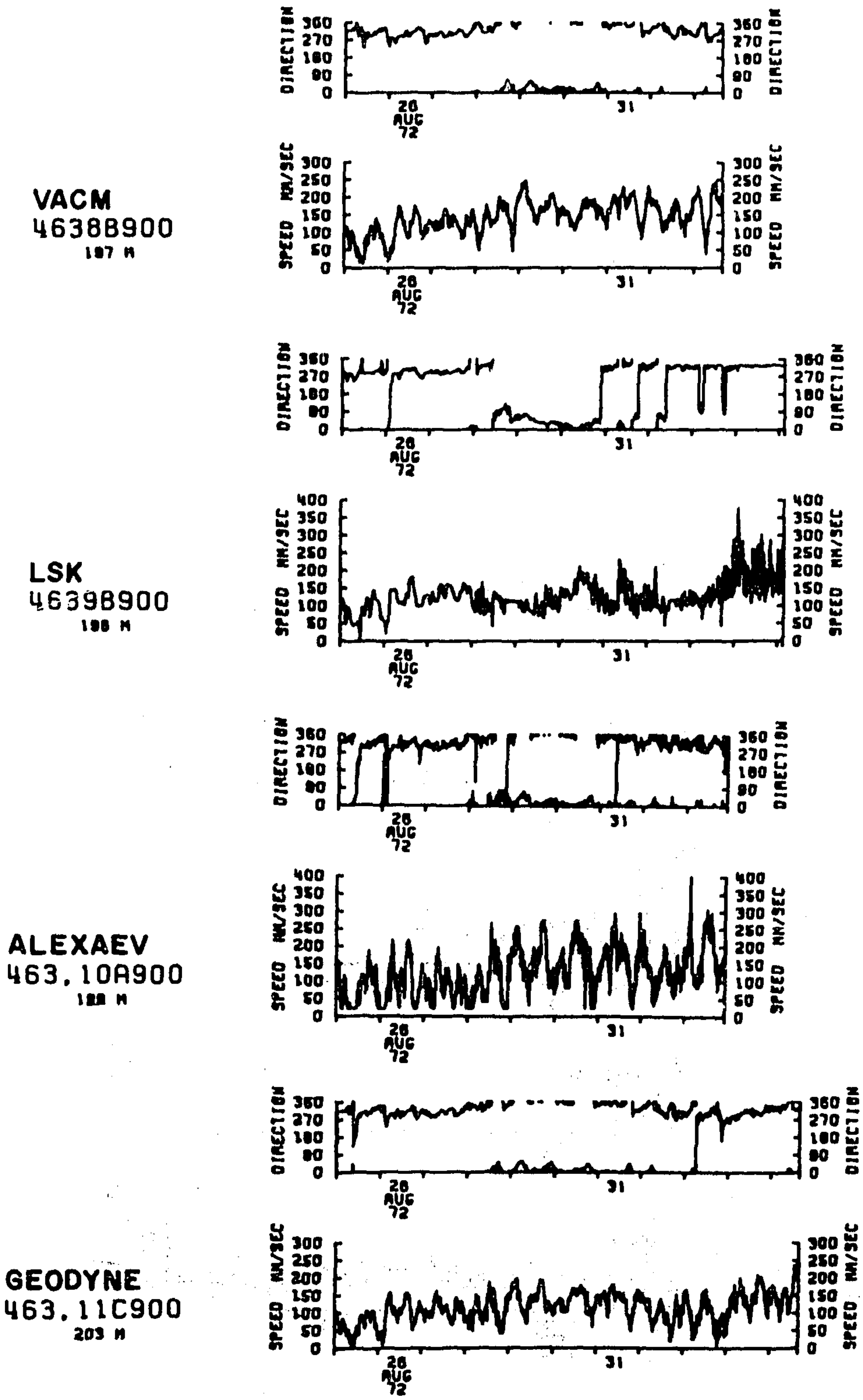

Figure 5A.

Speed and direction time series for the instruments at the 200 m level on surface mooring records.

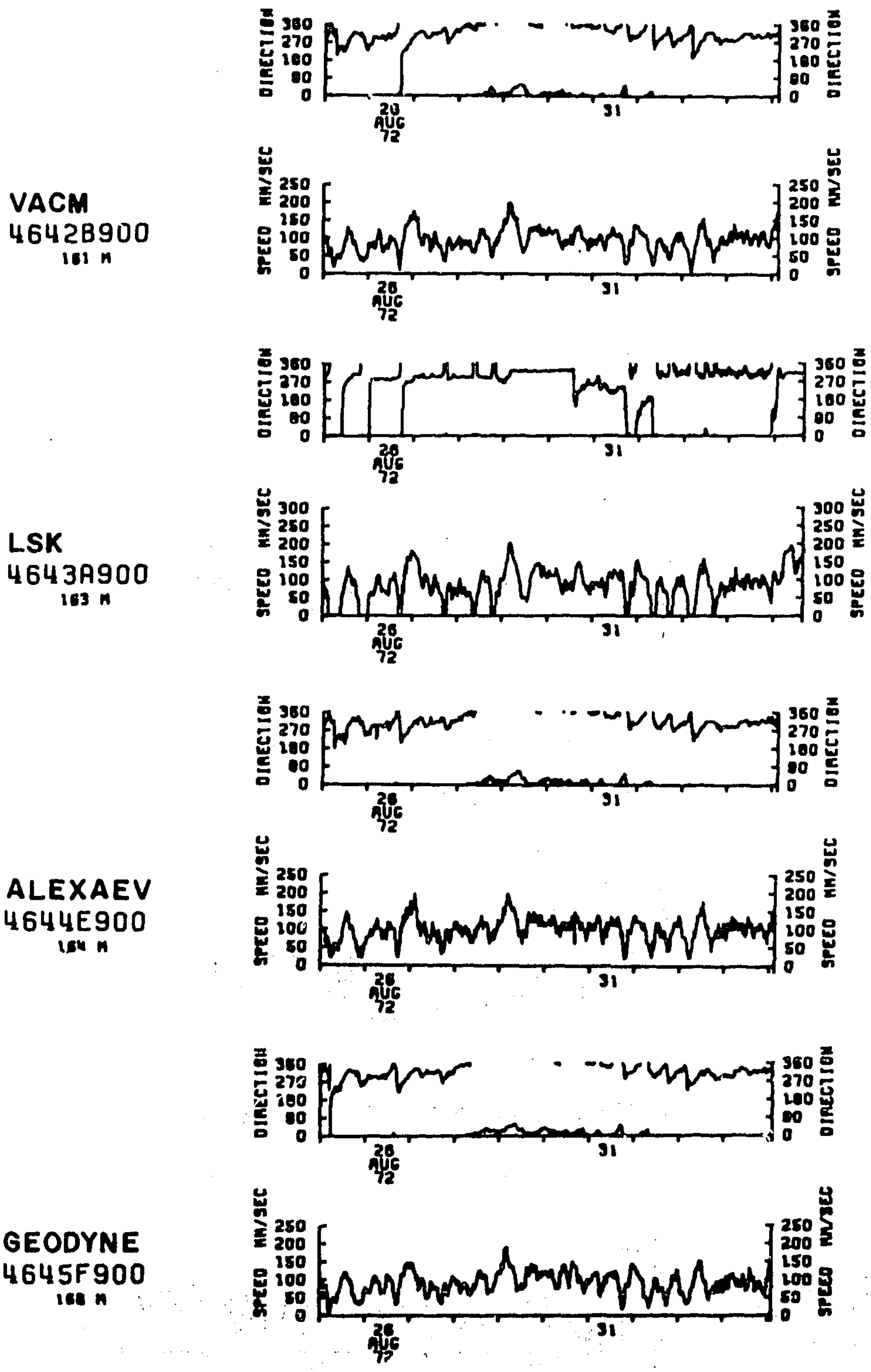

Figure 5B.

Speed and direction time series for the instruments at the 200 m level on subsurface mooring records.

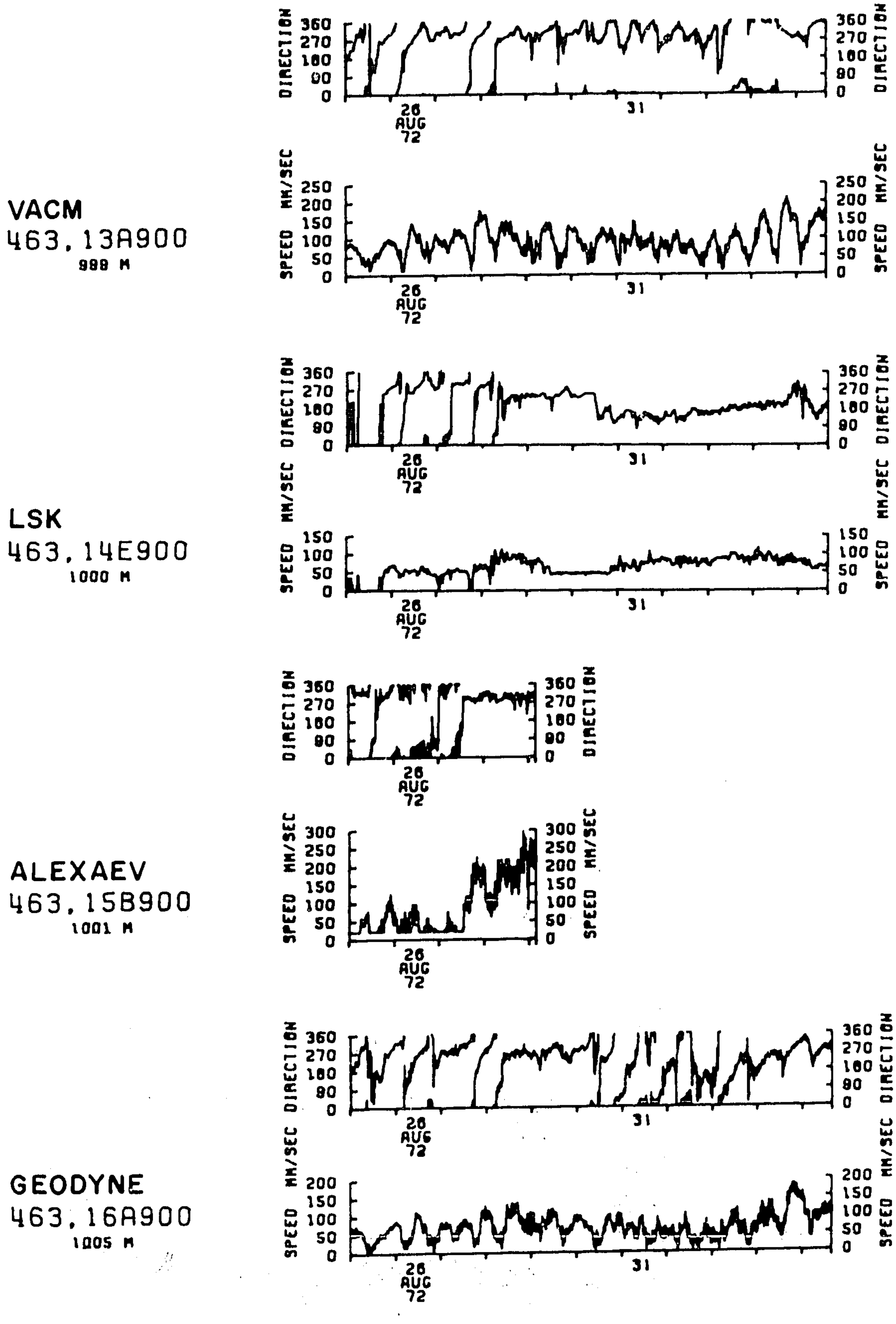

Figure 6A.

Speed and direction time series for the instruments at the 1000 meter level on surface mooring records.

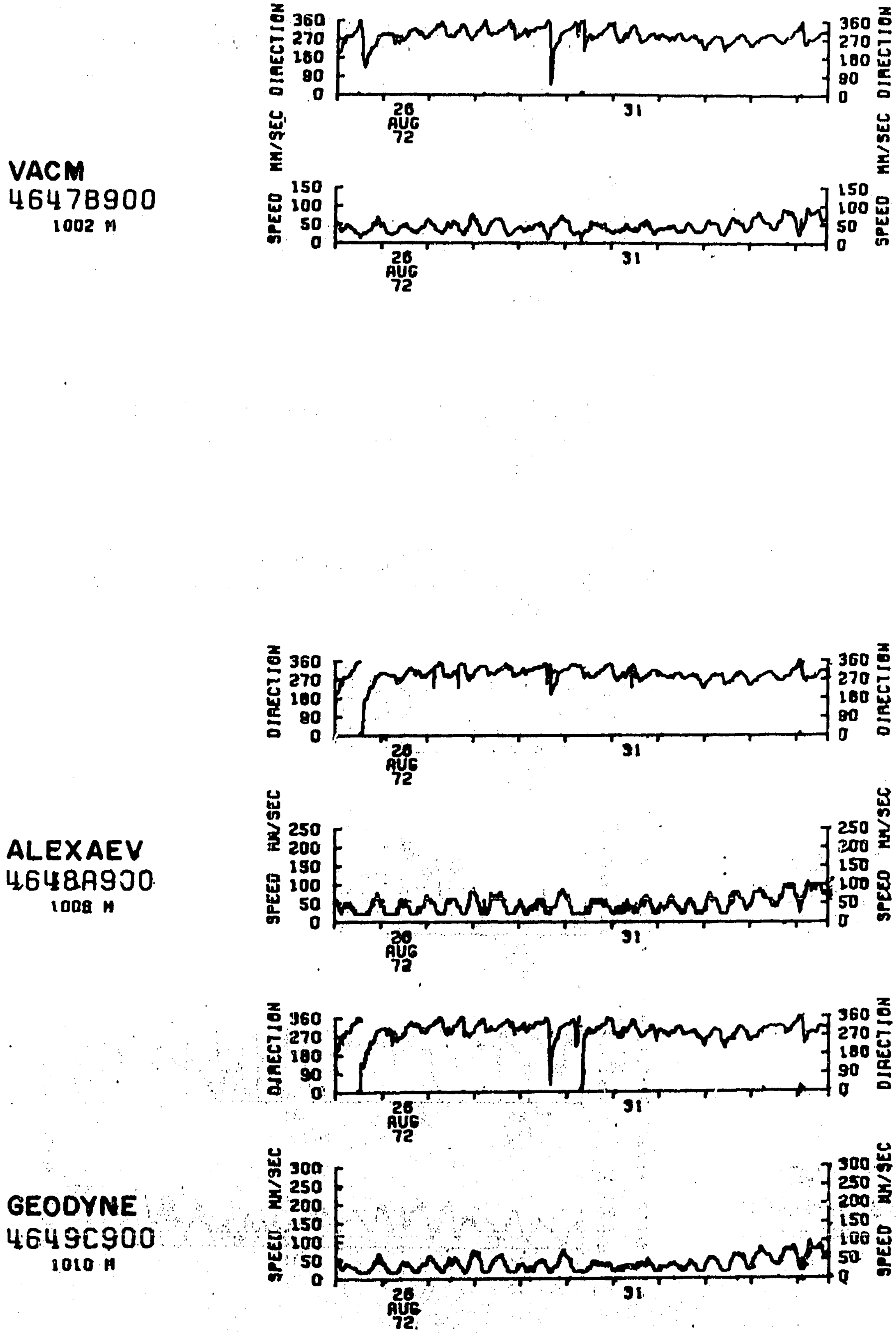

Figure 6B.

Speed and direction time series for the instruments at the 1000 meter level on subsurface mooring records.

Table 2   Net Current Properties

Instrument	$\overline{U}$ cm/sec	$\overline{V}$ cm/sec	Mean Velocity cm/sec	Net Direction	Vector Variance $(cm/sec)^2$
Surface 50 m A	-7.3	10.8	13.1	326°T	238.1
V	-3.9	9.5	10.3	338°	74.9
G	-1.6	8.4	8.6	349°	56.0
L	-3.3	10.5	11.0	342°	102.4
Surface 200 m A	-3.2	9.6	10.1	341°	50.9
V	-3.4	8.9	9.5	339°	46.2
G	-4.4	8.1	9.2	331°	30.1
L	-3.8	7.6	8.5	334°	52.9
Subsurface 200 m A	-3.5	6.7	7.6	332°	26.5
V	-4.1	6.0	7.3	326°	22.5
G	-2.7	6.4	7.0	338°	21.5
L	-6.0	2.9	6.6	296°	27.6
Surface 1000 m A	Short Record				
V	-5.3	4.2	6.8	309°	27.6
G	-3.8	-0.2	3.8	268°	23.2
L	-1.1	-3.0	3.2	200°	16.4
Subsurface 1000 m A	-3.9	1.6	4.2	293°	4.6
V	-3.7	1.3	3.9	289°	3.7
G	-3.0	1.5	3.3	296°	3.4

The 1000 m surface buoy records (Figure 6A) show similar but not identical speeds from the Geodyne and VACM instruments. However, after about 0600 GMT, August 30, the two direction records disagree. The Alexaev record is short as noted in Table 1. The Alexaev and LSK records disagree substantially with each other and with the other meters. These disagreements may point to instrument damage at an early stage of the experiment. On the subsurface mooring at this level (Figure 6B) the agreement among all the records of speed and direction is good.

5.2 Mean Current Properties

The mean properties of the current records are shown in Table 2. The mean velocities show a characteristic trend in virtually every group, i.e., the Alexaev meter gives the largest value, the VACM next followed by the Geodyne and LSK instruments. The mean velocity values for instruments in the same groups generally differ by less than 1 cm/sec; the exceptions are the 50 m group where values range from 13.1 to 8.6 cm/sec and the 1000 m group on the surface mooring where there were serious instrument malfunctions.

The net direction shows variations in the differences among the instruments in each group. The 200 m surface and 1000 m subsurface records have deviations from the respective mean directions of less than 6°. The 50 m and 200 m subsurface records also show fairly small deviations from the mean. However, the 1000 m surface records show large differences and this may again point to instrument damage.

In comparing the records at the same level but on different moorings, one notes that the velocities on the surface mooring are consistently higher than those on the subsurface mooring. This is true for all instruments. At 200 m the average ratio of the mean velocities (surface mooring/subsurface mooring) is 1.3; at 1000 m the ratio is 1.5.

5.3 Progressive Vector Diagrams

The net current can be considered as the velocity associated with the displacement vector drawn directly from the beginning to the end of a progressive vector diagram. The progressive vector diagrams constructed from these time series (Figure 7) give a clear representation of the similarities and the differences among the low frequency components of the records. At 50 m there are some differences in the mean direction within the group of meters. The LSK instrument shows a constant direction after 2 September which may indicate instrument damage. The Alexaev record contains considerably more low frequency energy than either the Geodyne or the VACM.

At 200 m there is general agreement among all instruments on the surface mooring and among all except the LSK meter on the subsurface mooring. However, there are marked differences between the surface and subsurface records. The velocities measured by all instruments on the surface mooring are greater than those measured on the subsurface mooring.

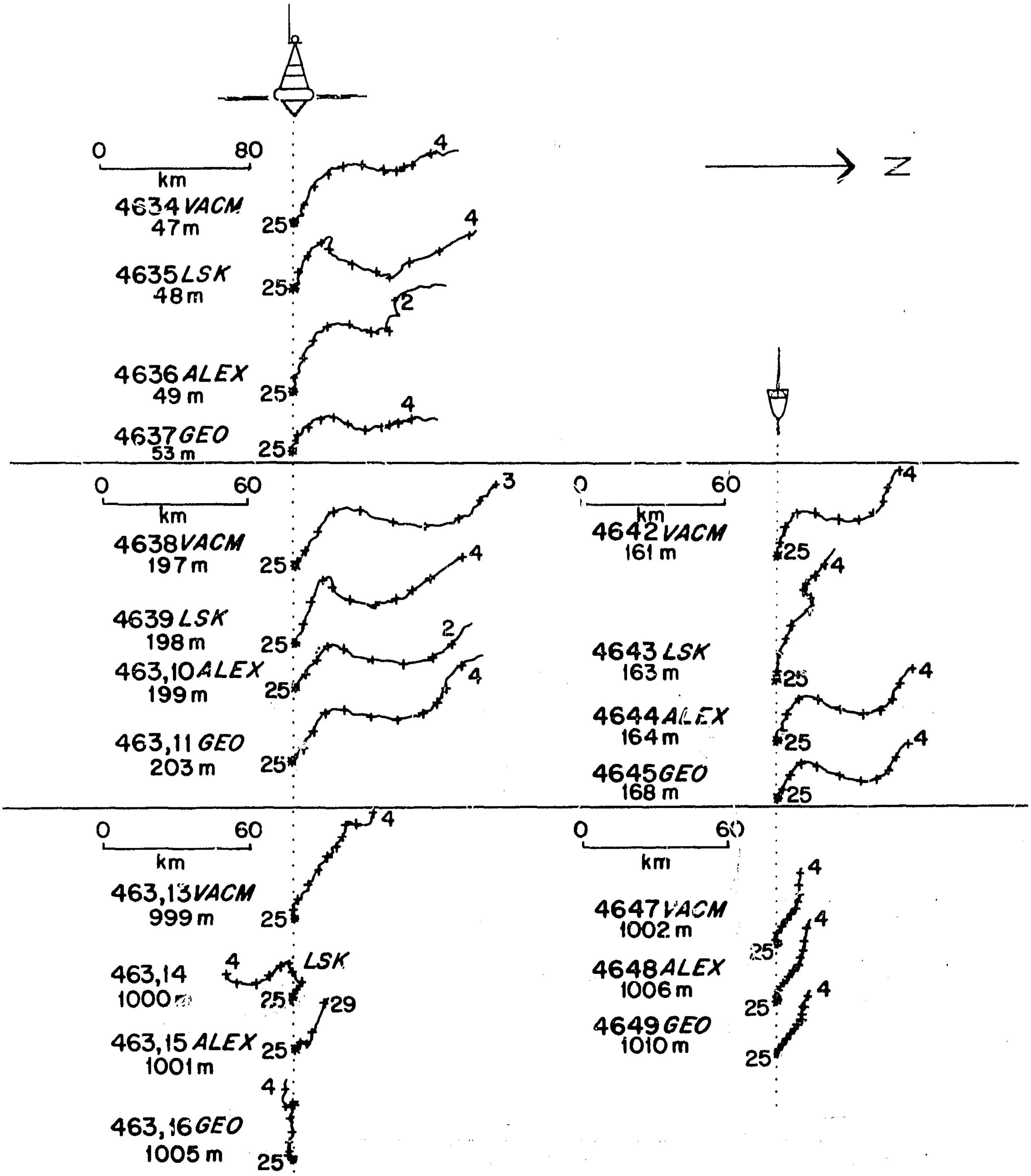

Figure 7.

Progressive vector diagrams for the records on both moorings. The dates correspond to the beginning of each day from August 25 to September 4th.

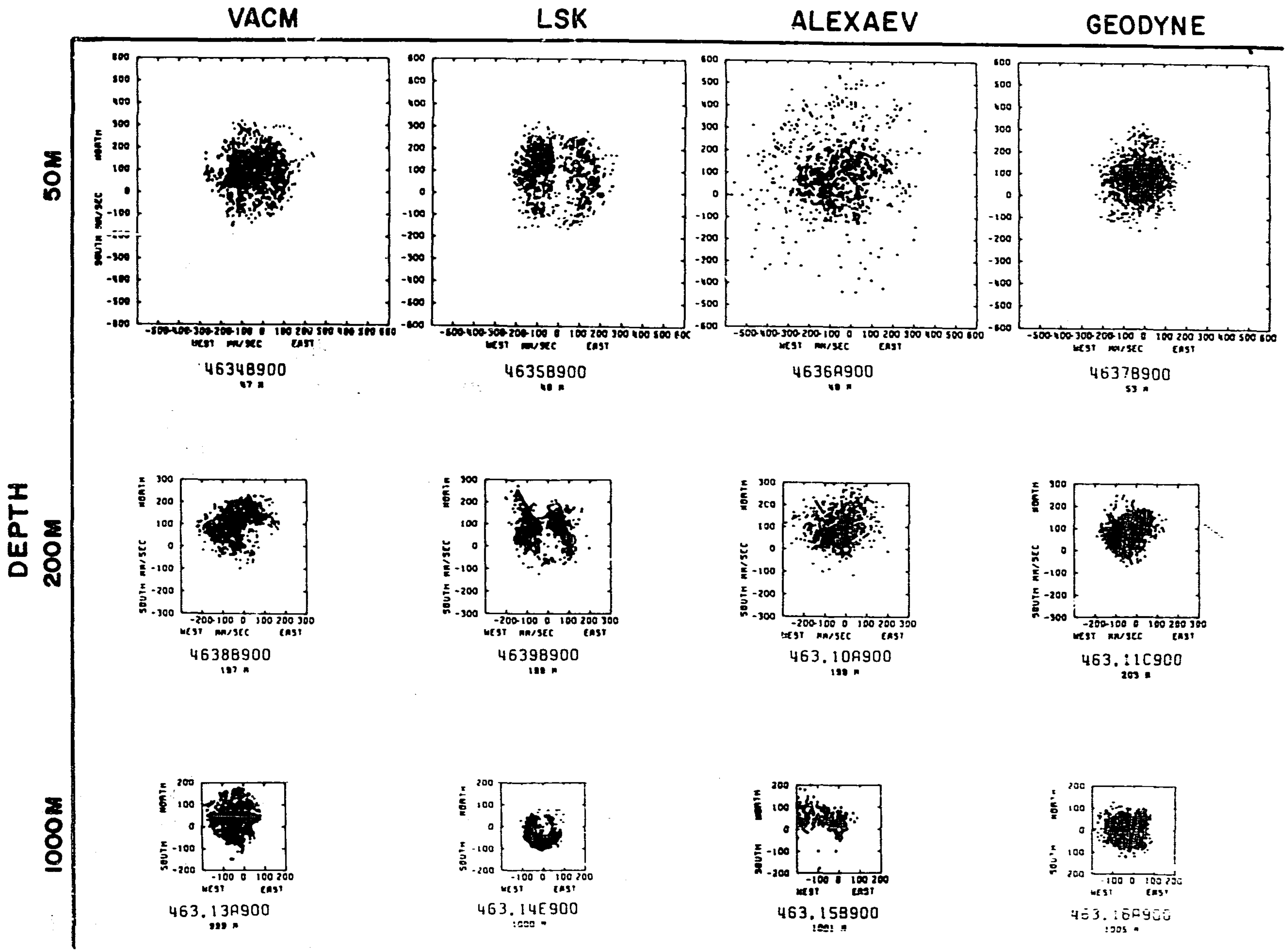

Figure 8A. Vector distribution diagrams for the data records on the surface mooring.

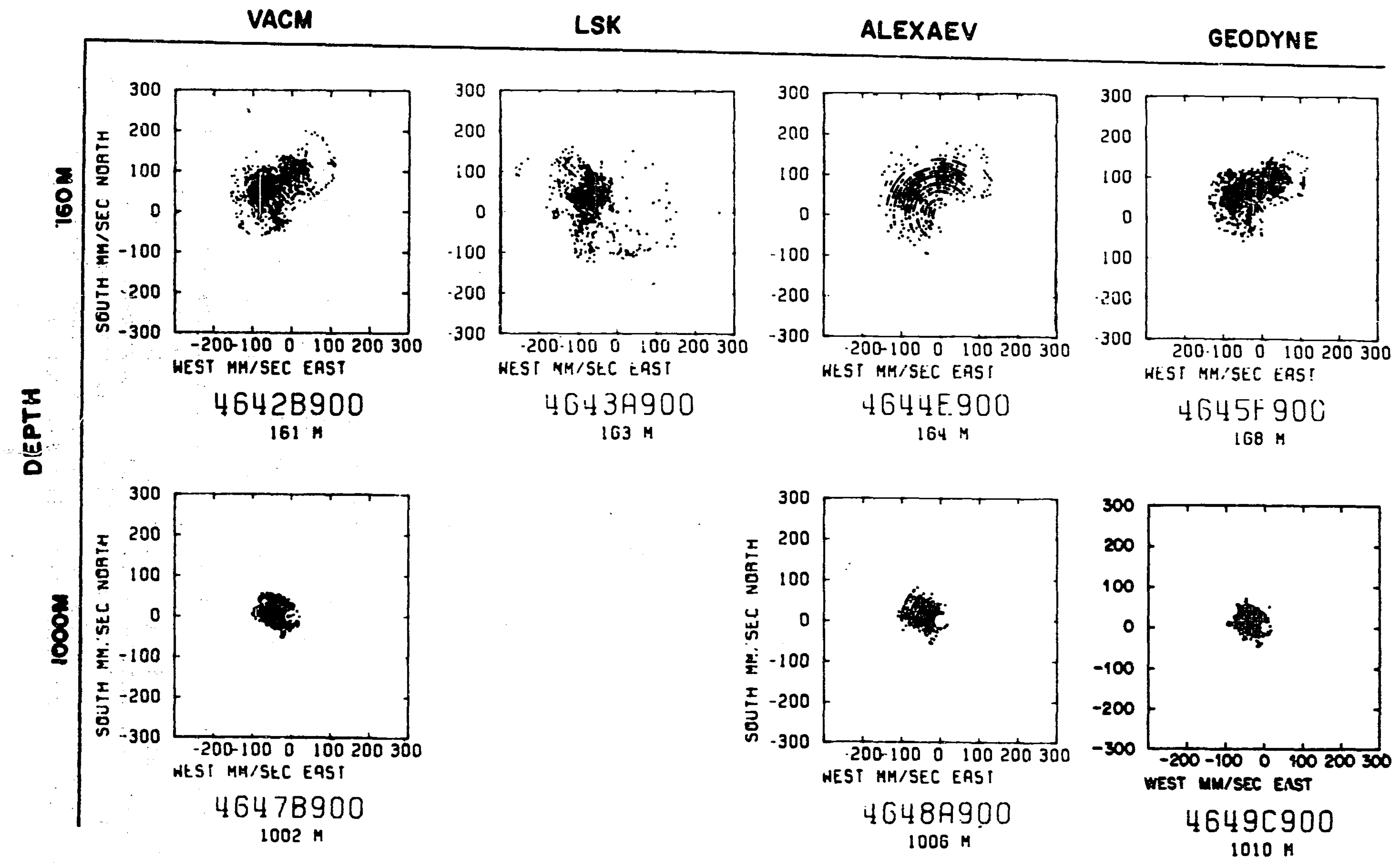

Figure 8B. Vector distribution diagrams for the data records on the subsurface mooring.

At 1000 m there is evidence that the severe damage to the instruments on the surface mooring has invalidated the records. The records from the subsurface mooring agree fairly well.

5.4 Current Variability

A consideration of the deviations of the currents from their mean values gives information concerning the instrument responses. The vector variance of each series is included in Table 2. This parameter reflects the variability seen by the sensor. As one would expect the vector variance drops continually for a given instrument as the mooring depth increases. Except at the 50 m level the agreement among the instruments is good. The most striking feature of the vector variance measurements is the large difference between similar instruments on the two moorings. The average ratio of surface to subsurface observations is 1.8 at 200 m and 7.1 at 1000 m.

In Figure 8 the vector distribution plots for the 18 available data records are shown. Each point on these plots corresponds to the head of a velocity vector from the 15-minute time series. The plots cover the standard data interval whenever possible. Since an extensive discussion of such plots was included in the SCOR-2 report only a few features will be noted here. First, one notices that there are no holes larger than the instrument thresholds in any of the distributions. This indicates a fairly good match between speed and direction sensors' response times. The result here is consistent with the observations in SCOR-2. The structure observed in the 200 m LSK record on the surface mooring may indicate instrument damage. A consistent feature in all records is the tightening of the distributions in the subsurface records as compared to the surface records. This again characterizes the latter as being relatively noisy.

5.5 Speed Comparison

The speeds measured by the different instruments at the same level can be compared by plotting the speed of one instrument versus the speed of another. Figures 9 and 10 show these plots for the surface and subsurface moorings respectively.

Considering first the instruments on the surface mooring, the speed plots show a large scatter at all levels. However, some features are clear. The Alexaev current meter tends to read high compared to any of the other instruments. This result agrees with the results of SCOR-2. The two instruments which agree most closely are the Geodyne 850 and the VACM. This is to be expected since they have similar sensors and only the sampling technique is different.

The speed intercomparison for instruments on the subsurface mooring (Figure 10) differs dramatically from that on the surface mooring. The scatter in the distributions has been greatly reduced. There is greater agreement between all instruments. The discrepancy between the incremental response of the Alexaev instrument and the other meter is greatly reduced. The SCOR-2 experiment employed only surface moorings, thus the speed differences were noted.

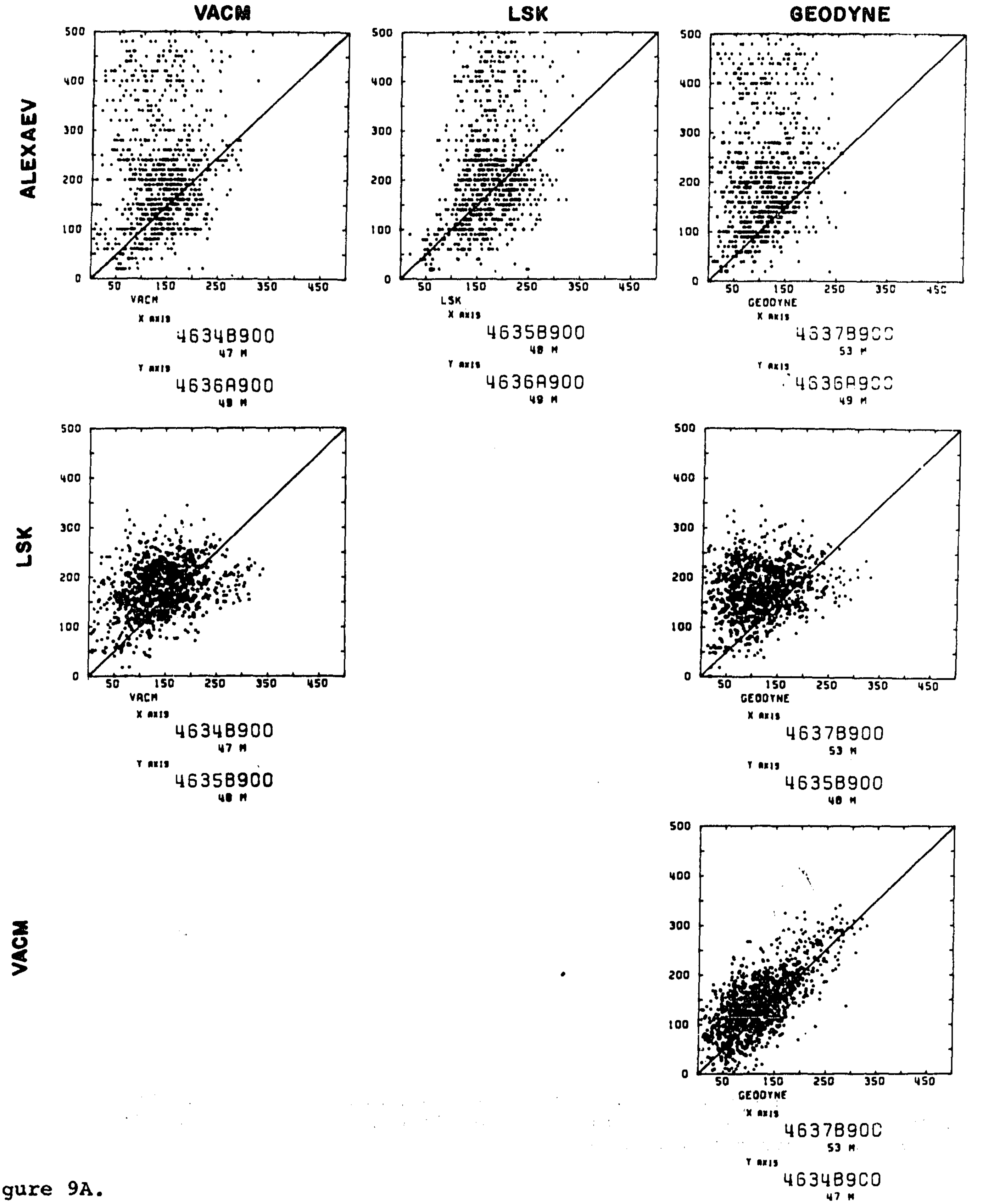

Figure 9A.

Comparison of the speed measurements for instruments at 50 m. The instruments at each level are compared. The diagonal line indicates the result if both instruments record the same speed.

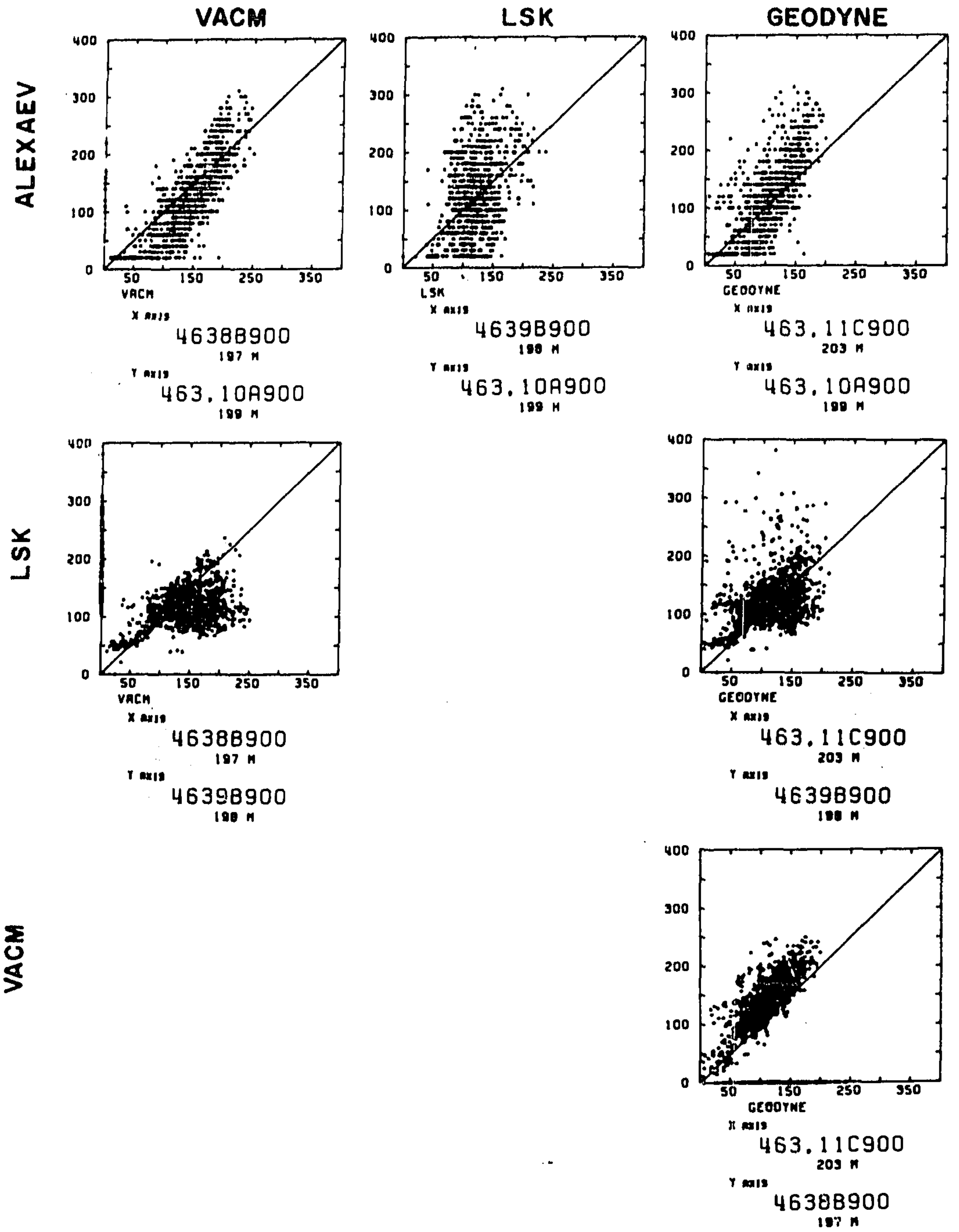

Figure 9B.

Comparison of the speed measurements for instruments at 200 m. The instruments at each level are compared. The diagonal line indicates the result if both instruments record the same speed.

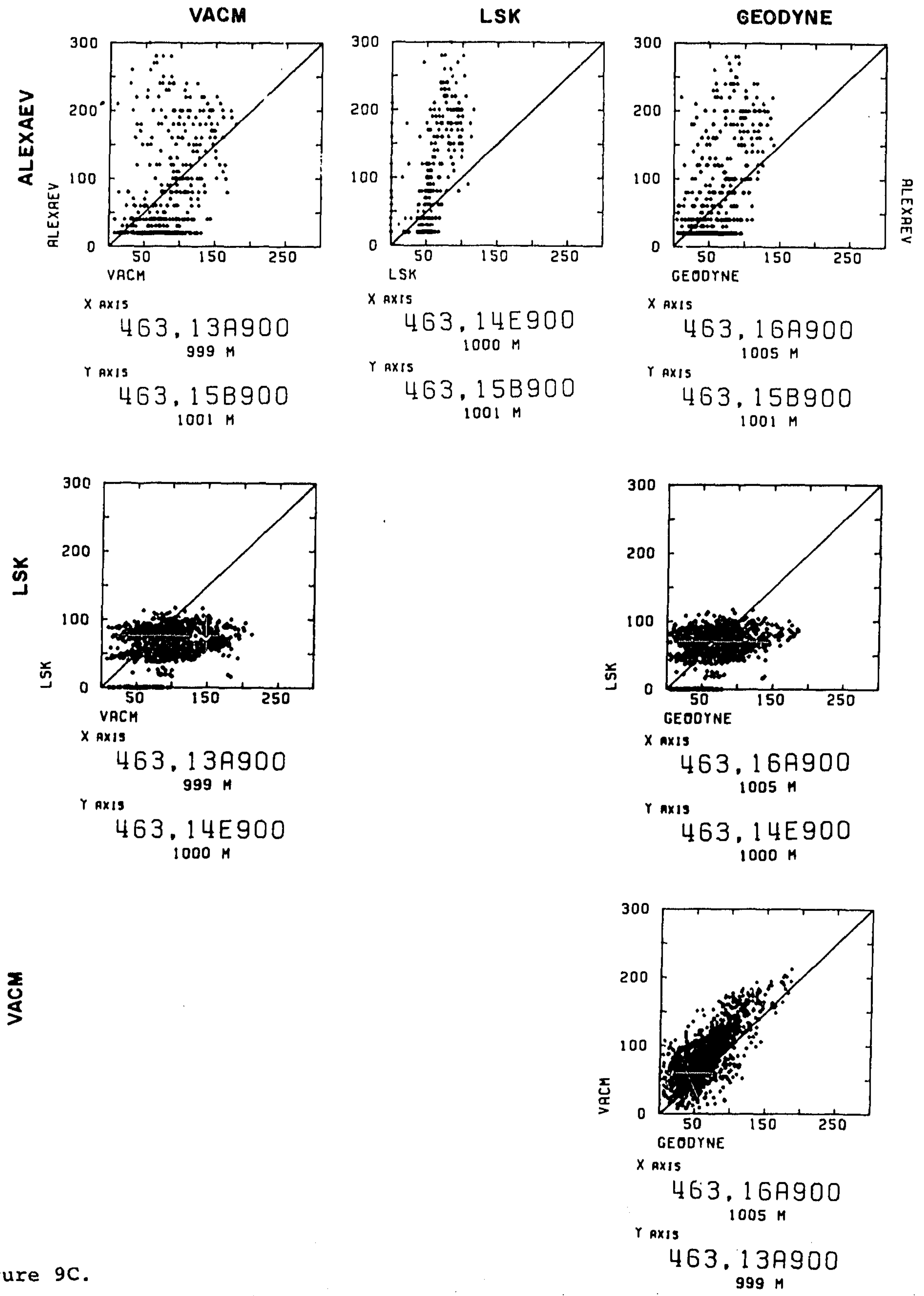

Figure 9C.

Comparison of the speed measurements for instruments at 1000 m. The instruments at each level are compared. The diagonal line indicates the result if both instruments record the same speed.

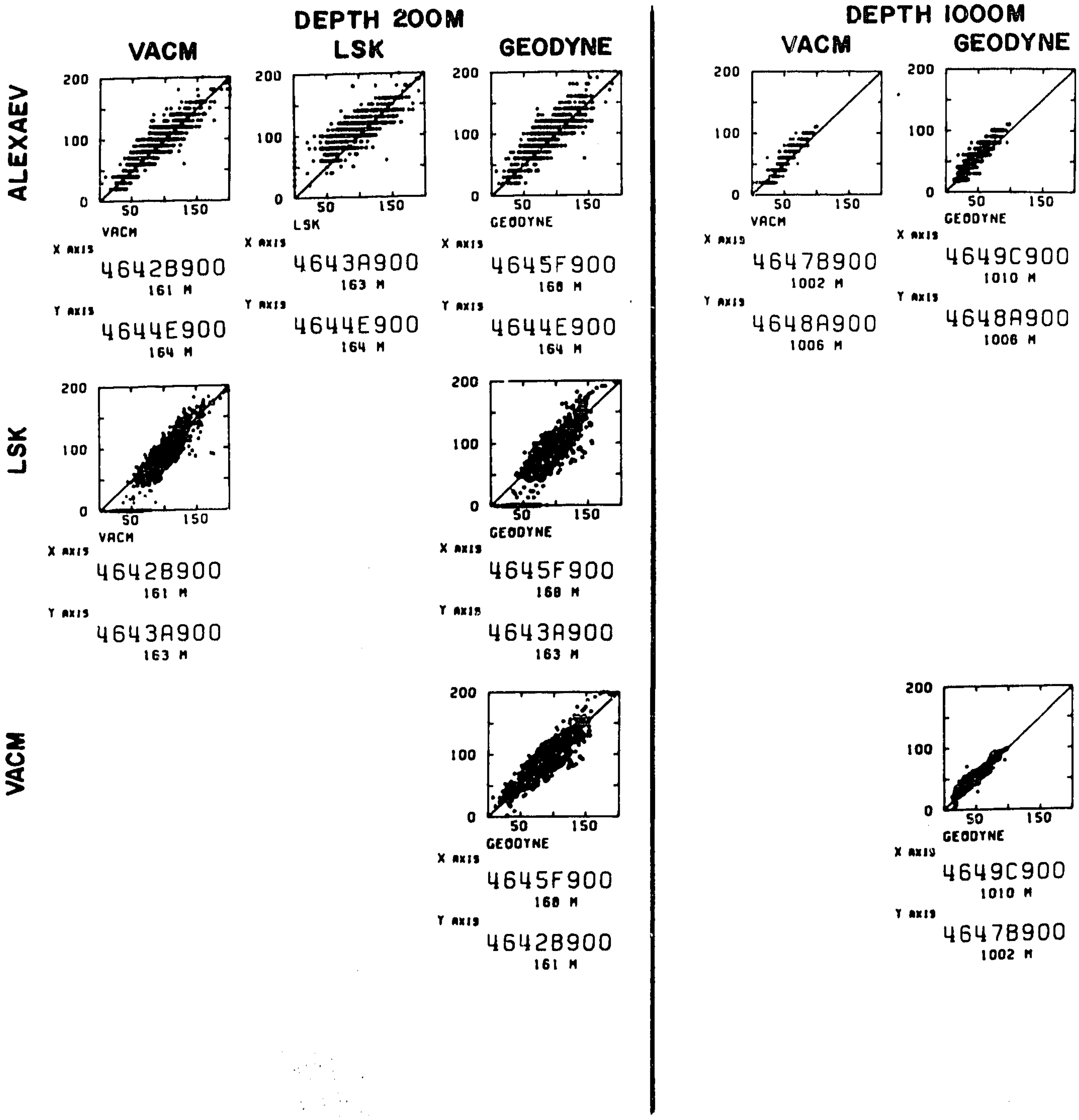

Figure 10.

Comparison of the speed measurements for instruments on the subsurface mooring. The instruments at each level are compared. The diagonal line indicates the result if both instruments record the same speed.

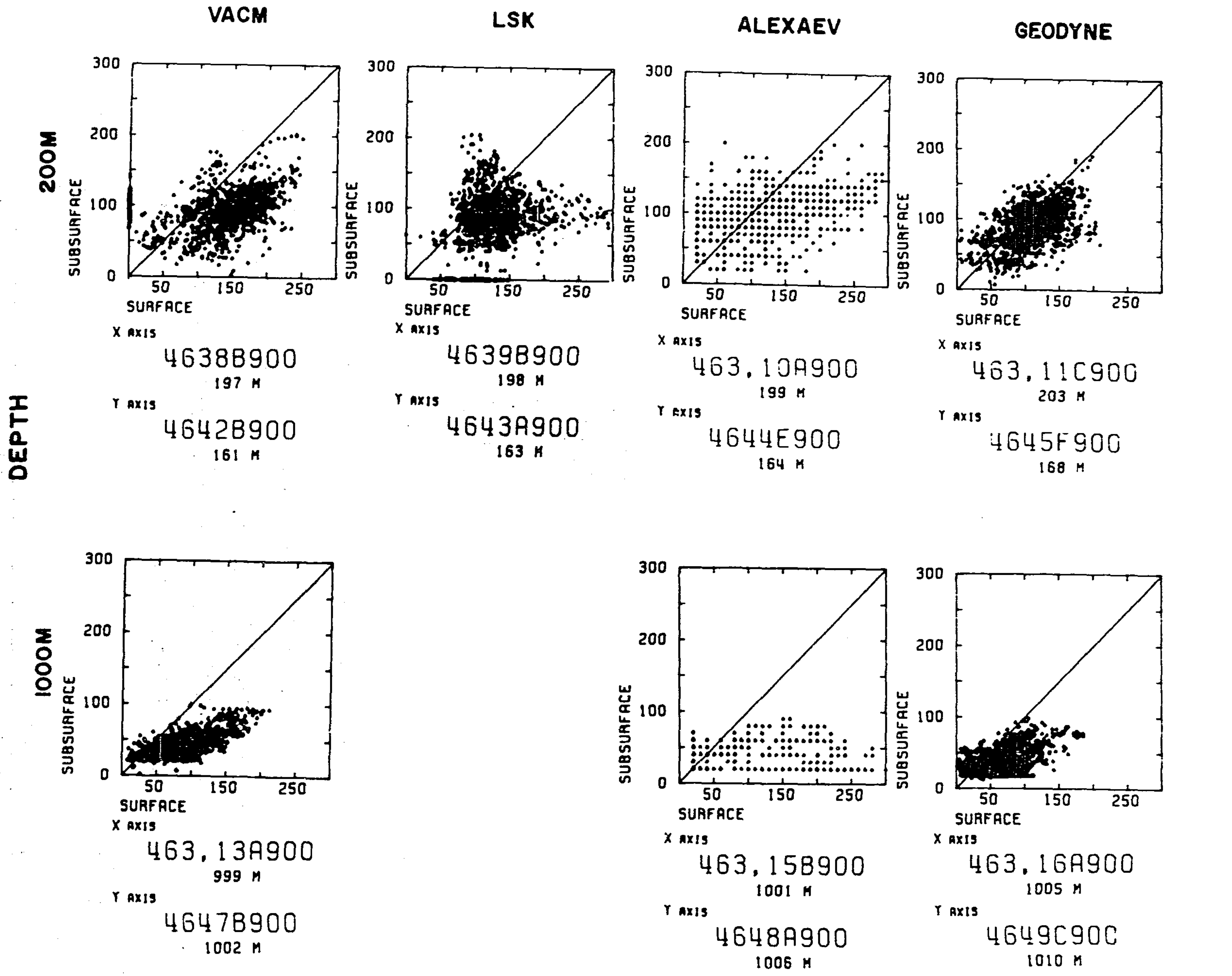

Figure 11. The comparison of speed measurements between surface and subsurface moorings for each instrument type. The instruments at each level are compared. The diagonal line indicates the results if both instruments record the same speed. Speed units are mm/sec.

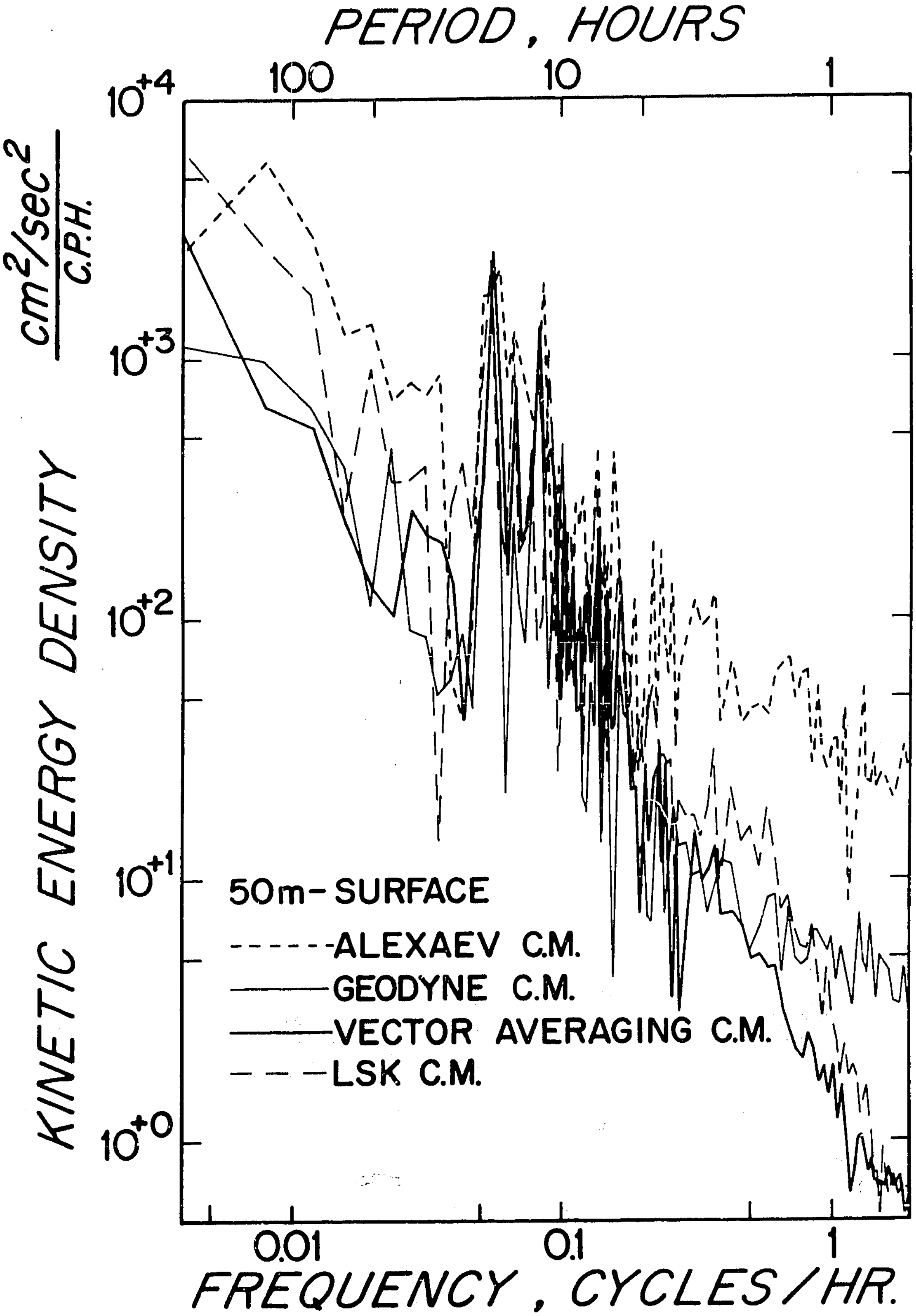

Figure 12.

The frequency spectra of the kinetic energy density for instruments at 50 m on the surface mooring.

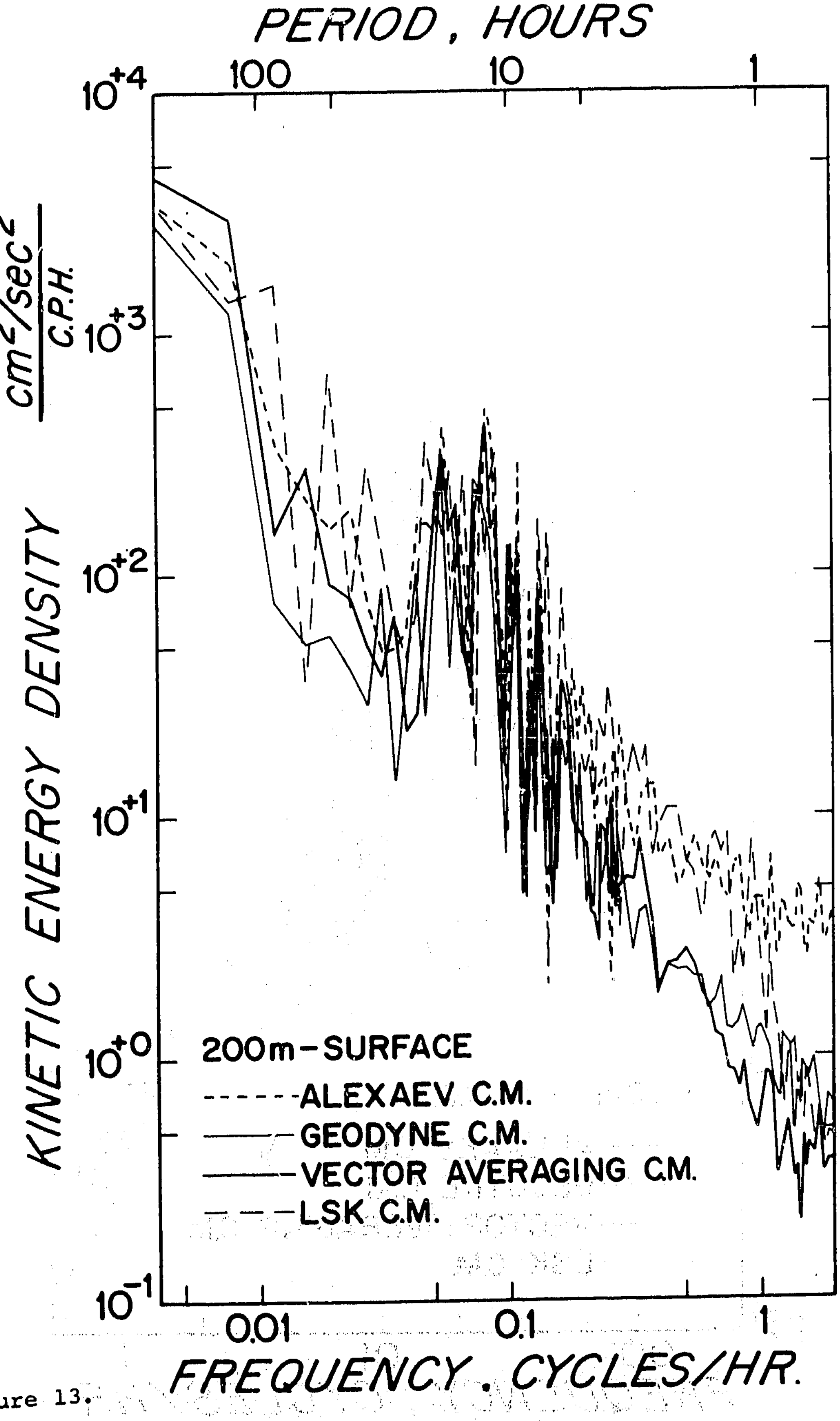

Figure 13.

The frequency spectra of the kinetic energy density for instruments at 200 m on the surface mooring.

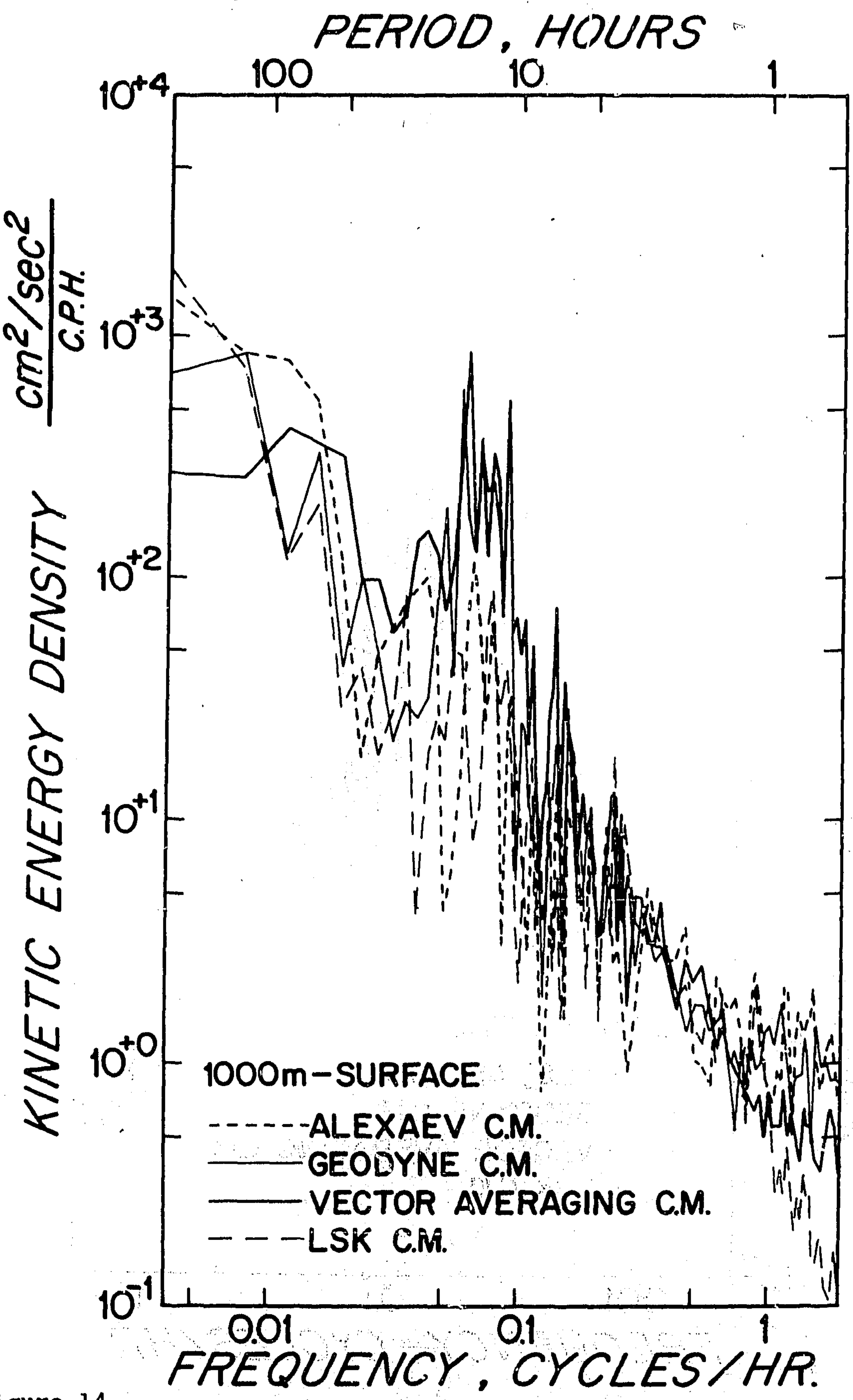

Figure 14.

The frequency spectra of the kinetic energy density for instruments at 1000 m on the surface mooring.

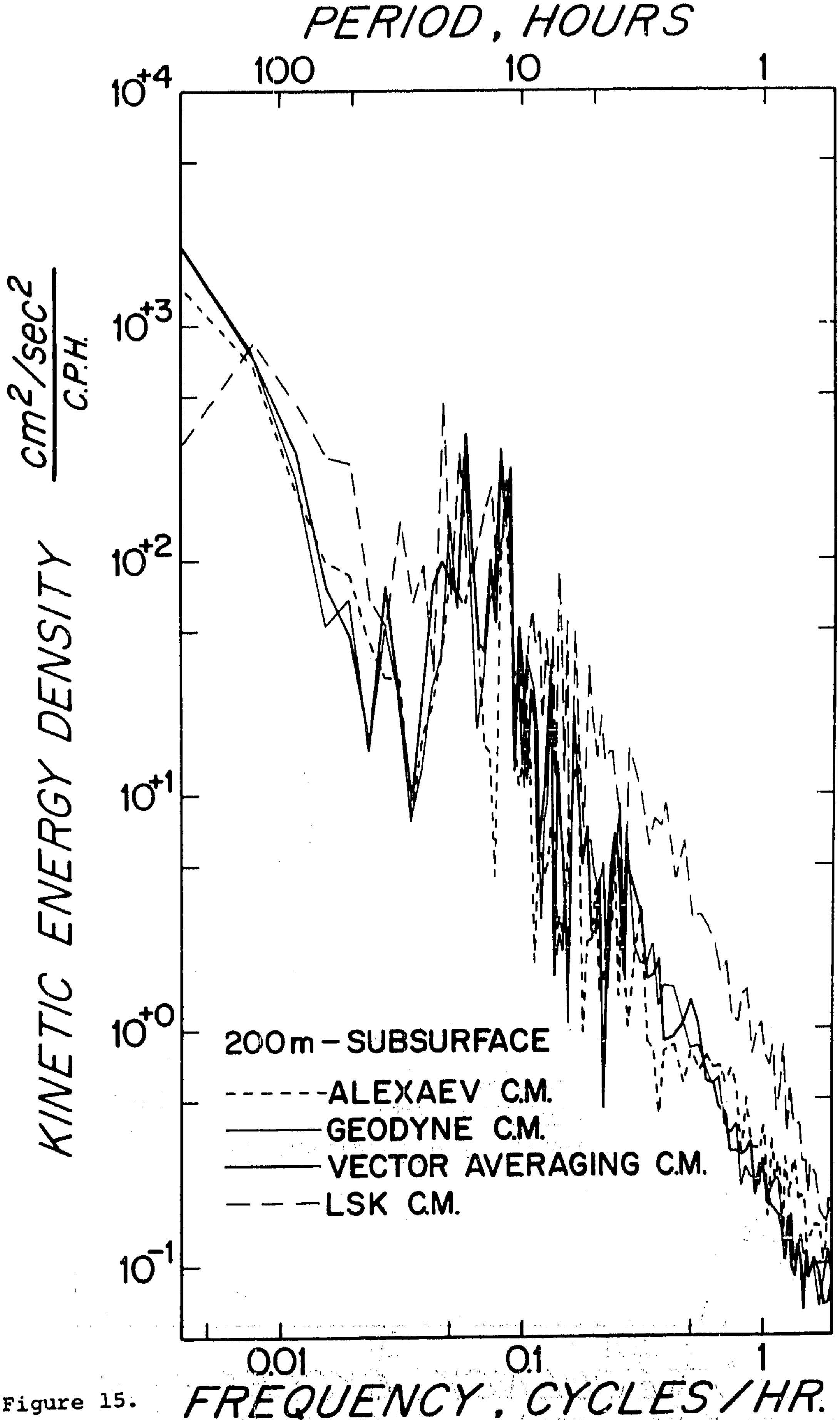

Figure 15.
The frequency spectra of the kinetic energy density for instruments at 200 m on the subsurface mooring.

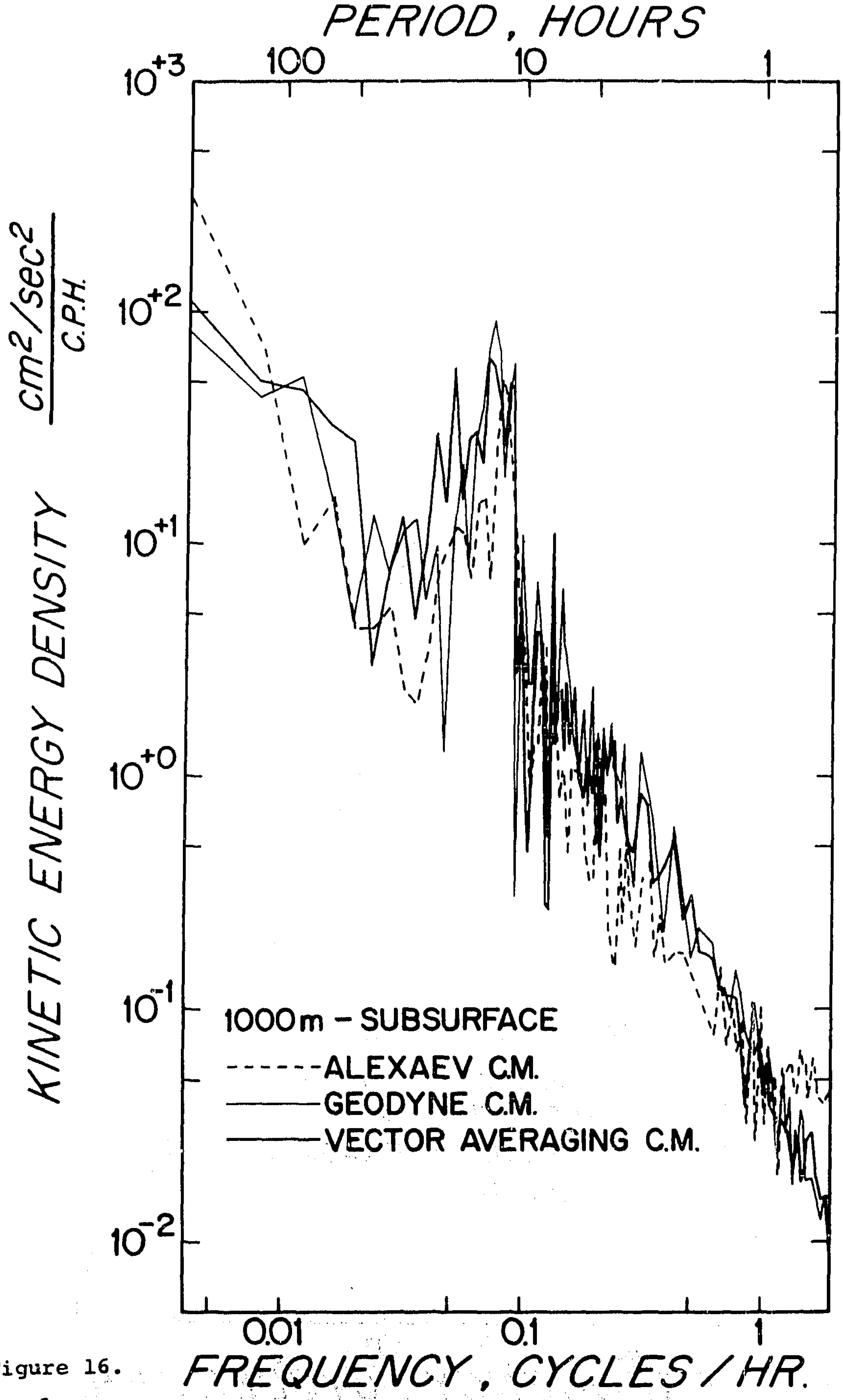

Figure 16.

The frequency spectra of the kinetic energy density for instruments at 1000 m on the subsurface mooring.

The relatively large scatter on the LSK intercomparison plots at 200 m on the subsurface buoy reflect the large difference in mean current properties noted earlier. This again may be due to instrument damage.

Figure 11 shows the speed comparison plots for similar instruments on the two different moorings. In general speeds on the surface mooring are higher; however, the large fluctuations sometimes yield a lower result. Taking the VACM record at 1000 m as an example, a speed of 5.0 cm/sec on the subsurface mooring can correspond to a speed of anywhere from 2.5 cm/sec to 15 cm/sec on the surface mooring with about equal probability. For most records there is little correlation between the speeds measured by the same instrument at the same level on the two different moorings.

5.6 Spectral Characteristics

Figures 12-16 give the observed spectra at each level. Any records which were shorter than 1024 data points were extended with zeros. Only in the 1000 m Alexaev record did this amount to a large fraction of the data points. In general the records at each level agree fairly well at low frequencies. The high frequency behavior depends on the mooring and the instrument.

On the surface mooring at 50 m and 200 m the energy density measured by the Alexaev meter is significantly higher near the Nyquist frequency than the energy density measured by the other meters, as is to be expected from the sampling interval used. At 200 m the LSK, Geodyne, and the VACM records agree at high frequencies. The Alexaev record is about a factor of five higher. At 1000 m there is fair agreement between all instruments except the LSK which has a lower energy level at high frequency.

In SCOR-2 it was noted that the LSK spectra generally fell more rapidly at high frequency than the other spectra. It was thought that this could be due to filtering in the meter or to an actual difference in the level of high frequency noise at the instrument. However, since the LSK and VACM records agree fairly well at high frequencies, it appears that the LSK instrument may be less sensitive to noise than the Alexaev or Geodyne. It is difficult to estimate how much of this difference may be due to manual smoothing of the LSK records in generating the 15-minute time series. The sampling technique used on the VACM should reduce its susceptibility to high frequency noise.

The spectra for the records from the subsurface mooring agree fairly well at both levels. Only the 200 m LSK record has a significantly different shape from the others. As mentioned earlier the progressive vector diagram for this instrument is also anomalous and may indicate a malfunction.

5.7 The Mooring Intercomparison

Throughout this report differences in current measurements obtained by one instrument on a surface mooring and one on a subsurface mooring have consistently appeared. These differences have

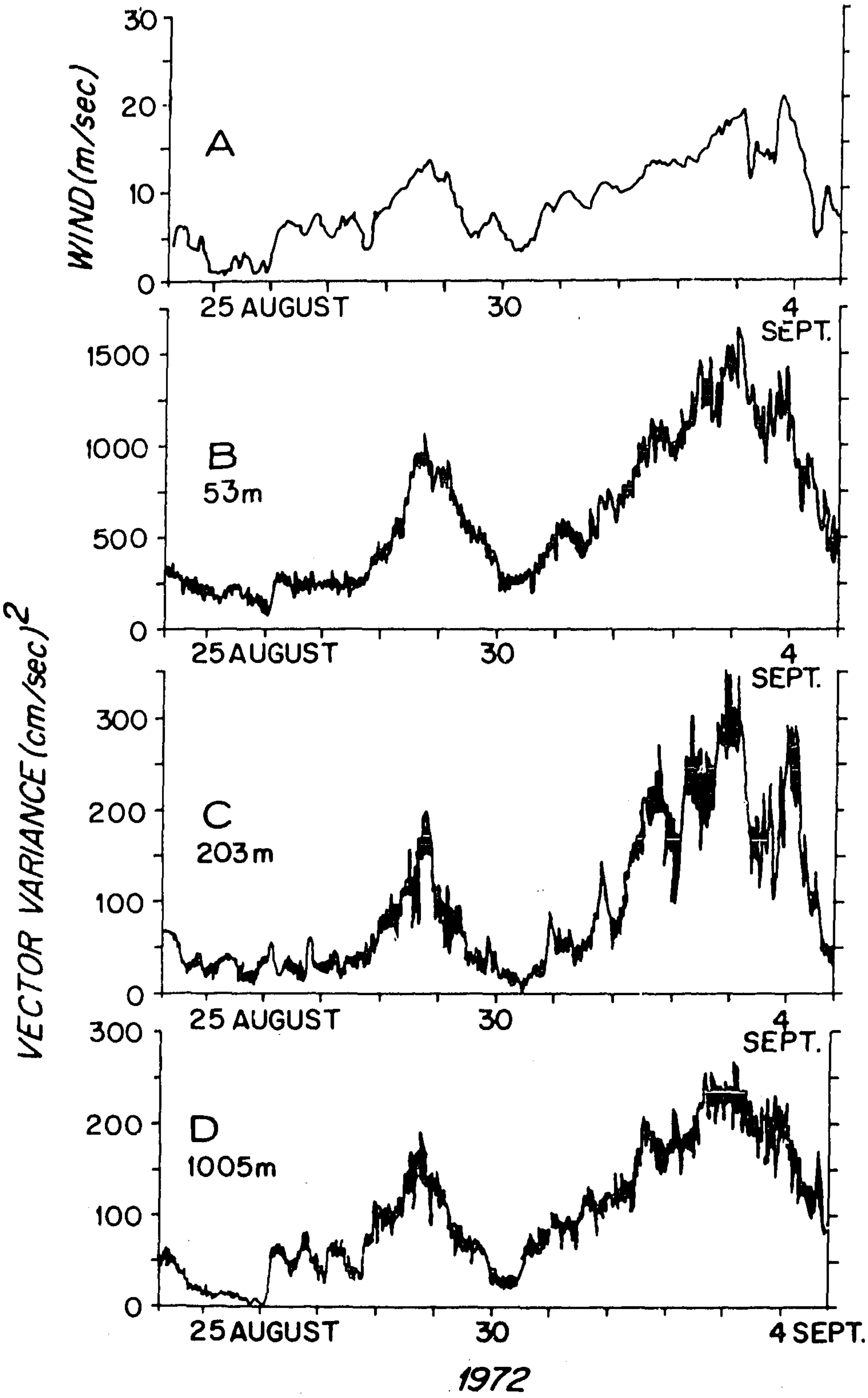

Figure 17.

Surface mooring records. (a) The wind record (4631) time series. The vector variance (see text for definition) for the samples in the Geodyne model 850 data bursts at (b) 53 meters (4637) (c) 203 meters (463,11) and (d) 1005 meters (463,16).

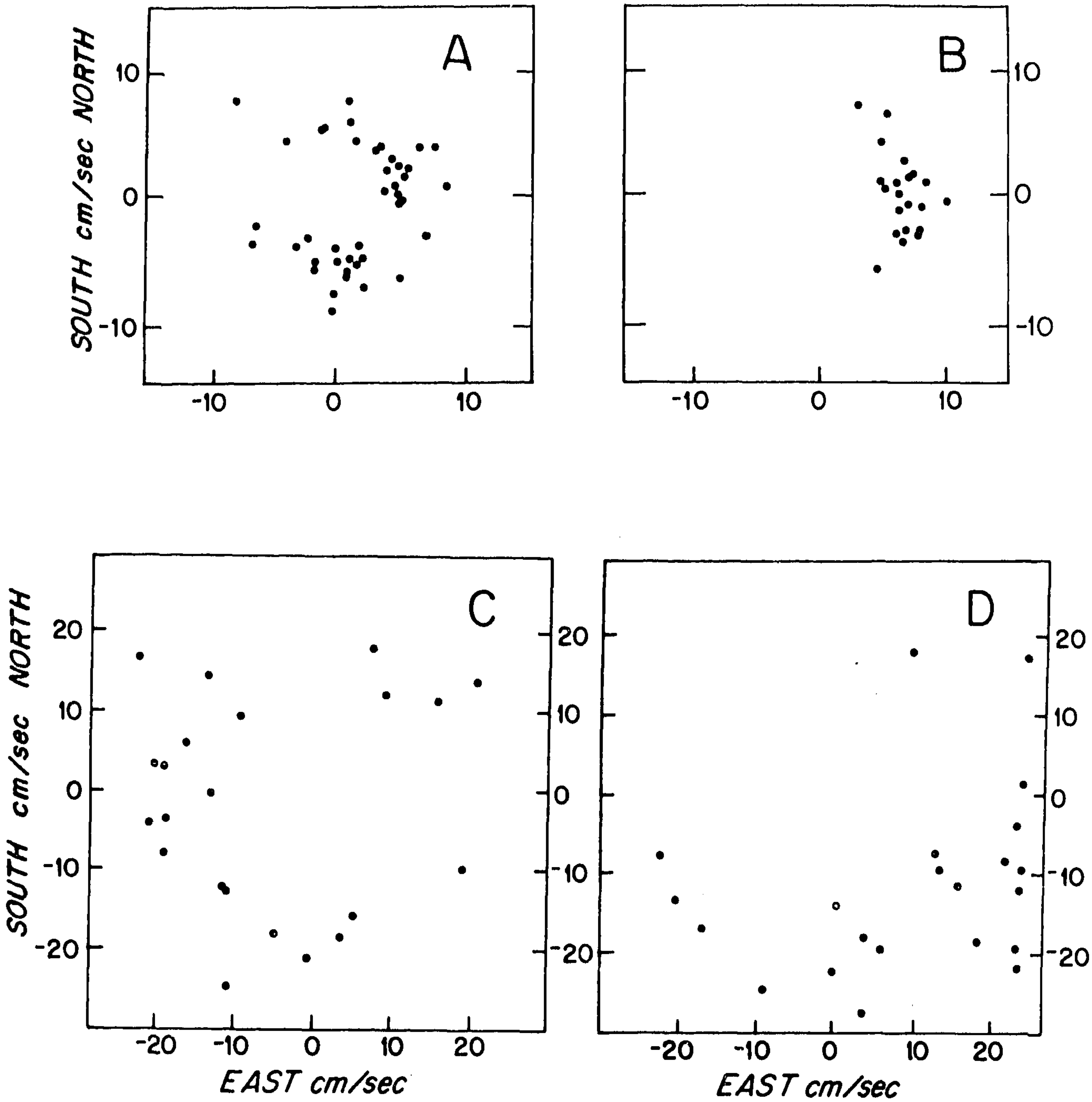

Figure 18.

Vector distribution diagram for the data samples in a Geodyne model 850 data burst. Record 463,16 was used.
(a) low wind speed, low mean current
(b) low wind speed, high mean current
(c) high wind speed, low current
(d) high wind speed, high current

been ascribed to noise generated by surface wave action and propagated along the mooring line. Some characteristics of this noise will be considered now.

The sampling technique of the Geodyne Model 850 current meter allows one to make an estimate of the noise present. The Model 850 samples a burst of 22 readings of speed and direction taken at nominal 5-second intervals and recorded every 3.75 minutes. The variances of the values within the bursts of data can be computed from the equation:

$$\sigma^2 = \frac{1}{n} \sum_{i=1}^{n} \left((E_i - \bar{E})^2 + (N_i - \bar{N})^2 \right)$$

where E_i and N_i are the individual values of east and north velocity components and $\bar{E}$ and $\bar{N}$ are the averages of these components. Fifteen-minute average values of σ^2 were calculated and the resultant time series is presented in Figure 17 for the three instrument levels on the surface mooring. Figure 17a shows the time series from the wind recorder for comparison. It is clear that the structure of the variance record is directly related to the surface wind. The features can easily be traced down to 1000 m. The attenuation between the 50 m record and the 200 m record is large, but there is not much loss from 200 m down to 1000 m. The vector variances for the subsurface records were also calculated. They were typically a factor of 500 smaller than those at 200 m on the surface buoy and show no correlation with the wind record.

These results indicate that the noise measured by an instrument on a surface mooring is correlated with the surface wind speed. Vector plots of the individual samples in a Model 850 burst are shown in Figure 18 for four different cases. The trend is what one would expect: when the current is small the vector fluctuations tend toward isotropy. When the current is large the vectors fluctuate about the mean; the angle of the fluctuations depends on the noise level. The amplification which is observed in the surface mooring records may be due to the vane not canceling all the noise contributions to the rotor rate.

6. Conclusions

(a) Agreement is excellent among all instrument types (except the LSK meter) at both levels on the subsurface mooring. The LSK meter may have been malfunctioning. The subsurface mooring appears to provide a quiet situation in which the conditions approximate those under which the instruments are calibrated.

(b) There are large differences in the high frequency parts of the energy spectra between the two types of mooring and also between the various instruments on the surface mooring. These differences indicate the presence of high frequency (above the Nyquist frequency) noise on the surface mooring. The response of the various current meters to this high frequency noise differs and is partly explainable in terms of the different sampling schemes used. The LSK and VACM spectra appear to be less affected than the Alexaev and Geodyne spectra.

(c) At both levels higher mean velocities are registered on the surface mooring than on the subsurface mooring.

(d) The differences observed in the second SCOR experiment between speeds measured by the Alexaev meter and those measured by the other meters are due to differences in the effects of the high frequency noise. On the subsurface mooring the records agree.

(e) The measurement of the burst vector variance in the Geodyne records from the surface mooring indicates that the surface wave noise is propagated throughout the mooring line. The low burst variance level observed on the subsurface mooring indicates that it is a much quieter situation.

7. Recommendations

(a) Wherever possible, existing current meters should be used in subsurface moorings. How deep the float should be will depend on the local situation and the purpose of the observations, but the possible effects of wave-induced motions should be kept in mind.

(b) Further study of the effects of mooring design and instrument mounting on the velocities measured by the current meters should be undertaken by the instrument users. In particular the problems inherent in near-surface measurements require additional attention.

(c) Designers and intending users of new types of current meters (e.g. electromagnetic, acoustic) should evaluate them by intercomparison with other current measuring techniques as a necessary part of the development of the current measuring system.

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Automatic recording C.M. of Alexaev system type BPV-2 and BPV-2p Izdatelstvo "Morskoi Transport", Leningrad, 1963, 56 pp. (in Russian).

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VACM:

Vector Averaging Current Meter (1973) AMF Electrical Products Development Division of AMF Incorporated. Alexandria, Virginia, U.S.A.

(b) Other References

Maltais, J. A. (1969) A nine-channel digital magnetic tape format for storing oceanographic data. W.H.O.I. Ref. 69-55.

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