Deep Sea Research (1980)
26A, Suppl.1 (GATE)

A NOTE ON NEAR-SURFACE VACM MEASUREMENTS MADE FROM THREE DIFFERENT KINDS OF SURFACE MOORINGS

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ABSTRACT

During a multi-institutional air-sea interaction experiment (GATE) in the central Atlantic North Equatorial Countercurrent in September 1974, vector-averaging current meter (VACM) measurements were made within the 30-m thick mixed layer from three different types of surface moorings. The moorings consisted of a single-point taut-line flexible mooring (E3), a spar-buoy (E1), and a 2-legged mooring (F1). Although the kinetic energy density spectral estimates of the E3, E1, and F1 records in the low frequency range were equivalent with 95% confidence, the mean progressive vector diagrams differed by 6 % in length and 4° in direction. At frequencies above 1 cph the variances of the 7.2 m F1 current vectors were about 1.5 times larger than the 7.6 m E3 data and the spectral levels of the 20 m E1 and 21.4 m E3 record were equivalent, suggesting that VACM current vectors recorded near the surface beneath a surface-following buoy do not contain detectable amounts of aliased high-frequency mooring motion.

INTRODUCTION

The influence of a single-point, taut-line, deep-sea mooring with a surface-following float upon upper ocean current measurements is poorly known. The quality of near-surface current measurements made from instruments suspended in-line with the mooring cable is degraded by waves, vortex shedding, longitudinal oscillations, and mooring drag of varying direction and magnitude (cf. McCullough, 1977). Even if a perfect current measuring sensor which recorded error-free data were developed, Pollard (1973) has indicated that near-surface measurements made beneath a surface-following float (i.e., a float that moves with the surface wave) would contain spurious currents. The first opportunity to compare near-surface vector-averaging current meter (VACM) measurements made from a long, compliant, flexible mooring, a spar-mooring, and a deep-sea mooring which was similar to a shallow-water mooring occurred during the September 1974 GATE C-Scale Oceanographic Experiment. In contrast to previous studies which occurred in regions of relatively small mean currents, the intercomparison described in this paper was made in the central Atlantic Equatorial Countercurrent where the mean surface currents were approximately 50 cm sec^{-1}.

Among the variety of surface moorings deployed during GATE were a single-point taut-line mooring with a surface-following float (E3), a 2-legged "H" mooring (F1), and a spar-buoy tethered to a surface mooring (E1). Comparisons between E3 and F1 VACM measurements at ~ 20 m depth are described. Because the E3 and E1 moorings were located about 35 km southwest and 20 km south of F1 ($8^{\circ}50'$N, $22^{\circ}53'$W), the natural variability in the sea limits the agreement to be expected. We assumed that the variability of the mixed layer velocity field having time and horizontal space scales less than about 10-hr and 10-km was statistically similar at each of the mooring sites.

Of the three deep-sea mooring configurations, F1 appeared to be the most stable platform and E3 was thought to be the least appropriate platform for upper ocean current measurements. Pressure measurements indicated that vertical displacements of the F1 right-joint at 56 m depth were less than 1 m (Siedler and Gerlach, 1976). In contrast to the fixed mooring point at 56 m depth, the corresponding mooring depth of E3 was about 4890 m (i.e., the water depth). As a consequence the radius of the excursion circle of the E3 buoy determined from ships' radar and satellite navigation systems was about 1.5 km, whereas ship-reports of the F1 position indicated that the motion of the F1 surface floats was less than the 0.5 km accuracy of the navigation system. The vertical displacements of the surface float were much less at E1 than at E3 and F1 because vertically shaped buoys or spar-buoys tend to damp out the high-frequency waves of short wavelength. The average tilt angle from vertical ($4.3^{\circ} \pm 1.2^{\circ}$) of the E3 mooring line at 31 m depth was small enough to consider the E3 current meters to be oriented along the vertical, similar to the F1 (and presumably E1) current meters.

OBSERVATIONS

The common record-lengths were 12.5-days beginning 0000 GMT 30 August for E3 and F1 and 8.5-days beginning 1800 GMT 2 September for E3 and E1. During the 12.5-day period, the average current speeds at 7.6 m at E3 and at 7.2 m at F1 were 46 cm sec^{-1} and 50 cm sec^{-1}, respectively. The average mixed layer current shear at E3 determined from four current measurements made between 7.6 m and 27.5 m was 1.0×10^{-2} sec^{-1}. The average wind speed recorded at E3 was 4.0 m sec^{-1} with several gusts reaching 9 m sec^{-1}. The average significant wave height at about 70 km northwest of F1 was 2.20 m. In summary, the environmental conditions consisted of large currents, weak winds and calm seas.

Spectral estimates of the kinetic energy were computed by first estimating the spectra of the east-component series and the north-component series from Cooley-Tukey Fourier transforms using the perfect Daniell frequency window of variable width. For each spectrum the sum over positive frequencies was equal to the total variance. At each frequency band the east and north spectral estimates were combined by taking half the sum of the two to form the horizontal kinetic energy spectrum. At all frequencies there was good correspondence between the shapes of the 7.2 m F1 and 7.6 m E3 spectra (Fig. 1A) and of the 20.0 m E1 and 21.4 m E3 spectra (Fig. 1B). At frequencies above about 1 cph the 7.2 m F1 estimates were about 1.5 times larger than the 7.6 m E3 data, and the 20 m E1 and 21.4 m E3 estimates were nearly equivalent. At lower frequencies the differences between spectral estimates obtained from the 7 m E3 and F1 records and from the 20 m E3 and E1 data were not large enough to be statistically significant at the 95 % confidence level. This is reflected in the good agreement of the progressive vector diagrams which are shown in Fig. 2 for the topmost instruments of E3 and F1. They differ only by 6 % in length and 4° in direction.

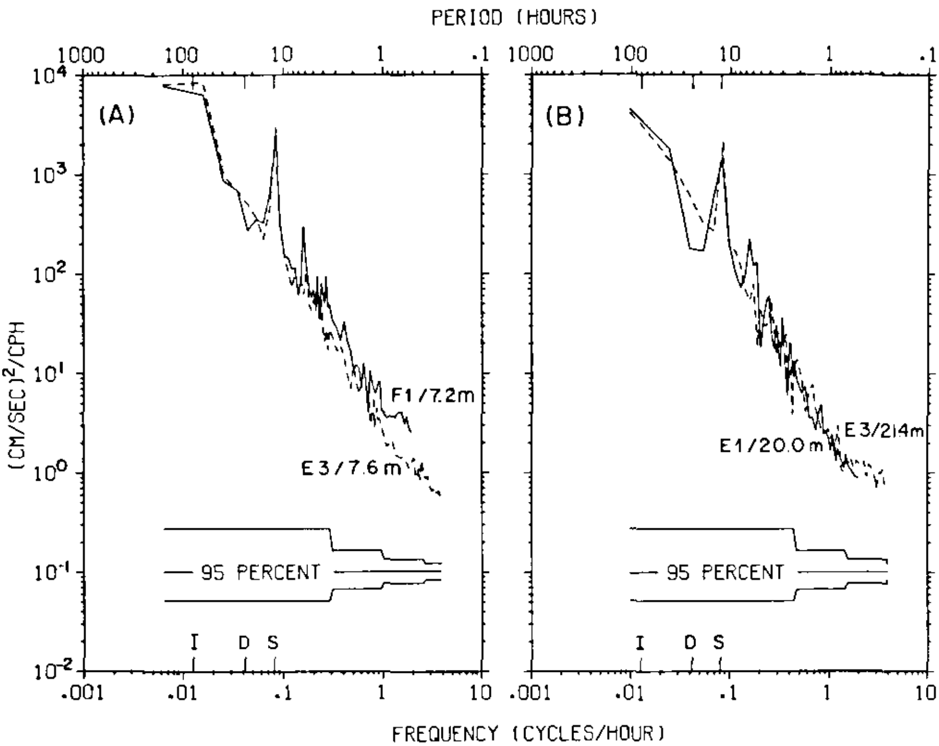

Fig. 1. Kinetic energy density spectral estimates of VACM measurements made at (A) ~7 m depth at E3 and F1 and at (B) ~20 m depth at E3 and E1. I, D and S indicate the inertial, diurnal and semidiurnal frequencies. The "95 percent" represents the 95 % confidence levels determined from the chi-square distribution and applicable to each curve.

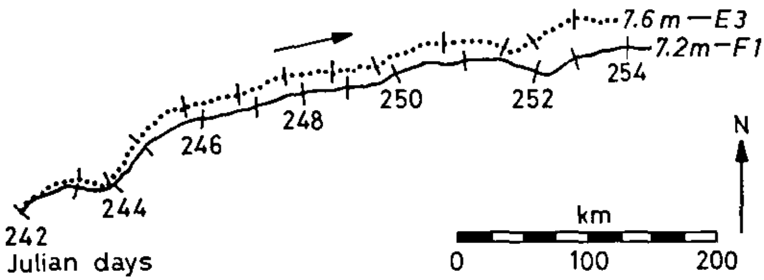

Fig. 2. Progressive vector diagrams of topmost instruments at moorings E3 and F1.

In addition to measuring the vector-mean east (u) and north (v) components, the VACM recorded the total number of rotor revolutions from which a rotor-count-speed (RCS) or scalar-speed was computed for each measurement interval. Because the Savonius rotor is an omnidirectional device, the RCS will always be equal to or greater than the vector-speed (VS) defined by $(u^2 + v^2)^{1/2}$. Daily mean values of RCS were about 20 % larger at F1 than at E3, whereas the difference between the VS values was generally less than 5 % (Fig. 3).

An estimate of errors in the recorded near-surface currents, e.g. by surface wave action and mooring motion, may be obtained from the root mean square difference

$$\Delta v = (\overline{RCS}^2 - \overline{VS}^2)^{1/2}$$

In Fig. 4 we display vertical profiles of Δv and of VS from moorings E3 and F1.

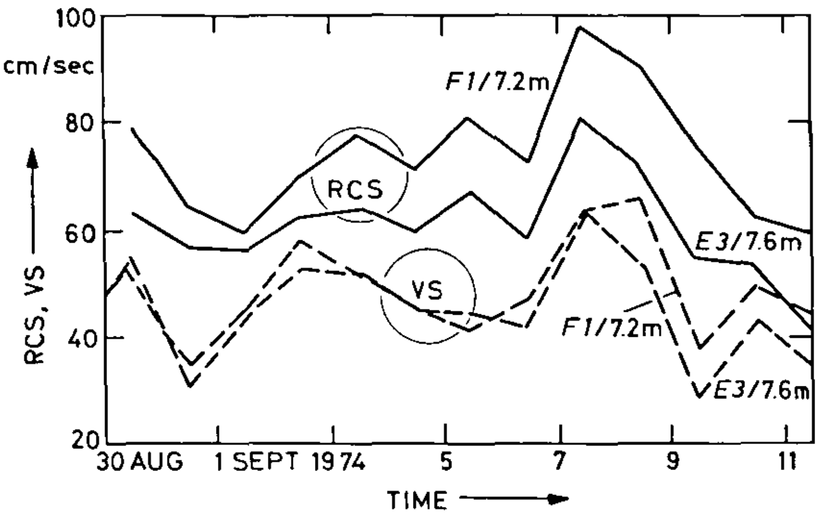

Fig. 3. Time-series of daily mean values of rotor-count-speed (RCS) or scalar-speed and of vector-speed (VS) determined from the VACM data recorded at 7.6 m at E3 and at 7.2 m at F1.

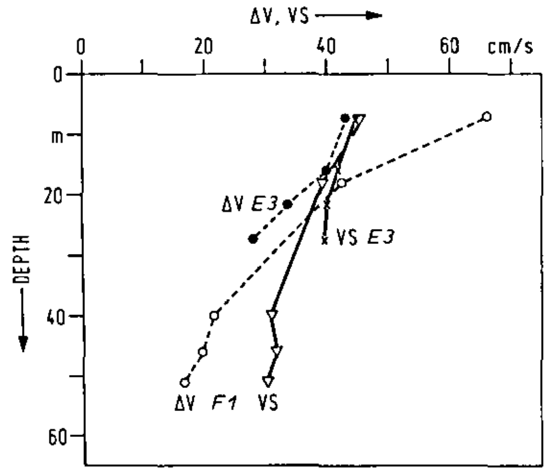

Fig. 4. Vertical profiles of 12 day vector averaged speed VS and the estimated amount of erroneous current signals Δv caused by surface waves and mooring motion.

DISCUSSION

The near-surface VACM records from the relatively stable F1 mooring contained more variability than the corresponding measurements made from the flexible E3 and E1 moorings. We had expected, a priori, to find the opposite result (e.g., see Gonella and Lamy, 1974) because we considered the E3 mooring to be less stable than F1. A current meter records the flow relative to the instrument. Because the horizontal displacements and the vertical motion (cf. Käse and others, 1978, Fig. 2 c) at F1 were smaller than at E3 and E1, the motions recorded by the VACM rotors at F1 would be larger than at E3. At E3 and E1 the VACMs were moved laterally with the surface waves and therefore recorded a smaller relative orbital wave motion than the VACMs at F1. Consequently, the rotor-count-speeds and the variability of the east and north component speeds at E3 and E1 were smaller than at F1. This is confirmed by the vertical profiles of Δv and VS (Fig. 3) showing that the topmost VACM at F1 contained 57 % higher contamination compared to E3 whereas only 1 % difference was found in the corresponding vector speed. We therefore conclude that the internal vector averaging of the VACM is capable of reducing a considerable amount of erroneous high frequency mooring and surface wave motion.

ACKNOWLEDGEMENTS

We wish to thank Dr. Raymond Pollard for providing unpublished E1 current measurements. This investigation was sponsored by the Deutsche Forschungsgemeinschaft (WZ and RK) and by NOAA's GATE Office and NOAA's Environmental Research Laboratories (Contribution no. 421).

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Received 2 October 1978, accepted in revised form 19 September 1979.