Automation of Research on Seas and Oceans

Proper movement of a current meter mounted on a suspended drift station*

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Abstract—In situ observations of the movement of a current meter attached to a long cable system of a drifting research vessel are discussed. A method is suggested which allows the cable configuration to be restored using measurement data on tangent orientation with respect to the given points. The compiled data indicate that the elements of the cable system shift by dozens of metres with a speed of the order of tens of cm per second. These shifts account for about 90% of the estimated value of current velocity energy pulsations in the frequency band corresponding to the proper frequency oscillations of the current meter and of the vessel's roll and-and-pitch motions.

Suspended drift stations (SDSs) set from the side of a drifting vessel are currently being widely used in oceanographic research. SDSs serve to carry out conventional bathymetric measurements. The station comprises an array of wave meters, distributed temperature sensors, and multiple sounding instruments lowered from the vessel's side into the sea. Recently, these stations are increasingly being employed for obtaining rapid estimates of the vertical distribution of the current velocity field in the area under study.

The purpose of this paper is to describe the SDS movements under natural conditions and to evaluate how large their contribution is to the volume of compiled current data. The results were obtained by means of a DISC-M probe and a direction-and-inclination meter, INNA [1, 2].

The probe was secured to the measuring system bearer cable with the aid of a support; the intention was to record at a frequency of 1 Hz the absolute values and direction of the on-running flow velocity vector, as well as the oscillations of two single-degree compound pendulums. These data help to identify that part of energy of high-frequency pulsations (0.01–0.60 Hz), which is due to proper movements of the instrument. For this, we use the formula

$$(\Gamma_{UV}(\omega) = (S_{UR}(\omega)) \otimes (S_{UR}(\omega)) \otimes (S_{RR}(\omega))^{-1},$$

where $(\Gamma_{UV}(\omega))$ is a tensor analogue to the 'coherent spectrum' which shows the relationship between the vector pulsations of the relative current velocity $U$ and the current meter's proper movement $V$, $(S_{RR}(\omega))$ is the tensor of the spectral density of the relative current velocity vector pulsations and the pendulum displacements $R$, $(S_{RR}(\omega))$ is the tensor of the pendulum displacement spectral density, $\omega$ is the frequency, $\otimes$ is the tensor product operator, and $\sim$ is the conjugation operator.

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The direction-and-inclination meter INNA was secured in parallel to the bearer cable of the measuring system; it is designed to perform the 1-Hz recordings of the three angular values that allow the determination of the cable's orientation at the fixing point. Orientation data on several cable sections may be useful for assessing the characteristic shift of the cable system elements. In addition, this helps us to find the curve's three-dimensional configuration, applying unity vectors of the correspondent tangents at the curve's given points. The solution involves a consistent determination of vector differences $r_n$ between the pairs of radius vectors of the points, indicating the curve sections considered.

In the first stage of handling the problem, we determine the orientation of the plane $M_0O'M$ (Fig. 1a) based on the tangents $M_0M_0$ and $O'M$ to the two adjacent points limiting an element curve section. The procedure is carried out using the angular values $\psi = UX'C$ and $\theta = \angle X'CC'$:

$$\Lambda = \lambda^{(+)} - \lambda^{(-)},$$

$$A_1 = \arccos(\cos \theta^{(+)} \cdot \cos \theta^{(-)} + \sin \theta^{(+)} \cdot \sin \theta^{(-)} \cdot \cos \Lambda),$$

$$A_2 = \arcsin(\sin \Lambda \cdot \sin \theta^{(-)}/\sin A_1),$$

$$A_3 = \arccotan(\cos A_2 \cdot \tan \theta^{(+)}) = \arccos(\sin A_2 \cdot \sin \theta^{(+)}).$$

Here, $\theta^{(+)} = UX'_i M'_0$ and $\theta^{(-)} = X'_i M$ are the larger and the smaller values, respectively, related to the same moment of time, of the tangent inclination (polar distance) with respect to the adjacent points which limit the curve's element section; and $\Lambda^{(+)} = UX'_i K_0$ and $\Lambda^{(-)} = UX'_i K$ indicate the direction (extent) of the tangents at issue.

In the second stage, we apply the well-known differential geometry theorem, according to which an arbitrary curve's elementary sections can be approximated through the arcs of contiguous parabolas. As we know, the errors of such an approximation have a third order of magnitude with regard to the elementary section's arc length and tend to decrease as the latter's curvature and twisting become less pronounced. The formulae below are based on the known geometric properties of the parabola and allow determination of the angle $\phi$, which controls

![Figure 1. Estimated movements of the suspended drift station elements: (a) to the method of simulation of the bearer cable configuration; (b) orientation variability of the SDS bearer cable at the position of INNA mounting; (c) estimations of the current velocity profile; (d) estimations of the movement of the probe INNA (conventional depth 406 m).](image-url)