Mean current velocity measurement from a movable base*

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Abstract — This paper discusses the possibility of measurement of the current velocity vector characteristics averaged over the time of continuous regular down-up probings from a moving carrier. The measurements can be carried out either from a moving vessel or from a helicopter, floating on or hovering above the sea surface. As an illustration for the suggested technique, in situ observations compiled by a free-component (±XYZ) VEGA-3 probe in the Guiana current region in March 1990 are provided. Comparison of the results with buoy data shows good agreement within the accuracy limits of the instruments employed.

The ability to reliably measure parameters of the vertical and horizontal structure of currents still remains one of the major challenges of designing marine instruments. The reason is that multiple measuring system elements are continually interacting with one another and with the marine environment. As a result of this, the motion of the current meter proper is interpreted by its sensitive elements as the motion of water, being indistinguishable, at the time of registration, from the real flow. This may generate errors (up to 100%) in the current velocity vector parameter measurements. Hence, the data provided through the calibration of various current meters become devaluated, as it is the characteristics of the total flow, governed by the equation given below, including the device's movements, that are being measured with the prescribed accuracy, rather than the characteristics of the current being observed:

\[ W(R_m, t) = U(R_m, t) - \frac{d}{dt} R_m(t) = U(R_m, t) - V(R_m, t), \]

where \( U \) is the true (net) current velocity in the observed area; \( V \) is the device's speed of movement (transport); \( W \) is the measured (relative) velocity of the impinging flow; \( R_m \) is the radius vector of the measuring element; and \( t \) is time.

These parameters become increasingly important when current measurements are made from a research vessel. In this case, equation (1) may be refined as follows:

\[ W(R_m, t) = U(R_m, t) - \left( \frac{d}{dt} R_{os}(t) + \frac{d}{dt} R_{sm}(t) \right) \]
\[ = U(R_m, t) - (V_s(R_{os}, t) + V_m(R_{sm}, t)), \]

where \( V_s \) is the ship's speed and \( V_m \) is the speed of the measuring device's slip relative to the ship. Vector \( V_s \) is determined by the ship-mounted navigation equipment, whereas the determination of \( V_m \) requires special solutions. Several techniques of determining this quantity are currently being used by oceanographers: (i) an analytical technique

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based on the application of hydromechanics techniques to assess the possible motions of the measuring system elements, and (ii) a technical one, involving current meters featuring inertial or hydroacoustic navigation devices. There exist other solutions based on the use of acoustic Doppler measuring systems. However, as practice and technical and economic estimates indicate, these solutions have low effectiveness because they command additional expenditure coupled with fitting the current meters and their carriers with special devices, with test area preparation, conducting measurements, and with the education of qualified personnel.

However, this problem can be modified and handled methodically using contemporary current meters without reconstructing them. The measuring device moving in the coordinate system, associated with the ship, makes a loop over a complete down-up cycle. Hence, the mean value of $d\mathbf{R}_{\text{sm}}(t)$ is equal to zero. Thus, we can exclude $V_m$ from equation (2), thereby essentially simplifying the problem. In this case, using the averages of the impinging current velocity, $W$, and of the vessel's mean speed, $V_s$, derived from a series of down-up probings, with each layer's kinematic characteristics within the studied field assumed constant on the adopted measurement cycle scale, we can obtain an average net current velocity $U$ in the layer being observed:

$$
(U(R_m, t)) = \left( W(R_m, t) + \frac{d}{dt} R_{\text{sm}}(t) \right) = (W(R_m, t)) + (V_s(R_s, t)), \quad (3)
$$

where $\langle \cdot, \cdot \rangle$ is the averaging operator. The same data allow us to evaluate the device's average slip relative to the ship during the down-up operations:

$$
\langle V_m(R_m, t) \rangle_{\text{dw}} = \langle W(R_m, t) \rangle - \langle W(R_m, t) \rangle_{\text{dw}}, \quad (4.1)
$$

$$
\langle V_m(R_m, t) \rangle_{\text{up}} = \langle W(R_m, t) \rangle - \langle W(R_m, t) \rangle_{\text{up}}, \quad (4.2)
$$

where $\langle V_m( \cdot ) \rangle_{\text{dw}}$ and $\langle V_m( \cdot ) \rangle_{\text{up}}$ are the respective slip vector averages of the current meter's down-up movements; and $\langle W( \cdot ) \rangle_{\text{dw}}$ and $\langle W( \cdot ) \rangle_{\text{up}}$ are the vector averages of the relative current velocity, observed during the lowering and recovering of the device.

Alongside this, the current estimates of $V_m(h, t)$, where $h$ is depth and $t$ is time, can be derived through the use of additional data provided, for instance, by the hydroacoustic tracking system, or from information about the orientation of the known measuring cable and the length of its wound-up part [1–4]. The characteristics of the current meter’s slip, thus determined, may be complemented and compared with the current meter data, using the formulae given above. This would permit us to refine the slip vector parameters on scales smaller than the measurement cycle, and hence to evaluate the current (within the measurement cycle) variability of the average parameters of the current field vertical structure within the known space–time limits. Furthermore, this allows us to specify the problems and vertical scales for which relations (4) can be applied directly, without involvement of the additional measurements suggested in refs 1–4.

The measurement technique discussed here has the following advantages. It can be employed as a basic component of the measuring devices designed to correctly average the data on the three-dimensional current velocity vector. The permissible limits of the carrier speed then depend solely on the velocity range used by the current meter. As a result, the quality of obtained data is ensured by the standard metrological testing methods, in contrast to the alternative solutions mentioned above. The suggested technique does not require any special rigging for the carrier when the measuring unit is being