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Abstract

Full Text

Geophysics

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Measurement of Electric Current in the Ocean

(Presented by Academician V. V. Shuleikin, October 2, 1956)

During the work of the first comprehensive Antarctic expedition on the *Ob'* in 1955-1956, a group from the Marine Hydrophysical Institute of the Academy of Sciences of the USSR carried out measurements of electric current in the Indian Ocean.*

It is known that in the World Ocean, just as in the Earth's lithosphere, there exist telluric currents, which were discovered in 1933 by A. T. Mironov⁽¹⁾ and in subsequent years were studied by him and by L. A. Korneva in the Black Sea, and by A. M. Gusev⁽⁴⁾ in the region of the North Pole.

The density of telluric currents in the sea is incomparably greater than in the solid shell of the Earth. Therefore V. V. Shuleikin assumes that the system of currents encompassing the World Ocean must influence the distribution of the elements of the Earth's magnetic field⁽²⁾. Experiments by L. A. Korneva, carried out on a model, and control calculations showed that both the displacement of the magnetic axis relative to the axis of rotation of the Earth and the location of regions of eastern and western declination are well explained qualitatively. At the same time, it turned out that the density of the currents measured in the surface layers of the water is entirely insufficient for a quantitative explanation of the phenomena⁽³⁾.

In undertaking systematic studies of the distribution of the density of telluric currents at various depths in different regions of the ocean, the Marine Hydrophysical Institute of the Academy of Sciences of the USSR has so far organized only reconnaissance measurements of current density at different depths in regions of the ocean visited by the diesel-electric vessel *Ob'*.

Of special interest was the sounding of the electric field in the region of the maximum value of the latitudinal component of the Earth's magnetic field (the latitudinal "focus") and in the region of the magnetic equator.

Our measurements of electric current were made from the ice cover in the Davis Sea, off the shores of Antarctica. The measurements were conducted at horizons of 0, 100, and 200 m. The second measurement was performed in the region of the latitudinal "focus" of the Indian Ocean down to a depth of 500 m. In the region of the magnetic equator, measurements of the gradient of the potentials of the electric current were made down to the ocean bottom.

For measuring the potential of the electric current in the ocean, lead electrodes proposed by L. A. Korneva were used, cast from chemically pure molten lead that had not been subjected to mechanical treatment. The electrodes were connected to cable of the KTPSH-03 type by means of special couplings designed by V. I. Lopatnikov. The couplings ensured reliable insulation of the place where the electrode and cable were joined.

Lowering the electrode to depth was carried out after a preliminary check of the constancy of the electrode's own e.m.f. The check was performed by prolonged (up to 3 days) measurement of the e.m.f. of electrodes lowered

* F. A. Gubin took part in the work on current measurements.

in a single vessel filled with seawater. The constancy of the electrodes' own emf was checked after each measurement of the natural potential difference of the electric current in the ocean. It should be noted that the lead electrodes have a very small intrinsic potential, not exceeding 0.05 mV, and that it is also constant. A successfully chosen electrode design ensured their resistance to mechanical influences throughout the voyage. The potential difference between two points in the ocean was recorded with a high-resistance direct-current potentiometer of the PPTV-1 type (by the compensation method) and with two sensitive millivoltmeters for monitoring.

To measure the potential of the oceanic current, the electrodes were separated by a certain distance, and the measurements were made along two lines arranged at an angle of approximately 90°. This made it possible to determine not only the magnitude of the potential gradient, but also the direction of the current. The position of the measuring lines relative to the cardinal points was determined by means of a direction finder mounted on the repeater of the gyrocompass. Off the coast of Antarctica, observations were carried out on two bases, 300 and 200 m long. For such spacing, one electrode with a cable was carried out onto the ice (the edge of the ice shelf), while the other was lowered by the EMIT* winch installed at the stern of the vessel.

In the open ocean, the horizontal measuring base did not exceed the length of the vessel, i.e., 130 m. One electrode was lowered from the foredeck, the other from the stern. The orientation of the measuring base relative to the cardinal points was provided by turning the entire vessel.

For immersing the cable with electrodes in the water and hauling them back on deck, depending on circumstances, electric winches adapted for the EMIT were used, or the capstan on the foredeck and the towing winch at the stern of the vessel. At one station the electrodes were lowered by hand on mooring winches.

Measurements of the horizontal potential gradient were made at depths of 0, 100, 200, 300, 500 m and at the bottom. Determination of the vertical potential gradient was performed at all stations where current measurements were made. Special attention in measuring the current was paid to recording the sign of

each electrode before they were spaced along the measuring base; naturally, the direction of the measuring line and the position on it of each numbered electrode were taken into account. In individual cases, the positions of the electrodes on the measuring base were deliberately interchanged. In this way the sign of the electrodes was checked. This method of measurement made it possible to determine, with sufficient accuracy, the direction of the current vector. When the electrodes were brought together at depth, the initial value of their own emf did not change. In reproducing the pattern of electric currents in the sea we proceeded from the assumption that electric currents flow in the sea under the influence of a voltage whose source is located outside the measuring electrodes. Therefore we assumed that the current flows through the body of the sea from the positive electrode to the negative one.

In the process of one-time measurements intended to determine the electric current in the ocean, there was reason to expect the action of various factors that could introduce substantial disturbances into the accuracy of the measurements. Thus, the chemical inhomogeneity of seawater at the places where the electrodes were lowered, the emf of induction in the water due to marine currents, and the emf of induction due to magnetic activity and high pressure in the case of measuring the vertical component of the electric current, when one of the electrodes is lowered to a great depth, are undoubtedly factors that introduce disturbances into the measurements. To avoid errors, we additionally determined: a) the chemical characteristics of seawater samples taken at the horizon—

* EMIT—electromagnetic current meter.

at the points where the current measurements were made; b) the sea current while the vessel was moored at the coastal icefast ice of Antarctica; c) the time of the measurements (in order to obtain information on the magnetic field from the nearest observatories) and, in addition, the deep electrode was specially held until the pressure emf was discharged.

The magnitude and direction of the ocean-current gradient were determined graphically. Plotting on paper the measured components of the current as vectors and taking their directions into account, we found the vector sum. The current density was determined from the formula

$$j = \lambda E \quad (1)$$

from Ohm's law, where λ is the electrical conductivity of seawater,* and E is the gradient of the potential of the electric current.

As a result of analyzing the materials from measurements of the electric current in the thickness of the ocean, we obtained the following values. Off the coast of Antarctica, at the point with coordinates 66°28'5 S, 94°44'0 E, the gradient of the potential of the electric current at the ocean surface (down to 10 m) was 4.2 mV/km and had a direction of 346°. The current density in the surface

layer did not exceed $1.14 \cdot 10^{-9}$ A/cm². With the immersion of the electrodes to greater depth, the potential gradient and current density increased. Thus, at the 100 m level the potential gradient had a magnitude of 5.9 mV/km, and the current density was $1.63 \cdot 10^{-9}$ A/cm², with a current direction of 341°. At the 200 m level the potential gradient and current density increased, respectively, to 7.0 mV/km and $1.90 \cdot 10^{-9}$ A/cm²; the current direction was 343°, i.e., it remained practically constant throughout the entire section. The magnitude of the vertical gradient of the electric potential was 3.5 mV/km.

The measurements of electric current at this station are of definite interest, since they were carried out in a region with tidal currents. During the current measurements at the 50 m level, the direction of the current changed from 98 to 146°, and the velocity changed from 7 to 28 cm/sec. Consequently, the variability of the tidal current in this region did not affect the general direction of the electric current.

In the region of the greatest value of the latitudinal component of the magnetic field (64°25'5 S, 92°44'0 E), at the 100 m level the potential gradient was 9.0 mV/km, the current density $2.41 \cdot 10^{-9}$ A/cm², and the current direction 267°. At the 500 m level a sharp increase in the gradient and current density was found, their values reaching, respectively, 41.0 mV/km and $1.2 \cdot 10^{-8}$ A/cm²; the current direction took the value 304°; the gradient of the potential of the vertical component of the electric current was 4.9 mV/km. And, finally, in the region of the magnetic equator (10°08' N, 51°40' E), at a depth of 100 m the measured value of the gradient did not exceed 7.1 mV/km, the current density was $3.37 \cdot 10^{-9}$ A/cm², and the current direction was 300°.

Measurement of the potential of the electric current at a depth of 500 m again gave a sharp increase in the gradient. At this level the current had a direction of 324°, the potential gradient was 55.0 mV/km, and the current density $2.19 \cdot 10^{-8}$ A/cm². Taking advantage of the fact that the depth at this station did not exceed 550 m, we measured the natural potential difference of the current on the bottom. In this case the magnitude of the potential gradient decreased somewhat in comparison with the gradient measured at a depth of 500 m, and proved to be 53.8 mV/km. This proves that the influence of high pressure on the lead electrodes at great depths is negligibly small and has practically no effect on measurements of the natural potential difference of electric currents. Taking into account the conditions of electrical conductivity of the near-bottom layer, we obtained a value of the current density at the ocean bottom equal to $2.14 \cdot 10^{-8}$ A/cm².

* The electrical conductivity of seawater was determined from Table 44 ⁽⁵⁾. For negative water temperatures an auxiliary graph was constructed. The data for t and S were taken for each level where the current was measured (*in situ*).

The direction of the electric current at the bottom was 315°. The potential gradient of the electric current vertically from the bottom to the ocean surface was 7.5 mV/km.

In conclusion, I consider it my pleasant duty to express my deep gratitude to the head of the marine section of the Combined Antarctic Expedition, Prof. V. G. Kort, and to all the members of the expedition' s hydrological detachment, headed by K. V. Moroshkin, for their assistance and help in carrying out the measurements. I also take this opportunity to express my sincere gratitude to S. V. Dobroklonsky, L. A. Korneva, and V. I. Lopatnikov for their assistance and valuable advice in preparing for the cruise at the Marine Hydrophysical Institute of the Academy of Sciences of the USSR.

Marine Hydrophysical Institute
Academy of Sciences of the USSR

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