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Abstract

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ON THE DETERMINATION OF THE ABSOLUTE ELEVATIONS OF THE ICE DOME OF ANTARCTICA

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Determining the relief of the sixth continent and, in particular, the elevations of the ice dome occupying the greater part of its surface is one of the principal tasks of research in Antarctica. These determinations and the construction of a hypsometric map of Antarctica constitute an independent geographical problem, but the solution of this problem is also connected with the solution of a number of other problems in meteorology, glaciology, and gravimetry.

Indeed, without knowing the exact values of the elevations of the continent, we cannot resolve the question of the position of the lower boundary of the ice cover, i.e., we cannot determine the subglacial relief of the continent. Without knowing the elevations, we also cannot determine the true field of air pressure over Antarctica, without which it is impossible to solve problems concerning the circulation of air in this region of the globe.

But all determinations of elevations in Antarctica, and especially in the interior regions of the continent, are associated with great difficulties. The point is that ordinary instrumental leveling, which provides high accuracy of determinations, is still impossible in Antarctica along routes of great length because of the extremely severe climatic conditions; and ordinary barometric leveling is inaccurate because of the pressure anomaly, of unknown magnitude, that constantly exists over the continent and is caused by the thermal influence of the Antarctic ice cover. Moreover, in solving meteorological problems the latter method is in general undesirable, since it is precisely this anomaly that must be determined, relying on knowledge of the exact elevation values of the terrain. This is why in all Soviet expeditions to Antarctica much attention was devoted to this question and methods were developed that would make it possible to eliminate the influence of the pressure anomaly on the magnitude of the determined elevations of the continental dome.

A very fruitful method proved to be the determination of elevations from an aircraft located beyond the distorting pressure field of the cold air layer. The altitude of the aircraft in this case was determined by the usual barometric formula, and the distance from the aircraft to the surface of the dome by a

Fig. 1. Diagram of flight routes

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radio altimeter. The difference between these quantities gave the elevation of the dome surface above sea level. This method was first used as early as the first expedition; thus the elevation of the first inland station, Pionerskaya, was refined. In an improved form this method was widely used by V. A. Bugaev in the work of the third expedition. Figure 1 gives a diagram of the flights made over Antarctica.

As a result of all the measurements, the expedition' s chief navigator B. S. Brodkin—participant in the principal flights—compiled the first hypsometric map of a considerable part of East Antarctica. The accuracy of the measurements made, while satisfying the requirements of some tasks, proved insufficient for the solution of a number of other problems.

In order to increase the accuracy of determinations, the Institute of Applied Geophysics of the Academy of Sciences of the USSR sought a new method for determining elevations that would not be connected with the necessity of measuring atmospheric pressure. It was proposed to determine the altitude of an aircraft flying over the dome by means of continuous, from the moment—

of the moment of takeoff, a recording of its vertical displacements or vertical accelerations.

The vertical speed of the aircraft, recorded on a tape moving proportionally to time t, is some function $u = f_1(t)$, and its vertical acceleration is $du/dt = f_2(t)$. The value of the aircraft' s flight altitude H that interests us is determined by integration, i.e., by determining the area under the curve of the aircraft' s vertical speed, or by successive double integration of the dependence of vertical acceleration on time,

Fig. 1. Diagram of flight routes

$$u = \int_{t_1}^{t_2} f_2(t)\,dt, \qquad u = \frac{dH}{dt}, \qquad H = \int_{t_1}^{t_2} f_1(t)\,dt. \tag{1}$$

The measured height of the terrain above sea level is then determined from the difference between the values of the aircraft' s altitude and the distance from the aircraft to the surface, determined by a radio altimeter.

The vertical speed of the aircraft can be recorded continuously with the aid of a variometer—an aircraft instrument that determines this element of motion from the rate of change of pressure. This is a fairly reliable method and, within certain limits, does not depend on the absolute magnitude of the pressure; however, as more rigorous determinations one should regard determinations from vertical accelerations recorded by a special accelerometer.

Fig. 2. Terrain profile (1) and flight altitude (2) toward Wilkes Land

Figure 2: Fig. 2. Terrain profile (1) and flight altitude (2) toward Wilkes Land

The accuracy of altitude determinations by this method will depend on the accuracy of two measurements: measurement of the flight altitude and measurement of the distance from the aircraft to the surface. Calculations show that the accuracy of the first measurements during a many-hour flight can be brought to 10 m; moreover, on returning to the initial point of the flight, the accumulated error can be determined. Radio altimeters can also provide the indicated accuracy. Existing radio altimeters do not give an entirely sharp reflection from the surface of loose snow, but this shortcoming of the method can be eliminated if

to perform a circling flight or, where possible, a landing. Naturally, in such cases the need to use a radio altimeter disappears.

Both methods of determining vertical velocity are insufficiently accurate during takeoff and landing of the aircraft; therefore the instrument must be switched on after takeoff, after determining the initial altitude with the aid of a radio altimeter. This is especially convenient to do when flying over the sea surface. The same procedure must be followed after returning from the flight, before landing.

The principle described above formed the basis of an instrument developed by A. M. Gusev and N. I. Lozovskii. With the aid of this instrument, during the changeover of the third Antarctic expedition and at the beginning of the work of the fourth Antarctic expedition, A. M. Gusev carried out determinations of the heights of the ice dome of East Antarctica along the route indicated in Fig. 1 by a dotted line. The flight route passed

Fig. 2. Terrain profile (1) and flight altitude (2) toward Wilkes Land

over Wilkes Land in the direction of Victoria Land and lasted about 13 hours. Up to the present time no flights had yet been made in this area, and the ice dome had been completely unexplored. During this flight V. A. Bugaev and V. I. Shlyakhov also determined the height of the dome by the former method, using an aneroid.

As a result of processing the instrument records, heights were obtained at various points along the flight route. The maximum height proved to be at its most distant point, which we reached 6 hours after departure from Mirny. Farther on, the terrain began to descend. In Fig. 2, 1 shows the terrain profile along the route Mirny—Pionerskaya—the most distant point of the flight, with coordinates 72°23′S, 130°30′E; 2 shows the flight altitude.

Throughout the entire flight, up to the indicated point, the heights determined by the new method proved to be somewhat higher than the heights determined from the aneroid. The maximum discrepancy reached 122 m. This discrepancy should be considered regular, since temperature observations showed that the aircraft was still within the cold air layer the whole time.

It is interesting to note that the magnitude of the discrepancy changed in full accordance with the notion of the influence of the pressure anomaly caused by the presence of a cold air layer over the Antarctic dome. In those cases when the aircraft was flying high above the surface, i.e., close to a horizontal isobaric surface, the discrepancies in the determinations by the two methods decreased; when the aircraft descended, the discrepancies increased. It should be noted that both methods have their positive and negative aspects, and for the time being they should be considered as complementing each other.

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Note: Figure translations are in progress. See original paper for figures.