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Abstract

Full Text

Geophysics

M. G. Antsilevich and A. D. Shevnin

On the Question of Geomagnetic Observations on the First Soviet Space Rocket

(Presented by Academician E. K. Fedorov, 5 VIII 1960)

The investigation of the geomagnetic field with the aid of the first Soviet space rocket showed ($\hat{1}$) that the measured field intensity decreases with height more rapidly than the calculated value (the field intensity of a geomagnetic dipole), reaching a minimum of 400 γ ($1 \gamma = 1 \cdot 10^{-5}$ oersted) at a distance of 20,800 km from the center of the Earth. It then increases to 800 γ at a distance of 22,000 km and thereafter slowly decreases (Fig. 1).

Fig. 1. Change in the Earth' s magnetic field with increasing distance from the Earth. **1** –field measured by the magnetograph; **2** –calculated field values.

One of the authors of the present paper (M. G. Antsilevich), upon examining the magnetograms of the Tashkent Observatory for 2 I 1959, noticed that on that day there had been a small geomagnetic disturbance of the worldwide-storm type with a sudden commencement, SC.

Further analysis of data from 16 geomagnetic observatories and 2 observatories for observations of telluric currents for 2 I 1959 showed that the geomagnetic disturbance began at 11 hr 20 min Universal Time, the maximum of the horizontal component occurred at 12 hr, and the minimum at 14 hr (Fig. 2). The amplitude of the sudden commencement SC was 10 γ , and the amplitude of the aperiodic variation D_{st} (between 12 and 14 hr) was 20 γ .

The course of the geomagnetic disturbance is more distinct at those observatories for which the disturbance occurred in the evening and nighttime hours, since it was not distorted by the daytime part of the quiet daily variation (Srednikan, Kazan, Irkutsk, Yuzhno-Sakhalinsk, Tbilisi, Memambetsu, Tashkent, Vladivostok, Kuiper, Kanoia, Kakioka). The SC is clearly visible on the magnetograms of all observatories. The irregular part of the disturbance D_i was almost absent.

20 points of the USSR, located between 151 and 231° geomagnetic longitude, recorded weak auroras from 11 to 21 hours Universal Time.

The presence of a geomagnetic disturbance almost without the irregular part D_i and of weak auroras indicates that at 11 h 20 min a weak corpuscular stream reached the vicinity of the Earth; it created a small equatorial current ring, which caused the D_{st} -variation. The first Soviet space rocket crossed the current system 6.5 hours after the sudden commencement and 3 hours after the minimum of the horizontal component of the geomagnetic field, i.e., during the period of decay of the current system. Nevertheless, the rocket's magnetic sensors detected the presence of a weak current system, which caused a jump of 400 γ in the geomagnetic-field intensity (Fig. 1).

Most probably, on 2 January 1959 the Earth was subjected to the action of a weak corpuscular stream from a decaying active region of the Sun, responsible for the large geomagnetic storm with sudden commencement on 4–5 December 1958 (active region No. 66a, from which at the beginning of January 1959, after one solar rotation, facula No. 019 remained) (2).

Let us carry out some approximate calculations. Suppose that the meridional section of the current ring, at least in the regions closest to the equatorial plane, has the profile of the lines of force of the geomagnetic field. Taking into account the fact that the space rocket passed through the zone of the current ring at some angle Φ to the geomagnetic equatorial plane, and using the equation of a magnetic line of force in the cylindrical coordinate system (R, Φ)

$$R = r_e \cos^2 \Phi,$$

Fig. 2. Observational data for the horizontal component H of the geomagnetic field (1–16) and the W–E component of telluric currents (17, 18) for 2 January 1959. The vertical segments on the right contain 20 γ for the H -component and 10 mV/km for the W–E component. The moment of the rocket's passage through the current ring is marked on the time axis by a cross. Direction of increase of the components is upward. Observatories: 1 –Eskdalemuir, 2 –Leningrad, 3 –Hartland, 4 –Srednikan, 5 –Prugonice, 6 –Kazan, 7 –Lvov, 8 –Odessa, 9 –Irkutsk, 10 –Yuzhno-Sakhalinsk, 11 –Tbilisi, 12 –Memambetsu, 13 –Tashkent, 14 –Vladivostok, 15 –Küyper, 16 –Hermanus, 17 –Kanoya, 18 –Kakioka

where r_e is the distance from the center of the Earth to the point of intersection of the equatorial plane by the line of force (Fig. 3), we obtain, for the equatorial distance of the inner boundary of the ring current ($R_1 \approx 20\,800$ km, $\Phi_1 \approx 26^\circ$),

$$r_{e1} \approx 25\,750 \text{ km } (\approx 4.0 R_\oplus),$$

where R_\oplus is the radius of the Earth. For the outer boundary of the current layer ($R_2 \approx 22\,000$ km, $\Phi_2 \approx 25^\circ$)

$$r_{e2} \simeq 26\,800 \text{ km } (\simeq 4.2 R_{\oplus}).$$

The thickness of the current layer in the equatorial plane is

$$2r_0 = r_{e2} - r_{e1} \simeq 1050 \text{ km } (\simeq 0.2 R_{\oplus}).$$

Using the formula for the magnetic field produced by a ring current I at the Earth's surface near the equator,

Fig. 3. Lines of force of the geomagnetic field bounding the current layer, and the projection of the rocket trajectory onto the plane of the geomagnetic meridian. r_{e1} and r_{e2} are the equatorial distances from the center of the Earth to, respectively, the inner and outer boundaries of the current layer; a is the projection of the rocket trajectory.

$$\Delta H = \frac{2\pi I}{r_{e\text{mean}}} \left[(1 + a^2)^{3/2} + \frac{3}{2} a^2 (1 - a^2)^{1/2} + \frac{3}{4} a^2 (1 + a^2)^{-1/2} + \dots \right],$$

where $a = R_{\oplus}/r_{e\text{mean}}$, and restricting ourselves to the second approximation, from ground-based data with $\Delta H \simeq 20\gamma$ (the amplitude of D_{st} at the equator) and $r_{e\text{mean}} \simeq 26\,280 \text{ km}$ we obtain

$$I \simeq 6.3 \cdot 10^5 \text{ a.}$$

Let us estimate the current intensity from the amplitude of the change in field intensity when the rocket crossed the current layer. For this purpose we use the formula for the field intensity of a current I flowing along an infinite rectilinear cylinder of radius r_0 . When passing through the cylinder along a diameter of the cross section, the field changes by

$$\Delta H = \frac{4I}{r_0}.$$

For $\Delta H \simeq 400\gamma$ and $r_0 \simeq 500 \text{ km}$, we obtain $I \simeq 5 \cdot 10^5 \text{ a.}$

Under the assumptions made concerning the configuration of the current, and with the approximate calculations, we note the same order of magnitude of the current intensity from the ground-based and rocket data. The results obtained do not contradict the supposition that the jump in the field detected by the rocket is connected with the existence of an equatorial current system that caused the small disturbance of the geomagnetic field on 2 January 1959.

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

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