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## Abstract

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## GEOPHYSICS

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# EXPERIMENTAL DETERMINATION OF THE OUTGOING RADIATION OF THE EARTH

*(Presented by Academician A. A. Blagonravov on 9 IV 1962)*

**1.** The magnitude of the outgoing thermal radiation of the Earth (concentrated, according to estimates, in the spectral region from 2.5 to 40 $\mu$) is one of the principal components of its energy balance. However, until now no direct experimental determination of this quantity has been carried out. The magnitude of the Earth' s outgoing radiation has been determined only by calculation, although, owing to a number of circumstances, the calculations cannot be sufficiently reliable. The inadequacy of computational methods is connected, for the troposphere, simply with the small volume of physical data characterizing the state of the atmosphere (temperature, distribution of humidity with altitude, etc.), and with the incompleteness of information on the molecular absorption spectra of its components under various physical conditions. For the stratosphere, moreover, the calculation method itself is insufficiently developed. In addition, the data obtained by calculation up to the present correspond only to mean values of the parameters and therefore give an idea only of the mean magnitude of the Earth' s outgoing thermal radiation, which in a number of cases is insufficient. It is interesting to note that experimental determination of the thermal radiation of some planets (for example, the Moon and Venus) has already been carried out repeatedly in astronomy and radio astronomy ([5]-[7]).

**2.** The possibility of lifting research apparatus into outer space on high-altitude rockets and artificial Earth satellites, as well as advances in the development of infrared physics and technology, made it possible to carry out a direct experimental determination of the Earth' s thermal outgoing radiation—not only of the total, average radiation, but also of the radiation of its individual regions. To conduct such investigations, a method of measurement and automatic apparatus registering the thermal radiation of the Earth were developed. In this method, the radiation from regions of the Earth was focused, by means of a mirror optical system, onto a low-inertia thermal receiver (bolometer), the signal from which was amplified and recorded by various types of autonomous recorders (magnetic and galvanometric), and was also transmitted to the Earth by a radiotelemetric system. The instrument employed a modulation principle for measuring radiation, making it possible to eliminate the influence on the measurement result of slow changes in the ambient temperature and in the voltage of the power sources. The modulation frequency was 80 Hz.

A drawback of the modulation principle in the case of recording low-intensity radiations with a spectral composition close to the radiation spectrum of the modulator is the considerable influence on the measurement of the modulator' s own radiation. This drawback was eliminated by carrying out differential modulation of the radiation fluxes from the Earth and from a standard, for which the radiation of outer space was used (its radiation was taken as zero, since it is negligibly small in comparison with the radiation of the Earth).

Information on the radiation of individual regions of the Earth was obtained by scanning the lower hemisphere with the optical system of the instrument (scanning angle 180°). The scanning period was about 30 sec. The apparatus made it possible to record integral radiation in the wavelength range from 2.5 to $40\,\mu$. In daytime experiments, reflected short-wave solar radiation (wavelengths less than $2.5\,\mu$) was excluded by filters (matted mirrors, deposited PbS, etc.). The spatial resolving power of the instrument in the scanning plane amounted to fractions of a degree.

3. The measurements were carried out in the middle belt of the European part of the USSR by instruments installed on board high-altitude geophysical rockets of the Academy of Sciences of the USSR. The rockets were launched vertically to altitudes of $100 \div 500$ km. They had a flight-stabilization system along all three axes, which is very important for obtaining unambiguous results. One of the experiments was conducted during the total solar eclipse of 15 II 1961. The apparatus was installed in the instrument compartment of the rocket. Calibration of the instrument was performed using standard radiators having the evaporation temperature of liquid nitrogen and the sublimation temperature of solid carbon dioxide at normal atmospheric pressure.

During the experiments, automatic periodic monitoring of the stability of the sensitivity (every 30 sec.) was carried out with the aid of a special standard radiator placed inside the instrument housing.

Measurements of the outgoing radiation of the Earth gave the results presented in Table 1. These data characterize the radiation from 1 cm$^2$ of the Earth' s surface into the upper hemisphere. They were obtained from the measured value of the radiation intensity under the assumption that Lambert's law is applicable. Table 1 also gives values of outgoing radiation calculated by other authors. Our data and those of other authors are of the same order of magnitude.

The observed difference in the radiation fluxes obtained at different times is associated with the influence of the meteorological situation. From the measured values of the thermal-radiation fluxes, the effective radiation temperature of the Earth into outer space $T_{\text{eff}}$ was calculated (the temperature of a black body emitting an equal flux). During the total solar eclipse, measurements were made in its various phases, and a change in the radiation flux was recorded—

**Table 1**

| Cloud conditions | Experiment 1, $Q$, W/cm² | Experiment 1, $T_{\text{eff}}$, K | Experiment 2, $Q$ | Experiment 2, $T_{\text{eff}}$ | Experiment 3, $Q$ | Experiment 3, $T_{\text{eff}}$ | Experiment 4, $Q$ | Experiment 4, $T_{\text{eff}}$ | Kondratyev and Filippovich (3), $Q$ | Kondratyev and Filippovich (3), $T_{\text{eff}}$ | Simpson (4), $Q$ | Simpson (4), $T_{\text{eff}}$ | Bauer and Philips (5), $Q$ | Bauer and Philips (5), $T_{\text{eff}}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cloudless | $1.2 \cdot 10^{-2}$ | 216 | $0.9 \cdot 10^{-2}$ | 200 | — | — | — | — | — | — | — | — | — | — |
| Average cloudiness | — | — | — | — | $1.4 \cdot 10^{-2}$ | 224 | — | 238 | $2.2 \cdot 10^{-2}$ | 250 | $1.9 \cdot 10^{-2}$ | 242 | $1.8 \cdot 10^{-2}$ | 238 |
| Continuous cloudiness | — | — | — | — | — | — | $1.8 \cdot 10^{-2}$ | 238 | $2.1 \cdot 10^{-2}$ | 248 | — | — | — | — |

**Notes.** Experiment 1: 27 VIII 1958, 7 h. 06 min. Moscow time, altitude of ascent 470 km, mean observed temperature 20° C. Experiment 2: 10 VII 1959, 4 h. 12 min. Moscow time, altitude of ascent 200 km, mean observed temperature +16°. Experiment 3: 15 VI 1960, 7 h. 42 min. Moscow time, altitude of ascent 200 km, mean observed temperature +15°. Experiment 4: 15 II 1961, about noon, altitude of ascent 100 km, mean observed temperature −2°.

tion. Table 1 gives the value of the flux corresponding to the total phase of the eclipse.

In conclusion, it should be noted that an important result of the work is also that the practical possibility was demonstrated of recording the infrared radiation of the Earth over a broad spectral interval (up to 40 $\mu$) by instruments launched into outer space; thus the development of a new method for investigating the physics of the Earth and the terrestrial atmosphere was initiated.

The data relating to the experiment during the solar eclipse were obtained with the participation of A. M. Kasatkina, S. V. Repolovsky, and I. P. Averyanov. The mechanical design of the instruments was carried out by V. E. Shervinsky. The authors express their sincere gratitude to them, as well as to the entire group of collaborators who contributed to the successful completion of this work.

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## REFERENCES

1. Newspaper *Pravda*, No. 242, 30 VIII 1958.

2. Newspaper *Pravda*, No. 195, 14 VII 1959.

3. K. Ya. Kondrat' ev, O. P. Filippovich, *Vestn. LGU*, No. 6 (1952).

4. K. Ya. Kondrat' ev, *Transfer of Long-Wave Radiation in the Atmosphere*, M.–L., 1950.

5. W. M. Sinton, *J. O. S. A.*, **45**, 975 (1955).

6. A. E. Salomonovich, *Astr. Zh.*, **35**, 129 (1958).

7. A. D. Kuz' min, A. E. Salomonovich, *Astr. Zh.*, **37**, 297 (1960).

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