STUDY OF IONOSPHERIC LAYERS

M. N. MARKOV, Ya. I. MERSON, M. R. SHAMILIEV

1966

SovietRxiv

Abstract

Full Text

UDC 550.388

GEOPHYSICS

M. N. MARKOV, Ya. I. MERSON, M. R. SHAMILIEV

STUDY OF IONOSPHERIC LAYERS

IN THE INFRARED REGION OF THE SPECTRUM

(Presented by Academician G. M. Petrov on 26 VII 1965)

During 1958–1963 we carried out systematic measurements of the radiation of the Earth and atmosphere into outer space in the infrared region of the spectrum ($0.8 \div 40\ \mu$), from altitudes of 25 to 500 km ([6,7,8]). The observations were conducted by us at different times of the year (June, August, October), in regions separated by distances of several thousand kilometers, with different directions of sighting of the apparatus relative to the cardinal points. In the measurements, the research apparatus was lifted by means of geophysical balloons and rockets.

As a result of these measurements it was established:

1. From atmospheric layers located at altitudes above 200 km, intense infrared (i.-r.) radiation is observed. In all cases the radiation of the upper atmosphere had maximum intensity in the altitude regions 250–300 km, 420–450 km, and about 500 km.

2. The radiation observed at these altitudes is concentrated predominantly in the spectral region $2.5 \div 8\ \mu$ in the sunlit part of the atmosphere.

3. The radiation of the upper atmosphere has a maximum intensity reaching $(3 \div 7) \cdot 10^{+2}$ W/m^2 when sighting in the tangential direction, when the radiation is integrated along a ray of length ~ 1000 km, which corresponds to isotropic radiation of 1 cm^3 equal to 10^{-3} erg/sec.

4. The radiation intensity depends on the action of solar radiation on the upper part of the atmosphere and increases during periods of maximum solar activity. Figure 1 gives curves of the dependence of the radiation intensity from the horizontal direction on the sighting altitude, obtained in the experiments of 1958, 1962, and 18 VI 1963. The special significance of the 1963 experiment should be noted; it fully confirmed the previously obtained results: in it, radiation was again recorded at altitudes of 280

Fig. 1. Dependence of the intensity of radiation from the horizontal direction on height

Figure 1: Fig. 1. Dependence of the intensity of radiation from the horizontal direction on height

> and 420 km and, in addition, at an altitude of 500 km. In this experiment the working region of the spectrum was limited to the range 2.5—40 μ.

An exhaustive interpretation of the results obtained lies beyond the scope of the present work. However, we consider it useful to give some estimates in order to confirm the fundamental possibility of linking the new data obtained by us with other information about the atmosphere. At present we do not have reliable data on the composition of the atmosphere at the altitudes of interest to us, in particular on neutral complex molecules and radicals of the type OH, NO, NH, etc., and, still less, on the absorption coefficients of these gases under conditions of high rarefaction and enormous thicknesses. It seems useful to consider a model of the atmosphere that does not include absorbing gases between the radiating layers. The altitude and angular distributions of the radiation can be reconciled with one another only under the assumption that the radiation is localized in definite layers (5-10 km) situated at certain altitudes close to the upper and lower boundaries

the F_2 layer of the ionosphere. Suppose that the thickness of the emitting layers at heights of 280, 420, and 500 km is 5 km, and that the effective field angle of the instrument (taking into account aberrations and the time constant of the amplifier) is about 0.5°. Then it is possible to calculate and construct the behavior of the relative intensity for the curves of the angular distribution of radiation, assuming that the intensity is proportional to the length of the emitting layer, with allowance for dilution of the radiation.

Fig. 1. Dependence of the intensity of radiation from the horizontal direction on height

Figure 2 shows such calculated and experimental (1963) curves. These curves were constructed in accordance with the character of the motion of the scanning system of the instrument by means of which the experiment was carried out. During scanning, the optical system of the instrument moved to a horizontal position and then returned back. Therefore the curves obtained are symmetric with respect to the horizon and correspond to different directions of motion of the optical system during scanning. It follows from this that there is satisfactory agreement between the calculated and experimental curves for all three observation heights (and also for intermediate heights). A small difference between the curves may be explained by the fact that the instrument does not record the fine structure of the transition regions, and, on the other hand, by the approximate nature of the assumptions made in the calculation concerning the size of the layers, their structure, the distribution of density in the layers

Fig. 2. Calculated (a) and experimental (b) data on the angular dependence of the radiation in the region adjacent to the horizontal direction of viewing, for various altitudes.

Figure 2: Fig. 2. Calculated (a) and experimental (b) data on the angular dependence of the radiation in the region adjacent to the horizontal direction of viewing, for various altitudes.

with height, and so on. Taking all these factors into account may lead to more exact agreement between the calculated and experimental curves.

For the model under consideration, we carried out additional calculations showing that, under certain natural assumptions, the experimental data make it possible to obtain the number of nonequilibrium acts of radiation, the isotropic flux of radiation, and so on. For a layer thickness of 5 km, the length of the emitting column of gas along the layer is about 500 km (limited by the curvature of the Earth). Thus, for a measured flux of 10^2 W/m^2, the volume density of radiation will be about $2 \cdot 10^{-10}$ W/cm^3 (10^{-3} erg/cm^3); this flux is about 0.07% of the solar constant. Consequently, the flux obtained by us corresponds to 1 act of radiation per second. In the spectral region where the radiation is mainly concentrated (2.5—8.0 μ), there are rotational-vibrational absorption bands of molecules that enter into the composition of the atmosphere, in particular H_2O, CO_2, NO, CH_4, and others.

One of the assumptions about the mechanism of radiation may consist in the fact that the molecules of the atmospheric gas at certain heights are excited

by the solar flux, and rotational-vibrational transitions in their energy spectrum are responsible for the radiation. But the data on the neutral composition of the atmosphere at altitudes of 200–500 km are not sufficiently well determined ([1]). Only the ionic composition is known; its fraction in the total number of particles is quite small (for example, at an altitude of 300 km it is about 0.1% ([9])). If, however, one makes the assumption that the ionic composition to some

Fig. 2. Calculated (*a*) and experimental (*b*) data on the angular dependence of the radiation in the region adjacent to the horizontal direction of viewing, for various altitudes

extent reflects the concentration of neutral particles, then one may conclude that NO molecules play the decisive role in the radiation (at least at an altitude of 280 km). The concentration of NO ions at altitudes of about 200 km in some cases reaches 50% of the total number of atmospheric ions, and the NO molecule has an intense absorption band near 5.3 μ (according to data ([2])). Thus, under these assumptions, the concentration of neutral NO molecules, for example, in the lower layer, could reach 10^9 cm^{-3}, and the total number of radiating particles for a path length of about 500 km would be $\sim 10^{17}$. Rough estimates show that, in this case, for the observed radiation intensity the effective temperature, determined from the NO absorption band, reaches on the order of 2000° K.

One cannot exclude assumptions about a complex mechanism of excitation of atmospheric molecules as a result of photochemical reactions, recombination processes, etc. At present, however, there are not sufficient grounds for singling out one mechanism or another. Estimates of the energy of electromagnetic solar radiation in various regions of the spectrum show that

that its magnitude is insufficient for the observed intensity, and the necessary fluxes may apparently be due only to corpuscular radiation from the Sun. Indeed, according to data ([3–5]), at least during auroras, corpuscular fluxes reaching an altitude of 100 km amount to several thousand erg/sec $\cdot$ cm^2, which corresponds to the magnitude of the IR-radiation flux obtained by us, and is even higher.

Table 1

Sun	Earth
Experiment of 27 VIII 1958	**Experiment of 27 VIII 1958**
During the 2 days and during the experiment a flare storm was observed	Planetary index of the magnetic field $K_p = 4 \div 5$
Experiment of 6 VI 1963	**Experiment of 6 VI 1963**
31 V and 1 VI —a small number of flocculi; 4 VI —one very weak flare; 6 VI —no flares	From 4 VI to 6 VI $K_p = 0$
Experiment of 18 VI 1963	**Experiment of 18 VI 1963**
11–12 VI —a considerable number of flocculi; 16 VI —6 flares	18 VI $K_p = 3.5$

Since the intensity of the IR radiation of the atmosphere is influenced by processes on the Sun and, in particular, by fluxes of solar corpuscular radiation reaching the upper atmosphere of the Earth, Table 1 gives characteristics of the state of the Sun and of the Earth’ s magnetic field (which depends on solar activity) for the days on which the experiments were carried out. The graphs shown in Fig. 1 indicate that in 1958 (the year of maximum solar activity) the radiation of the ionosphere was substantially greater than in the experiments of 1962 and 1963 (years of a quiet Sun). In the 1963 experiments, the radiation of the ionospheric layers on 18 VI was considerably higher than on 6 VI, when it was insignificant.

Thus, one may regard as established (of course, from individual measurements) the fact of a correlation between the IR radiation of the ionosphere and flares near the central meridian of the solar disk.

Received
21 VII 1965

REFERENCES

1. K. Ya. Kondrat' ev, *Meteorological Investigations with the Aid of Rockets and Satellites*, 1962.

2. R. H. Gilete, E. H. Eyster, *Phys. Rev.*, **56**, 1113 (1939).

3. *Investigations of the Upper Atmosphere with the Aid of Rockets and Satellites*, IL, 1961.

4. Yu. I. Gal' perin, V. I. Krasovskii et al., *Cosmic Research*, **1**, 1963, p. 126.

5. Kh. S. V. Massey, R. L. F. Boyd, *The Upper Atmosphere*, 1962.

6. L. V. Il' vensov, M. N. Markov et al., DAN, **146**, No. 2 (1962).

7. I. P. Aver' yanov, A. M. Kasatkin et al., *Artificial Earth Satellites*, issue 14, 1962, p. 49.

8. M. N. Markov, Ya. I. Merson, M. R. Shamilev, *Cosmic Research*, 1963, 1, issue 2, p. 235, 1963.

9. B. A. Mirtov, *The Gaseous Composition of the Earth' s Atmosphere and Methods of Its Analysis*, Publishing House of the USSR Academy of Sciences, 1961.

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