Coincidence Counter Studies of the Variation of Intensities of Cosmic-Ray Showers and Vertical Rays with Barometric Pressure[1]

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Using three Geiger-Müller counters in triangular arrangement below a lead plate 1.2 cm thick, cosmic-ray shower intensities at sea level were found to diminish with increasing barometer by the factor 0.00542 ± 0.00027 per mm mercury, corresponding to an exponential absorption coefficient of 0.41 per meter of water. Vertical rays measured with three counters in line showed a barometer effect of 0.00362 ± 0.00044 per mm mercury or 0.28 per meter of water. The showers are thus more sensitive to barometric changes than the total cosmic radiation as had been found by experiments at different elevations.

THE ratio of the frequency of occurrence of cosmic-ray showers to the total cosmic-ray intensity has been found by several observers[2–5] to increase with elevation above sea level. Coincidence counter studies by Johnson indicated an apparent absorption coefficient[6] for simple showers of 0.5 per meter of water and Rossi found changes in the intensities of slightly more complex showers corresponding to an absorption coefficient of 0.65 per meter of water. As further confirmation of these findings we have determined the dependence of shower intensities upon barometric pressure as it varies at a single station.

Three bundles of counters were used, each containing three counters in parallel. The sensitive volume of a single counter was 20 cm long by 2.5 cm diameter. Each bundle was incased in an aluminum tube 9 cm in diameter. Coincidences between bundles were selected and recorded by means of a circuit already described.[7] Recording dials were photographed automatically at intervals of one hour and barometric pressures for corresponding times were obtained from the reports of the Philadelphia Branch of the U. S. Weather Bureau. The apparatus was operated in a thin wooden structure on the roof of the Bartol Laboratory approximately 100 meters above sea level.

In the first run the tubes were arranged as indicated by the insert diagrams of Figs. 1 and 2 and were covered by a lead plate $10 \times 25 \times 1.2$ cm^3. The duration of this run was approximately four weeks. The records for five days of this time are plotted in Fig. 1 where the solid line joins points representing the numbers of counts in four hour intervals, and the dotted line represents the variation of the barometer plotted on an inverted scale. It is clear that a distinct correlation exists between the two curves.

In calculating the average barometer effect all of the shower rates corresponding to each 0.1-inch interval of the barometer have been averaged and the probable error of each average has been computed in the usual way from the dispersion. These averages with their probable errors are plotted against barometric pressure in Fig. 2. The best straight line was found by a least-squares solution in which each point was weighted inversely as the square of its probable error. The solution is represented by the solid line, the slope of which gives the average barometer effect. The probable error of the slope is indicated by the two dotted lines. From the solution we find a barometer effect for this arrangement of counters of 0.00542 ± 0.00027 per mm mercury, corresponding to 0.41 per meter of water. This accords with the value 0.5 found by altering the elevation.

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[1] Presented at the Washington Meeting of the American Physical Society 1934. Phys. Rev. **45**, 758 (1934).

[2] T. H. Johnson, Phys. Rev. **45**, 569 (1934); **47**, 318 (1935).

[3] B. Rossi and S. de Benedetti, Ricerca Scient. (5) **1**, 594 (1934).

[4] D. D. Montgomery and C. G. Montgomery, Phys. Rev. **47**, 339 (1935).

[5] R. D. Bennett, G. S. Brown and H. A. Rahmel, Phys. Rev. **47**, 339 (1935).

[6] $\mu = (1/I)dI/dh$.

[7] T. H. Johnson and J. C. Street, J. Frank. Inst. **215**, 239 (1933).

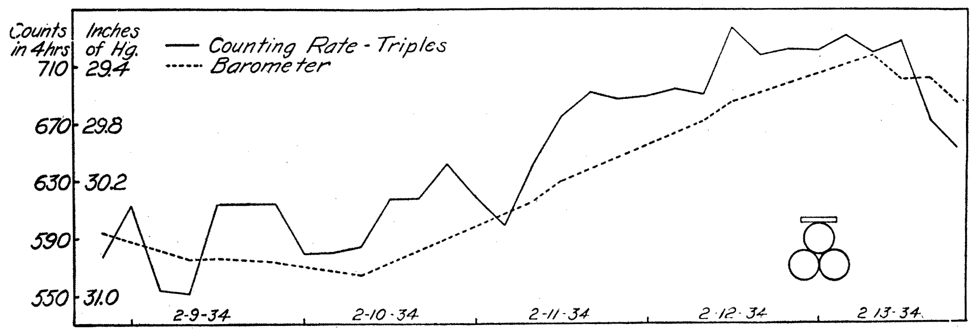

FIG. 1. A five-day run showing the variation of showers with barometer reading.

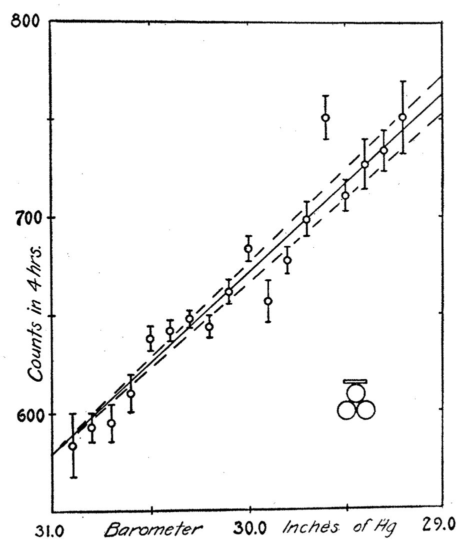

FIG. 2. Average shower intensities *vs.* barometer reading.

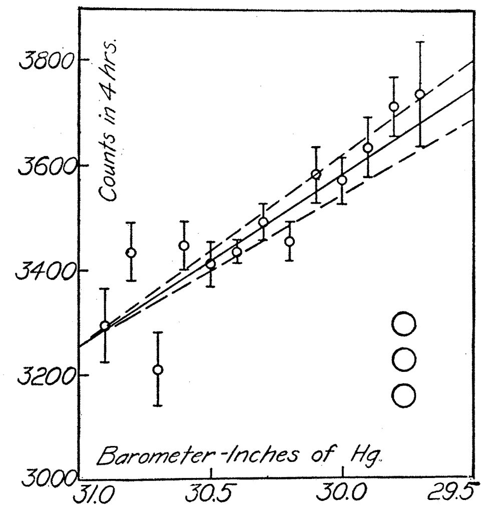

FIG. 3. Average vertical intensity *vs.* barometer reading.

We have likewise determined the barometer coefficient of the vertical rays, using an arrangement of the same counters represented by the insert of Fig. 3. In this case the outside counters were separated 25 cm and the arrangement included rays within 17 degrees either side of the vertical in one dimension and 38 degrees in the other. The average counting rates with probable errors for each 0.1-inch interval of barometer are plotted in Fig. 3 and from the least-squares solution we find a barometer effect of 0.00362 ± 0.00044 per mm mercury or 0.28 per meter of water. According to the four-component analysis of Bowen, Millikan and Neher[8] the

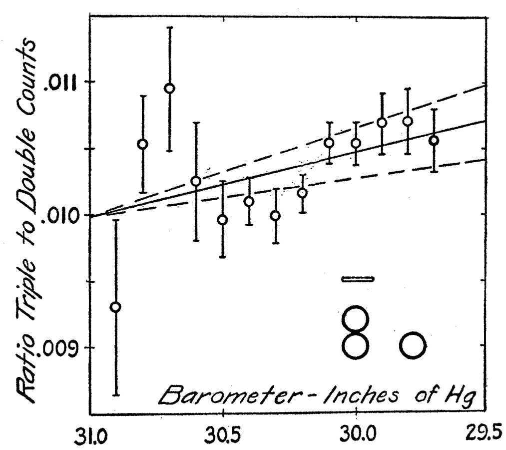

FIG. 4. Ratio of shower intensity to vertical intensity *vs.* barometer reading.

[8] I. S. Bowen, R. A. Millikan and H. V. Neher, Phys. Rev. **44**, 264 (1933).

average vertical absorption coefficient at sea level should be 0.325 per meter of water which agrees satisfactorily with our value.

These experiments have confirmed our expectation that the shower intensities would have a higher barometer effect than the total radiation. However for added confirmation a third experiment was made with the arrangement represented by the insert of Fig. 4. In this case the double coincidences of the two vertical counters were recorded simultaneously with the triple coincidences and the ratio of triples to doubles was computed for each hourly interval. The ratios were then subjected to an analysis similar to that described above. The average values of the ratio for each interval of the barometer are represented in Fig. 4 and from these, by least-squares analysis, we find a barometer effect of 0.0019 ± 0.00079 per mm mercury. It is noted that the barometer effect for the ratio is equal, within the probable errors, to the difference $0.0054 - 0.0036 = 0.0018$ of the barometer effects found for showers and verticals individually.

We conclude that the showers at sea level are either produced to a greater extent by a soft component of the primary radiation which becomes filtered out to a greater extent in the case of the higher barometric pressures, or, as suggested by Swann,[9] the intensity of showers in equilibrium with a corpuscular primary radiation is greater for lower barometric pressures where average energies are greater.

[9] W. F. G. Swann, Phys. Rev. **46**, 828 (1934); **47**, 250 (1935).

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The Absorption of Sunlight by the Earth's Atmosphere in the Remote Infrared Region of the Spectrum

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Spectroheliometric observations on the absorption spectrum of the Earth's atmosphere have been extended from 5μ to 21μ. The long wave limit of transmission imposed by the atmosphere occurs at 13.5μ. It is occasioned primarily by ν_2 of CO_2 and to a lesser extent by ν_2 of O_3. The carbon dioxide absorption blends with the pure rotation spectrum of water vapor at approximately 17μ to render the region beyond 13.5μ opaque to stellar radiation.

Introduction

There are several reasons why an analysis of the remote infrared telluric spectrum is consequent to our spectral studies of planetary atmospheres. With the ultimate application of high resolution to the study of fine structure of the atmospheric absorption bands we shall be possessed of an excellent means of determining not only the atmospheric content of the absorbing gases, but certain atmospheric temperatures and pressures as well. Thus, for example, we shall be able to ascertain the mean temperature and pressure as well as the content of the ozone layer. Furthermore, it is of considerable importance to locate the atmospheric windows; that is, regions in the spectrum through which stellar radiation can reach the Earth's surface. Finally, the most important single factor influencing the climate of our planet is the atmosphere's reaction to radiation emitted by the Earth's solid and liquid surface; that is, the "blanketing effect," an accurate treatment of which requires a knowledge of just that region of the telluric spectrum observed in the present investigation, since the near-black body emission of the Earth's surface is almost entirely confined to the region between 5μ and 50μ.

The Near Infrared Telluric Spectrum

Inasmuch as the present work marks the conclusion of an investigation initiated almost a