World-Wide Changes in Cosmic-Ray Intensity

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Introduction

In a former investigation[1] variations in the average cosmic-ray intensity for intervals of one-third month, at each of four widely separated stations (see Table I) were shown to be well represented—over the entire period for which data were then available (minimum period 17 months)—as the sum of two components. One component consisted of a systematic 12-month seasonal wave, S, and the other of an irregular world-wide component, W.

The coefficient of correlation between the means of W, for intervals of one-third month, at any two of the stations was found to be about 0.90. This high correlation permitted a reliable determination of the ratio of W for each station to that for Huancayo. These ratios are given in Table I, in which are also indicated the amplitude and date of maximum of S originally obtained[1] for each station. (Procedure for separating S and W and for the derivation of the relative magnitudes of W are given in reference 1.)

World-Wide Effects Based on Recently Extended Data

The purpose of the present paper is to extend the determination of monthly means of W at each station to include all data now available. Fig. 1 indicates the variations in the observed monthly means of cosmic-ray intensity (after correction to constant barometric pressure) at each of the first four stations in Table I.

Figure 2 indicates the reliability of the original[1] determination of S and its constancy at Cheltenham and Christchurch. The wave in Fig. 2 is the original S for Christchurch minus that for Cheltenham. The points indicate, for each month, the difference of observed monthly means for Christchurch and for Cheltenham. The close approximation of the wave to the points indicates the excellent agreement between the monthly means of W at these two stations (see Fig. 3). In Fig. 3, W for Huancayo, August, 1938, to March, 1939, was sometimes as much as two percent above W for the other stations. This discrepancy probably arises since, during this interval, the electrometer and insulators of the cosmic-ray meter at Huancayo were not kept properly dried, as they were at all other times. Fig. 3 shows that by May, 1939, when the original practice of renewing driers weekly—as is done regularly at Cheltenham and at Christchurch—was resumed, W for Huancayo was again in fair agreement with W for Cheltenham. The discrepancy at Huancayo is further indicated in Fig. 4, in which the wave is the original S for Christchurch. The circles result from deducting the observed monthly means (shown in Fig. 1) at Huancayo from those at Christchurch—the procedure used originally to determine S for Christchurch. These points are well fitted by the wave except from July to December, 1938—the interval during improper drying of electrometer and insulators at Huancayo. The open squares in Fig. 4 were obtained by subtracting from the observed monthly means at Christchurch the monthly means of W for Cheltenham, obtained by deducting S from the

TABLE I. *Location and elevation of cosmic-ray stations, magnitude of world-wide component relative to Huancayo, and amplitude and time of maximum for seasonal wave for each.*

Station	Latitude	Longitude	Geomagnetic latitude	Elevation above sea level	World-wide effect relative to Huancayo	Seasonal wave Amplitude[a]	Seasonal wave Date of maximum
Cheltenham, United States	38.7°N	76.8°W	50.1°N	72 m	1.11	1.6%	January 19
Teoloyucan, Mexico	19.2°N	99.2°W	29.7°N	2285	1.58	1.0	January 24
Huancayo, Peru	12.0°S	75.3°W	0.6°S	3350	1.00	0.0	——
Christchurch, New Zealand	43.5°S	172.6°E	48.0°S	8	1.05	0.8	July 28
Hafelekar, Germany	47.3°N	11.3°E	48.4°N	2300	1.59[b]	1.9	January 15

[a] In percent of total cosmic-ray intensity.
[b] From world-wide effects in two different magnetic storms only.

[1] S. E. Forbush, Phys. Rev. **54**, 975–988 (1938).

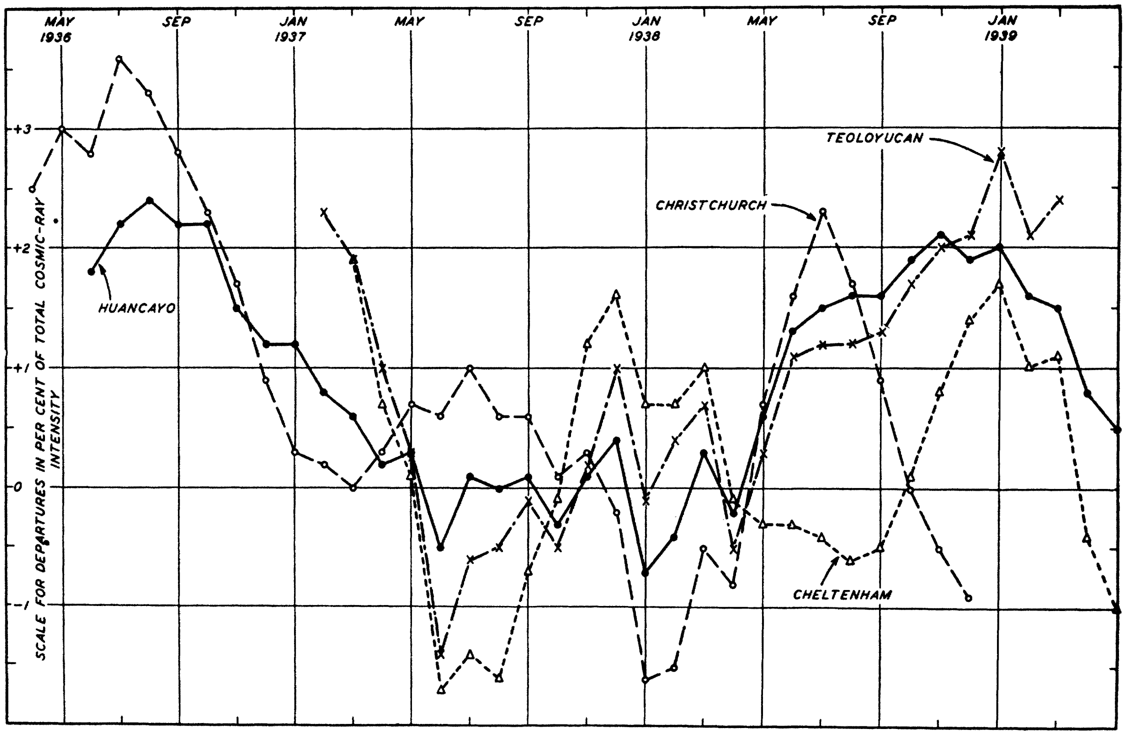

FIG. 1. Departures monthly means cosmic-ray intensity from mean for year beginning April, 1937.

observed monthly means at Cheltenham. The open squares closely fit the original S for Christchurch even in the interval when the circles depart from the wave.

The original S for Teoloyucan was derived from data for April, 1937, to April, 1938, and was obtained by deducting the monthly means of $W\times1.58$ (see Table I) for Huancayo from the observed monthly means indicated in Fig. 1 for Teoloyucan.

In Fig. 5 is shown the result of deducting separately from the observed monthly means at Teoloyucan the monthly means of $W\times1.42$ for Cheltenham and of $W\times1.42$ for Christchurch (from Table I; 1.42 is taken for the ratio of W at Teoloyucan to W at Cheltenham or Christchurch). To fit satisfactorily the two sets of points in Fig. 5 it was necessary to assume, in addition to the original S for Teoloyucan, a linear increase with time in the observed monthly means. Such increase is quite artificial and is possibly an indication of inadequate insulation similar to that at Huancayo. For Teoloyucan W is now obtained by deducting the ordinates of the smooth curve in Fig. 5 from the observed monthly means in Fig. 1. In Fig. 3 W for Teolo-

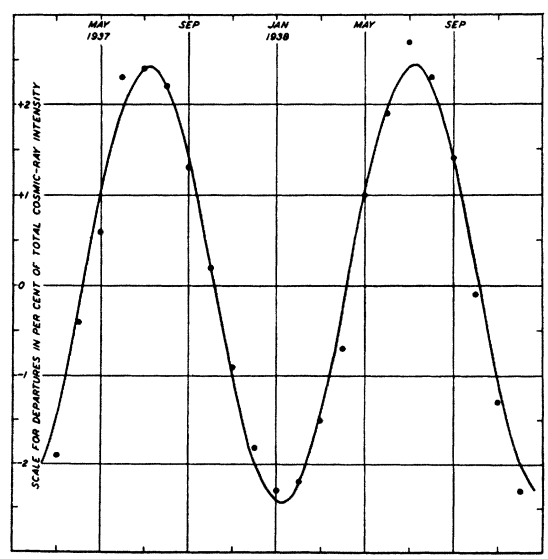

FIG. 2. Departures monthly means cosmic-ray intensity from mean for year beginning April, 1937, for Christchurch minus corresponding departures for Cheltenham; indicated wave derived from difference: adopted seasonal wave for Christchurch minus adopted seasonal wave for Cheltenham.

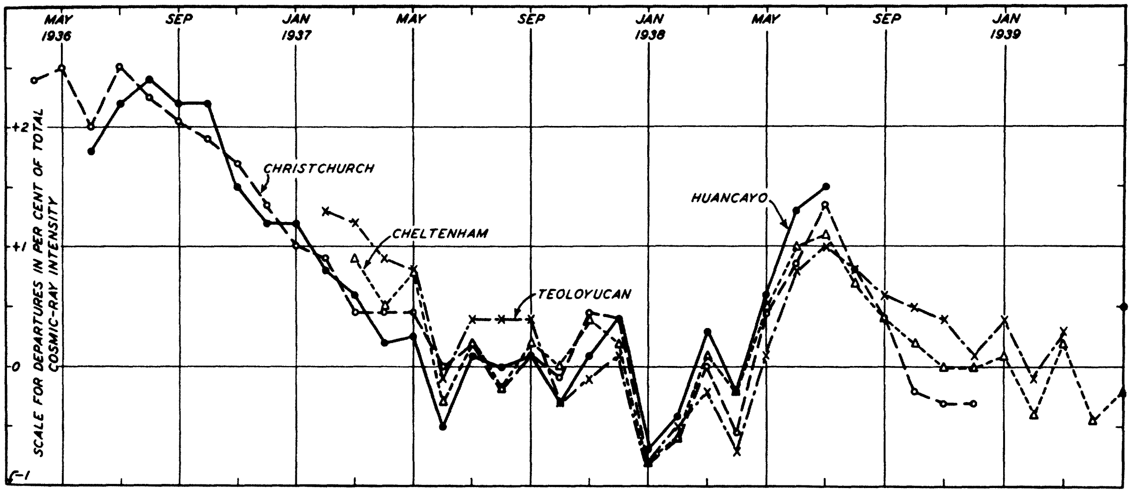

FIG. 3. Departures monthly means world-wide component cosmic-ray intensity from mean for year beginning April, 1937, at four stations referred to Huancayo.

yucan has been reduced to Huancayo (for comparison) using the factor 1/1.58 (see Table I).

It should be emphasized that excellent agreement in W for different stations, over long intervals of time, can be expected only in the complete absence of instrumental changes. If the indicated discrepancies result from such changes then the world-wide effect provides a reliable means of checking the stability of the different meters. Whether this is actually the case can doubtless be determined from further data.

In any case, these discrepancies cannot materially alter the high correlation[1] between changes in the means of W for each one-third month, of which one example is shown in Fig. 6.

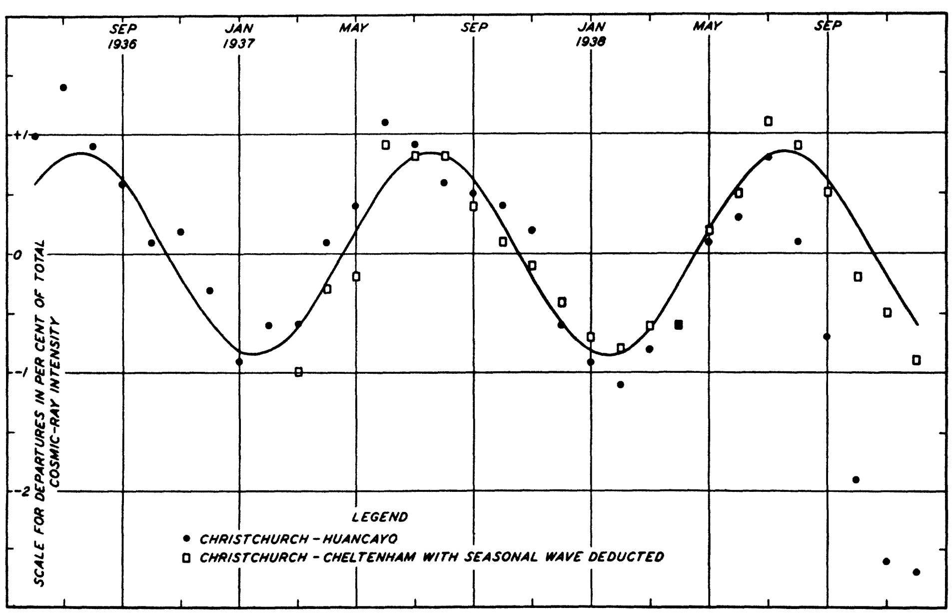

FIG. 4. Departures monthly means cosmic-ray intensity from mean for year beginning April, 1937, for Christchurch minus corresponding departures for Huancayo, and for Christchurch minus corresponding departures for Cheltenham with seasonal wave deducted; adopted seasonal wave for Christchurch indicated.

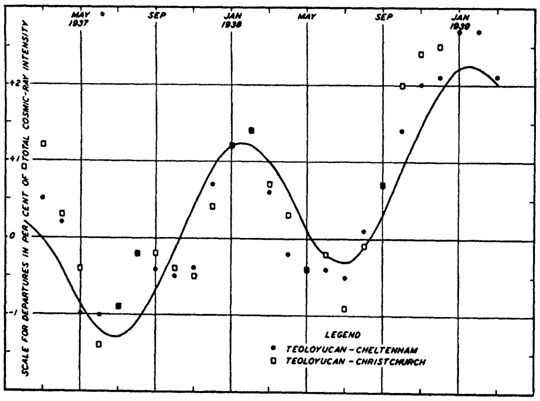

FIG. 5. Departures monthly means cosmic-ray intensity from mean for year beginning April, 1937, for Teoloyucan after deducting corresponding departures, world-wide component derived separately from data for Cheltenham and for Christchurch; adopted seasonal wave plus linear change for Teoloyucan indicated.

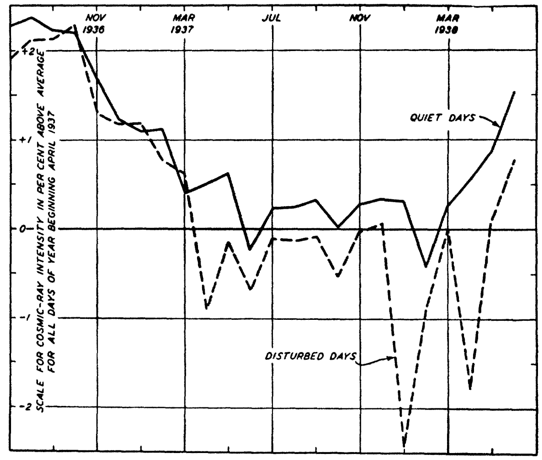

FIG. 7. Cosmic-ray intensity at Huancayo, Peru, averaged for the five international magnetically quiet days, and for the five international magnetically disturbed days of each month, July, 1936 to June, 1938.

Association Between World-Wide Effects and Terrestrial Magnetic Activity

The largest world-wide effects in cosmic-ray intensity have occurred,[2] during magnetic storms, as decreases simultaneous with decreases in magnetic horizontal intensity at the equator. While some magnetic storms[2] have occurred without detectable changes in cosmic-ray intensity there is a definite tendency for lower cosmic-ray intensity to occur on days of greatest magnetic disturbance. Designating each month's average value of cosmic-ray intensity for the five international magnetically disturbed days

[2] S. E. Forbush, Terr. Mag. **43**, 203–218 (1938).

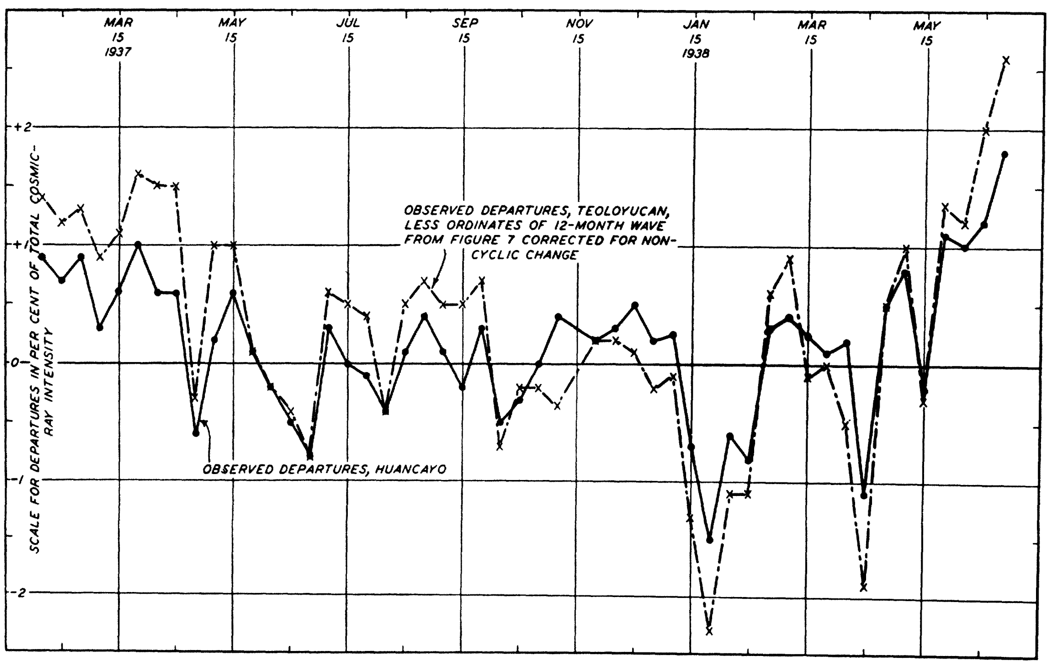

FIG. 6. Departures cosmic-ray intensity for each one-third month from mean for year beginning April, 1937, for Teoloyucan after deducting 12-month wave, and for Huancayo. (Fig. 7 in legend applies to Fig. 7 of reference 1.)

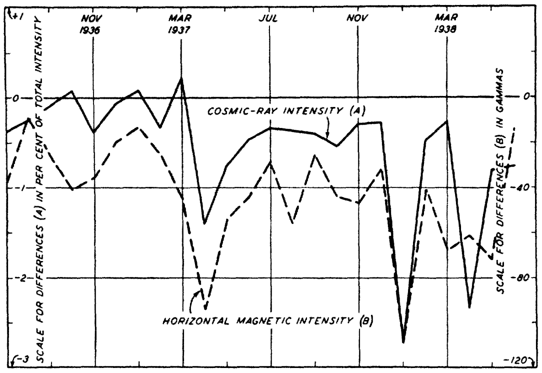

FIG. 8. Monthly difference, average for five international magnetically disturbed days minus average for five international magnetically quiet days, for cosmic-ray intensity and for horizontal magnetic intensity at Huancayo, Peru, July, 1936 to June, 1938.

by C_D and that for the five international magnetically quiet days by C_Q, then C_D is nearly always less than C_Q. In Fig. 7 C_D and C_Q are shown for July, 1936, to June, 1938, at Huancayo. In three cases C_D is slightly above C_Q. Fig. 8 indicates for each month the difference (C_D-C_Q) and the corresponding difference (H_D-H_Q) for magnetic horizontal intensity at Huancayo. Considerable correspondence is evident between the two curves of Fig. 8. This evidence, together with that from magnetic-storm effects,[2] suggests that the world-wide changes in cosmic-ray intensity result from alteration of the trajectories of cosmic-ray particles in the external field superposed on that of the earth during magnetic disturbance. The main effect on cosmic-ray particles probably arises from the Störmer[3] equatorial ring-current. The curve for quiet days in Fig. 7 suggests that the Störmer ring may even be present on magnetically quiet days.

Dr. D. la Cour, Director of the Danish Meteorological Institute, which cooperates with the Carnegie Institution of Washington's Committee for Coordination of Cosmic-Ray Investigations by operating a Compton-Bennett cosmic-ray meter at its Godhavn Magnetic Observatory, has just advised that the cosmic-ray intensity was especially low at Godhavn during the magnetic storms which occurred near the end of April, 1939. During this period the cosmic-ray intensity at Cheltenham and Huancayo decreased about three percent. If the observation of a simultaneous decrease at Godhavn is confirmed, it will be of particular interest in view of the geomagnetic latitude (75° North) of that station.

[3] C. Störmer, Terr. Mag. 35, 193–208 (1930).