THE SEMIDIURNAL VARIATION OF MESON INTENSITY

BY VIKRAM SARABHAI

(The Department of Physics, Indian Institute of Science, Bangalore)

Received January 6, 1945

INTRODUCTION

FOR over a decade it has been known that the cosmic ray intensity at any particular place is not constant at all times. The small periodic and irregular variations in the intensity have been extensively studied at various stations; and the variations have been correlated with changes of the meteorological elements of pressure and temperature, and of the magnetic elements due to terrestrial and solar causes.

As shown recently by Duperier[1], the negative correlation between atmospheric pressure and cosmic ray intensity is due not only to an increase in the absorbing air mass with an increase of pressure, but also to the raising of the effective level at which mesons are formed, with a consequent increase in their probability of decay. The negative correlation with seasonal temperature of the atmosphere is also explained in terms of meson decay on lines originally suggested by Blackett[2]; but the experimental results are somewhat complicated by the fact that the temperature of the atmosphere near the earth's surface does not give a representative picture of the state of affairs at high altitudes. However, the work of Hess *et al.*[3] has indicated the methods by which the difficulties can be overcome by using radiosonde data. With respect to changes in intensity brought about by the variation of the magnetic field, Vallarta and Goddart[4] have shown how different factors depending on the latitude of the station are operative. The experiments indicate that the correlation between the intensity and the field at the place in question is negative for diurnal and seasonal changes but that it is positive during a magnetic storm.

While thus a good deal of theoretical and experimental study has been made of the variation of cosmic ray intensity; it is impossible to directly make use of this knowledge for correcting the results of accurate cosmic ray experiments because of the simple reason that normally one is not in possession of data of all the meteorological and magnetic factors responsible for the intensity variations. During the course of a recent investigation on the intensity of slow mesons by the method of shower anticoincidences[5], it was noticed in fact that large variations lying outside the statistical error were taking place in the measured intensity at different times of the day and from day to day. It was proposed to correct for this by means of another independent apparatus which had a counting rate large enough to make the statistical error negligible, and which followed the variations of the shower anticoincidence intensity. Thus a detailed study was begun of the variation of intensity as measured by different counter arrangements. As there are few puublished results of similar studies at stations near the geomagnetic equator, and the observations at Huancayo and Kodaikanal[6] were made with ionization chambers where intensities from all directions were measured, a correlation with atmospheric pressure was also attempted in the present work.

Experimental Results

To study the variation of intensity with local mean time, the hourly values of intensities were measured with counter arrangements giving the following:—

A. The total intensity as measured by two counters placed vertically on top of each other in double coincidence, giving a mean counting rate of 56·23 counts per minute. As the counters were touching each other, the solid angle was very wide, and there must also be a considerable side shower effect.

B. The shower rate measured under 1·5 cms. of lead by two parallel horizontal counters touching each other, and in double coincidence giving a mean counting rate of 21·605 counts per minute. Single particles incident at a zenith angle greater than 45° could also register a coincidence in this arrangement.

C. The shower anticoincidence rate measured with 1·5 cms. of lead at X (see earlier paper[5]) giving a mean counting rate of 1·5445 counts per minute. The vertical rate was in this case measured with quadruple coincidences in order to eliminate the side shower effect; and the vertically incident particles accompanied by showers either from the air above or the lead block at X were eliminated by the shower anticoincidence counters. It has been shown[5] that this counting rate is essentially due to the vertically incident mesons.

In addition to the above, the pressure was recorded continuously during the experiment with a microbarograph and hourly readings with a Fortin's barometer were taken as a check. Indian Standard Time is used throughout this paper and is one hour and twenty minutes in advance of the local mean time.

The result with the various arrangements is shown in Table I. It can be seen that A and B show the well-known diurnal variation of intensity with a maximum during the afternoon and a minimum during the night. Considering that in both these arrangements we are measuring an effect which is due to showers as well as single particles and that wide solid angles are subtended, it is not surprising that we obtain a variation which is similar in both cases and agrees with the results of the other workers who have studied this aspect with ionisation chambers. It should be noticed, however, that the percentage variation of B is much greater than of A. If this is due to the larger proportion of showers to single particles in B, we would be led to the conclusion that this phenomenon is mainly connected with the soft component.

TABLE I

Mean percentage variation of intensity and atmospheric pressure averaged for six hours in each column

Arrangement	Total counts	I.S.T. (1 hour and 20 minutes in advance of local mean time)			
		0300 to 0900	0900 to 1500	1500 to 2100	2100 to 0300
A from 8-9-1944 to 21-9-1944	872303	− ·037 ± ·147%	+ ·052 ± ·147%	+ ·244 ± ·147%	− ·260 ± ·147%
B from 10-9-1944 to 21-9-1944	342227	−1·127 ± ·229%	+ ·043 ± ·229%	+1·385 ±0·229%	− ·295 ± ·229%
C from 18-9-1944 to 24-9-1944	11120	−3·05 ±1·14%	+0·99 ±1·28%	−1·43 ±1·28%	+3·50 ±1·14%
Atmospheric pressure from 18-9-1944 to 24-9-1944		− ·0034%	+ ·0766%	− ·1117%	+ ·0418%

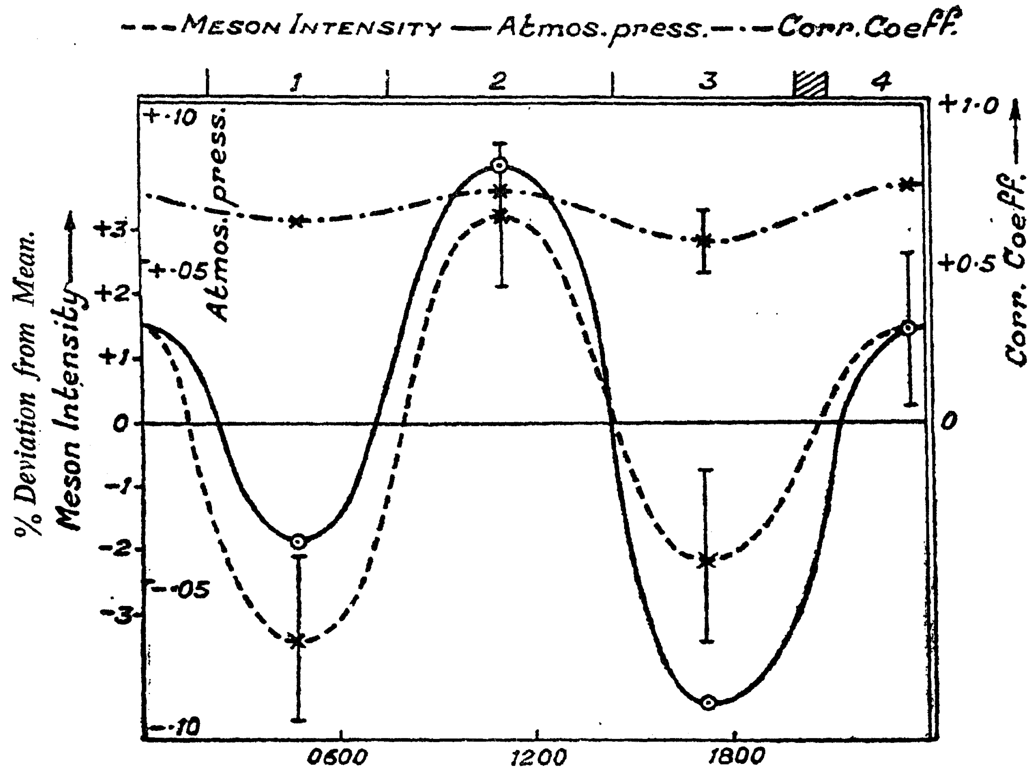
The course of variation of C is however totally different. We find, in the first place, that over 12 hour periods the intensity is slightly greater in the night than during the day. But in addition, we can clearly see a semidiurnal variation with a period of approximately 12 hours. What is more remarkable is that this variation is correlated with the semidiurnal variation of pressure and the total correlation coefficient comes out to be $+\cdot 46 \pm \cdot 11$. In order to quantitatively study this aspect, it was necessary to eliminate the secular changes of both the meson intensity and the atmospheric pressure. The importance of doing this is realised when we consider that the secular changes of pressure are negatively correlated with the intensity, as opposed to the positive correlation found in the semidiurnal variation. The elimination of these secular changes was carried out by taking the 24 hourly means and adjusting them to the total mean, making the assumption that the secular change is linear between any two 24 hourly means. The result of this correction is to reduce the mean of each day to the common mean, so that only the semidiurnal variation is left in the data. The figures given for C and the barometric pressure in Table I refer to the variation after correcting for the secular change.

TABLE II

Mean percentage variation of meson intensity and atmospheric pressure averaged over periods during which atmospheric pressure is either entirely above or below mean values in the semidiurnal variation

Arrangement	Total counts	Mean rate per minute	I. S. T.			
			0200 to 0730	0730 to 1430	1430 to 2000	2100 to 0200
C From 8–12–44 to 12–12–44	11113	1·8546 ±0·0118	−3·45 ±1·38	+3·26 ±1·12	−2·13 ±1·37	+1·41 ±1·28
Atmospheric pressure from 8–12–44 to 12–12–44			−0·0371	+0·0807	−0·0885	+0·2820
Correlation coefficient			+·62 ±·20	+·72 ±·14	+·56 ±·23	+·65 ±·17

Table II and Fig. 1 show the results of an independent experiment carried out from the 8th to the 12th of December at the Bangalore Meteorological Office to check the results of C obtained in the first experiment. In this case hourly values were not taken, but only at times corresponding to the epochs of the semidiurnal variation of pressure where the pressure is at its mean value. This is necessary for a proper correlation of the two variations because the semidiurnal pressure change does not have an exactly 12 hour period. Each of the four intervals now taken corresponds either to pressures entirely above mean or to those entirely below. The values between 2000 and 2100 hours were not considered as during this period the functioning of the apparatus was checked. The second experiment has shown a strong positive correlation of ·623 ± ·097. This represents the over all coefficient, but in Table II and the figure the correlation coefficient for each of the four periods is also shown. With the data so far available it is extremely probable that the positive correlation obtained in both cases is significant but quantitative



I. S. T. (1*hr.* 20 *mins. in advance of local mean time*)

FIG. 1. Graph showing the semidiurnal variation of meson intensity and the atmospheric pressure and the correlation coefficient connecting the two. Table II. Data obtained at the Bangalore Meteorological Office from 8-12-44 to 12-12-44.

treatment is not undertaken till the phenomenon has been completely confirmed by more extensive experiments now in progress.

DISCUSSION

A positive correlation between the semidiurnal variation of atmospheric pressure and the meson intensity has not so far been reported to the knowledge of this author. The semidiurnal variation itself seems to have been noticed independently by two German authors[7,8] as I have recently, after the completion of the above experiments, come across two abstracts of papers published since the outbreak of war. Ehmert[8] has suggested a connection with the oscillations of the atmosphere causing the semidiurnal variation of pressure; but details of his paper are not available. The somewhat puzzling positive correlation is explained very simply on the meson decay hypothesis if one considers the now accepted view about the nature of the atmospheric oscillations. The problem has been worked out in detail by Pekeris since the earliest work of Rayleigh. According to our present knowledge, the atmosphere has two free modes of vibration; one of these consists of a stationary wave of 12 hour period travelling along the parallels of latitude and having a node at about 30 km. The atmosphere vibrates horizontally in opposite phase above and below this level. It immediately follows therefore that a rise in pressure at the surface corresponds to a rarifaction in levels above 30 km., resulting in an effective lowering of the meson forming layer with an increase in the surface meson intensity. Apart from the theoretical justification for this view, it is found that the explanation of the semidiurnal variation of the magnetic field also requires a similar idea of phase inversion in the upper atmosphere.

A positive correlation between meson intensity and pressure does not necessarily imply that there is a causal relationship between the two. The above given reason can only be proved to be correct if it is known that the variation of meson intensity is not caused by the semidiurnal variation of the magnetic field with which it appears to be negatively correlated. Probably both the factors are operative; but as in magnetic storms there is a positive correlation with intensity, this point requires further study before an answer can be given.

It is worthwhile considering the reason why this effect has not been noticed in the earlier investigations. It is clear, in the first place, that as at sea level the soft component is almost entirely secondary to the hard component, the study of the variation will be confused unless each component is studied by itself. Several of the ionisation chamber studies cannot be said to conform to this condition. Furthermore, the effect will be properly brought out only in instruments with narrowly restricted solid angles. A wide aperture will tend to blur the true variation and flatten the maximum. Lastly it must be remembered that the semidiurnal variation of pressure is strongest in the tropics and becomes quite negligible in temperate latitudes. As most of the other investigations have been done in higher latitudes, the effect might have escaped notice due to its small amplitude.

The picture presented here would, if confirmed, give a powerful tool for the study of the levels of meson formation. It is true that the heights of formation will have to be considerably higher than what was commonly supposed some years back. But after the experiments of Schein *et al.*[10] who found a continuously increasing meson intensity upto the stratosphere, the view that mesons are mainly created within the troposphere is being slowly given up. Further experiments are now being undertaken to clarify the issues and to determine the time variation of cosmic rays measured with other counter arrangements not using the method of shower anticoincidences.

I am deeply grateful to Prof. Sir C. V. Raman for his interest and helpful discussions. For help in taking round the dial readings, I am thankful to Messrs. B. V. A. Iyer, H. R. Sreenivasiengar and C. R. Ananda Rao; and later the staff of the Bangalore Meteorological Office. This work would not have been possible but for the whole-hearted co-operation of the Indian Meteorological Department and particularly Dr. K. R. Ramanadhan and Messrs. D. Basu and R. Pisharoty.

Summary

An investigation of the diurnal variation of the cosmic ray intensity with different counter arrangements has been made. The results obtained are similar to those reported by previous investigators, except in the case of the meson intensity measured with the method of shower anticoincidences. Here a semidiurnal variation which is positively correlated with the semidiurnal variation of pressure has been found. An explanation in terms of the meson decay and the nature of the daily atmospheric oscillations has been suggested. The possibility of gaining knowledge about the altitude of the meson forming layer has been mentioned.

Bibliography

1. Duperier, A. .. *Terr. Mag. and Atmos. Elect.*, 1944, **49**, 1.
2. Blackett, P. M. S. .. *Phys. Rev.*, 1938, **54**, 973.
3. Hess, Benedetto and Altmann *Ibid.*, 1942, **61**, 266.
4. Vallarta and Goddart .. *Rev. Mod. Phys.*, 1939, **11**, 180.
5. Sarabhai, V. .. *Proc. Ind. Acad. Sci.*, *A*, 1944, **19**, 37.
6. Das and Salaruddin .. *Ind. J. of Phys.*, 1940, **14**, 191.
7. Regener and Rau .. *Naturwiss.*, 1939, **27**, 803.
8. Ehmert, A. .. *Ibid.*, 1940, **28**, 28.
9. Pekeris, C. L. .. *P.R.S.*, *A*, 1937, **158**, 650.
10. Schein, Jesse and Wollan .. *Phy. Rev.*, 1941, **59**, 615.

1207-44 Printed at The Bangalore Press, Bangalore City by G. Srinivasa Rao, Superintendent and Published by The Indian Academy of Sciences, Bangalore