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AN ANALYSIS OF THE SOLAR DAILY VARIATIONS OF THE PRIMARY COSMIC RADIATION MEASURED WITH THE IGY NEUTRON MONITOR NETWORK

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ABSTRACT

A study of the solar daily variation of the cosmic ray nucleonic component was made by performing harmonic analysis of the monthly averaged data from neutron monitor stations. Pressure corrected data recorded during the IGY were used.

It was observed that the amplitude of the daily variation, averaged over monthly periods, has large variations from period to period, which are of worldwide character; however the time of maximum for each given station remains practically constant.

Attention is given to the dependence of the amplitude with latitude;the results show no outstanding variation from equator to about 60° geographic, and a rapid drop for higher latitudes. The time of maximum amplitude shifts gradually from early to late afternoon hours with increasing latitude.

A comparison of data from northern and southern latitudes shows no asymmetry either in amplitude or time of maximum.

INTRODUCTION

The intensity variations of the primary cosmic radiation have been extensively studied with meson telescopes and ionisation chambers, but little with neutron monitors [1,2,3,4,5].

During the IGY there was in operation a network of about forty neutron monitors, continuous recording stations for the registration of the nucleonic component of the cosmic radiation.

The use of neutron monitors for the measurement of the primary cosmic radiation has the advantage that the corrections for the variation of the altitude of the pressure levels, so important for meson telescopes and ionisation chambers, can be neglected[5,6].

The analysis published so far[7,8] using data from neutron monitors are based on a rather limited number of recording stations. In

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1. H. Elliot - Time variations of cosmic ray intensity, Progress in Cosmic Ray Physics I, 453, 1952.

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5. L. I. Dorman - Cosmic Ray Variations Moscow 1957.

6. J. A. Simpson, W. Fonger and S. B. Treiman Physical Review 90, 934, 1953.

7. J. W. Firor, W. H. Fonger and J. A. Simpson Physical Review 94, 1031, 1954.

8. A. M. Conforto, J. A. Simpson Nuovo Cimento VI, 1052, 1957.

such cases one has to reckon with the major difficulties involved in the adoption of neutron monitors as recorders: securing longterm stability of equipment and avoiding spurious pulses which can easely modify results on small effects as the daily variation.

The large number of recording stations of the IGY network and their convenient worlwide distribution has produced a wealth of data which allows us to compare results from nearby monitors so as to isolate instrumental effects and to examine in much more detail than previously possible the intensity variations.

In this paper we have aimed at analysing the results from IGY neutron monitors for a study of the solar daily variation.

DATA SOURCES

The analysis presented in this paper is based on data from the stations listed in table I. In this table are given the geographic latitude and longitude, geomagnetic latitude, the altitude and the average bihourly counting rate of each station.

It is far from representing all the IGY stations, as for many we haven't received in time the data or we had too few of them to justify their use. Whenever possible we have used data from June 1957 to December 1958, but sometimes shorter periods were considered when we hadn't available the complete data.

DATA ANALYSIS

For a complete analysis of the daily variation an analysis of each individual day would be most desirable. In such case it would

TABLE I

STATION	COUNTRY	Geographic lat.	Geographic long.	Geomagn. latitude	Altitude (meters)	Counts per 2 hrs
Lae	New-Guinea	6.7ºS	147ºE	16ºS	S.level	16.500
Kodaikanal	India	10.2ºN	77ºE	1ºN	2520	38.500
Huancayo	Peru	12.0ºS	75ºW	0º	3350	325.000
R. de Janeiro	Brazil	22.9ºS	43ºW	12ºS	0	26.500
Mt. Norikura	Japan	36.1ºN	137ºN	25ºN	2840	227.500
Climax	U. S. A.	39.4ºN	106ºW	49ºN	3400	720.000
Chicago	U. S. A.	41.8ºN	87ºW	52ºN	s.level	42.000
Mt. Wellington	N. Zealand	42.9ºS	147ºE	51ºS	725	71.600
Mt. Washington	U. S. A.	44.2ºN	71ºW	55ºN	1909	128.000
Ottawa	Canada	45.4ºN	75ºW	56ºN	101	34.000
Deep River	Canada	46.1ºN	77ºW	57ºN	145	106.000
Zugspitze	Germany	47.4ºN	10ºE	48ºN	2960	430.000
Herstmonceux	England	50.8ºN	0º	53ºN	23	82.500
Sulphur Mt.	Canada	51.2ºN	115ºW	58ºN	2283	185.000
Goettingen	Germany	51.5ºN	9ºE	52ºN	273	60.000
Churchill	Canada	58.7ºN	94ºW	68ºN	39	34.500
Uppsala	Sweden	59.8ºN	17ºE	58ºN	s.level	48.000
Yakutsk	U.S.S.R.	62.0ºN	129ºE	51ºN	99	29.700
Mawson	Antartida	67.6ºN	62ºE	73ºS	0	33.800
Resolute	Canada	74.6ºN	94ºW	82ºN	17	37.000
Thule	Greenland	76.5ºN	68ºW	88ºN	s.level	41.000

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be necessary to eliminate slow non periodic variations (by the method of moving averages) and to add results from several stations to obtain a meaningfull statistical accuracy. Because of the enormous amount of computation work required by the latter we chosed to consider the daily variation averaged over longer periods.

In this paper we used the monthly mean of the corresponding bihourly data, as given in the standard IGY neutron monitor data sheets. In the cases that we had only the uncorrected data barometric corrections with a coefficient of 9.6%/cm Hg has been made.

The shape of the average daily variation is a good approximation to an harmonic wave. The second harmonic has an amplitude of only 15% of the amplitude of the first the maximum being at around 13 hours local solar time. In Fig. 1 one sees for instance both the first and the combination of the first and second harmonics averaged for twelve intermediate latitude stations during the IGY period plotted against the local solar mean time. The low precision in the determination of the 2nd harmonic* and especially the harmonics of higher order of still lower amplitude prevents us from making a meaningfull analysis of their detailed characteristics.

For the latter reasons in this anlysis we will characterise the daily variation by the amplitude of the first harmonic and by its phase expressed in local solar time. Hereafter when speaking of amplitude or time of maximum of the daily variation we will refer to the corresponding data of the first harmonic.

AMPLITUDE CHANGES OF THE DAILY VARIATION

When we consider the monthly averaged amplitude of the daily variation we can see that there are large changes from month to month. That these changes are not due to statistics or spurious effects can be seen from Fig. 2, where the values of the amplitude for 3 very near stations are plotted against the month. From these cur-

* The maximum amplitude of the second harmonics corresponds to a variation of only 1 part in 2000 in the average counting rate.

ves one can also estimate the influence of spurious effects on the measurement of the monthly amplitude and justify the small divergences between the points for each month in Fig. 3 or in Fig. 4.

That these variations are independent of longitude of the observatory can be seen in Fig. 3, where are plotted data from European, North American and Japanese monitors of similar latitudes but widely different longitudes.

We can judge the effect of the latitude from Fig. 4, where data from equatorial, intermediate and polar latitude stations are plotted. In the shape of these curves the similarity is retained except for a decrease of the mean amplitude for polar stations.

This effect was first noted by Firor et al.[7] comparing results from two neutron monitors, at Huancayo and Climax, and an ionisation chamber at Freiburg in Germany at an earlier period (3/51 to 3/53) of observation. We can now extend this observation to a much broader field.

Our data does not show any difference between stations in different hemispheres.

By the worldwide effect of the month to month variations, we justify the calculation of the average value of the amplitude for each month by combining simultaneous data from all the intermediate latitude stations. The result is drawn in Fig. 5.

VARIATION OF THE AMPLITUDE WITH GEOGRAPHIC LATITUDE

In order to examine the latitude dependence of the amplitude we combined corresponding values of amplitude at the various intermediate latitude stations. The result is displaied by Fig. 4. We then calculated the average of the monthly quocients between the amplitudes at the station we investigate and the average amplitude at intermediate latitudes. The resulting points give the relative latitude dependence of the amplitude and are shown in Fig. 6 against geographic latitude. In this way we can allow for the fact that we do not always have complete data for all the IGY period and compensate for the month variations in amplitude.

We can note here that the amplitude remains almost constant to the latitude of 60° geographic, up to the latitude cut-of-point of the cosmic radiation, droping rapidly towards zero at the geographic pole. In a previous paper, Firor et al.[7] compared neutron monitors at λ geog. = 12° and λ geog. = 39° giving a latitude effect of 1.48 ± 0.2.

From values from northern and southern hemispheres we observe that they match well each other suggesting a symmetry of the effect (Fig. 6). The same symmetry is true for the meson component and was observed by Elliot using eight years of shielded ionisation chamber data[1].

VARIATION OF THE TIME OF MAXIMUM WITH LATITUDE

The time of maximum of the daily variation at any given station does not show any dependence with the month that cannot be attributed to statistical or spurious effects. It does not depends on the variations of the amplitude. Indeed, due to our short period of observation and as they refer to a period of maximum solar activity we must not expect any strong systematic variation of time of maximum[2].

If we plot the time of maximum of the daily variation averaged for all the IGY in local solar time against the geographic latitude, we obtain the results of Fig. 7. We have drawn also, through these points, the best least-square fit. No difference can be seen between points from the northern and southern hemispheres. The time of maximum shifts from about 11h30 to 18h as we go from the equator to the pole.

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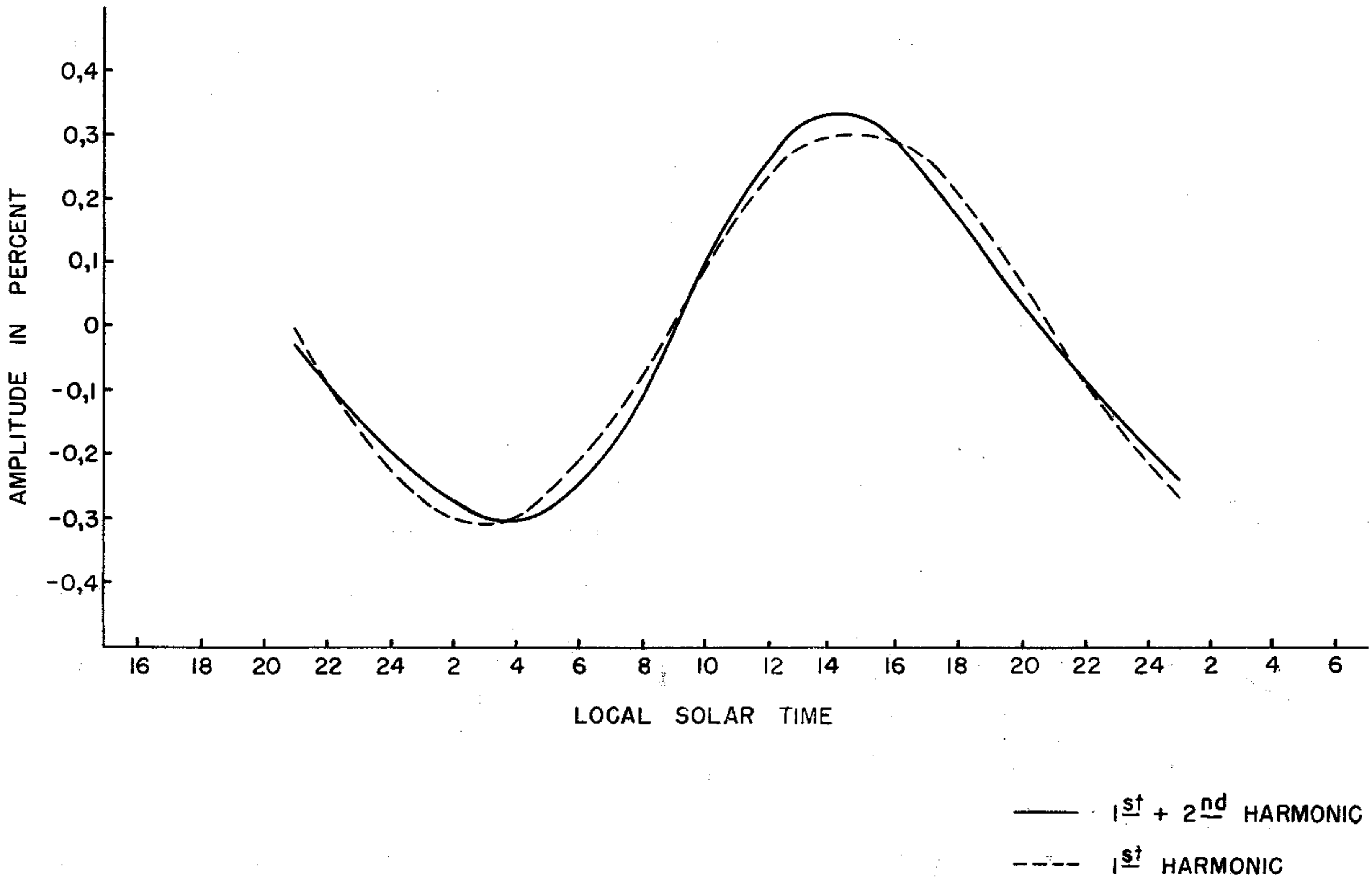


Fig. 1 - Averaged shape of cosmic radiation solar daily variation. Data from twelve neutron monitors located beween 30 and 60 degrees geographic latitude was used.

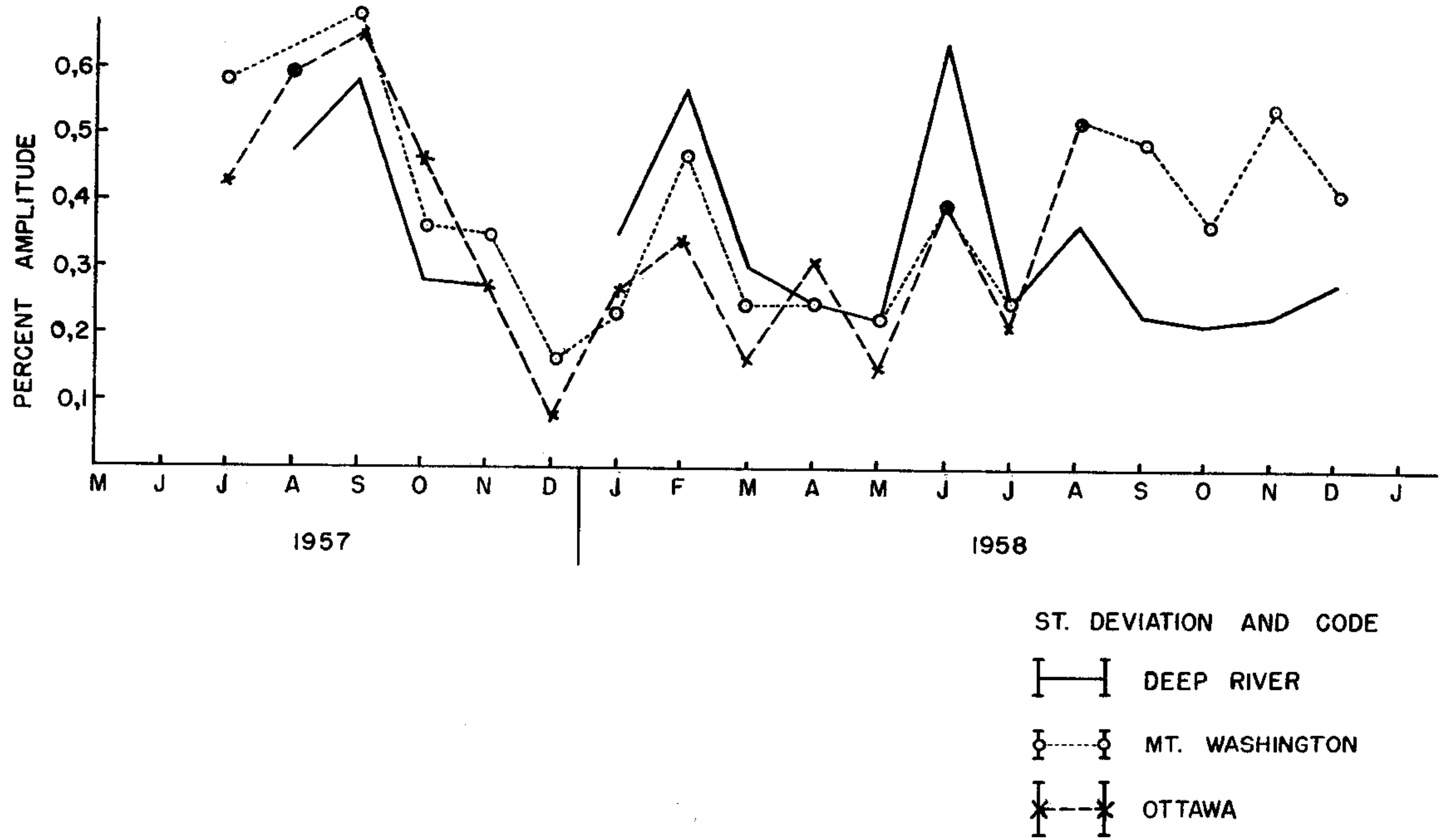
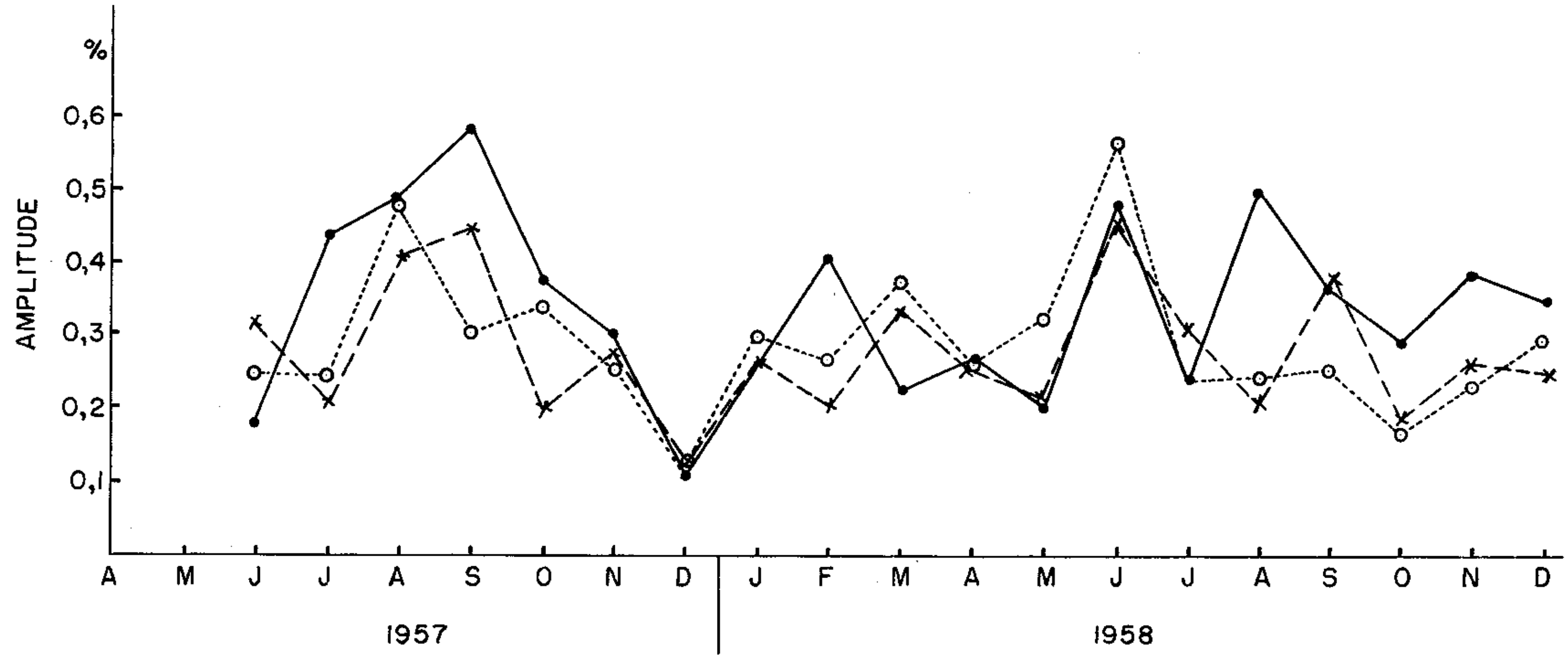


Fig. 2 - A comparison of the curves of the monthly averaged amplitudes of the daily variation for a group of three near station: Deep River, Ottawa and Mt. Washington.



<u>Fig. 3</u> - A comparison of the plot of monthly averaged amplitude of the Daily Variation is shown for three groups of stations with similar latitude but different longitude. North America is represented by Chicago, Climax, Deep River, Ottawa and Mt. Washington. For Europe were used Zugspitze, Herstmonceux and Goettingen. The Japanese station is Mt. Norikura.

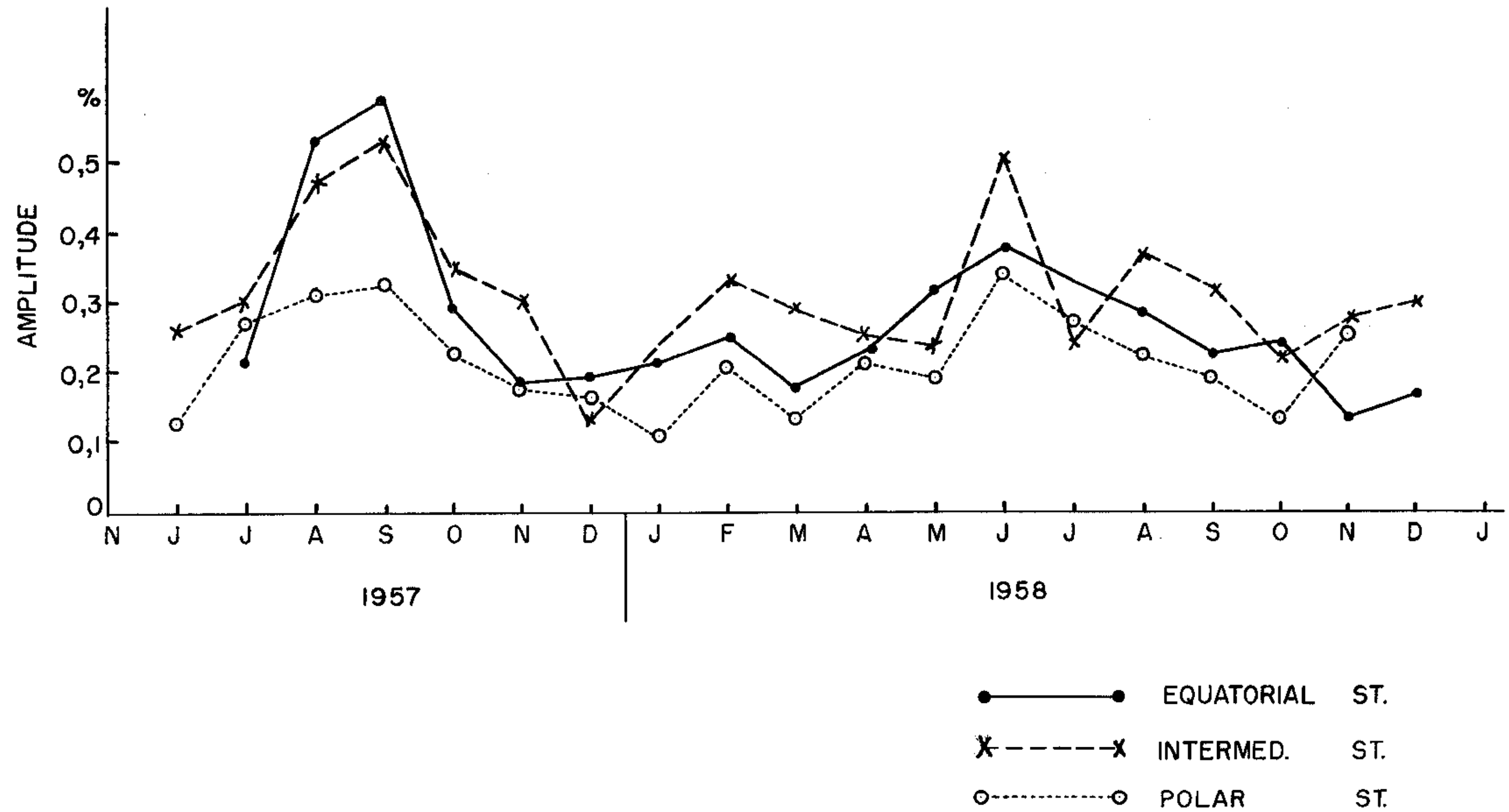


Fig. 4 - Displayed are the three curves of the monthly averaged amplitude of the Daily Variation for equatorial, intermediate and polar latitudes. The equaterial stations are Huancayo, Lae, Kodai kanal. The intermediate latitude stations are Chicago, Goettingen, Deep River, Herstmonceux, Mt. Norikura, Mt. Washington, Mt. Wellington, Ottawa, Sulphur Mountain, Zugspitze. The polar stations are Mawson and Resolute Bay.

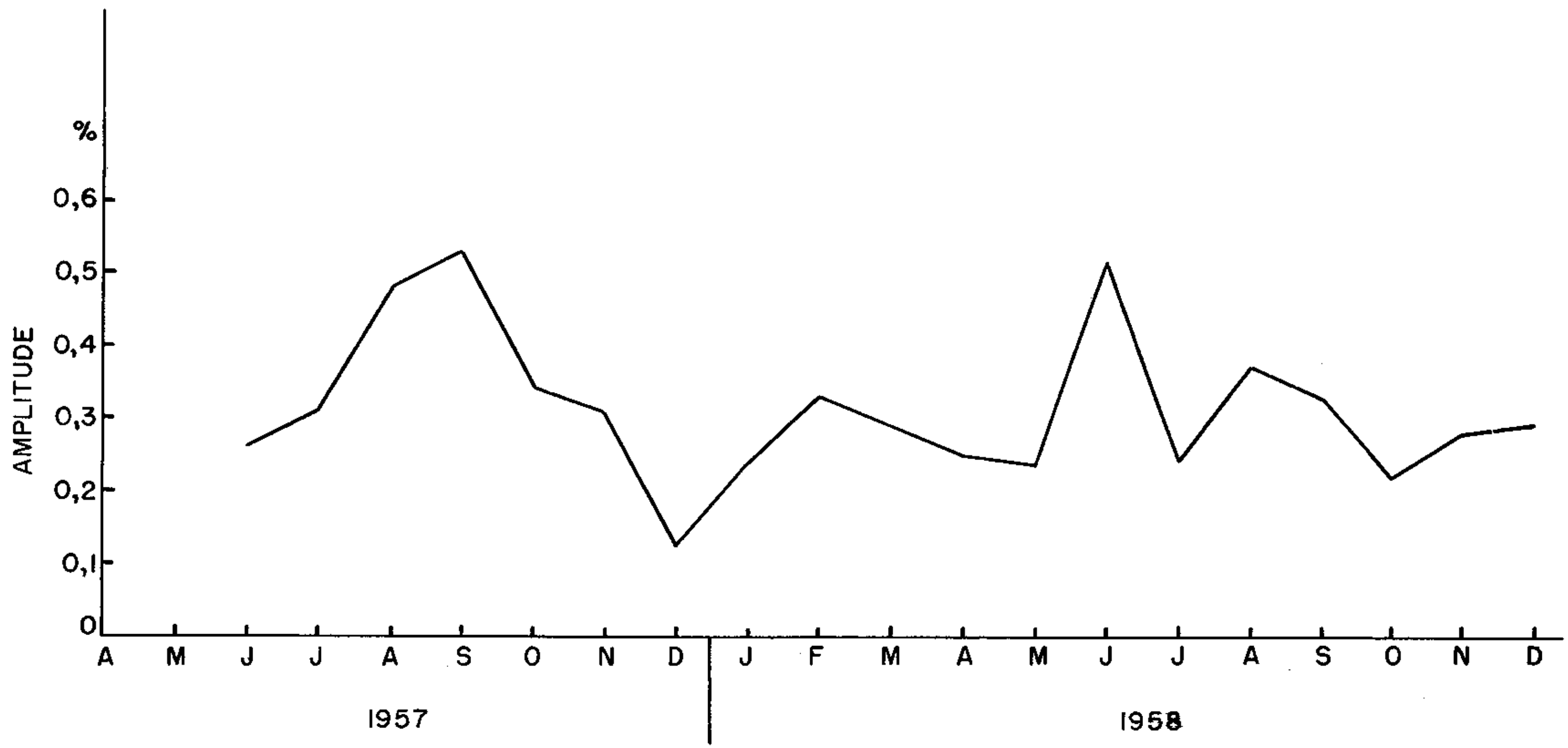


Fig. 5 - Average amplitude of the daily variation vs. the month for stations at moderate latitude (λ between 31° and 51°). Data from neutron monitors at Chicago, Deep River, Goettingen, Herstmonceux, Mt. Norikura, Mt. Washington, Mt. Wellington, Ottawa, Sulphur Mountain, and Zugspitze.

Values were plotted wherever data from five stations was available.

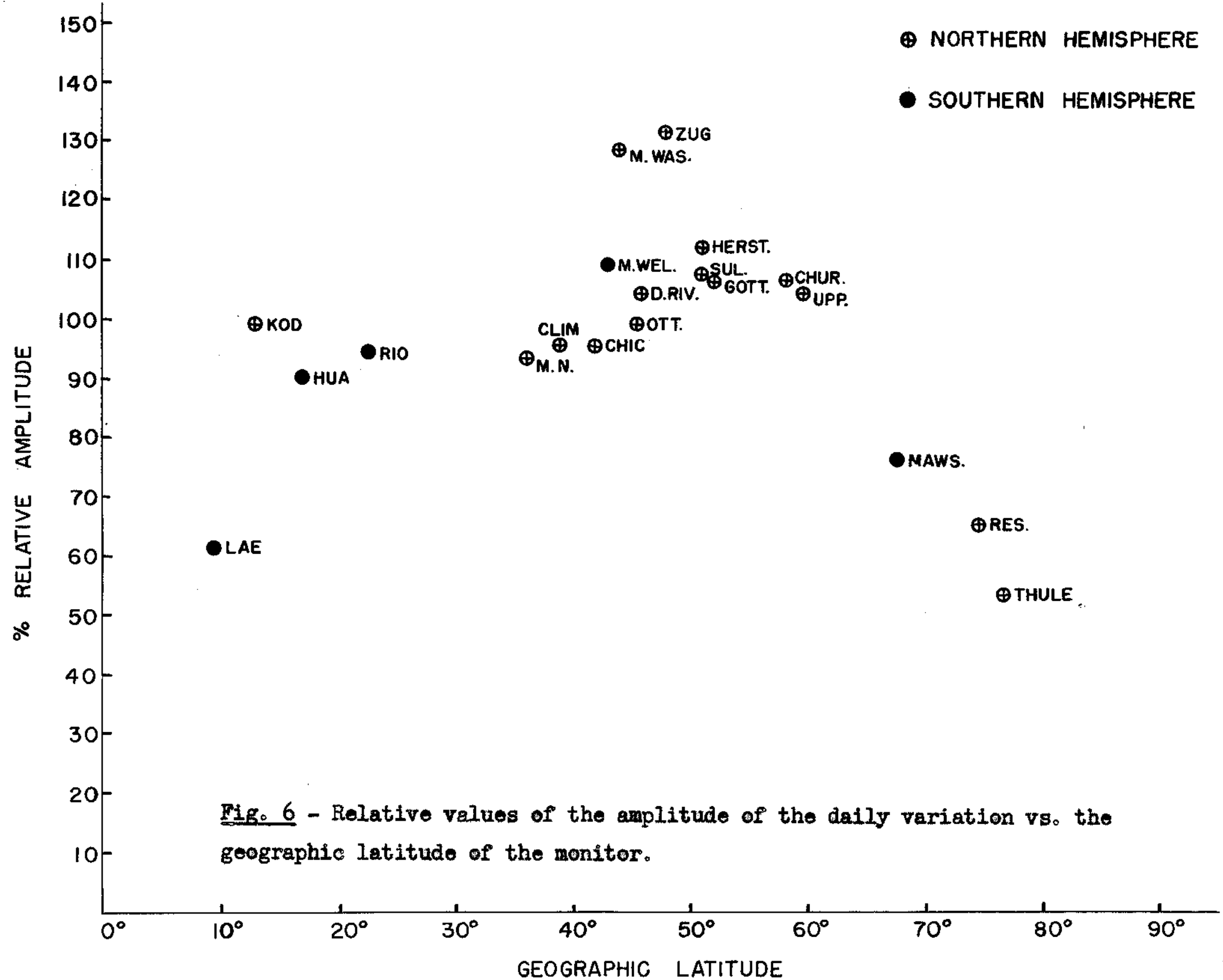


Fig. 6 - Relative values of the amplitude of the daily variation vs. the geographic latitude of the monitor.

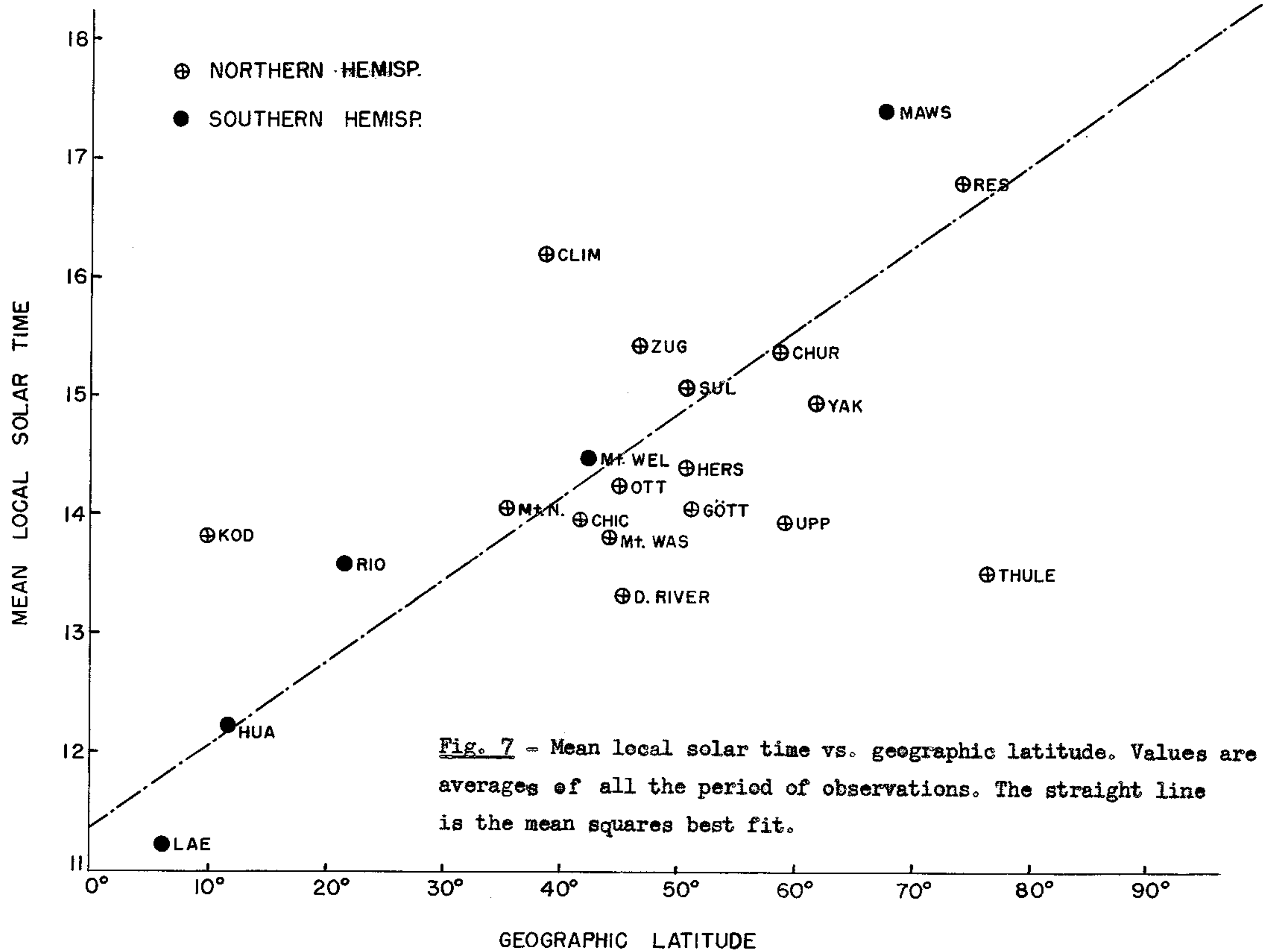


Fig. 7 - Mean local solar time vs. geographic latitude. Values are averages of all the period of observations. The straight line is the mean squares best fit.