CHARACTERISTICS OF GEOMAGNETIC CONTINUOUS PULSATIONS AT HALLEY BAY IN 1963

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ABSTRACT. Records of continuous pulsations, *Pc*, in the period range 10–600 sec. have been examined for three selected months (June, September and December) of 1963, and the characteristics of period, amplitude and distribution determined. The pulsations were found to fall largely into two groups. Their relation to the level of magnetic activity, as measured by *K* indices, is discussed.

A SIGNALS RESEARCH AND DEVELOPMENT ESTABLISHMENT (S.R.D.E.) Fluxgate magnetometer was installed at Halley Bay in April 1963. Band II of this instrument was designed to record pulsations with periods from 1 to 100 sec. The records of one winter month (June), one equinoctial month (September) and one summer month (December) of 1963 have been examined in detail, and analyses of the population, periods and amplitudes are given.

The records of the La Cour magnetographs, which have been operated at Halley Bay since May 1957 (MacDowall and Blackie, 1960), show pulsations with periods from 100 to 600 sec. Similar analyses have been attempted for these longer period pulsations but they are restricted in detail by the chart speed and scale values of the La Cour instruments.

The pulsations examined are of the type known in the literature as continuous pulsations, *Pc*.

DESCRIPTION OF FLUXGATE RECORDING SYSTEM

The following brief description of the principles of operation of the fluxgate system is based on the operating instructions supplied by Mr. P. J. Stevens of S.R.D.E. A fluxgate head contains two parallel cores, each a cylinder 10 cm. long, of Permalloy C, a high-permeability material which is easily saturated by a magnetic field. Each core has 2,000 turns primary and 5,000 turns secondary windings. The cores are driven hard into saturation by a current at 5·1 Kc./sec. in the primary windings. The windings are so connected that to a first order the drive current is not coupled into the secondary windings. In the presence of an external magnetic field, saturation occurs earlier on one half-cycle and later on the following half-cycle, thereby inducing even harmonics of the drive current in the secondary windings. The amplitude of the second harmonic is proportional to the external field component parallel to the cores. This harmonic is selectively amplified, and after detection, the output spectrum is filtered, amplified and recorded as follows:

	Band I	*Band II*
Period band	DC–100 sec.	100–1 sec.
Sensitivity	7·5 γ/mm. nominal	0·125 γ/mm. nominal
Chart width	150 γ—0—150 γ	2·5 γ—0—2·5 γ
Chart speed	2·5 cm./hr. nominal	30 cm./hr. nominal

The instrument measures the magnetic fields along the axes of the fluxgate, which are set up as follows:

Channel 1	magnetic north/south	horizontal
Channel 2	magnetic east/west	horizontal—zero field plane
Channel 3		vertical.

The fields present on channels 1 and 3 are backed off by means of a stable current being passed through a coil surrounding the fluxgates. All fluxgates are thus initially placed in zero field, and the magnetometer measures and records subsequent variations from this datum.

Suppose that on setting up channel 1, H was H_0 and D was D_0, then the channel records $H \cos (D-D_0)-H_0, \sim \Delta H$; if on setting up channel 2, D was D_1, then the channel records $H \sin (D-D_1), \sim H_0 \Delta D$; if on setting up channel 3, Z was Z_0, then the channel records $Z-Z_0 = \Delta Z$.

Scaling Procedure

Measurements have been made only when the pulsations appear continuous for at least 15 min. Analysis has been confined to the horizontal field components—channels 1 and 2 of the fluxgates, and H and D on the La Cour magnetograms. The level of activity on the Band II, channel 3 fluxgate record was much lower than on the other two channels, and the trace was blurred due to the presence of a component with periods about 2 sec.

Period

The nominal pass-band for the fluxgate Band II is 1 to 100 sec., but the chart speed, 30 cm./hr., is too slow to resolve clearly periods less than 10 sec. (12 sec. : 1 mm.). Scaling was confined to the period range 10 to 100 sec.

Measured periods are the mean over 4 c., chosen as typical of the hour under consideration. Time marks were controlled by a Synchronome clock and corrections have been applied for variations in paper speed.

Resolution of the La Cour magnetograms is poor (1 mm. : 240 sec.) and it was only possible to group the pulsations into 10 bands, each 50 sec. in width, covering the period range 100 to 600 sec.

Amplitude

A character figure, 1 to 5, has been assigned for each hour, corresponding to the upper bound in gammas; 6 is used to indicate amplitudes greater than 5γ, the limit of the recording system, e.g. 4 signifies pulsations between 3 and 4 γ peak to peak.

Whereas the frequencies of pulsations recorded on channels 1 and 2 were essentially similar, the amplitudes varied widely. The amplitude data shown represent the mean of the ranges on the two channels, and purport to include only the contribution from the period range 10 to 100 sec., longer periods having been subtracted subjectively.

The La Cour records were too insensitive to permit amplitude measurements. Instead, the amount of pulsation activity has been assessed on the following scale:

0—no pulsations visible during the hour under consideration.
1—pulsations visible but not continuous throughout the hour.
2—pulsations continuous throughout the hour.

Analysis of Results

Period distribution of pulsations

The pulsations recorded by the fluxgate have been classified by period into nine bands: band 1 with period 10–20 sec., band 2 with period 20–30 sec., etc. The distribution in each of the 3 months analysed is shown in Fig. 1. Pulsations occur most frequently in bands 2 and 3 (period 20–40 sec.) and least frequently in bands 7 and 8. The distribution of the longer period pulsations recorded by the La Cour magnetograph is shown in Fig. 2. Another peak in the period distribution is seen in the period band 150–200 sec.

Obayashi and Jacobs (1958) have discussed, in terms of a model upper atmosphere, the variation of peak pulsation period with geomagnetic latitude. The peak found at Halley Bay, in the band 150–200 sec., is in good agreement with their findings, as shown in Fig. 3.

Fig. 4 shows the diurnal variation of magnetic activity, as measured by the equivalent 3-hr. range, *ak* (Bartels, 1956), for each of the 3 months studied. The mean diurnal variation of occurrence in bands 1–9 is shown in Fig. 5. Band 1 seems to be closely related to the level of magnetic activity. Bands 2, 3 and 4 appear to be essentially confined to daylight hours, with a maximum around local noon (which occurs in the 14th hr. U.T.). No particular structure is obvious in bands 5–9.

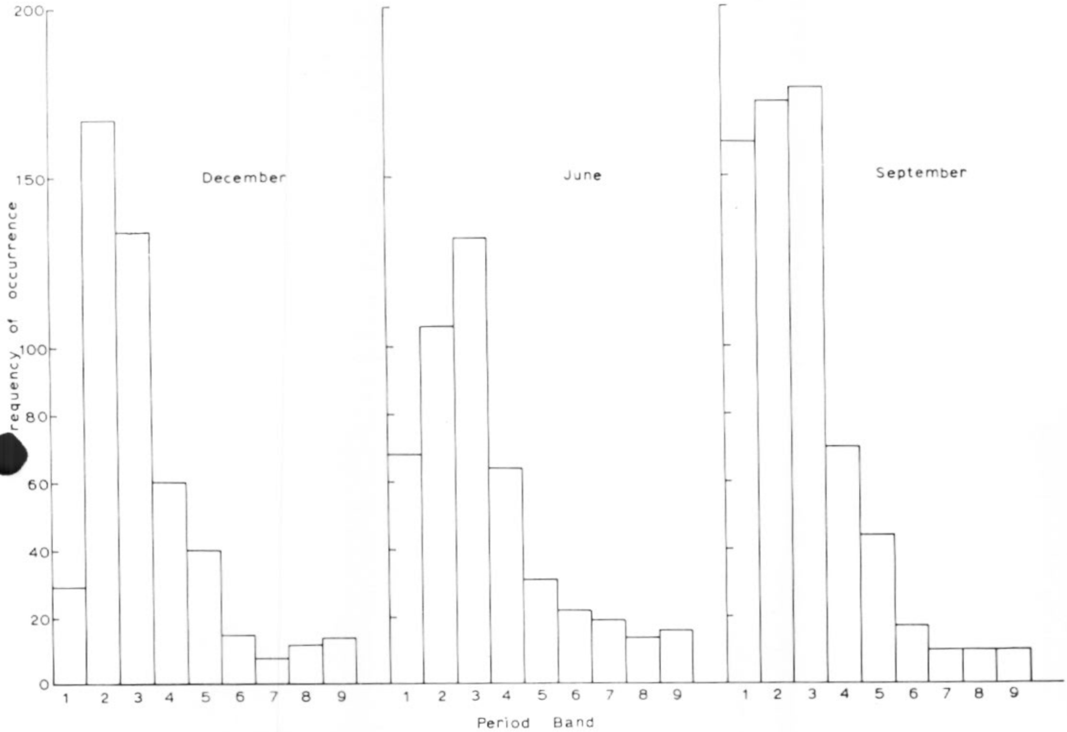

Fig. 1. Frequency of occurrence of shorter period pulsations, in bands 1–9, from fluxgate magnetometer records.

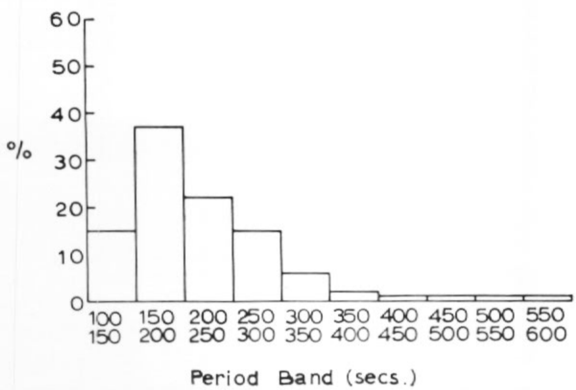

Fig. 2. Percentage distribution of longer period pulsations, from La Cour magnetograms.

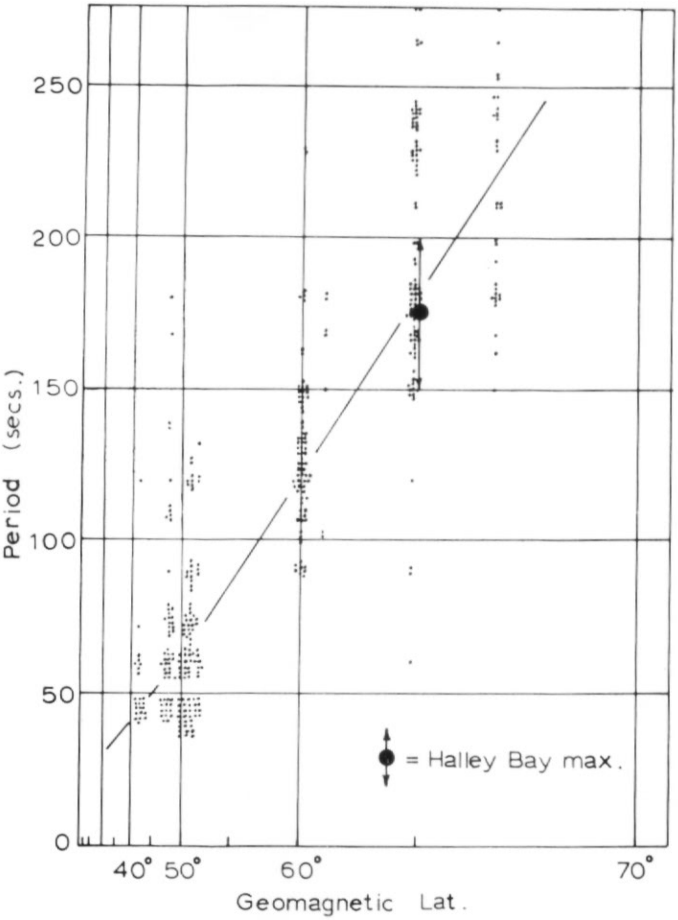

Fig. 3. "Observed periods of geomagnetic pulsations" (after Obayashi and Jacobs (1958)).

The more frequent occurrence of pulsations in band 1 during disturbed periods is further illustrated in Fig. 6. This shows a superposed epoch analysis of 11 storms with sudden commencements, for storm-time −24 to +40 hr. Similar analyses of bands 2, 3 and 4 showed no increase at the time of the sudden commencement. The local time control of these bands is apparently still effective in disturbed periods.

The *K* index in September took all values from 0 to 9. Fig. 7 shows the mean period of the pulsations for each value of *K*. It is apparent that shorter period pulsations occur more frequently at the higher levels of magnetic activity.

Amplitude range of pulsations

The mean diurnal variations of range of all pulsations recorded by the fluxgate, grouped for international quiet, disturbed and ordinary days, are shown in Fig. 8. This system of classification is entirely relative; the days are respectively the five quietest (on a planetary scale), the five most disturbed and the remaining days, of each month. The actual level of magnetic activity on disturbed days, for example, may vary greatly; thus in 1963 the disturbed days of December show only slightly more activity than the quiet days of September. Referring back to Fig. 4, it appears as if at low levels of magnetic activity ($ak < 15$, say) the amplitude range of the pulsations was under solar control. Thus, all the December (summer) curves have

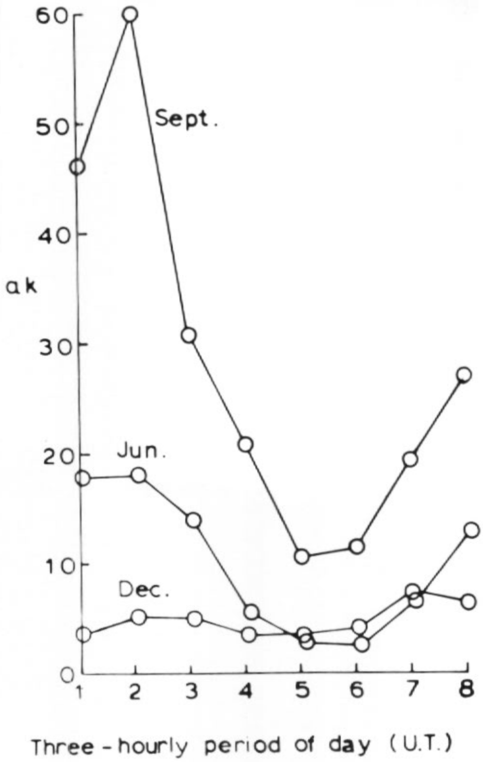

Fig. 4. Monthly mean equivalent 3-hr. range, *ak*, of magnetic activity, for June, September and December 1963. (Lower limit K9, 1,500 γ.)

a pronounced maximum around local noon (in the 14th hr. U.T.); the effect is weaker on the quiet- and ordinary-day curves for September, and weaker again on the quiet-day curve for June (winter). The disturbed-day curve for June is similar in shape to that of *ak* in Fig. 4, and the ordinary-day curve for September shows an enhanced range of pulsation amplitude in the early morning at much the same time as the peak in *ak* for that month. The disturbed-day curve for September is not representative of the true diurnal variation, since from 06.00 to 18.00 hr. U.T. the records are almost entirely "off-scale" (character figure 6). Nevertheless, it is clear that the range is less during the night than during the day.

The day-to-day variability of range is shown in Fig. 9a, b and c; it is apparently closely similar to the variability of the daily mean *K* index. The correlation coefficients between these two parameters for June, September and December were $+0\cdot73$, $+0\cdot77$ and $+0\cdot67$, respectively.

Populations of pulsations on fluxgate and La Cour records

Fig. 9 also shows the number of hours, expressed as the percentage of a day, in which pulsations occurred, with periods 10–100 sec. and with periods 100–600 sec. There is a clear correlation between the occurrence of pulsations in either band and the mean *K* index. However, even during several successive 3-hr. periods with $K = 0$, the percentage incidence of pulsations rarely falls below 20.

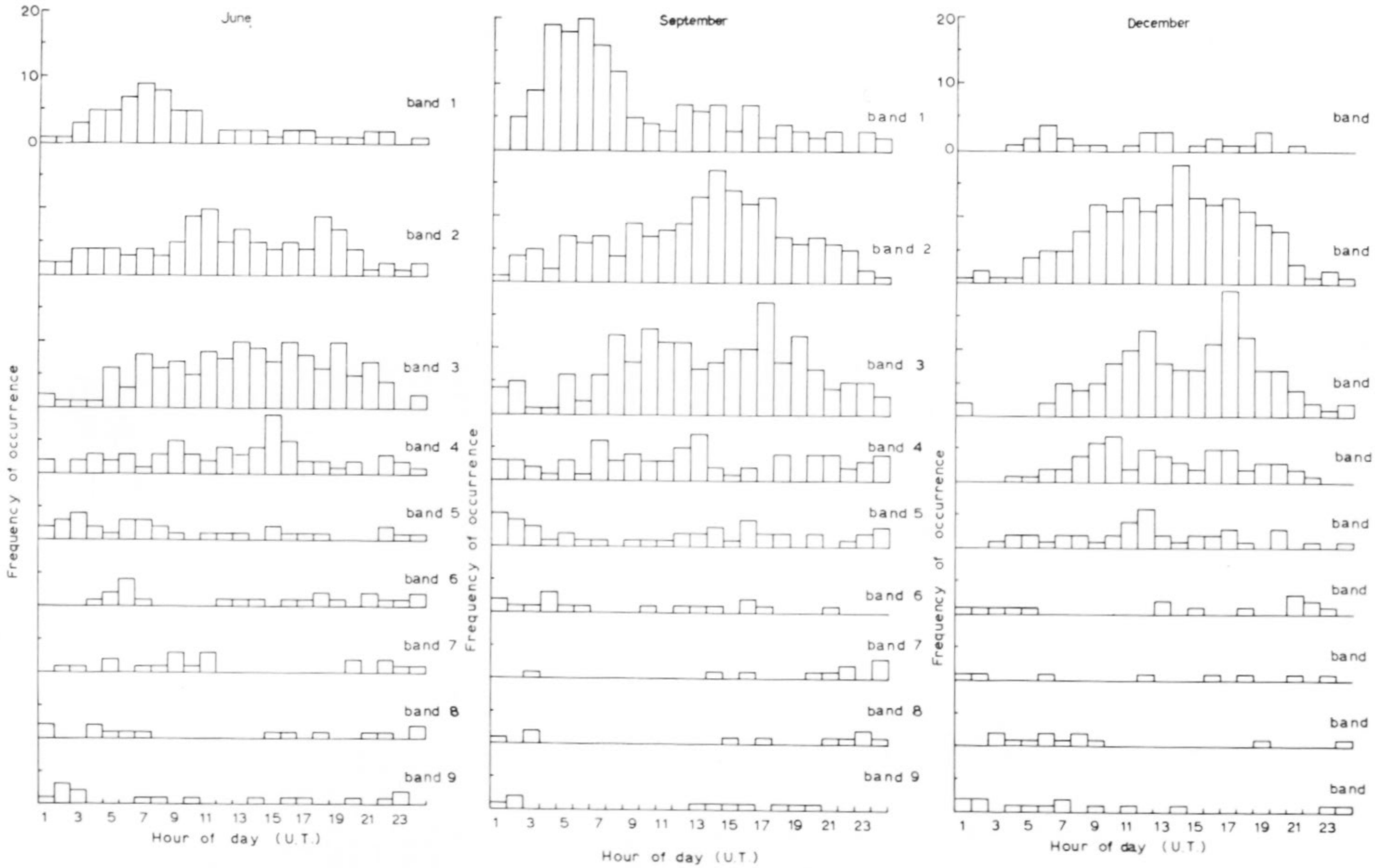

Fig. 5. Mean diurnal variation of occurrence of pulsations in bands 1–9 for June, September and December 1963.

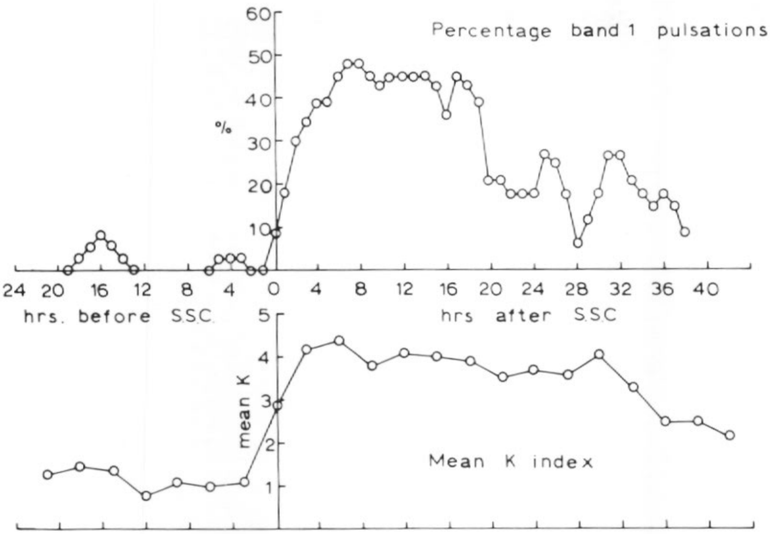

Fig. 6. Storm-time variation of occurrence of band 1 pulsations, from 11 storms with sudden commencements in June, September and December 1963.

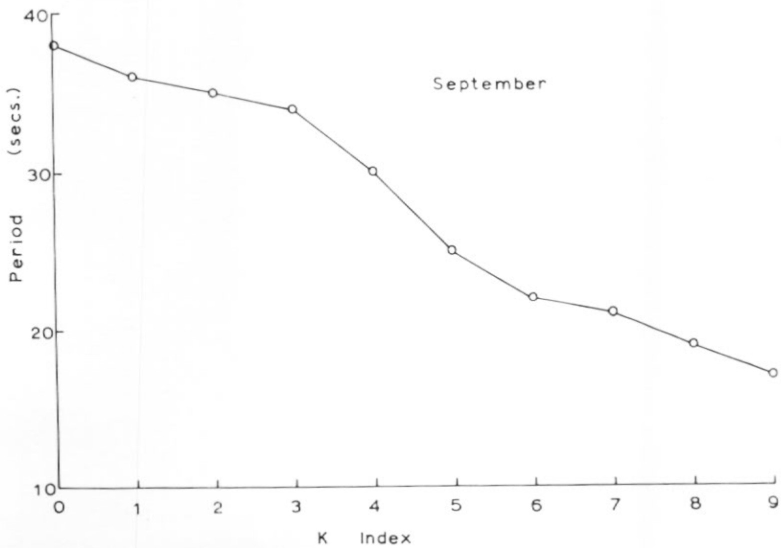

Fig. 7. Variation of period pulsations with *K* index for September 1963.

Conclusions

On the magnetic records from Halley Bay, it was possible to observe pulsations with periods in the range 10–600 sec. The distribution with period showed two peaks: for periods 10–40 sec. and periods 150–200 sec.

The distribution within the former group appears to be related to the level of magnetic activity; shorter periods become more frequent with increase in magnetic activity. At low levels of magnetic activity, the amplitude of the pulsations has a diurnal variation suggestive

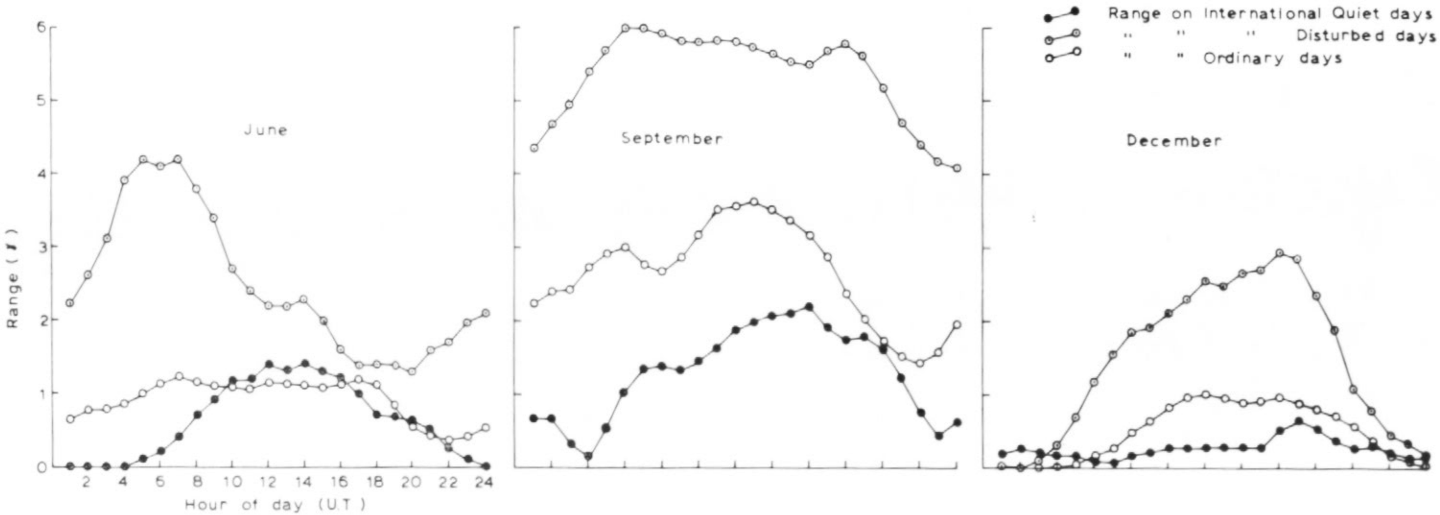

Fig. 8. Mean diurnal variation of range of pulsations for June, September and December 1963.

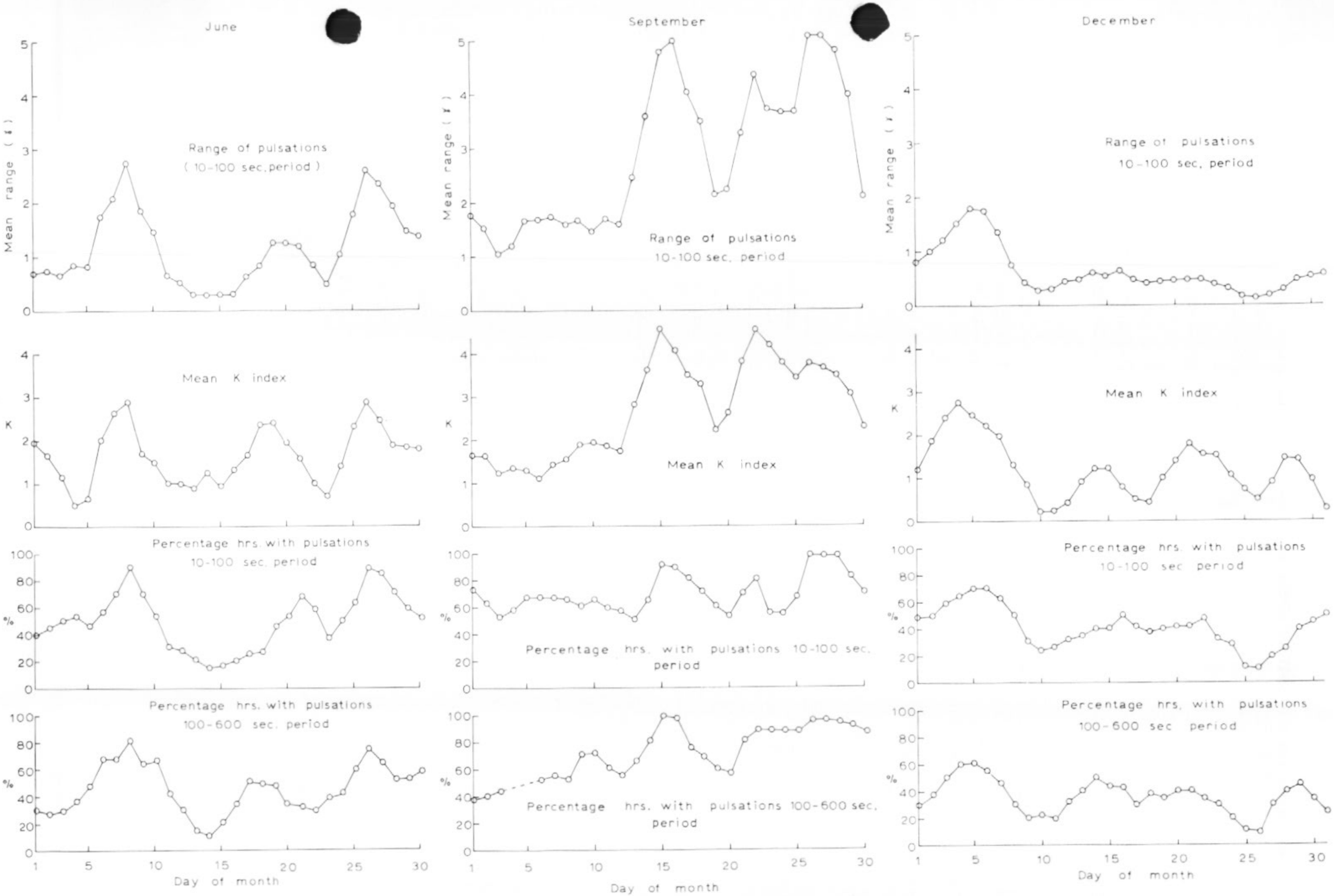

Fig. 9. Daily means of range of pulsations and *K* index, and percentage of hours with pulsations (1) with periods 10–100 sec. and (2) with periods 100–600 sec. for June, September and December 1963.

of solar control; the amplitude is small during the night and rises to a smooth maximum centred around local noon.

The second peak occurs at periods which are in good agreement with a latitude-dependent model proposed by Obayashi and Jacobs (1958).

On a daily basis, the percentage of hours with pulsations in each group is closely related to the level of magnetic activity.

In the notation proposed by Jacobs and others (1965), the pulsations discussed above are *Pc* 3, *Pc* 4 and *Pc* 5 (period ranges: 10–45, 45–150 and 150–600 sec., respectively). The main components of the distribution at Halley Bay are *Pc* 3 and the short-period end of *Pc* 5.

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