160 m PULSATIONS IN THE MAGNETOSPHERE OF THE EARTH POSSIBLY CAUSED BY OSCILLATIONS OF THE SUN*

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Abstract. The measurements of the amplitudes envelope of Pc 3–4 geomagnetic micropulsations obtained at the Borok Geophysical Observatory were analysed by the cosinor method to search for magnetospheric pulsations with a period of about 160 m. 216 days of observations in 1974–1978 were used. It was found that Pc 3–4 amplitudes are modulated by the period 160.010 m with a stable phase. The maximum of the Pc 3–4 amplitudes follows approximately 20 m after the maximum of the solar expansion velocity (for the center of the disk) in the optical observations of Severny *et al.* This modulation of the Pc 3–4 amplitudes could be caused by the presence of an oscillating component in solar UV radiation over the wavelength range 100–900 Å. The amplitude of the UV flux variation may be as large as 2–4%.

1. Introduction

After the discovery of oscillations of the Sun with a period of 160 m (Severny *et al.*, 1976; Brookes *et al.*, 1976) it was suggested that it might be possible to find some effect of these oscillations in the magnetosphere of the Earth. At least two mechanisms which may transfer the effect of the oscillations to the Earth may be considered (see Gul'elmi *et al.*, 1977; Vladimirsky *et al.*, 1981): (1) The oscillating Sun can generate long-period MHD waves. These waves could be carried by the solar wind to influence the magnetosphere. (2) Solar oscillations are probably accompanied by small temperature variations. A corresponding modulation of UV radiation might be expected in this case. Thus, the presence of a 160 m periodic component in the ionospheric current systems is possible because of the electron density modulation.

Some authors have detected a presence of 160 m periods in magnetospheric phenomena such a s the H component of the geomagnetic field (Winch *et al.*, 1963; Toth, 1977), the occurrence of substorms (Tverskaia and Chorosheva, 1975), and *AE*-index (Gul'elmi *et al.*, 1977; Gaivoronskaia and Ljachova, 1979).

2. Observational Data and Processing

To search for possible magnetospheric effects of the oscillations of the Sun, an amplitude envelope of Pc 3–4 geomagnetic micropulsations was used. These micropulsations are quasi-sinusoidal oscillations of the geomagnetic field in approximately the

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0.1–0.01 Hz frequency range. They are dayside phenomena. Pc 3 can be generated at the boundary of the magnetosphere (Gul'elmi, 1976), so their amplitudes would depend on the parameters of the solar wind and IMF. It is known that the ionosphere also influences micropulsations. Pc 3–4 micropulsation amplitudes were measured at Borok Geophysical Observatory using standard flux-meter instrumentation. Envelope data were obtained from the usual records in 3 m steps from 02^h to 10^h UT. This time is optimal for Pc 3–4 measurements at this observatory. The data were taken for days which included those when optical observations of oscillations of the Sun were made in the Crimea by Severny *et al.* (1976). 216 days of observation in 1974–1978 were analysed. The linear trend was removed from the data to reduce the diurnal variation in solar time. These corrected envelope data were then reduced by cosinor analysis (Emel'janov, 1976). Each daily segment of the data is approximated in this method by relation $x(t) = A \cos(2\pi/T)(t - \varphi) + h$, using a least-squares best fit with a reference time of 00^h00^m January 1, 1974. Thus, an estimate of amplitude A and phase φ may be obtained for each day, with its error, for any period T to be studied. The distribution of the phases is a very good way of investigating any oscillation features. The mean values of $\overline{A}$ and $\overline{\varphi}$ were also calculated for some groups of days (month, year).

The same computer program was also used for processing the data from the optical observations of oscillations of the Sun (the measurements were presented by A. Severny, V. Kotov, and T. Tsap for the interval 1974–1980). Very good detailed agreement was found between the cosinor analysis results and those obtained by the superposed epoch method (Scherrer *et al.*, 1980).

3. Results

The modulation of Pc 3–4 amplitudes with period 160 m is seen in the power spectra for nearly every day (examples in Figure 1) but significant values of A and φ were obtained for only individual days. To find the precise value of the period, the relationship was obtained between a trial period and the deviation of its distribution of phase estimates from uniform, as measured by χ^2 (5 degrees of freedom) calculated for all the data. This relationship is presented in Figure 2a. The distribution of the phases for some periods is shown in Figure 2b. As one can see in Figure 2a, there are two maxima for the periods $T = 160$ m and $T = 160.010$ m. The first, large maximum is caused by the ninth harmonic of the day and probably by pulsations with a period ≈ 180 m which occurred during local time (see Nikol'ski, 1980; Galkin, 1980). The second maximum (with a lower significance) corresponds precisely to the period which was found in the optical observations. If this maximum is real, a systematic drift of the mean phase $\overline{\varphi}$ from year to year might be revealed for the period $T = 160$ m. Evidence for such a drift is shown in Figure 3. All the data are used here. The line is a least-squares best fit. The shift of mean phase $\overline{\varphi}$ is equal to 1.69 ± 0.36 radians per year. The real error of the slope of the line is probably greater if one takes into account the small dependence of the phase on the geomagnetic activity level. The measured value of the phase shift is not far from the 1.24 radians per year, which would correspond to a period of 160.010 m.

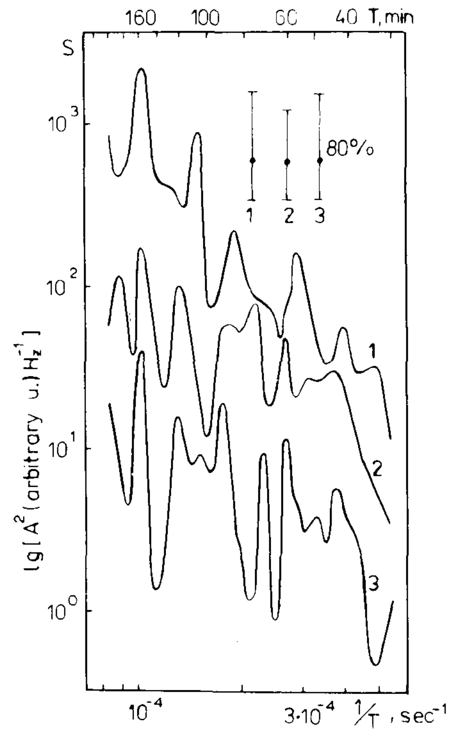

Fig. 1. The modulation power spectrum of the amplitudes of micropulsations Pc 3–4 (Borok Observatory; 32 s data from Gul'elmi *et al.* (1977)). S is spectral density, and errors correspond to a 80% confidence level. (1) 24 September, 1973; 06^h05^m–12^h00^m UT. (2) 12 November, 1973; 05^h00^m–08^h56^m UT. (3) 22 April, 1972; 07^h00^m–11^h00^m UT.

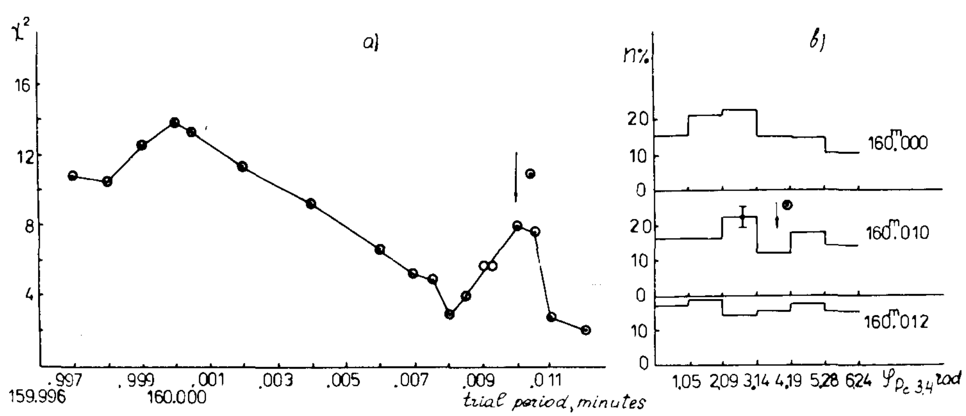

Fig. 2. (a) The relationship between the trial period and the phases distribution deviation from uniform (as measured by χ^2 for 5 degrees of freedom). The value of the period for solar oscillations derived from optical observations is indicated by an arrow. (b) The distribution of the phases for the periods 160 m; 160.010 m and 160.012 m. The stable phase for the period of 160.010 m is about 4.5 radians. The phase of the maximum of solar expansion velocity (for the center of the solar disk) according to Severny *et al.* (1976) is indicated by an arrow.

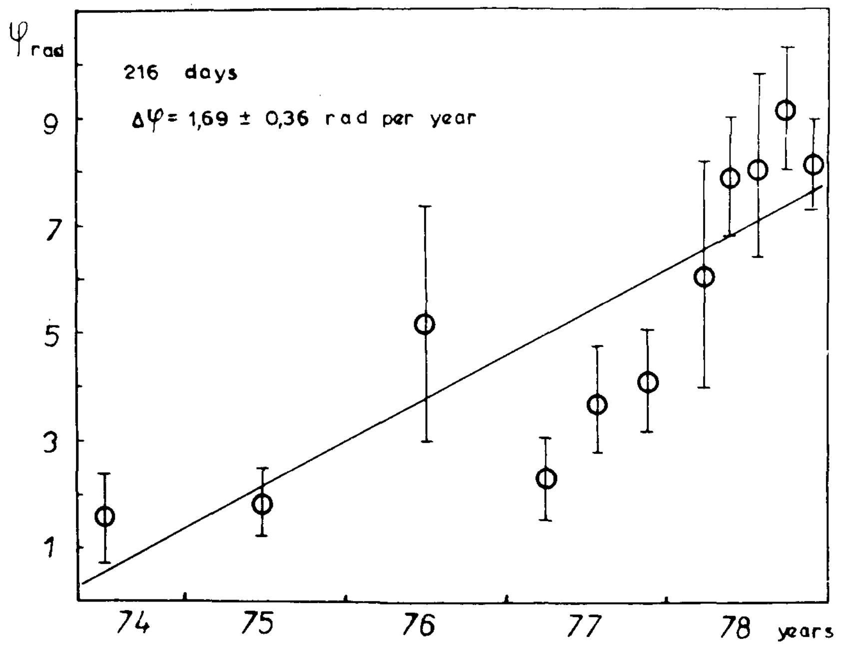

Fig. 3. The drift of the mean phase φ for the period 160 m calculated for the whole set of data. The line is a least-squares best fit and the slope is equal to 1.69 ± 0.36 radians per year.

It is hard to estimate with confidence the value of the stable (non-drifting) phase for the period 160.010 m. This phase is probably equal to ≈ 4.5 radians. If this estimate is correct, the maximum of the Pc 3–4 amplitudes follows approximately 20 m after the maximum of the solar expansion velocity (for the center of the solar disk) in the optical observations of Severny *et al.* (3.70 ± 0.24 radians in our notation).

4. Discussion

The most simple explanation for the existence of Pc 3–4 modulations with a stable phase for $T = 160.010$ m is to assume the presence of a variation in the ionospheric electron density caused by a periodic change in the solar UV radiation. If Pc 3–4 amplitude is dependent on the parameters of the F1 ionosphere, UV flux variations would take place over the wavelength range 100–900 Å. The relative amplitude of Pc 3–4 modulation is equal (in some approximation) to the relative change of electron density and, consequently, to the relative variation of UV emission. The average amplitude of modulation is about 0.04. According to the measurements of Titheridge (1971), the variation of the integral concentration of electrons over the periods from 02^h to 04^h is about 0.02 – this is in good agreement with our estimate. The delay time between the increase of UV flux and the increase of Pc 3–4 amplitude is small, so the maximum of UV radiation follows ≈ 23 m after the maximum of the expansion velocity in the optical observations.

5. Conclusions

Strong evidence has been obtained that Pc 3–4 micropulsation are modulated by a period nearly coinciding with the period of solar oscillations (160.010 m). The modulation might be caused by the presence of an oscillating component in the solar UV radiation over the wavelength range 100–900 Å. The amplitude of such variations may be as large as 2 to 4%.

All these results are based on the limited data from one observatory; they are therefore in need of confirmation.

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