SHORT-PERIOD TERMS IN TIME AND LATITUDE OBSERVATIONS MADE WITH THE HERSTMONCEUX PHOTOGRAPHIC ZENITH TUBE.

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The effects of some short-period tidal and nutational terms in the observations of the Herstmonceux PZT have been re-examined using observations that extend over a longer period and have been re-reduced using improved catalogue positions. Analytic smoothing of these data has furnished observational residuals that reveal very clearly the effects of short period terms with relatively small amplitudes.

Investigations of tidal and nutational effects (O'Hora, 1973, a, b) in the observations made with the photographic zenith tube (PZT) of the Royal Greenwich Observatory at Herstmonceux, revealed the effects of lunar semi-diurnal (ie with period half a lunar day) deflexions of the vertical with great clarity, but the expected principal fortnightly terms at 14.77, 14.19 and 13.66 solar days could not be detected so distinctly. Even so subsequent work (McCarthy, 1976) showed that the amplitudes that had been deduced for the 14.19-day period were in good agreement with those given by the PZTs at Washington and Richmond.

A new working catalogue with improved star positions and proper motions for the declination zone of the Herstmonceux PZT has since been derived (RGO, 1977). It is based on observations by the PZTs at Herstmonceux and Calgary which differ by only 4" in latitude. The new catalogue came into use for current work in 1975 but it has since been used in the re-reduction of all observations previously made at Herstmonceux. The homogeneous series of observations obtained in this way covers the years 1958-76 (inclusive) and comprises just over 2600 PZT plates.

Adopted smooth values of the time and latitude observations over the 19 years were then derived by means of the Vondrák method (Vondrák, 1969), using a smoothing factor of $\varepsilon = 10^{-7}$ day^{-5} which acts as a low pass filter giving smoothed values that are unaffected by variations with periods less than about 30 days. The effects of such terms are, however, conserved with an increased signal to noise ratio in the observational residuals, computed in the sense observed minus adopted. The residuals fall within the range $-0\overset{s}{.}028$ to $+0\overset{s}{.}025$ for time and $-0\overset{''}{.}26$ to $+0\overset{''}{.}24$ for latitude and 96% are smaller than $|0\overset{s}{.}013|$ and $|0\overset{''}{.}13|$ for time

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and latitude, respectively. The scatter in the residuals is thus relatively small and the analytic method of smoothing has furnished residuals of enhanced consistency. Residuals used in earlier analyses had been derived using graphical methods of smoothing that depend on personal judgement.

The improved residuals were prepared very recently so that only preliminary investigations of them have so far been carried out. A re-examination of the fortnightly periods was made using, in the first place, the same methods as those employed before in order to assess how much the improved data have ameliorated the precision with which the coefficients of these terms can be determined.

The principal fortnightly terms are:

(i) a term with period 14.77 days caused by deflexions of the vertical arising from lunar semi-diurnal tides. The deflexions are proportional to trigonometric functions of 2H, where H is the hour angle of the Moon and because H, for a given time of day at any observing station, undergoes a phase change of 2π in a synodic month, 2H changes by 2π in half a synodic month, nominally 14.77 days. Thus 14.77 days is the alias period of the term whose true period is half a lunar day.

(ii) a term with an alias period of 14.19 days arising from a nearly diurnal term with argument (α - 2L) and period 1.07 days, where α is the local sidereal time and L is the mean longitude of the Moon. For analytical purposes it is more convenient to treat it as an annual rather than a daily cycle, in which case the period of (α - 2L) reduces to 14.19 days. The (α - 2L) term is principally due to the use of the pole of rotation for defining the reference axis employed in the reduction of both time and latitude observations (Atkinson, 1973).

(iii) a term with period 13.66 days due to the zonal lunar tide. This tide is a function of the square of the sine of the declination of the Moon and consequently the tidal term has a period of 13.66 days.

It should be noted that errors in the adopted nutation constants with arguments that are functions of 2L should also affect the residuals.

In the analyses least-squares solutions for periodic terms were carried out for 200 trial periods with an average separation of 0.007 days from each other and an amplitude spectrum was traced over the 1.4 day range, between 13.5 and 14.9 days. The same method was employed in analysing both the time and latitude observations and the results obtained are shown in Figure 1.

Compared with earlier results, there is a marked increase in the signal to noise ratio in the amplitude spectrum. In the time results, shown in Figure 1, the three peaks at 13.66, 14.19 and 14.77 days are very prominent. Independent and more rigorous solutions of the data for cyclic terms with these periods as argument were carried out; the computed coefficients are given in Table 1. The statistical quantities in this table, and elsewhere in this paper, are standard errors.

The results for latitude, shown in Figure 1, are also an improvement on earlier work, with well defined peaks at 14.19 and 14.77 days. Tidal activity gives no response at 13.66 days in latitude because the zonal tide with this period only causes the moment of inertia of the Earth to vary without affecting the pole of inertia. The computed amplitudes for these two terms are given in Table 2.

As explained above, the terms at 14.77 and 14.19 days are alias terms arising from activities with frequencies of 1.9323 and 0.9295 cycles per day, respectively, and with respective arguments of 2H and (α - 2L) (Melchior, 1966, and Atkinson, 1973). The 13.66-day term is fundamental, with argument 2L. For each alias period solutions were also made using as argument the fundamental period, with equations of condition determined by coefficients dependent on the position of the Moon at the time of observation. The results for these solutions are included in Tables 1 and 2 which show that in all cases the amplitude obtained from solutions with the alias period as argument is smaller than that obtained by solution of the fundamental; the aliasing is not perfect as it would be if the observations were made at the same time every night. In the case of the 13.66-day term, which is itself fundamental, very nearly the same amplitude is obtained when 2L is used as argument. As well as giving more precise values for the amplitudes, the solutions of the fundamental terms determine the phases of the variations.

The solutions with argument 2H show clearly the effects in time and latitude of deflexions of the vertical in the planes of the prime vertical and of the meridian, respectively. These deflexions are also proportional to the square of the cosine of the Moon's declination (O'Hora, 1973, a), so a further solution for these terms was made in which this variation of amplitude was allowed for. In this solution the phases of the periodic terms were also evaluated.

Table 1. Fortnightly Terms in Time

Period	Amplitude	Argument	Amplitude
14.77 days	1.00 ± 0.14 ms	2H	1.30 ± 0.15 ms
14.19 "	1.01 ± 0.14	α - 2L	1.23 ± 0.14
13.66 "	0.97 ± 0.14	2L	1.04 ± 0.14

Table 2. Fortnightly Terms in Latitude

Period	Amplitude	Argument	Amplitude
14.77 days	0.″0130 ± 0.″0016	2H	0.″0186 ± 0.″0017
14.19 "	0.0061 ± 0.0015	α - 2L	0.0093 ± 0.0015

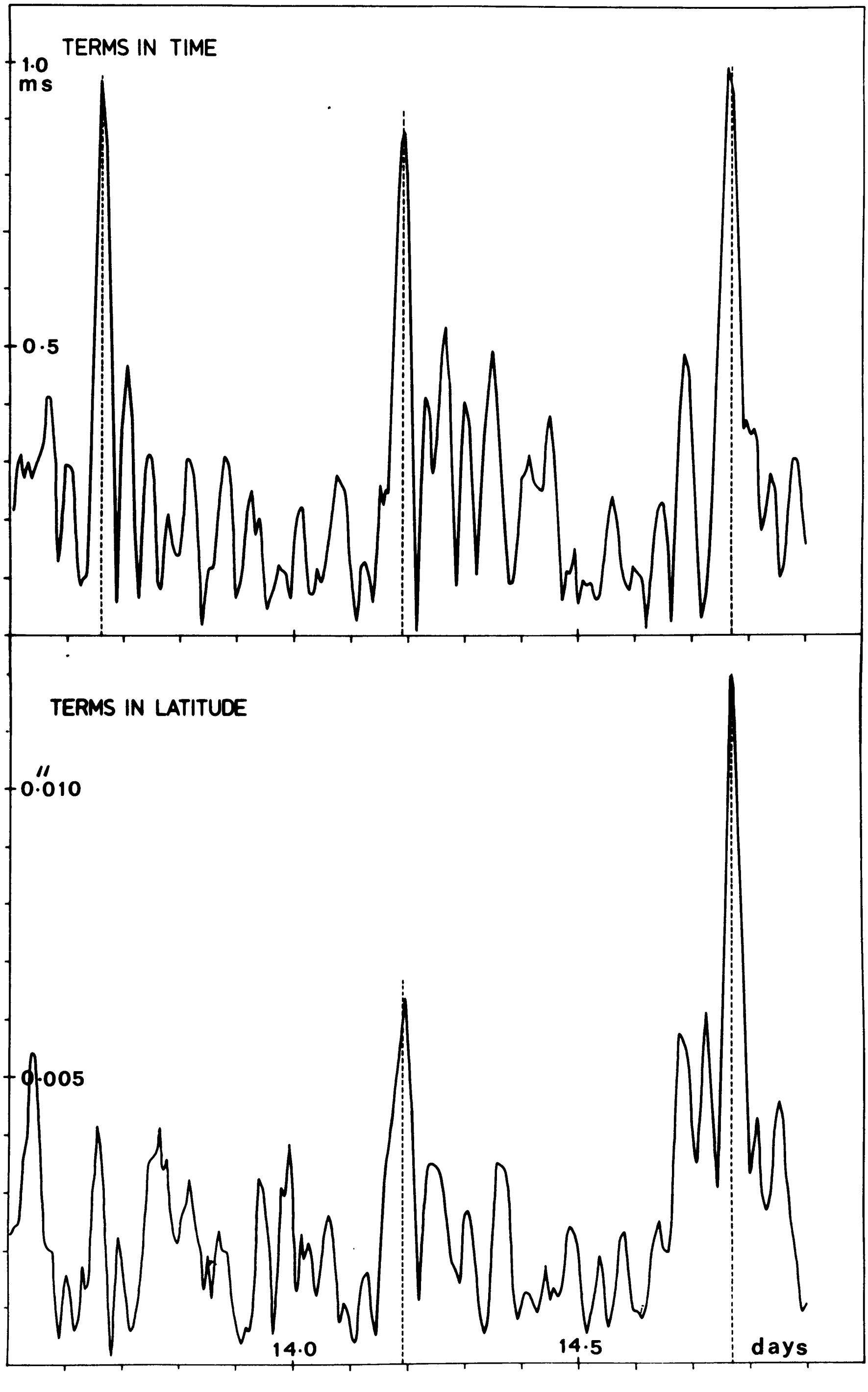

Figure 1. Amplitudes of fortnightly terms in the time and latitude observations of the Herstmonceux PZT.

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Table 3. Variation of Observations with Hour Angle of Moon (H)

2H	Time		Latitude	
	Mean Residual	Weight	Mean Residual	Weight
15°	+0.00 ms	2923	+0".0135	3043
45	+0.39	2689	+0.0074	2800
75	+0.92	3397	-0.0074	3465
105	+1.28	3083	-0.0085	3145
135	+1.31	3109	-0.0178	3155
165	+0.67	2866	-0.0162	2970
195	+0.30	2976	-0.0108	3084
225	-1.04	2648	+0.0002	2721
255	-1.24	3360	+0.0005	3406
285	-1.18	3227	+0.0140	3254
315	-0.50	3210	+0.0116	3358
345	-0.98	3206	+0.0183	3266

Let r_o denote an observational residual, time or latitude, of weight w (the number of stars observed) and with corresponding lunar hour angle H and declination δ, computed for the epoch of observation. Each residual was first corrected for effects of the variation in the declination of the Moon to obtain r_c, using the relationship

$$r_c = r_o/\cos^2\delta,$$

a relationship that holds for both time and latitude.

A preliminary examination was made by sorting the corrected residuals (ie r_c values) into 24 groups corresponding to the value of H at the time of observation. But the deflexions are a function of 2H, and so groups 12 hours apart were combined. The same method was employed for both time and latitude and the results are summarized in Table 3 in which the weighted mean values of residuals for each 30° interval of 2H are listed.

The differences in weight between the time and latitude values in the table are due to failure to obtain time results owing to malfunction of timing equipment on occasions where images giving useful latitude results have been obtained. Least-squares analyses of individual plate results were also made using the same equation of condition:-

$$(A + B \sin 2H + C \cos 2H)\sqrt{w} = r_c\sqrt{w}$$

for both time and latitude.

The solutions yielded the following expressions for lunar semi-diurnal tidal effects:

$$0^s.0013 \pm 0^s.0002 \sin(2H - 19^\circ.8 \pm 6^\circ.9) \text{ in time}$$
$$\text{and } 0''.019 \pm 0''.002 \cos(2H + 28^\circ.7 \pm 5^\circ.1) \text{ in latitude}$$

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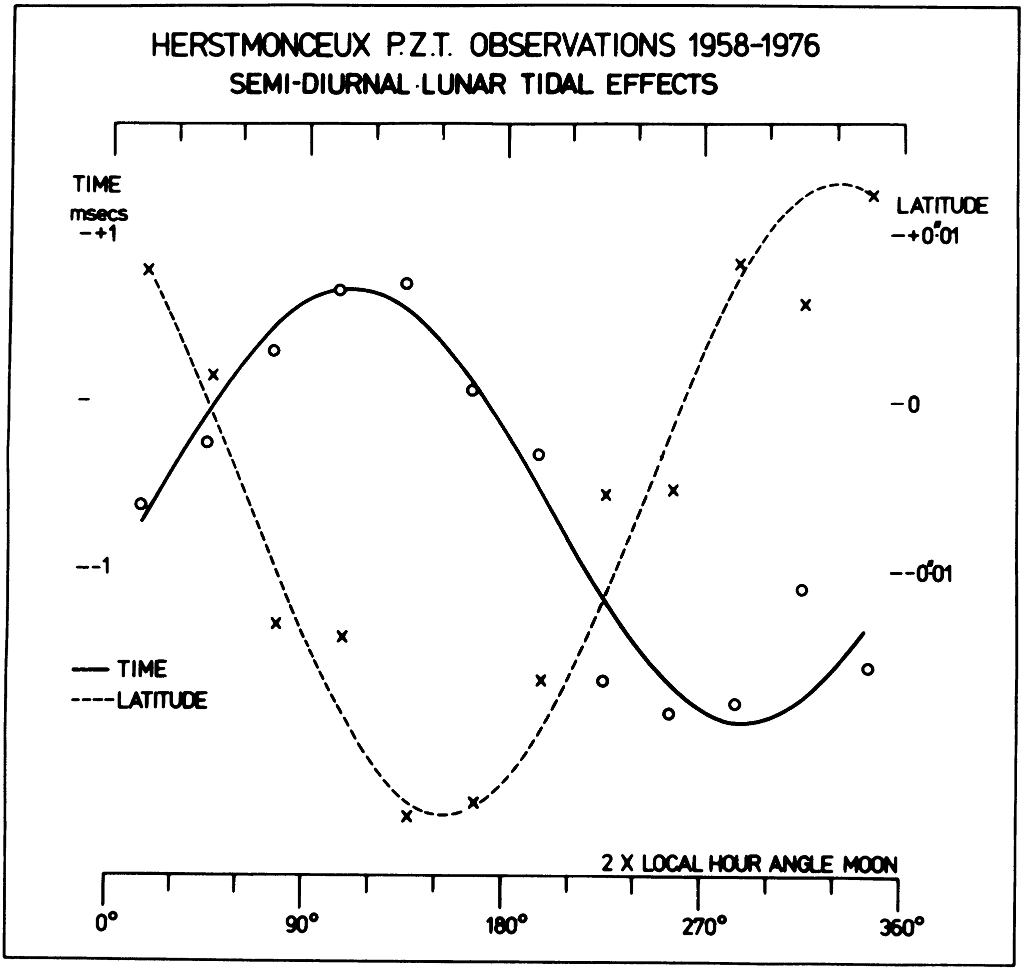

Figure 2. Lunar semi-diurnal tidal effects in the time and latitude observations of the Herstmonceux PZT

The curves in Figure 2 have been computed from these expressions; the plotted points in the diagram represent the data given in Table 3.

PZT observations normally extend over 3 hours and frequently up to 5 hours. Because the amplitudes of the semi-diurnal variations have been computed from average values of such extended observations some smoothing of variations is inevitable. It is also recognised that the variation in the diurnal motion of the Sun has been neglected, as well as lunar parallax.

As explained above only preliminary analyses of the data have so far been carried out. Further refinements are now being made in the time observations to enable more extensive analyses to be undertaken, using more rigorous methods.

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Bibliography

Atkinson, R. d'E. (1973). Astron. J. 78, 147.
McCarthy, D.D. (1976). Astron. J. 81, 482.
Melchior, P. (1966). The Earth Tides, Pergamon Press Ltd., Oxford.
O'Hora, N.P.J. (1973, a). Phys. Earth Planet. Inter. 7, 92.
O'Hora, N.P.J. (1973, b). Astron. J. 78, 1115,
R G O (1977). Greenwich Time Report, 1976 I, Royal Greenwich Observatory, Herstmonceux Castle, Hailsham, East Sussex, BN27 1RP.
Vondrak, J. (1969). Bull. of the Astron. Inst. of Czechoslovakia, 20, 349.