ROTATIONAL ACCELERATIONS

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Abstract. Rotational accelerations of the Earth arise from changes in speed of rotation: periodic, irregular, and secular. Changes are caused by winds, Earth tides, ocean tides, and motions of the core. The semimonthly lunar body tide produces the maximum acceleration.

1. Introduction

This paper discusses the magnitudes of rotational accelerations of the Earth as obtained from astronomical observation. The accelerations are of interest because they are proportional to the rotational torques and provide information on the stresses induced in the Earth's crust. Periodic, irregular, and secular variations in speed of rotation have been observed. These are due to winds, ocean tides, Earth tides, motions of the core, and possibly other effects.

The rotational acceleration of the Earth with respect to atomic time, A.1, denoted α, is obtained by forming the second derivative of the observed quantity $H=$ UT1–A.1. It is more convenient, however, to work with $K=$ UT2–A.1, where UT2 = UT1 + ΔSV; the variations in K are much smaller than those of H. ΔSV, which is the seasonal variation, is given by an adopted formula,

$$\Delta SV = 25.1 \text{ ms} \sin(2\pi t - 0.499) - 9.2 \text{ ms} \sin(4\pi t - 0.862). \quad (1)$$

2. Periodic Accelerations

Let H contain a periodic term of the form $\Delta\tau = A\sin(2\pi\, t/P)$ where A is the amplitude, t is the time, and P is the period. Then the maximum acceleration, α_M, is proportional to $A/P^2 = Af^2$ where f is the frequency. Large α_M's may be expected to be found among periodic terms of high frequency.

Terms of period 1 yr, 0.5 yr, and approximately 1 month and 0.5 month have been observed. The first two correspond to periods of winds and of bodily tides, induced in the Earth by the Sun, and the last two to bodily tides induced by the Moon. Table I lists data for terms with the above periods. A_0 is the observed coefficient. A_C is the

TABLE I

	P	f	A_O	α_M	Tide	A_C
(1)	1.0 yr	1 c/yr	25.1 ms	8.6×10^{-11}/d	Sa	1.4 ms
(2)	0.5 yr	2	9.2	12.6	Ssa	4.3
(3)	27.6 d	13.3	0.8	50	Mm	0.8
(4)	13.6 d	27.0	0.8	200	Mf	1.0

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theoretical coefficient of the bodily tide term. α_M is expressed as the fractional change in speed of rotation per unit of time. A fractional change in speed of $+1\times10^{-11}$ is equivalent to a decrease of 0.864 μs in the length of the day (l.o.d.), roughly 1 μs. The lunar terms combined produce a maximum change in l.o.d. of 0.2 μs per day.

The values of A_0 for the 1-yr and 0.5-yr terms are taken from formula (1); variations from year to year in the observed coefficients are small. The large discrepency between A_0 and A_C in line (1) means that the observed variation is caused by an effect other than tidal distortion; it is due chiefly to winds. There is also a discordance between A_0 and A_C for line (2). Semiannual wind effects are probably present.

The lunar tidal terms were predicted by Jeffreys in 1928. They were found by Markowitz (1959) from analysis of PZT observations of the U.S. Naval Observatory from 1951 to 1958 and by Guinot (1970a) from analysis of the BIH results for 1967, 68, and 69. Values of A_0 for these terms are based on the combined results. Values of A_C were obtained by combining lunar terms of nearly the same period for the years of observation. A_0 and A_C are in good agreement for these terms, and the observed variations are considered to be due to bodily tides.

3. Irregular Variations

The non-periodic variation in $H = \mathrm{UT1} - \mathrm{A.1}$ was studied in a previous paper (Markowitz, 1970). The non-periodic acceleration can be represented by the sum of (a) a continuous acceleration which persists for about 4 or 5 yr and then changes fairly abruptly, possibly within 6 months, to a new value, plus (b) deviations which persist for several weeks or several months. Presumably, (a) is due to action of the core and variations (b) are due to winds.

Successive values of the acceleration component (a) obtained since 1955.5, when the caesium beam atomic clock became available, are: -1.4, $+0.3$, -1.0, and -0.2, in units of 1×10^{-11}/d. The maximum accelerations found for type (b) are about $5\times$ $\times10^{-11}$/d from the 90-day means (Figure 4) and 20×10^{-11}/d from the 30-day means (Figure 2).

Presumably, even higher accelerations may occur over shorter intervals, say of 1 day to 1 week. Guinot (1970b) has called attention to apparently sudden changes in the raw, 5-day means of UT2-UTC of about 10 μs, which occurred between 8 to 13 April 1968 and 24 to 29 March 1971. Such changes, if real, would mean that very large accelerations can occur during short intervals. However, an analysis which I have made of the raw 5-day means of UT2-UTC, published in the *Annual Reports* of the BIH for 1968 and 1969, and additional data for 1970 and part of 1971, kindly furnished by Dr Guinot, indicate that the discontinuities may be accidental.

4. Discussion

Maximum accelerations derived from observation, based on results in Markowitz (1970) and this paper are approximately:

Lunar body tide, semimonthly	200×10^{-11}/d
Winds	20
Irregular variation (from core)	5
Lunar-tidal couple (water)	0.05

One notices that the maximum rotational acceleration produced by lunar tides in deforming the solid Earth is 4000 times as large as that produced through the action of water against the sea bottom. Also, the acceleration produced by core-mantle interaction is small compared to that produced by winds, about one-fourth. This means that it will be difficult to separate short interval core effects from wind effects. where 'short interval' means anything from zero to 1 yr.

Classical astronomical methods enable the average speed of rotation of the Earth to be determined for intervals as short as 2 weeks. Lunar-laser ranging and VLBI techniques may give speeds over much shorter intervals, say day to day. However, the problem of separating core and wind effects will still remain.

It was noted in (Markowitz, 1970) that no correlation has been obtained between major earthquakes and irregular changes in acceleration or in speed of rotation. The torques which produce the irregular accelerations are feeble compared to those produced by the semimonthly lunar body tide, and the latter does not produce major earthquakes every two weeks. Hence, from this point of view the lack of correlation is to be expected.

References

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