NEW DETERMINATION OF THE "DECADE" FLUCTUATIONS IN THE ROTATION OF THE EARTH 1860-1978

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Abstract*

Observations of the Earth's rotation have shown irregular variations of rate which have characteristic times of decades. These have been attributed to transfer of angular momentum between core and mantle by some mechanism such as inertial coupling, viscous stress, electromagnetic coupling or stresses produced by topographic features on the core mantle boundary.

Possible mechanisms must be tested against observed fluctuations in the Earth's rotation, such as those derived by Brouwer in 1952. His results were based on the observed departure of the Moon from its predicted position relative to the stars, and it occurred to us that it ought to be possible to improve upon the accuracy of Brouwer's results by analysing more observations than were available to him and by correcting occultation data for the irregularities of the Moon's outline.

In conjunction with the US Naval Observatory we have collected and analysed 50 000 independent observations of occultations of stars by the Moon in the years 1861 to 1954, and our results for the variations in the rotation of the Earth are presented here. I hope that they will provide geophysicists with tighter and more reliable constraints on their models for core-mantle coupling.

Each occultation observation provides a measure of the cumulative rotational displacement $\Delta\Theta$ of the Earth from a fixed direction. In order to simplify the subsequent analysis, observations within individual years have been combined to obtain independent annual solutions for the angle $\Delta\Theta$. For 1955 and later years we have derived similar annual solutions from the BIH values for the difference between UT and atomic time. Our points are less erratic than Brouwer's and they tend to lie on a smooth curve.

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First and second time derivatives of $\Delta\Theta$ have been estimated from these annual solutions to obtain the length-of-day and its rate of change throughout the entire interval. The derivatives at a given date were obtained from least squares fits of quadratic functions to, respectively, 5 and 11 consecutive points centered on that date.

The magnitude of the torque on the mantle is given by the product of the observed angular acceleration and the principal moment of inertia. Around 1900 the torque changed by 10^{18} newton metres in about 5 years. The torque curves are similar in the periods between 1930-1950 and 1955-1975: the time reference during the former period was based on the lunar motion, whereas atomic time was used throughout the second period.

Estimation of the time derivati·es in this work has necessarily entailed some smoothing of the data, and there was the risk that significant detail might be lost. The 11-point estimator was chosen in the light of a power spectrum analysis of the second differences of the annual values of $\Delta\Theta$; this showed a broad peak in power around a period of 30 years, and a general rise in power at shorter periods which was to be expected in a spectrum formed from second differences. There are no significant peaks of power at periods shorter than about 30 years, except for the rise at the Nyquist period of 2 years which I interpret as evidence of the annual variation.

In order to check this interpretation of the occultation results I have performed a power spectrum analysis of the values of $\Delta\Theta$ taken at 50 day intervals from the BIH results for TAI-UT2. The spectrum shows significant peaks of power at periods of $\frac{1}{2}$ year and 1 year, caused by random fluctuations in the amplitude of the seasonal variation, but there are no significant peaks at periods between 1 and 8 years. The time-range of the data is too short to draw any conclusions about periods longer than 8 years, but the results are not incompatible with my conclusion from the occultation data that most of the power in the decade fluctuations is at periods longer than 30 years.

DISCUSSION:

S.K. Runcorn: Would you comment on the possible significance of the shortness of the interval in which changes of slope of the $\Delta\Theta$ curve become established, especially just before 1900?

L.V. Morrison: The power spectrum analysis of the independent annual values of $\Delta\Theta$ shows no significant peaks in the power at periods shorter than about 30 years.

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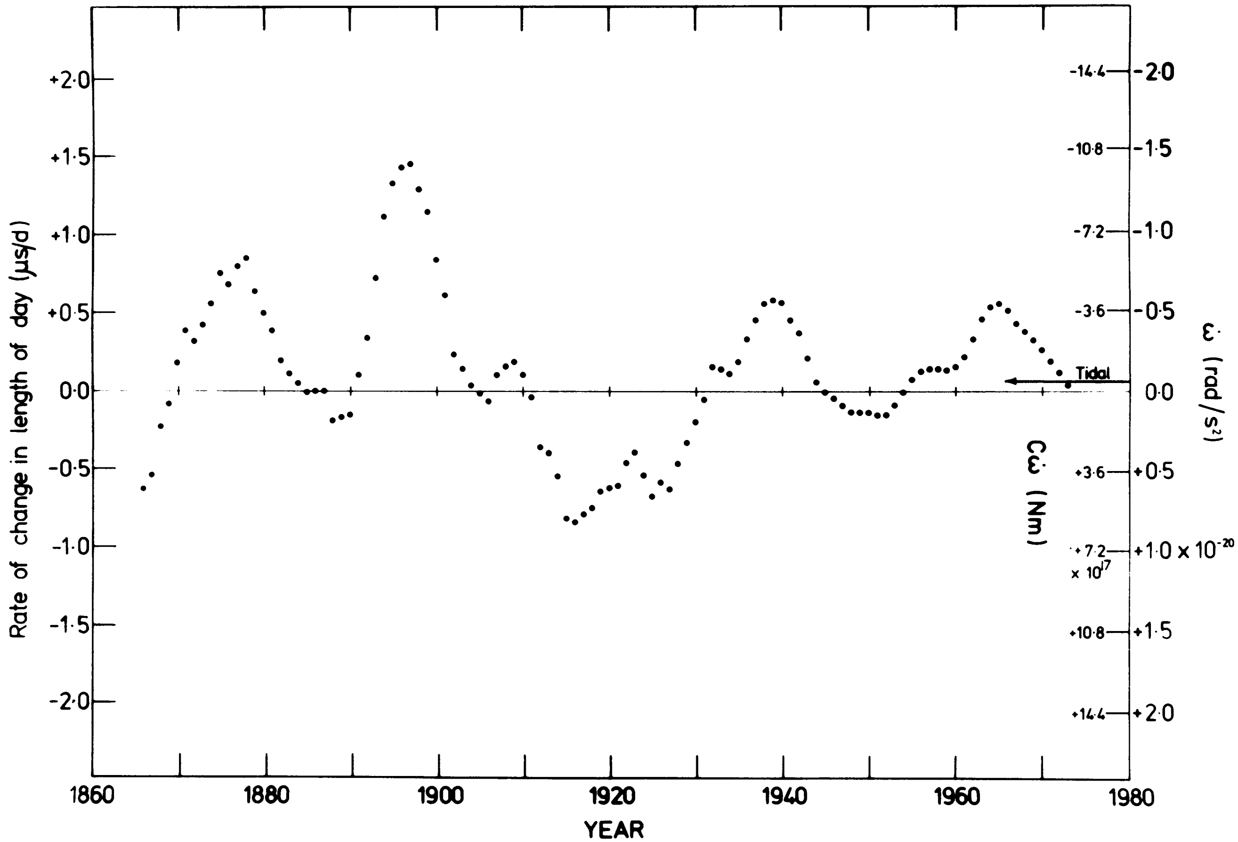

Figure 1. The second time derivative of $\Delta\Theta$, obtained by fitting a moving quadratic polynomial to 11 successive annual values. The inside right-hand ordinate measures the torque operating on the mantle in units of 10^{17} newton metres. The arrow marked "tidal" indicates the level of the combined lunar, solar and atmospheric tidal torque.

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