# THE EARTH'S VARIABLE ROTATION: GEOPHYSICAL CAUSES AND CONSEQUENCES

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# PREFACE

The Earth's rotation has occupied the interest of astronomers, mathematicians and geophysicists for at least the last 200 yr. This continued involvement, in what must have initially been thought of as a straightforward problem, is a consequence of the multitude of factors that perturb the rotational motion from what it would be if the Earth were wholly rigid. Forces and deformations in the atmosphere, oceans, crust, mantle and core all perturb the rotation to varying degrees from the idealized rigid body motion, and a complete discussion requires one to delve into many aspects of the Earth and planetary sciences. It is undoubtedly this interdisciplinary aspect that has drawn astronomers, oceanographers, meteorologists and solid Earth physicists to the subject.

Geophysical studies of the Earth's rotation have their roots in the works of Lord Kelvin, Sir George Howard Darwin and Sir Harold Jeffreys amongst others. Munk & MacDonald, in 1960, thoroughly reviewed the subject in their monograph *The Rotation of the Earth; a geophysical discussion.* Their work has dominated the subject ever since and it is unusual to find any aspect of the problem that they have not touched upon. Yet since 1960, and probably because of their very considerable effort at clarifying the subject, much new information, both of an observational and of a geophysical nature, has become available. Some of this is collected in symposia proceedings, in particular those edited by Marsden & Cameron (1966) and by Mansinha, Smylie & Beck (1970). Short reviews of recent results have been given by Rochester (1970, 1973) and Lambeck (1978*b*). Important developments over the last 15 yr include the following.

(1) Precise length-of-day data have become available owing to recent improvements in both universal time and in atomic time. These data have led to high-frequency information in the length-of-

day spectrum that was previously only suspected. They have also led to an improved understanding of year-to-year fluctuations in the seasonal terms and opened up the possibility of using the astronomical data as constraints on the atmospheric circulation.

(2) The pole positions from 1900 to 1970 have been re-evaluated and more reliable Chandler wobble parameters can now be estimated. Precise data have also become available from the analysis of satellite orbit perturbations.

(3) Geophysical knowledge of the Earth's interior has undergone a very considerable revision since 1960, leading to an improved understanding of the geophysical excitation functions that perturb the rotation. Considerably more information has become available on ocean and atmospheric excitation functions.

(4) An important recent literature exists on the interpretation of the ancient and medieval eclipse data, providing more reliable estimates of the secular tidal acceleration of the Earth's spin and of the Moon's orbital motion. The tidal dissipation question has also been re-analysed.

(5) New evidence on the Earth's acceleration over the geological past is available from various sources, and this has further consequences on the past evolution of the Earth–Moon system. This is perhaps the one area of progress not foreshadowed in Munk & MacDonald's monograph. Progress in paleomagnetism has also led to further insight into the question of polar wander.

Developments in space science and technology have spurred new interest in the subject of the Earth's rotation. Precise tracking of satellites for gravitational studies, laser ranging to the Moon for studying the lunar motion, long-baseline interferometry observations for deciphering extra-galactic radio sources, and the precise manoeuvring of interplanetary flights all require an equally precise tracking of the motions of the tracking stations and of the Earth's rotation axis. At the same time, these new techniques permit the rotational motions to be measured with a precision and resolution that will ultimately yield major improvements over conventional astronomical observations. The impact of these new methods on the geophysical discussion has been small until now, but in the next few years numerous new excitation functions can be expected to rise out

of the measurement noise. It is hoped that the present discussion will point the way to the interpretation of these new data.

The progress since about 1960 forms the rationale for the present work. As in Munk & MacDonald's monograph, the emphasis is on the geophysical discussion, on the evaluation of the geophysical excitation functions driving the variable rotation so as to explain the astronomical record, and on the use of the latter for obtaining further geophysical insight into the Earth.

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Kurt Lambeck