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Final Technical Report For

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Nutation and Polar Motion of the Earth

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I. Goals of this Contract

Prior to this effort we had developed a powerful and general theoretical technique for studying numerically the elastic-gravitational response of a rotating, conservative, geophysically realistic Earth model (Smith 1974, 1976; Wahr 1981a). We had applied this technique to studies of the Earth's free (Smith 1977) and forced (Wahr 1981b, 1981c) nutation and polar motion.

Under NAS 5-25887 we propose to extend these results to account for some of the effects of nonconservative (dissipative) processes in the Earth. In particular we proposed studying magnetic, viscous, and topographic coupling at the core-mantle boundary and the effects of physical dispersion due to anelasticity in the Earth's rheology.

As a separate effort we proposed to study Lunar Laser Ranging data to look for unmodelled variations in UT1, polar motion, and nutation. Our focus in this portion of the study was to search for the Earth's "free core nutation," also known as the "nearly-diurnal free wobble." This is a theoretically predicted free motion of the Earth which has never been unambiguously observed.

II. Results

The detailed results of these efforts are embodied in the five appendices to this report:

App. A The Period and Q of the Chandler Wobble (Smith and Dahlen)

App. B Effect of the Fluid Core on Changes in the Length of Day due to Long Period Tides (Wahr, Sasao and Smith)

App. C An Excitation Mechanism for the Free Core Nutation (Sasao and Wahr)

App. D A Diurnal Resonance in the Ocean Tide and in the Earth's Load Response to the Resonant Free Core Nutation (Wahr and Sasao)

App. E An Analysis of Lunar Laser Ranging Data for the Earth's Free Core Nutation (Wahr and Larden)

(The first four, A-D, are reprints of published articles while the last is in press.) Here we summarize the principal results of those articles.

A) Core-mantle coupling

Viscous, electromagnetic or topographic coupling between the solid mantle and the outer portion of the fluid outer core will, in general, lead to non-conservative forces and thus to dissipation. Theoretical studies in this area are valuable because they may yield ways to study the physics of the core-mantle boundary with nutation and polar motion observations.

We examined such interactions for polar motion (App. A) and tidally-induced changes in l.o.d. (App. B). In the first instance, boundary effects were found to be small compared to those arising from mantle elasticity. In the second study we concluded that signatures of unknown origin in l.o.d. (i.e., noise) would mask the likely effects.

B) Anelasticity and Dispersion

Imperfections in the Earth's nearly elastic rheology cause the damping of free oscillations and also induce frequency dependence in the local elastic parameters. We investigated the effect of these mechanisms for the Chandler wobble, a case we chose because it is a free motion with well-determined period and Q and because it has a frequency much different from that at which most geophysical earth models apply. In App. A we show that anelasticity contributes significantly to both the period and Q of the wobble; it may well be the dominant damping mechanism. We also showed that the observed period of the wobble strongly constrains the anelastic processes which may operate over periods of 10 seconds to 430 days.

C) Effects of the Oceans

The oceans are potentially capable of damping, altering, and exciting both polar motion and nutation. Our efforts in understanding these processes have not been directed toward developing new dynamical models of the oceans themselves but, rather, toward studying the implications of extant ocean tidal models for polar motion and nutation.

App. A treats the effects of quasi-static ocean models on the period and Q of the Chandler wobble. In that article we argue that the quasi-static model has a strong dynamical justification and, as we show, is in agreement with observations.

App. C deals with the possibility that the oceans and atmosphere may excite the free core nutation. This calculation is significant because it is the only quantitatively-understood mechanism known which might excite that normal mode to observable levels.

App. D deals with the effect of the oceans on the Earth's forced nutations. These effects are at or below conventional (astrometric) noise levels but will become significant as new observational techniques lead to improved measurements.

D) Analysis of Lunar laser Ranging Residual

About a decade of LLR residuals were examined, as reported in App. E, for evidence of a free core nutation signature. This is the best data set ever available for such a study. The results were negative but led to an upper bound on that motion about three times smaller than estimates based on astrometric data.

III. Acknowledgement

The results reported here result from in general, collaboration between investigators supported by this contract (Smith and Wahr) and scientists supported by other means (Dahlen and Sasso). During a part of this period Smith was an Alfred P. Sloan Foundation Fellow.