EARTH LIBRATIONS DUE TO CORE-MANTLE COUPLINGS

N. RAMBAUX[1,2], T. VAN HOOLST[1], V. DEHANT[1], E. BOIS[3]

[1] Royal Observatory of Belgium, 3, avenue circulaire, 1180 Bruxelles

[2] Facultés Universitaires Notre-Dame de la Paix, 8 rue des remparts, 81000 Namur

[3] Observatoire de la Côte d'Azur, B.P. 4229, F-06304 NICE Cedex 4

e-mail: Nicolas.Rambaux@oma.be

ABSTRACT. We present a study of the dynamical behavior of the liquid core inside the Earth related to the mantle by inertial coupling. In order to integrate the terrestrial core-mantle interaction in a realistic model of the Earth's rotation, we have used our SONYR model (Spin-Orbit N-bodY Relativistic model) of the solar System including the Earth's spin-orbit motion. We obtain the dynamical behavior of the rotational motion of the Earth considered as a homogeneous body and as a model with two layers. The comparison of the dynamical evolution of these two models of internal structure permits to clarify the impact of the core's motion on the librations/nutations. We estimate the proper frequencies, the Free Core Nutation and the Chandler Wobble, of the two-layer Earth model. Moreover, we compute the dynamical motion of the core itself, and find that it has a larger amplitude than the dynamical motion of the mantle.

1. TWO-LAYER MODEL OF THE EARTH

In order to perform the terrestrial core-mantle interaction in a realistic model of the Earth's rotation, we have used the SONYR model of the Solar System including the Earth's spin-orbit motion. The SONYR model is a numerical approach to integrate the spin-orbit N-body problem,

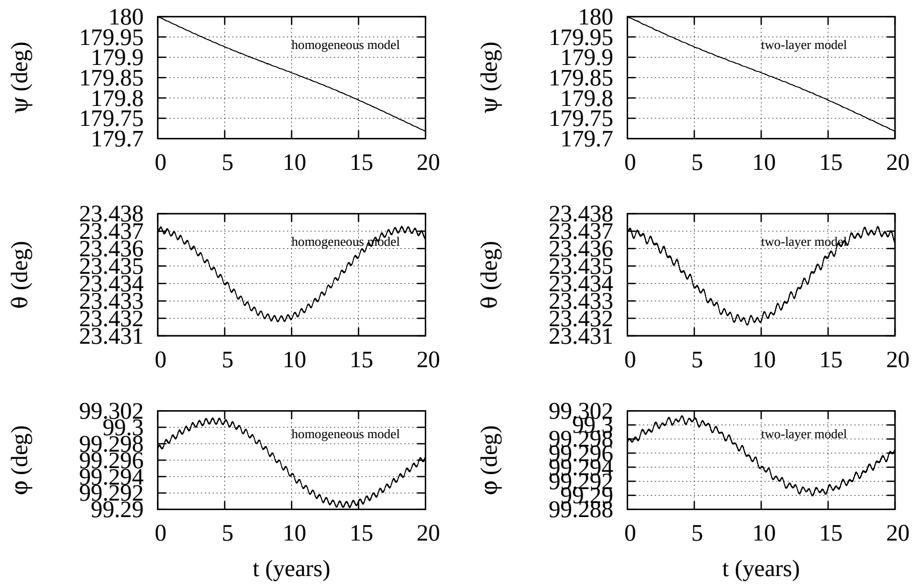

Figure 1: The rotational motion of the Earth's mantle in an homogenous and a two layer model expressed by the classical 3-1-3 Eulerian sequence (ψ, θ, ϕ) with respect to the ecliptic reference frame.

and to identify the different families of libration, of the terrestrial planets, with special emphasis for this paper on the Earth's spin-orbit motion (for details see Bois 2000; Bois and Vokrouhlicky 1995; Rambaux and Bois 2004). We obtain the dynamical behavior of the rotational motion of the Earth considered as a homogeneous body and as a model with two layers. In order to perform the core-mantle coupling, we have included the Poincaré model (see, e.g., Poincaré 1910; Moritz, 1980). The coupling between the mantle and core in this model is called inertial coupling, and is due to the pressure of the fluid on the core-mantle boundary. Figure 1 presents the comparison of the two models in the classical 3-1-3 Eulerian angles . The curves characterize the dynamical motion of the Earth considered as a homogeneous body and for the two-layer model.

In the case of the Earth composed of two layers, we have estimated the periods of two rotational normal modes, the Free Core Nutation (FCN, this period is defined with respect to an inertial reference frame) and the Chandler Wobble (CW, this period is expressed with respect to an Earth-fixed, co-rotating reference frame) at 333.5 and 275.2 days, respectively. Analytical models give 334.8 days for the FCN in the Poincaré case (Dehant *et. al.* 1999) and 274.1 days for the CW (Legros and Amalvict, 1985), these values are in a very good agreement with our model. Note that in contrast to the analytical expressions, SONYR also takes into account non-linear interactions and couplings between the three Euler angles, thus allowing to estimate the impact of these terms on the rotational behavior of the planet.

2. MOTION OF THE CORE INSIDE THE EARTH

We also investigated the dynamical behavior of the core itself. Generally speaking, the mean motion of the core follows the motion of the mantle. However, the dynamical motion of the core has a larger amplitude, the amplitude of the CW normal mode is of the order of 9 arcseconds, than the dynamical motion of the mantle for periods smaller than one year. The core performes oscillations, with amplitudes of the order of 230 meters at the core-mantle boundary. Due to this large motion of the core, it is possible to detect a signature of its presence in the nutation observations as already done by Herring et al. (1986).

We have included the presence of a core acting by inertial coupling on the rotational motion of the planet in the SONYR model. SONYR then becomes a model at the intersection between Celestial Mechanics and Geophysics. We have studied the impact of the core on the well-known rotational motion of the Earth. We clarified the signature of the core in the librations/nutations of the Earth, and we investigated in detail the motion of the core inside the mantle in the framework of the Poincaré model. Our approach allows coupling between spin-orbit in that framework, which has never been done before. Let us note that the SONYR model not only permits to study the rotation of Earth with different layers but can also be used for the Mercury, the Moon, Venus and Mars.

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3. REFERENCES

Bois, 1995, Astron. Astrophys., 296, 850-857
Bois 2000, CRAS, tome 1, Srie IV, 809-823
Bois and Vockrouhlicky, 1995, Astron. Astrophys., 300, 559-567
Dehant *et. al.*, 1999, Celestial Mechanics and Dynamical Astronomy, 72, p.245-310
Herring, T., C. Gwinn, and I Shapiro, 1986, J. Geophys. Res., 91, 4745-4755.
Legros and Almavict, 1985, Annale Geophysicae, 3, 5, 655-670
Moritz, 1980, report III No 342, eds. The Ohio State University, 109
Poincaré, 1910, Bull. Astron., 27, 321
Rambaux and Bois, 2004, Astron. Astrophys., 413, 381-393.