IMPROVED ANALYTIC NUTATION MODEL

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Models describing earth's nutations can be separated into two major components, plus several small perturbations, of which ocean tides and solid friction are the most significant. The primary element of a successful model is an accurate rigid earth nutation theory. The effect of mantle elasticity and differential nutation of the fluid core is then obtained as a correction factor which multiplies the rigid body result. Wahr's (1981) theory is certainly the most sophisticated elastodynamic response model. However, we have found that the simple model of Sasao et al., (1980) differs from Wahr's theory term by term by less than 0.3mas if a modern earth structure model (1066B) is used to evaluate the nutation structure constants.

The complex version of Euler's equations is

$$A\quad (D-ie\Omega)m + (D+i\Omega(A_f m_f+Ac_{21}) = -iAe\Omega\phi\ .$$

$$Dm + \left[D+i(1+e_f)\right]m_f + Dc_{21}^{f} = 0$$

where $D=\frac{d}{dt}$, $e=(C-A)/A$, $e_f=(c_f-A_f)/A$, $\Omega=2\pi/\text{day}$, $m=(\Omega_x+i\Omega_y)/\Omega$ and $i=\sqrt{-1}$. The rigid polar motion m_r due to a periodic external potential variation $\theta=\phi_o$ expi $(n-\Omega)$ is obtained in the limit $n=0$; $m_r=(e/[1-e])\phi_o$, and the scale factor is simply $m(n)/m_r$. The off-diagonal variations in the moment of inertia of whole earth c_{21} and fluid core c_{21}^f depend on four structure constants κ, ζ, γ and β; $c_{21}=\kappa(m-\phi)+\zeta m_f$; & $c_{21}^f=\gamma(m-\phi)+\beta m_f$. The values obtained from a standard elastic theory analysis are $e=3.259\text{x}10^{-3}$, $e_f=2.555\text{x}10^{-3}$, $A_f=0.1139A$, $\gamma=1.963\text{x}10^{-3}$, $\zeta=2.253\text{x}10^{-4}$, $\kappa=1.048\text{x}10^{-3}$ and $\beta=6.214\text{x}10^{-3}$. The FCN frequency obtained (-458.5d) is in excellent agreement with Wahr's value of -460d.

The effect of oceans has also been estimated using a similar model in which the effective c_{21} and c_{21}^f corrections due to the combined ocean mass and load terms are: $\kappa^o=0.066f\kappa(i-1)$ $\zeta^o=0.0061f\kappa(1-i)$, $\gamma^o=0.029f\gamma(1-i)$ and $\beta^o=0.0020f\gamma(i-1)$. From an intercomparison of Laplace ocean models and Lageos data, we find $f=1$ for the O1 tide (equivalent to 13.66d prograde nutation) and ≅0.8 for the P1 (semi-

M. J. Reid and J. M. Moran (eds.), The Impact of VLBI on Astrophysics and Geophysics, 379–380.

annual nutation) and K_1 tides. Although f is probably accurate to ±25% or better, ocean currents contribute an additional source of angular momentum variation which could be as large as the ocean mass effect and which may add 0.3mas to the 13.66d nutation, based on a related study of the M2 tide's effect on UTI (Baader et al., 1983).

Solid friction can be modelled by multiplying $\{\gamma,\beta\}$ and $\{\kappa,\zeta\}$ by $(1+i/Q_c)$ and $(1+i/Q_t)$, respectively. We find that $Q_c \approx Q_t$ to within ~20%. For a plausible $Q_t=100$, solid friction adds ~0.2mas to a few terms. Ocean and solid friction equally contribute to a FCN damping time of ~ 50 yr.

Herring et al.'s latest VLBI solution indicates that the annual residual is -2.2mas relative to Wahr (1981). If the FCN frequency is reduced to -430.5d by changing e_f to 2.681×10^{-3}, the resulting VLBI residuals (minus ocean and solid friction effects) relative to the improved SOS theory are shown below.

	OCEAN CORRECTIONS			SOLID FRICTION		VLBI RES.
	WAHR	OUR RESULTS		CORE:	TIDE:	Herring
Period	SASAO	MASS	LOAD	$Q_C=100$	$Q_t=100$	et al. 1987)
13.66d	0.02 (j)	-0.22 (j)	0.24 (j)		0.09i	-0.36 - 0.06i
182.62	0.61 (j)	-0.07 (j)	0.69 (j)	0.01i	0.30i	-0.31 - 0.10i
-365.26	0.17 (j)	<0.01	0.21 (j)	0.12i	0.12i	0.30i
						±0.10mas

Table 1: Oceanic and tidal corrections to improved SOS theory (with FCN=-430d), compared to Herring et al., (1987) VLBI solution. Here $j=1-i$, $i=\sqrt{-1}$

Acknowledgement

The research in this publication was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract NAS7-100 with the National Aeronautics and Space Administration.

References

Baader, H. -R., P. Brosche, W. Hovel, J. Geophys., 52, 140-142, 1983.
Herring, T.A., C.R. Gwinn, B.A. Buffett and I.I. Shapiro, to appear in IAU Symp. 128: Earth Rotation & Reference Frames for Geodesy, 1987.
Sasao, T.S., S. Okubo and M. Saito, in Proc. IAU Symp. No. 78, Nutations and Earth Rotation, Kiev, 1977, (eds. E.P. Federov, M.L. Smith, P.L. Bender), Reidel, Dordrecht, 165-183, 1980.
Wahr, J.M., Geophys. J. Roy. astr. Soc., 64, 705-727, 1981.
Wahr, J.M. and T.S. Sasao, Geophys. J. Roy. astr. Soc., 64, 747-765, 1981.