Preliminary Results of the Free Core Nutation Eigenperiod Obtained by Stacking SG Observations at GGP Stations*

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Abstract

The tidal gravity results obtained from total 92 years at 19 Global Geodynamics Projects (GGP) stations (after loading correction with 6 different ocean models) are stacked in order to determine the free core nutation resonant parameters. The eigenperiod as of 429.9 sidereal days (sd) with error range (427.2, 432.7 sd) is obtained that agrees with the recent models as 429.5 sd (Dehant et al 1999) and 430.04 sd (Mathews et al, 2001).

1 Introduction

Since Jeffreys mentioned in 1957 the frequency dependents of the tidal amplitude factors in the diurnal wave band, many studies have been developed in theoretical and experimental aspects. Considering that the Earth occupies a rotating, slightly elliptical deformable core-mantle boundary, the dynamic influence of the liquid core leads to a rotation eigenmode associated with the wobble with respect to the mantle, it is the free core nutation (FCN). Based on the angular momentum equations, the FCN eigenperiod and quality factor can be theoretically computed by using a numerical integration technique (Wahr and Sasao, 1981, Mathews et al 2001). The researches show that the resonance of the liquid core will enhance wave amplitudes as P1, K1, y1 and j1, therefore it is possible for us to retrieve the FCN resonant parameters from diurnal tidal gravity.

The determined eigenperiods in the previous studies are about 10% less than those in theoretical prediction (Wahr et al 1981). They are different (1) when using the data from various stations, (2) when using various global ocean tidal models and (3) when using different kind of observations. More than 19 stations around the world, equipped with superconducting gravimeters (SGs), are now taking part in the Global Geodynamics Projects (GGP). By using tidal gravity observations at GGP stations for the length of totally 92 years, the FCN parameters will be determined by using a stacking technique in this paper. The discrepancies of the resonance parameters from different stations when using various ocean models are investigated.

2 Tidal gravity observations at GGP network

The tidal gravity observations recorded from SGs are from stations Bandung (Indonisia), Brussels (Belgium), Boulder (American), Brasimone (Italy), Cantley (Canada), Canberra (Australia), Esashi (Japan), Kyoto (Japan), Matsushiro (Japan), Membach (Belgium), Metsahovi (Finland), Moxa (Germany), Potsdam (Germany), Strasbourg (France), Sutherland (South African), Syowa (South Pole), Vienna (Austria), Wettzell (Germany), Wuhan (China). The tidal gravity data recorded from LCR-ET tidal gravimeter at station Pecny (Czech Republic) are also adopted since their quality. The 3 series at Moxa (1st series is from lower sphere, 2nd series is from upper sphere, and 3rd series is from stacking data of lower and upper spheres), 2 series at Strasbourg (old and new series), 3 series at Sutherland (same as the sation Moxa) and 4 series at Wetzell (one series from old period and other 3 series are same as Moxa) are included (Ducarme et al, 2002).

By using a remove restore technique, the minute tidal gravity samplings are pre-processed using a Tsoft technique (Vauterin, 1998) in the International Centre for Earth Tides (ICET). The hourly samplings are obtained after applying for a filtering technique, the tidal parameters and their RMS are determined by using Eterna 3.4 (Wenzel 1996). The atmospheric pressure signals are removed by using the regression coefficients between gravity residuals and station pressure.

The ocean tidal signals should be carefully removed before explanation of the results in geodynamics (Sato et al, 1994, Sun et al, 2002). Previous studies show that the correlation between the predicted load vectors and the observed ones is up to 90% (Melchior and Francis 1996, Sun, 2002). Based on 6 ocean models (Scw80, Csr3.0, Fes95.2, Tpxo2, Csr4.0 and Ori96), the load vectors are computed using a standard procedure (Agnew, 1997). The loading vectors for small waves y1 and j1 are obtained by using an interpolation technique in which we considered the ocean resonance phenomena (Wahr and Sasao, 1981).

The main wave tidal gravity parameters with frequency at core resonance (P1, K1, y1 and j1) before (d, Dj) and after (d', Dj') loading correction (Csr4.0) are given in table 1. The discrepancy of these corrected amplitude factors with respect to theoretical values (Dehant et al., 1999) and experimental models (Sun et al, 2002) is investigated. The numerical results show the corrected results are much approach to the theoretical values, this signifies the effectiveness of the loading correction for both principle and weak tidal components (Sun et al 2002).

3 Numerical results and discussions

A similar treatment in determining the FCN parameters same as the one in previous studies as Defraigne et al. (1994) and Xu et al. (2001) is used. The fitting equations are deduced by modelling the observed complex diurnal tidal gravity parameter to theoretical ones with consideration of removing the signals of wave O1. After oceanic loading correction, the eigenperiod T_{FCN} ranges to be from 415 to 440 sd, except for the stations Sutherland (468.3 sd) and Syowa (464.5 sd). It shows that the high inner data quality is important in the determination of the FCN eigenperiod. The large discrepancy for stations Sutherland and Syowa relates to the un-accuracy of the ocean tidal models. By stacking the tidal observations separately from various regions, we obtained T_{FCN} as 427.5 sd with error range (418.6, 436.8 sd) for 4 stations in Asia, 427.1 sd with error range (410.8, 444.8 sd) for 9 stations in Europe, 426.4 sd with error range (420.6, 432.3 sd,) for 2 stations in Northern American and 440.9 sd with error range (423.5, 459.7 sd) for 4 stations in Southern hemisphere.

Stacking tidal gravity observations obtained from 20 GGP stations, the T_{FCN} as of 429.9 sd with error range (427.2, 432.7 sd) is obtained. It corresponds well to those in previous researches as 433.6 sd with error range (433.1, 434.1 sd, Defraigne et al 1994) and 429.0 sd with error range (424.3, 433.7 sd, Xu et al, 2001). They correspond also to those deduced from the VLBI as 429.5 sd (Dehant et al 1999) and 430.04 sd when considering the electro-magnetic force coupling at mantle-core boundary (Mathews et al, 2002). As the theoretical prediction of the T_{FCN} is as of 455.8 to 467.4 sd (Wahr, 1981, Mathews et al, 1991), the convinced explanation to the T_{FCN} discrepancy of 30 sd, is the dynamic ellipticity of the fluid core may be about 4.8% larger than the hydrostatic one.

The quality factor relates to the damping properties of the Earth, such as the viscosity of the mantle, the tidal friction in the ocean bottom, the electro-magnetic and viscous coupling between the core and mantle. It mainly depends on the phase differences in tidal gravity observations, it is found that the quality factors differ from one station to another, and from one ocean model to another, the discrepancy is quite large. However, the discrepancy of the T_{FCN} when using various ocean models is about 2.0% for most stations. The eigenperiod to inverse quality factors is given in figures 1. It is found that the results when stacking tidal gravity observations corrected with loading vectors averaged with 6 ocean models are situated at the figure center. It proves that the stacking technique can be used to reduce effectively the local influence of the ocean tides, atmospheric pressure, underground water level change, and other station environmental perturbations.

4 Preliminary conclusions

Based on the numerical results and discussions, we conclude: the high quality observations are important in the determination of the FCN parameters. The ocean tides are one of the main perturbations, the discrepancy of the T_{FCN} when using various ocean models is about 2.0%. The determined T_{FCN} is as 429.9 sd with error ±0.65% when stacking the tidal gravity observations from 19 GGP stations, it is in good agreement with those determined from recent theoretical studies.

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References

[1] Agnew DC, A program for computing ocean-tide loading, J. Geophysical Research, 1997, 102(B3): 5109-5110.

[2] Defraigne P, Dehant V, Hinderer J. Staking gravity tide measurements and nutation observations in order to determine the complex eigenfrequency of nearly diurnal free wobble. J. Geophys. Res., 1994, 99 (B5): 9203–9213.

[3] Dehant, V., Defraigne, P. and Wahr, J. (1999): Tides for a convective Earth, J. Geophys. Res., 104, B1, 1035–1058.

[4] Ducarme B, Sun H.P and Xu JQ, New investigation of tidal gravity results from the GGP Network, 2002,

[5] Mathews P.M. (2001): Love numbers and gravimetric factor for diurnal tides. Journal of the Deodetic Society of Japan, 2001, 47(1), 231–236.

[6] Melchior P and Francis O. Comparison of recent ocean tide models using ground-based tidal gravity measurements. Marine Geodesy, 1996, 19: 291–330

[7] Sato T, Tamura Y, Higashi T, Takemoto S, Nakagawa I, Morimoto N, Fukuda Y,Segawa J and Seama J, 1994. Resonance parameters of the free core nutation measured from three superconducting gravimeters in Japan, J. Geomag. Geoelectr., 46, 571–586.

[8] Sun He-Ping, Hou-Tze Hsu, Gerhard Jentzsch, Jian-Qiao Xu, Tidal gravity observations obtained with a superconducting gravimeter at Wuhan/China and its application to geodynamics, Journal of Geodynamics, 2002, 33(1-2): 187–198.

[9] Sun He-Ping, Xu Jian-Qiao and Ducarme Bernard. Experimental earth tidal models of the core resonance obtained by stacking tidal gravity observations from the GGP Stations, GGP work shop, Jena, March 11–15, 2002.

[10] Wahr J M, Sasao T. A diurnal resonance in the ocean tide and in the Earth's load response duo to the resonant free 'core nutation'. Geophys. J. R. astr. Soc.. 1981, 64: 747–765.

[11] Wenzel, H.G.(1996): The nanogal software: data processing package ETERNA 3.3, Bull. Inf. Marées Terrestres, 124, 9425–9439.

[12] Xu Jian-Qiao, Sun He-Ping and Luo Shao-Cong. Investigation of the Earth's free core nutation by using global tidal gravity observations with superconducting gravimeters. Science in China, 2001, 31(9): 719–726 (in Chinese).

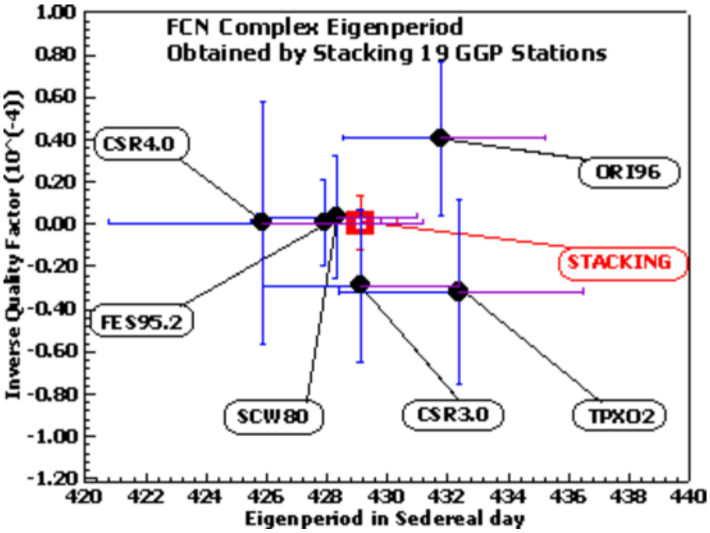

Figure 1 Comparison of the resonant parameters when using various ocean models

Table 1 Main tidal wave amplitude factors before and after ocean loading correction (Csr4.0)

	P1 wave				K1 wave				y1 wave				j1 wave			
	observed		corrected		observed		corrected		observed		corrected		observed		corrected	
station	d	Dj(°)	d¢	Dj¢(°)	d	Dj(°)	d¢	Dj¢(°)	d	Dj(°)	d¢	Dj¢(°)	d	Dj(°)	d¢	Dj¢(°)
Bandung	1.1685	9.87	1.1377	-0.45	1.1641	11.02	1.1215	0.34	1.6061	-1.73	1.6041	-7.34	1.2145	6.19	1.1903	-3.10

Brussels	1.1524	0.15	1.1541	-0.20	1.1401	0.25	1.1406	-0.05	1.2365	-0.47	1.2372	-0.69	1.1746	0.05	1.1752	-0.23
Boulder	1.1659	1.27	1.1501	0.09	1.1540	1.30	1.1369	0.06	1.2675	2.08	1.2547	1.30	1.1798	2.61	1.1632	1.59
Brasimone	1.1453	0.20	1.1466	-0.16	1.1329	0.22	1.1333	-0.11	1.3132	3.60	1.3134	3.37	1.1708	-0.32	1.1715	-0.65
Cantley	1.1608	0.48	1.1545	-0.03	1.1480	0.57	1.1405	0.03	1.2815	-0.46	1.2767	-0.80	1.1810	0.75	1.1749	0.31
Canberra	1.1528	-0.82	1.1561	0.03	1.1367	-0.84	1.1400	0.08	1.2460	0.77	1.2503	1.37	1.1661	-0.99	1.1721	-0.17
Esashi	1.2131	0.31	1.1515	-0.16	1.2007	0.31	1.1406	-0.11	1.3163	-1.10	1.2719	-1.40	1.2395	0.64	1.1839	0.37
Kyoto	1.2002	-0.08	1.1477	0.09	1.1870	-0.20	1.1360	0.01	1.4702	5.70	1.4328	5.99	1.1651	0.61	1.1177	0.89
Matsushiro	1.1947	-0.06	1.1450	-0.10	1.1838	-0.08	1.1354	-0.10	1.2587	0.18	1.2226	0.20	1.2065	-0.48	1.1612	-0.46
Membach	1.1496	0.24	1.1507	-0.08	1.1373	0.28	1.1374	0.01	1.2821	1.00	1.2823	0.81	1.1626	0.63	1.1628	0.37
Metsahovi	1.1548	0.05	1.1592	0.09	1.1407	0.07	1.1443	0.25	1.2553	1.00	1.2580	1.11	1.1764	-0.51	1.1795	-0.33
Moxa	1.1491	0.21	1.1503	-0.04	1.1363	0.24	1.1366	0.05	1.2646	0.09	1.2650	-0.06	1.1699	0.16	1.1704	-0.03
Pecny	1.1512	0.18	1.1525	-0.04	1.1364	0.15	1.1370	-0.02	1.2629	3.66	1.2634	3.53	1.1670	0.88	1.1678	0.71
Potsdam	1.1504	0.16	1.1515	-0.06	1.1374	0.26	1.1377	0.11	1.2582	0.69	1.2586	0.57	1.1777	-0.14	1.1783	-0.29
Strasbourg	1.1497	0.18	1.1506	-0.13	1.1370	0.23	1.1368	-0.02	1.2679	-0.56	1.2680	-0.74	1.1675	0.78	1.1674	0.53
Sutherland	1.1510	-0.54	1.1498	-0.11	1.1355	-0.51	1.1363	-0.12	1.2198	-0.80	1.2205	-0.49	1.1729	-1.00	1.1742	-0.58
Syowa	1.2144	0.16	1.1546	-0.37	1.1992	0.19	1.1457	-0.41	1.2798	1.39	1.2435	1.11	1.2021	0.13	1.1606	-0.24
Vienna	1.1472	0.15	1.1490	-0.08	1.1339	0.19	1.1351	0.01	1.2781	0.71	1.2792	0.58	1.1692	0.16	1.1706	-0.02
Wettzell	1.1492	0.28	1.1505	0.03	1.1353	0.34	1.1358	0.15	1.2659	-0.79	1.2665	-0.94	1.1671	0.32	1.1678	0.12
Wuhan	1.1663	-0.43	1.1519	-0.01	1.1531	-0.47	1.1403	-0.03	1.2711	-1.43	1.2612	-1.16	1.1912	0.17	1.1792	0.54