8 Tidal variations in the Earth's rotation

8.1 Effect of the tidal deformation (zonal tides) on Earth's rotation

Periodic variations in UT1 due to tidal deformation of the polar moment of inertia were first derived by Yoder *et al.* (1981) and included the tidal deformation (zonal tides) of the Earth with a decoupled core, an elastic mantle and equilibrium oceans. This model used effective Love numbers that differ from the bulk value of 0.301 because of the oceans and the fluid core, producing different theoretical values of the ratio k/C (defined as the quantity which scales the rotational series, where k is that part of the Love number which causes the tidal variation in the moment of inertia of the coupled mantle and oceans and C is the dimensionless polar moment of inertia of the coupled values) for the fortnightly and monthly terms. However, Yoder *et al.* (1981) recommend the value of 0.94 for k/C for both cases.

Past versions of the IERS Conventions defined regularized UT1[1] as UT1 with the effect of the corrected tides with periods less than 35 days removed and UT1S as UT1 with the effects of all tidal constituents removed, including the long-period tides (up to 18.6 years). However, the IERS Conventions recommend that only UT1 and length of day (here noted Δ) be used in routine data exchange applications in order to avoid possible confusion regarding the exact implementation of tidal models. In research applications, analysts must be careful to specify unambiguously any tidal models used.

Table 8.1 provides corrections for the tidal variations in the Earth's rotation with periods from 5 days to 18.6 years. These corrections (δUT1, $\delta\Delta$, $\delta\omega$) represent the effect of tidal deformation on the physical variations in the rotation of the Earth and are the sum of: (1) the Yoder *et al.* (1981) elastic body and equilibrium ocean tide model assuming a value of 0.94 for k/C; (2) the in-phase and out-of-phase components of the Wahr and Bergen (1986) inelastic body tide model for the QMU Earth model of Sailor and Dziewonski (1978) assuming a frequency dependence of $(f_m/f)^\alpha$ where $\alpha = 0.15$, f_m is the seismic frequency corresponding to a period of 200 s, and f is the tidal frequency; and (3) the data assimilating dynamic ocean tide model "A" of Kantha *et al.* (1998) from which the equilibrium model of Yoder *et al.* (1981) was removed (see Gross (2009) for an evaluation of these and other tide models). To obtain variations free from tidal effects, these corrections should be subtracted from the observed UT1−UTC, length of day (Δ) and rotation velocity (ω). The difference between this newly recommended model and that in the *Conventions 2003* is mainly at the fortnightly tidal period where the UT1 amplitude difference is approximately 6 μs. The total amplitude of the fortnightly tide in UT1 is about 785 μs.

$$\delta \mathrm{UT1} = \sum_{i=1}^{62} B_i \sin\xi_i + C_i \cos\xi_i,$$

$$\delta\Delta = \sum_{i=1}^{62} B_i' \cos\xi_i + C_i' \sin\xi_i,$$

$$\delta\omega = \sum_{i=1}^{62} B_i'' \cos\xi_i + C_i'' \sin\xi_i,$$

$$\xi_i = \sum_{j=1}^{5} a_{ij}\alpha_j,$$

B_i, C_i, B_i', C_i', B_i'', and C_i'' are given in columns 7–12 respectively in Table 8.1. a_{ij} are the integer multipliers of the α_j for the i^{th} tide given in the first five columns of Table 8.1. The arguments α_j (l, l', F, D or Ω) are given in Section 5.7.2.

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[1] UT1R was adopted at The Eighteenth General Assembly of the International Astronomical Union to be UT1 with the short period tides removed, *i.e.*, periods less than 35 days, and that these tabulations be based on Yoder *et al.* (1981). See: Transactions of the International Astronomical Union, 1983, Proceedings of the Eighteenth General Assembly, Vol. XVIIIB, 17–26 August, 1982, Patras, Greece, pp. 238–240.

The routine "RG_ZONT2.F", available from the IERS Conventions website <[2]>, implements the model from Table 8.1.

In the past there has been some confusion over comparison of models appearing in the *IERS Conventions* and the values published in the Yoder *et al.* (1981) paper. J. Williams (2005, private communication) points out that there are four known errors in the Yoder *et al.* (1981) table. (1) The amplitude of term 22 (14.73-day period) should read −50 instead of 50. (2) The period of term 58 (1095.17-day period) should read −1095.17 instead of 1095.17, (*i.e.* the motion is retrograde). (3) The amplitude of term 59 (1305.47-day period) should read −448 instead of −449. (4) The amplitude of term 60 (3232.85-day period) should read +43 instead of −43.

To avoid confusion among possible tidal models, it is recommended that the terms δUT1, $\delta\Delta$, $\delta\omega$ be followed by the model name in parenthesis, *e.g.* δUT1(Yoder *et al.*, 1981).

8.2 Diurnal and semi-diurnal variations due to ocean tides

The routine "ORTHO_EOP.F", available from the IERS Conventions website < [3]>, provides corrections for modeling the diurnal and sub-diurnal variations in polar motion and UT1. It was provided by Eanes (2000) and based on Ray *et al.* (1994). The difference with the older model of the Conventions (1996) can exceed 100 microarcseconds for polar motion and 10 microseconds for UT1.

The model includes 71 tidal constituents with amplitudes on the order of tenths of milliarcseconds in polar motion and tens of microseconds in UT1. The coefficients of these terms have been derived by the IERS Earth Orientation Center from time series of these variations determined from "ORTHO_EOP.F", and are reported in Tables 8.2a and 8.2b for polar motion and in Tables 8.3a and 8.3b for UT1 and length of day (LOD). Previous versions of Tables 8.3a and 8.3b provided LOD with a resolution that was better than that for UT1. For consistency between the two and between these tables and Table 5.1b in Chapter 5, one digit has been removed for the LOD values in Tables 8.3a and 8.3b. Because these tables cannot be found in the code of "ORTHO_EOP.F", the IERS Earth Orientation Center has implemented them in the alternative software "interp.f" <[3]>. The two routines agree at the level of a few microarcseconds in polar motion and a few tenths of a microsecond in UT1.

8.3 Tidal variations in polar motion and polar motion excitation due to long period ocean tides

Table 8.4 provides corrections for the tidal variations in polar motion and polar motion excitation with periods from 9 days to 18.6 years in terms of the amplitude A and phase ϕ of the prograde (subscript p) and retrograde (subscript r) components defined for polar motion $\vec{\mathbf{p}}(t)$ by:

$$\vec{\mathbf{p}}(t) = p_x(t) - ip_y(t) = A_p e^{i\phi_p} e^{i\alpha(t)} + A_r e^{i\phi_r} e^{-i\alpha(t)}, \tag{8.1}$$

and for polar motion excitation $\vec{\chi}(t) \equiv \vec{\mathbf{p}}(t) + \dfrac{i}{\sigma_0}\dfrac{d\vec{\mathbf{p}}(t)}{dt}$ by:

$$\vec{\chi}(t) = \chi_x(t) + i\chi_y(t) = A_p e^{i\phi_p} e^{i\alpha(t)} + A_r e^{i\phi_r} e^{-i\alpha(t)} \tag{8.2}$$

where by convention $p_y(t)$ is defined to be positive toward 90°W longitude, $\chi_y(t)$ is defined to be positive toward 90°E longitude, σ_0 is the complex-valued frequency of the Chandler wobble, and $\alpha(t)$ is the tidal argument, the expansion of which in terms of $(l, l', F, D,$ and $\Omega)$ is given in Table 8.4. These corrections are from the Dickman and Nam (1995) long-period spherical harmonic ocean tide model as reported by Dickman and Gross (2010). To obtain variations free from tidal effects,

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[2] ftp://tai.bipm.org/iers/conv2010/chapter8/

[3] ftp://hpiers.obspm.fr/eop-pc/models/interp.f

the sum of these corrections should be subtracted from the observed polar motion and polar motion excitation values. The effect on polar motion is largest for the fortnightly tide. Empirical fits to polar motion data give (prograde, retrograde) amplitudes of (69, 89) μas at M_f. The model yields (prograde, retrograde) polar motion amplitudes of (66, 74) μas at M_f.

Table 8.1: Zonal tide terms. Columns headed by the titles δUT1, $\delta\Delta$, and $\delta\omega$ provide the regularized forms of UT1, the duration of the day Δ, and the angular velocity of the Earth, ω. The units are 10^{-4} s for UT1, 10^{-5} s for Δ, and 10^{-14} rad/s for ω. The column titled "Period" provides the approximate value of the period with a positive or negative sign to indicate a prograde or retrograde motion.

ARGUMENT					PERIOD	δUT1		$\delta\Delta$		$\delta\omega$	
l	l'	F	D	Ω	Days	B_i	C_i	B'_i	C'_i	B''_i	C''_i
1	0	2	2	2	5.64	-0.0235	0.0000	0.2617	0.0000	-0.2209	0.0000
2	0	2	0	1	6.85	-0.0404	0.0000	0.3706	0.0000	-0.3128	0.0000
2	0	2	0	2	6.86	-0.0987	0.0000	0.9041	0.0000	-0.7630	0.0000
0	0	2	2	1	7.09	-0.0508	0.0000	0.4499	0.0000	-0.3797	0.0000
0	0	2	2	2	7.10	-0.1231	0.0000	1.0904	0.0000	-0.9203	0.0000
1	0	2	0	0	9.11	-0.0385	0.0000	0.2659	0.0000	-0.2244	0.0000
1	0	2	0	1	9.12	-0.4108	0.0000	2.8298	0.0000	-2.3884	0.0000
1	0	2	0	2	9.13	-0.9926	0.0000	6.8291	0.0000	-5.7637	0.0000
3	0	0	0	0	9.18	-0.0179	0.0000	0.1222	0.0000	-0.1031	0.0000
-1	0	2	2	1	9.54	-0.0818	0.0000	0.5384	0.0000	-0.4544	0.0000
-1	0	2	2	2	9.56	-0.1974	0.0000	1.2978	0.0000	-1.0953	0.0000
1	0	0	2	0	9.61	-0.0761	0.0000	0.4976	0.0000	-0.4200	0.0000
2	0	2	-2	2	12.81	0.0216	0.0000	-0.1060	0.0000	0.0895	0.0000
0	1	2	0	2	13.17	0.0254	0.0000	-0.1211	0.0000	0.1022	0.0000
0	0	2	0	0	13.61	-0.2989	0.0000	1.3804	0.0000	-1.1650	0.0000
0	0	2	0	1	13.63	-3.1873	0.2010	14.6890	0.9266	-12.3974	-0.7820
0	0	2	0	2	13.66	-7.8468	0.5320	36.0910	2.4469	-30.4606	-2.0652
2	0	0	0	-1	13.75	0.0216	0.0000	-0.0988	0.0000	0.0834	0.0000
2	0	0	0	0	13.78	-0.3384	0.0000	1.5433	0.0000	-1.3025	0.0000
2	0	0	0	1	13.81	0.0179	0.0000	-0.0813	0.0000	0.0686	0.0000
0	-1	2	0	2	14.19	-0.0244	0.0000	0.1082	0.0000	-0.0913	0.0000
0	0	0	2	-1	14.73	0.0470	0.0000	-0.2004	0.0000	0.1692	0.0000
0	0	0	2	0	14.77	-0.7341	0.0000	3.1240	0.0000	-2.6367	0.0000
0	0	0	2	1	14.80	-0.0526	0.0000	0.2235	0.0000	-0.1886	0.0000
0	-1	0	2	0	15.39	-0.0508	0.0000	0.2073	0.0000	-0.1749	0.0000
1	0	2	-2	1	23.86	0.0498	0.0000	-0.1312	0.0000	0.1107	0.0000
1	0	2	-2	2	23.94	0.1006	0.0000	-0.2640	0.0000	0.2228	0.0000
1	1	0	0	0	25.62	0.0395	0.0000	-0.0968	0.0000	0.0817	0.0000
-1	0	2	0	0	26.88	0.0470	0.0000	-0.1099	0.0000	0.0927	0.0000
-1	0	2	0	1	26.98	0.1767	0.0000	-0.4115	0.0000	0.3473	0.0000
-1	0	2	0	2	27.09	0.4352	0.0000	-1.0093	0.0000	0.8519	0.0000

(continued on next page)

(Table 8.1: continued)

1	0	0	0	-1	27.44	0.5339	0.0000	-1.2224	0.0000	1.0317	0.0000
1	0	0	0	0	27.56	-8.4046	0.2500	19.1647	0.5701	-16.1749	-0.4811
1	0	0	0	1	27.67	0.5443	0.0000	-1.2360	0.0000	1.0432	0.0000
0	0	0	1	0	29.53	0.0470	0.0000	-0.1000	0.0000	0.0844	0.0000
1	-1	0	0	0	29.80	-0.0555	0.0000	0.1169	0.0000	-0.0987	0.0000
-1	0	0	2	-1	31.66	0.1175	0.0000	-0.2332	0.0000	0.1968	0.0000
-1	0	0	2	0	31.81	-1.8236	0.0000	3.6018	0.0000	-3.0399	0.0000
-1	0	0	2	1	31.96	0.1316	0.0000	-0.2587	0.0000	0.2183	0.0000
1	0	-2	2	-1	32.61	0.0179	0.0000	-0.0344	0.0000	0.0290	0.0000
-1	-1	0	2	0	34.85	-0.0855	0.0000	0.1542	0.0000	-0.1302	0.0000
0	2	2	-2	2	91.31	-0.0573	0.0000	0.0395	0.0000	-0.0333	0.0000
0	1	2	-2	1	119.61	0.0329	0.0000	-0.0173	0.0000	0.0146	0.0000
0	1	2	-2	2	121.75	-1.8847	0.0000	0.9726	0.0000	-0.8209	0.0000
0	0	2	-2	0	173.31	0.2510	0.0000	-0.0910	0.0000	0.0768	0.0000
0	0	2	-2	1	177.84	1.1703	0.0000	-0.4135	0.0000	0.3490	0.0000
0	0	2	-2	2	182.62	-49.7174	0.4330	17.1056	0.1490	-14.4370	-0.1257
0	2	0	0	0	182.63	-0.1936	0.0000	0.0666	0.0000	-0.0562	0.0000
2	0	0	-2	-1	199.84	0.0489	0.0000	-0.0154	0.0000	0.0130	0.0000
2	0	0	-2	0	205.89	-0.5471	0.0000	0.1670	0.0000	-0.1409	0.0000
2	0	0	-2	1	212.32	0.0367	0.0000	-0.0108	0.0000	0.0092	0.0000
0	-1	2	-2	1	346.60	-0.0451	0.0000	0.0082	0.0000	-0.0069	0.0000
0	1	0	0	-1	346.64	0.0921	0.0000	-0.0167	0.0000	0.0141	0.0000
0	-1	2	-2	2	365.22	0.8281	0.0000	-0.1425	0.0000	0.1202	0.0000
0	1	0	0	0	365.26	-15.8887	0.1530	2.7332	0.0263	-2.3068	-0.0222
0	1	0	0	1	386.00	-0.1382	0.0000	0.0225	0.0000	-0.0190	0.0000
1	0	0	-1	0	411.78	0.0348	0.0000	-0.0053	0.0000	0.0045	0.0000
2	0	-2	0	0	-1095.18	-0.1372	0.0000	-0.0079	0.0000	0.0066	0.0000
-2	0	2	0	1	1305.48	0.4211	0.0000	-0.0203	0.0000	0.0171	0.0000
-1	1	0	1	0	3232.86	-0.0404	0.0000	0.0008	0.0000	-0.0007	0.0000
0	0	0	0	2	-3399.19	7.8998	0.0000	0.1460	0.0000	-0.1232	0.0000
0	0	0	0	1	-6798.38	-1617.2681	0.0000	-14.9471	0.0000	12.6153	0.0000

Table 8.2a: Coefficients of sin(argument) and cos(argument) of diurnal variations in pole coordinates x_p and y_p caused by ocean tides. The units are μas; γ denotes GMST+π.

	argument						Doodson	Period	x_p		y_p	
Tide	γ	l	l'	F	D	Ω	number	(days)	sin	cos	sin	cos
	1	-1	0	-2	-2	-2	117.655	1.2113611	0.0	0.9	-0.9	-0.1
	1	-2	0	-2	0	-1	125.745	1.1671262	0.1	0.6	-0.6	0.1
$2Q_1$	1	-2	0	-2	0	-2	125.755	1.1669259	0.3	3.4	-3.4	0.3
	1	0	0	-2	-2	-1	127.545	1.1605476	0.1	0.8	-0.8	0.1
σ_1	1	0	0	-2	-2	-2	127.555	1.1603495	0.5	4.2	-4.1	0.5
	1	-1	0	-2	0	-1	135.645	1.1196993	1.2	5.0	-5.0	1.2
Q_1	1	-1	0	-2	0	-2	135.655	1.1195148	6.2	26.3	-26.3	6.2
	1	1	0	-2	-2	-1	137.445	1.1136429	0.2	0.9	-0.9	0.2
RO_1	1	1	0	-2	-2	-2	137.455	1.1134606	1.3	5.0	-5.0	1.3
	1	0	0	-2	0	0	145.535	1.0761465	-0.3	-0.8	0.8	-0.3
	1	0	0	-2	0	-1	145.545	1.0759762	9.2	25.1	-25.1	9.2
O_1	1	0	0	-2	0	-2	145.555	1.0758059	48.8	132.9	-132.9	48.8
	1	-2	0	0	0	0	145.755	1.0750901	-0.3	-0.9	0.9	-0.3
TO_1	1	0	0	0	-2	0	147.555	1.0695055	-0.7	-1.7	1.7	-0.7
	1	-1	0	-2	2	-2	153.655	1.0406147	-0.4	-0.9	0.9	-0.4
	1	1	0	-2	0	-1	155.445	1.0355395	-0.3	-0.6	0.6	-0.3
	1	1	0	-2	0	-2	155.455	1.0353817	-1.6	-3.5	3.5	-1.6
M_1	1	-1	0	0	0	0	155.655	1.0347187	-4.5	-9.6	9.6	-4.5
	1	-1	0	0	0	-1	155.665	1.0345612	-0.9	-1.9	1.9	-0.9
χ_1	1	1	0	0	-2	0	157.455	1.0295447	-0.9	-1.8	1.8	-0.9
π_1	1	0	-1	-2	2	-2	162.556	1.0055058	1.5	3.0	-3.0	1.5
	1	0	0	-2	2	-1	163.545	1.0028933	-0.3	-0.6	0.6	-0.3
P_1	1	0	0	-2	2	-2	163.555	1.0027454	26.1	51.2	-51.2	26.1
	1	0	1	-2	2	-2	164.554	1.0000001	-0.2	-0.4	0.4	-0.2
S_1	1	0	-1	0	0	0	164.556	0.9999999	-0.6	-1.2	1.2	-0.6
	1	0	0	0	0	1	165.545	0.9974159	1.5	3.0	-3.0	1.5
K_1	1	0	0	0	0	0	165.555	0.9972696	-77.5	-151.7	151.7	-77.5
	1	0	0	0	0	-1	165.565	0.9971233	-10.5	-20.6	20.6	-10.5
	1	0	0	0	0	-2	165.575	0.9969771	0.2	0.4	-0.4	0.2
ψ_1	1	0	1	0	0	0	166.554	0.9945541	-0.6	-1.2	1.2	-0.6
ϕ_1	1	0	0	2	-2	2	167.555	0.9918532	-1.1	-2.1	2.1	-1.1
TT_1	1	-1	0	0	2	0	173.655	0.9669565	-0.7	-1.4	1.4	-0.7
J_1	1	1	0	0	0	0	175.455	0.9624365	-3.5	-7.3	7.3	-3.5
	1	1	0	0	0	-1	175.465	0.9623003	-0.7	-1.4	1.4	-0.7
So_1	1	0	0	0	2	0	183.555	0.9341741	-0.4	-1.1	1.1	-0.4
	1	2	0	0	0	0	185.355	0.9299547	-0.2	-0.5	0.5	-0.2
Oo_1	1	0	0	2	0	2	185.555	0.9294198	-1.1	-3.4	3.4	-1.1
	1	0	0	2	0	1	185.565	0.9292927	-0.7	-2.2	2.2	-0.7
	1	0	0	2	0	0	185.575	0.9291657	-0.1	-0.5	0.5	-0.1
ν_1	1	1	0	2	0	2	195.455	0.8990932	0.0	-0.6	0.6	0.0
	1	1	0	2	0	1	195.465	0.8989743	0.0	-0.4	0.4	0.0

Table 8.2b: Coefficients of sin(argument) and cos(argument) of semidiurnal variations in pole coordinates x_p and y_p caused by ocean tides. The units are μas; γ denotes GMST+ π.

Tide	argument						Doodson number	Period (days)	x_p		y_p	
	γ	l	l'	F	D	Ω			sin	cos	sin	cos
	2	-3	0	-2	0	-2	225.855	0.5484264	-0.5	0.0	0.6	0.2
	2	-1	0	-2	-2	-2	227.655	0.5469695	-1.3	-0.2	1.5	0.7
$2N_2$	2	-2	0	-2	0	-2	235.755	0.5377239	-6.1	-1.6	3.1	3.4
μ_2	2	0	0	-2	-2	-2	237.555	0.5363232	-7.6	-2.0	3.4	4.2
	2	0	1	-2	-2	-2	238.554	0.5355369	-0.5	-0.1	0.2	0.3
	2	-1	-1	-2	0	-2	244.656	0.5281939	0.5	0.1	-0.1	-0.3
	2	-1	0	-2	0	-1	245.645	0.5274721	2.1	0.5	-0.4	-1.2
N_2	2	-1	0	-2	0	-2	245.655	0.5274312	-56.9	-12.9	11.1	32.9
	2	-1	1	-2	0	-2	246.654	0.5266707	-0.5	-0.1	0.1	0.3
ν_2	2	1	0	-2	-2	-2	247.455	0.5260835	-11.0	-2.4	1.9	6.4
	2	1	1	-2	-2	-2	248.454	0.5253269	-0.5	-0.1	0.1	0.3
	2	-2	0	-2	2	-2	253.755	0.5188292	1.0	0.1	-0.1	-0.6
	2	0	-1	-2	0	-2	254.556	0.5182593	1.1	0.1	-0.1	-0.7
	2	0	0	-2	0	-1	255.545	0.5175645	12.3	1.0	-1.4	-7.3
M_2	2	0	0	-2	0	-2	255.555	0.5175251	-330.2	-27.0	37.6	195.9
	2	0	1	-2	0	-2	256.554	0.5167928	-1.0	-0.1	0.1	0.6
λ_2	2	-1	0	-2	2	-2	263.655	0.5092406	2.5	-0.3	-0.4	-1.5
L_2	2	1	0	-2	0	-2	265.455	0.5079842	9.4	-1.4	-1.9	-5.6
	2	-1	0	0	0	0	265.655	0.5078245	-2.4	0.4	0.5	1.4
	2	-1	0	0	0	-1	265.665	0.5077866	-1.0	0.2	0.2	0.6
T_2	2	0	-1	-2	2	-2	272.556	0.5006854	-8.5	3.5	3.3	5.1
S_2	2	0	0	-2	2	-2	273.555	0.5000000	-144.1	63.6	59.2	86.6
R_2	2	0	1	-2	2	-2	274.554	0.4993165	1.2	-0.6	-0.5	-0.7
	2	0	0	0	0	1	275.545	0.4986714	0.5	-0.2	-0.2	-0.3
K_2	2	0	0	0	0	0	275.555	0.4986348	-38.5	19.1	17.7	23.1
	2	0	0	0	0	-1	275.565	0.4985982	-11.4	5.8	5.3	6.9
	2	0	0	0	0	-2	275.575	0.4985616	-1.2	0.6	0.6	0.7
	2	1	0	0	0	0	285.455	0.4897717	-1.8	1.8	1.7	1.0
	2	1	0	0	0	-1	285.465	0.4897365	-0.8	0.8	0.8	0.5
	2	0	0	2	0	2	295.555	0.4810750	-0.3	0.6	0.7	0.2

Table 8.3a: Coefficients of sin(argument) and cos(argument) of diurnal variations in UT1 and LOD caused by ocean tides. The units are μs; γ denotes GMST+ π.

	argument						Doodson	Period	UT1		LOD	
Tide	γ	l	l'	F	D	Ω	number	(days)	sin	cos	sin	cos
	1	-1	0	-2	-2	-2	117.655	1.2113611	0.40	-0.08	-0.4	-2.1
	1	-2	0	-2	0	-1	125.745	1.1671262	0.19	-0.06	-0.3	-1.1
$2Q_1$	1	-2	0	-2	0	-2	125.755	1.1669259	1.03	-0.31	-1.7	-5.6
	1	0	0	-2	-2	-1	127.545	1.1605476	0.22	-0.07	-0.4	-1.2
σ_1	1	0	0	-2	-2	-2	127.555	1.1603495	1.19	-0.39	-2.1	-6.4
	1	-1	0	-2	0	-1	135.645	1.1196993	0.97	-0.47	-2.7	-5.4
Q_1	1	-1	0	-2	0	-2	135.655	1.1195148	5.12	-2.50	-14.0	-28.7
	1	1	0	-2	-2	-1	137.445	1.1136429	0.17	-0.09	-0.5	-1.0
RO_1	1	1	0	-2	-2	-2	137.455	1.1134606	0.91	-0.47	-2.7	-5.1
	1	0	0	-2	0	0	145.535	1.0761465	-0.09	0.07	0.4	0.5
	1	0	0	-2	0	-1	145.545	1.0759762	3.03	-2.28	-13.3	-17.7
O_1	1	0	0	-2	0	-2	145.555	1.0758059	16.02	-12.07	-70.5	-93.6
	1	-2	0	0	0	0	145.755	1.0750901	-0.10	0.08	0.5	0.6
TO_1	1	0	0	0	-2	0	147.555	1.0695055	-0.19	0.15	0.9	1.1
	1	-1	0	-2	2	-2	153.655	1.0406147	-0.08	0.07	0.5	0.5
	1	1	0	-2	0	-1	155.445	1.0355395	-0.06	0.05	0.3	0.4
	1	1	0	-2	0	-2	155.455	1.0353817	-0.31	0.27	1.7	1.9
M_1	1	-1	0	0	0	0	155.655	1.0347187	-0.86	0.75	4.6	5.2
	1	-1	0	0	0	-1	155.665	1.0345612	-0.17	0.15	0.9	1.0
χ_1	1	1	0	0	-2	0	157.455	1.0295447	-0.16	0.14	0.8	1.0
π_1	1	0	-1	-2	2	-2	162.556	1.0055058	0.31	-0.19	-1.2	-2.0
	1	0	0	-2	2	-1	163.545	1.0028933	-0.06	0.03	0.2	0.4
P_1	1	0	0	-2	2	-2	163.555	1.0027454	5.51	-3.10	-19.4	-34.5
	1	0	1	-2	2	-2	164.554	1.0000001	-0.05	0.02	0.2	0.3
S_1	1	0	-1	0	0	0	164.556	0.9999999	-0.13	0.07	0.4	0.8
	1	0	0	0	0	1	165.545	0.9974159	0.35	-0.17	-1.1	-2.2
K_1	1	0	0	0	0	0	165.555	0.9972696	-17.62	8.55	53.9	111.0
	1	0	0	0	0	-1	165.565	0.9971233	-2.39	1.16	7.3	15.1
	1	0	0	0	0	-2	165.575	0.9969771	0.05	-0.03	-0.2	-0.3
ψ_1	1	0	1	0	0	0	166.554	0.9945541	-0.14	0.06	0.4	0.9
ϕ_1	1	0	0	2	-2	2	167.555	0.9918532	-0.27	0.11	0.7	1.7
TT_1	1	-1	0	0	2	0	173.655	0.9669565	-0.29	0.04	0.3	1.9
J_1	1	1	0	0	0	0	175.455	0.9624365	-1.61	0.19	1.2	10.5
	1	1	0	0	0	-1	175.465	0.9623003	-0.32	0.04	0.2	2.1
So_1	1	0	0	0	2	0	183.555	0.9341741	-0.41	-0.01	-0.0	2.7
	1	2	0	0	0	0	185.355	0.9299547	-0.21	-0.01	-0.0	1.4
Oo_1	1	0	0	2	0	2	185.555	0.9294198	-1.44	-0.04	-0.3	9.7
	1	0	0	2	0	1	185.565	0.9292927	-0.92	-0.02	-0.2	6.2
	1	0	0	2	0	0	185.575	0.9291657	-0.19	0.00	-0.0	1.3
ν_1	1	1	0	2	0	2	195.455	0.8990932	-0.40	-0.02	-0.2	2.8
	1	1	0	2	0	1	195.465	0.8989743	-0.25	-0.02	-0.1	1.8

Table 8.3b: Coefficients of sin(argument) and cos(argument) of semidiurnal variations in UT1 and LOD caused by ocean tides. The units are μs; γ denotes GMST+ π.

	argument						Doodson	Period	UT1		LOD	
Tide	γ	l	l'	F	D	Ω	number	(days)	sin	cos	sin	cos
	2	-3	0	-2	0	-2	225.855	0.5484264	-0.09	-0.01	-0.1	1.0
	2	-1	0	-2	-2	-2	227.655	0.5469695	-0.22	-0.03	-0.4	2.6
$2N_2$	2	-2	0	-2	0	-2	235.755	0.5377239	-0.64	-0.18	-2.1	7.4
μ_2	2	0	0	-2	-2	-2	237.555	0.5363232	-0.74	-0.22	-2.6	8.7
	2	0	1	-2	-2	-2	238.554	0.5355369	-0.05	-0.02	-0.2	0.6
	2	-1	-1	-2	0	-2	244.656	0.5281939	0.03	0.01	0.2	-0.4
	2	-1	0	-2	0	-1	245.645	0.5274721	0.14	0.06	0.7	-1.7
N_2	2	-1	0	-2	0	-2	245.655	0.5274312	-3.79	-1.56	-18.6	45.2
	2	-1	1	-2	0	-2	246.654	0.5266707	-0.03	-0.01	-0.2	0.4
ν_2	2	1	0	-2	-2	-2	247.455	0.5260835	-0.70	-0.30	-3.6	8.3
	2	1	1	-2	-2	-2	248.454	0.5253269	-0.03	-0.01	-0.2	0.4
	2	-2	0	-2	2	-2	253.755	0.5188292	0.05	0.02	0.3	-0.6
	2	0	-1	-2	0	-2	254.556	0.5182593	0.06	0.03	0.3	-0.7
	2	0	0	-2	0	-1	255.545	0.5175645	0.60	0.27	3.2	-7.3
M_2	2	0	0	-2	0	-2	255.555	0.5175251	-16.19	-7.25	-86.8	196.6
	2	0	1	-2	0	-2	256.554	0.5167928	-0.05	-0.02	-0.3	0.6
λ_2	2	-1	0	-2	2	-2	263.655	0.5092406	0.11	0.03	0.4	-1.4
L_2	2	1	0	-2	0	-2	265.455	0.5079842	0.42	0.12	1.4	-5.3
	2	-1	0	0	0	0	265.655	0.5078245	-0.11	-0.03	-0.4	1.3
	2	-1	0	0	0	-1	265.665	0.5077866	-0.05	-0.01	-0.2	0.6
T_2	2	0	-1	-2	2	-2	272.556	0.5006854	-0.44	-0.02	-0.2	5.5
S_2	2	0	0	-2	2	-2	273.555	0.5000000	-7.55	-0.16	-2.0	94.8
R_2	2	0	1	-2	2	-2	274.554	0.4993165	0.06	0.00	0.0	-0.8
	2	0	0	0	0	1	275.545	0.4986714	0.03	0.00	-0.0	-0.3
K_2	2	0	0	0	0	0	275.555	0.4986348	-2.10	0.04	0.5	26.5
	2	0	0	0	0	-1	275.565	0.4985982	-0.63	0.01	0.2	7.9
	2	0	0	0	0	-2	275.575	0.4985616	-0.07	0.00	0.0	0.9
	2	1	0	0	0	0	285.455	0.4897717	-0.15	0.04	0.5	1.9
	2	1	0	0	0	-1	285.465	0.4897365	-0.06	0.02	0.2	0.8
	2	0	0	2	0	2	295.555	0.4810750	-0.05	0.02	0.2	0.6

Table 8.4: Ocean tidal variations in polar motion and polar motion excitation.

							Polar Motion				Polar Motion Excitation			
							Prograde		Retrograde		Prograde		Retrograde	
Tide	Argument					Period	amp	phase	amp	phase	amp	phase	amp	phase
	l	l'	F	D	Ω	(days)	(μas)	(°)	(μas)	(°)	(μas)	(°)	(μas)	(°)
m_{tm}	1	0	2	0	1	9.12	4.43	-112.62	5.57	21.33	205.83	67.21	269.95	21.17
M_{tm}	1	0	2	0	2	9.13	10.72	-112.56	13.48	21.30	497.59	67.27	652.59	21.14
m_f	0	0	2	0	1	13.63	27.35	-91.42	30.59	13.31	841.32	88.42	1002.12	13.15
M_f	0	0	2	0	2	13.66	66.09	-91.31	73.86	13.27	2028.73	88.53	2414.94	13.11
M_{sf}	0	0	0	2	0	14.77	5.94	-87.13	6.42	11.75	168.13	92.70	194.74	11.60
M_m	1	0	0	0	0	27.56	43.74	-56.70	31.12	-0.91	643.61	123.13	520.16	-1.06
M_{sm}	-1	0	0	2	0	31.81	8.85	-51.11	5.42	-4.21	111.62	128.72	79.23	-4.36
S_{sa}	0	0	2	-2	2	182.62	86.48	-20.30	99.77	175.57	118.56	159.42	336.32	175.46
S_a	0	1	0	0	0	365.26	17.96	-17.38	152.15	170.60	3.33	161.60	332.53	170.51
M_n	0	0	0	0	1	-6798.38	208.17	166.89	186.98	166.67	221.43	166.88	175.07	166.68

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