To: Ad Hoc Working Group on HF-EOP

From: Richard Ray (GSFC)

Re: Indexing and argument conventions for tides

Date: December 15, 2017

REVISED Addendum to previous memo

My colleague, Leonid Petrov, wishes a plague on both houses, Woolard's and Doodson's, and he suggests adding a column to our tables that evaluates each tidal argument at epoch J2000. Along with the known frequency of each wave, this then allows any user to evaluate the tidal predictions without fussing about with astronomical longitudes and odd phase conventions. This seems a very reasonable request. My original suggestion still stands, because I think it is still important to those of us that develop these models to maintain consistency with other tidal communities and to explicitly include information in the tables that connects the tidal coefficients back to the real ocean and to the tide-generating potential. Leonid's suggestion simply adds another column to the table.

A predicted time series for any tidal frequency can then be computed simply from

$$y(t) = A\cos(\Theta - G) = C\cos\Theta + S\sin\Theta \tag{1}$$

for amplitude A, phase lag G, or components C, S, and where the argument is

$$\Theta = \omega(T - T_0) + V_0. \tag{2}$$

If the time T is in UT, then for a J2000 time origin we should set

$$T_0 = 2000 \text{ January 1, 11:58:55},$$

assuming that ΔT was 65 s or so at J2000.

This approach, based on pure harmonics of known tidal frequencies, is admittedly only an approximation to the standard approach. The standard approach, be it Woolard's or Doodson's, depends on both UT and TT (as John Gipson noted in his earlier memo to this group). The first variable in the standard tidal argument—either GMST or lunar time τ—depends on UT; the other (astronomical) variables are functions of TT. So if there are large changes in ΔT, the pure-harmonic approach fails to model this properly. To see the magnitude of the possible errors, I computed

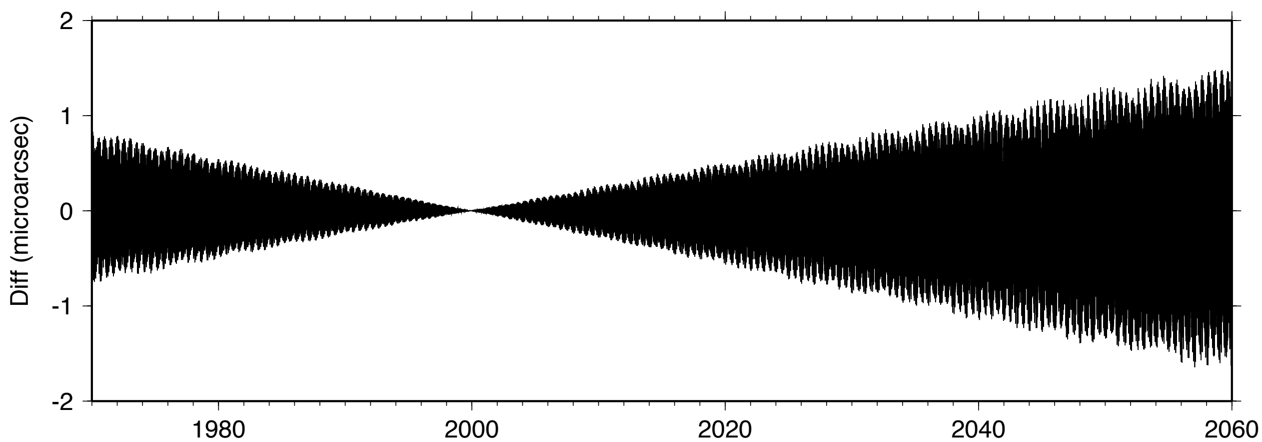

Figure 1: The error in the predicted position of the x-component of polar motion commmitted by using the pure-harmonic approach of Eqns. (1–2).

predicted polar motion (x component) over the years 1970–2060 two ways: the standard way using Doodson arguments and the pure harmonic way described above. The extrapolation of ΔT into the future reaches over 100 seconds in 2060 (which may or may not be realistic). The differences in x (μas) are shown in Figure 1. So long as ΔT stays near its J2000 value, the errors are very small. Eventually they exceed 1 μas, which presumably can still be considered small, depending on the application. It's possible that some of the error circa 2060 and onwards could also arise from the fact that the astronomical mean longitudes are not strictly linear functions of TT (here I employed the standard polynomial expansions in the IERS's `fundarg` routine). I haven't investigated which is the largest error source.

My suggested version of the current IERS-2010 model for tidal UT1, including a column for the J2000 phase V_0, is attached. (Note that the earlier version of this Addendum had a mistake in V_0 for a few constituents.) This table is based on the original tables in the Chao et al. (1996) paper, with additional minor constituents and nodal sidelines added via standard admittance calculations. We may still quibble with where to draw the cutoff used for minor lines; it's easy to add more.

TIDAL UT1 -- Chao et al (1996) Model C

	Doodson No.							Freq(°/h)	CTE	J2000(°)	Amp	Phase	COS	SIN
2Q1	1	-3	0	2	0	0	-1	12.854286	0.00664	23.640	1.109	15.99	1.066	0.306
sig1	1	-3	2	0	0	0	-1	12.927140	0.00802	57.866	1.271	17.16	1.214	0.375
	1	-2	0	1	-1	0	-1	13.396454	0.00947	283.648	1.059	25.95	0.952	0.463
Q1	1	-2	0	1	0	0	-1	13.398661	0.05018	158.603	5.600	26.00	5.033	2.455
rho1	1	-2	2	-1	0	0	-1	13.471515	0.00954	192.830	1.009	27.51	0.895	0.466
	1	-1	0	0	-1	0	-1	13.940829	0.04945	58.611	3.799	36.96	3.035	2.284
O1	1	-1	0	0	0	0	-1	13.943036	0.26216	293.567	20.100	37.00	16.053	12.096
tau1	1	-1	2	0	0	0	1	14.025173	0.00343	314.499	0.250	38.33	0.196	0.155
	1	0	0	-1	0	0	1	14.487410	0.00740	248.530	0.428	40.81	0.324	0.280
M1	1	0	0	1	0	0	1	14.496694	0.02060	55.236	1.188	40.74	0.900	0.775
	1	0	0	1	1	0	1	14.498900	0.00414	290.192	0.238	40.72	0.181	0.156
chi1	1	0	2	-1	0	0	1	14.569548	0.00392	89.462	0.220	39.96	0.169	0.142
pi1	1	1	-3	0	0	1	-1	14.917865	0.00713	171.738	0.379	30.99	0.325	0.195
P1	1	1	-2	0	0	0	-1	14.958931	0.12201	169.267	5.900	29.00	5.160	2.860
	1	1	-1	0	0	1	1	15.000002	0.00289	192.671	0.156	27.74	0.138	0.073
	1	1	0	0	-1	0	-1	15.038862	0.00729	135.244	0.411	26.09	0.369	0.181
K1	1	1	0	0	0	0	1	15.041069	0.36873	190.200	19.700	26.00	17.706	8.636
	1	1	0	0	1	0	1	15.043275	0.05001	65.155	2.846	25.90	2.560	1.244
psi1	1	1	1	0	0	-1	1	15.082135	0.00293	187.729	0.104	24.21	0.095	0.043
phi1	1	1	2	0	0	0	1	15.123206	0.00525	31.132	0.274	22.37	0.253	0.104
the1	1	2	-2	1	0	0	1	15.512590	0.00397	290.937	0.275	5.54	0.273	0.027
J1	1	2	0	-1	0	0	1	15.585443	0.02062	325.163	1.521	2.93	1.519	0.078
	1	2	0	-1	1	0	1	15.587650	0.00409	200.118	0.302	2.85	0.302	0.015
SO1	1	3	-2	0	0	0	1	16.056964	0.00342	65.900	0.393	351.21	0.388	-0.060
OO1	1	3	0	0	0	0	1	16.139102	0.01129	266.832	1.401	349.93	1.379	-0.245
	1	3	0	0	1	0	1	16.141308	0.00723	141.788	0.899	349.90	0.885	-0.158
ups1	1	4	0	-1	0	0	1	16.683476	0.00216	41.796	0.427	344.76	0.412	-0.112
eps2	2	-3	2	1	0	0	0	27.423834	0.00467	113.103	0.251	262.01	-0.035	-0.249
2N2	2	-2	0	2	0	0	0	27.895355	0.01601	213.840	0.686	254.93	-0.178	-0.662
mu2	2	-2	2	0	0	0	0	27.968208	0.01932	248.066	0.800	253.87	-0.222	-0.769
	2	-1	0	1	-1	0	2	28.437523	0.00451	293.848	0.153	248.02	-0.057	-0.142
N2	2	-1	0	1	0	0	0	28.439730	0.12101	348.803	4.100	248.00	-1.536	-3.801
nu2	2	-1	2	-1	0	0	0	28.512583	0.02298	23.029	0.757	247.35	-0.292	-0.699
alp2	2	0	-1	0	0	1	2	28.943038	0.00218	306.237	0.062	245.88	-0.025	-0.056
	2	0	0	0	-1	0	2	28.981898	0.02357	68.811	0.661	245.99	-0.269	-0.604
M2	2	0	0	0	0	0	0	28.984104	0.63193	123.766	17.700	246.00	-7.199	-16.170
lam2	2	1	-2	1	0	0	2	29.455625	0.00466	44.503	0.117	251.57	-0.037	-0.111
L2	2	1	0	-1	0	0	2	29.528479	0.01786	78.729	0.446	253.15	-0.129	-0.427
	2	1	0	1	0	0	0	29.537763	0.00447	65.436	0.112	253.37	-0.032	-0.107
T2	2	2	-3	0	0	1	0	29.958933	0.01718	1.938	0.440	265.63	-0.033	-0.438
S2	2	2	-2	0	0	0	0	30.000000	0.29402	359.467	7.600	267.00	-0.398	-7.590
R2	2	2	-1	0	0	-1	2	30.041067	0.00246	176.996	0.064	268.38	-0.002	-0.064
K2	2	2	0	0	0	0	0	30.082137	0.07992	200.399	2.000	259.00	-0.382	-1.963
	2	2	0	0	1	0	0	30.084344	0.02383	75.355	0.631	269.83	-0.002	-0.631
	2	2	0	0	2	0	0	30.086550	0.00259	310.310	0.069	269.91	-0.000	-0.069
eta2	2	3	0	-1	0	0	0	30.626512	0.00447	335.362	0.154	286.33	0.043	-0.148